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SPECIAL ISSUE

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Guest Editors

This special issue of the journal "Reliability: Theory and Applications" contains quality articles on innovative approaches to risk minimization. We would like to express our gratitude to all the participants of the RISK-2022 Conference for the submitted articles and the reviewers for their effective work in evaluating the submitted materials. We sincerely appreciate their excellent timely responses. The invited editors are also very grateful to the secretary, Doctor of Sci., Alexander Bochkov, for his constant support and constructiveness in the process of reviewing and drafting the proposal of the special issue. We hope that this special issue will make a significant contribution to improving the scientific field of assessment, analysis and management of natural and man-made risks.

Prof. Dr. Enrico Zio,
Mines – Paris, PSL University, France
e-mail: enrico.zio@mines-paristech.fr
Politecnico di Milano, Italy
e-mail: enrico.zio@polimi.it

Prof. Dr. Vugar Aliyev,
CEO & Founder
International Event Organizer Company
AMIR Technical Services LLC,
e-mail: prof.vugar.aliyev@gmail.com

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The Fourth Eurasian Conference
Innovations in Minimization of Natural and Technological Risks

Satellite Symposium
Technological, Environmental and Economic Risks of the Oil and Gas Sector

ORGANIZERS

- International Event Organizer Company AMIR Technical Services;
- University of Architecture and Construction, Azerbaijan
- Technical University, Georgia;
- City University of Hong Kong;
- International Group on Reliability - Gnedenko Forum, the USA;
- Eurasian SEISMO Association

OBJECTIVES

- Identification and transfer of "know-how" knowledge and technologies on innovative approaches to minimize risks;
- Support of the UN Sendai Framework for Action on Disaster Risk Reduction 2015-2030.

Table of Contents

The fight against climate change is one of the key tasks both at the international level and in a single country. All regions of the world today are assessing the negative consequences of global warming, developing regulatory mechanisms in order to reduce the negative impact on the climate and adapt to it as much as possible, as well as transform economies to move towards a low-carbon development model. Goals are set and commitments are made to reduce greenhouse gas (GHG) emissions. More than 140 countries, accounting for 90% of global GHG emissions, have already reported targets for achieving carbon neutrality. Accordingly, business and entire sectors of the economy determine their opportunities in this direction, setting their own goals and identifying tools for reducing emissions and developing new technological solutions. Obviously, it is impossible to immediately switch to a new economic model and technologies with zero greenhouse gas emissions. For some industries, in principle, such solutions are complex, and alternatives to them appear extremely slowly. To achieve carbon neutrality goals, carbon dioxide capture, capture and storage projects play an important role. A climate project is a set of measures that reduce (prevent) greenhouse gas emissions or increase GHG1 absorption. The result of the implementation of climate projects are carbon units, expressed as the number of avoided or absorbed emissions in tons of CO2 equivalent. Special requirements are imposed on these projects and their justification, and their results are confirmed by external experts.

Gold mining is attracting increasing attention in many countries of the world. On the other hand, this sector causes numerous environmental and human health issues. The main problems are associated with: (i) Acid Mine Drainage (AMD) with low pH values and high concentrations of heavy metals, (ii) using large quantities of hazardous chemicals such as mercury and cyanide and (iii) mining dust. Degree of the impact depends of the scale mining (small or large scale), type of mine (surface and underground) as well as of the chemical reagents that use in the production process. Modern technology has made it possible to reduce environmental impacts of mining activities.
This brief review looks at the gold mining sector (industrial and artisanal) and its key impact on environmental as well as on health of workers and communities (residents who live in proximity to the mine).

The global problem is to achieve the set goals for reducing emissions, it is necessary to invest in the development of new ways to reduce carbon emissions in the atmosphere by accelerating convergence in key areas. Looming climate tipping points require public and private participation in scaling up climate responses by creating opportunities for rapid progress that improve human conditions through the provision of ecosystem services and socio-economic development. Efforts to mitigate climate change are based on two imperatives: decarbonizing our energy production systems and removing carbon dioxide (CO_2) from the atmosphere. As described below, Natural Climate Solutions (NCS) represent a promising path to restoring climate stability by reducing atmospheric CO_2 emissions while maintaining and improving critical production systems and ecosystem services.

collection of materials in this direction during 1930-2020, the hydrogeological conditions of the Shirvan plain were studied. Based on the analysis of the results the regime types of groundwater were separated and a correlative dependence was found between regime types and factors forming the regime. Five genetic types have been identified according to the factors forming the regime and the synchrony of changes in groundwater levels. Under the influence of natural and anthropogenic factors, the level of groundwater, the degree of mineralization, the chemical composition, the chemical composition and salinity of the soils have changed. During the period from 1958 to 2020, the level of groundwater in the area increased by more than 4.1 m due to irrigated agriculture, and their mineralization degree decreased by 16.2 g/l due to filtration of the surface water and removal of mineralized water through drainage. As a result of the analysis regime types of groundwater were separated and a correlative dependence was found between regime types and factors forming the regime. According to the factors forming the regime and the synchrony of changes in groundwater levels, the genetic types of the regime-climate, hydrological, irrigation, irrigation-drainage, irrigation were separated and their areas of distribution were determined. The climate type regime is characterized by a high correlation between the rise and fall of groundwater level and the seasonal and perennial periodicity of atmospheric precipitation, the hydrological type is characterized by a similar dependence on the surface flow, the irrigation-drainage type is characterized by a similar dependence between irrigation water and surface water basins.

The research is aimed at developing and approbation of decision-making algorithm to ensure environmental safety of oil refining areas for local population based on the mechanism of health risk assessment. Its implementation at all stages of the life cycle of environmentally hazardous production facilities ensures compliance with the regulatory level of environmental impacts on the border of the enterprise sanitary protection zone and the adjacent residential areas.
Methodologically, the research is based on conceptual provisions of the risk management theory and corresponding standards of ISO 31000 series, which prescribe regulated risk management procedures: risk identification (by risk hazards and their sources); risk assessment and their prioritization by degree of significance; planning and implementation of risk management tools; monitoring residual risks. Risk assessment was performed using the standard Russian health risk assessment methodology.
The algorithm is a set of sequential procedures for making decisions to ensure the residual health risk meets regulatory requirements. Emphasis is placed on the stages of design and operation of an environmentally hazardous facility when the level of health risks posed is particularly sensitive to the results of the decisions made. Timely identification of hazards and assessment of health risks allows to define the location of environmentally hazardous facilities at the design, considering their risk-posing capacity. During operation stage, the riskiest areas of the sanitary protection zone boundary and the industrial site, priority facilities and chemical toxicants (in terms of created risks) are identified. This provides a basis for adjusting the industrial and environmental control programs, prioritizing investment programs and plans of environmental protection (considering the expected reduction of the health risk), as well as operational documentation (to minimize the possibility of creating high risk emissions). Risk management tools are used - risk avoidance, reducing the severity of consequences, reducing the probability of risks.
The algorithm makes it possible to ensure meeting the regulatory requirements for residual health risk during the operation of environmentally hazardous oil refinery facility, while avoiding significant financial costs because of environmentally insufficient planning and technological decisions made. The algorithm can be used for the operating industrial facilities and new construction objects, regardless of the industry specifics. It is applicable to chemical pollution of atmospheric air, acoustic and electromagnetic influence, pollution of water.

THE FINAL DECISION

Fourth Eurasian Conference and Symposium RISK-2022

"Innovations in Minimization of Natural and Technological Risks"

October 11 – 13, 2022, Baku, AZERBAIJAN

We are the participants of the 4th Eurasian Conference and Symposium "Innovations in Minimization of Natural and Technological Risks" having discussion and summary international experience of traditional and innovative approaches to the analysis, assessment and management of natural and man-made risks, declare that the main goals of the RISK-2022 conference have been achieved:

- bringing together scientists and specialists in the field of analysis, assessment and management of natural and man-made risks and providing them with the opportunity to exchange information, ideas and innovative solutions;
- promoting the transfer of innovative and advanced knowledge about natural and man-made risks, and technologies for their minimization;
- promoting mutual understanding and professional interaction of scientists, specialists and organizations in order to develop the theory and improve the best practices for minimizing natural and man-made risks;
- deepening cooperation and mutual understanding between industry actors, scientific and academic institutions in the analysis, assessment and management of natural and man-made risks;
- supporting the Sendai (Japan) UN Framework for Action on Disaster Risk Reduction 2015–2030. As a guiding baseline document, reflecting strategic objectives and priority areas for action, as well as expected results on a better understanding of disaster risk in all its aspects;
- identification of the innovative approaches to identify various types of natural and anthropogenic hazards, methods of analyzing and assessing them and methods of making managerial decisions that ensure the safety of the population and sustainable socio-economic development of various regions of the Eurasian continent.

We are the participants of the 4th Eurasian conference and symposium "Innovations in Minimization Natural and Technological Risks" confirming our commitment to an active position in the formation of national and interstate mechanisms for ensuring the safety of the population and territories. We consider that it is important to involve all stakeholders in the risk analysis, risk assessment and risk management.

We call for uniting efforts of scientists and specialists from Eurasian countries to increase the efficiency and responsibility of solutions to minimize the risks of natural and anthropogenic emergencies which is expressing the concerning about the scale of losses from accidents and disasters caused by natural and man-made disasters,

We consider the existing of an organic relationship between minimizing the risk of emergencies and sustainable development of the country are important which involve all stakeholders in the analysis, risk assessment and risk management.

Considering the consensus of the conference participants, we express our support for the proposal of the chairman of the conference to hold the next Eurasian conference and symposium in Baku, Azerbaijan, in 2023. The 5th Eurasian Conference RISK-2023 will be timed to coincide with the 100th anniversary of Heydar Aliyev, the national leader of the Azerbaijani people.

On behalf of the Organizing Committee of RISK-2022 Conference and Symposium,

Prof. Enrico ZIO
Prof. Vugar ALIYEV

SENSITIVITY ANALYSIS OF RISK CHARACTERISTICS TO THE TYPE OF INITIAL INFORMATION BASED ON A PIPELINE MONITORING SYSTEM

Vladimir Rykov[1,2,3], Mais Farkhadov[4], Olga Kochueva[2], Elvira Zaripova[5]

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[1]Peoples' Friendship University of Russia (RUDN University), Russia
[2]Gubkin Oil & Gas Russian State University, Russia
[3]Kharkevich Institute for Information Transmission Problems of RAS, Russia
[4]V. A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Russia
[5]Moscow University of the Ministry of Internal Affairs of the Russian Federation named after V. J. Kikot, Russia
vladimir_rykov@mail.ru , mais.farhadov@gmail.com , olgakoch@mail.ru , ezarip@gmail.com

Abstract

The aim of our research is to construct a risk tree, determine the main risks characteristics, find the most dangerous paths of the risk scenario development with respect to maximization of the failure probability criterion and analyze the sensitivity of results with respect to the shape of system components lifetime distributions and coefficient of variation. Our investigation is based on an example of the automated system for remote monitoring of underwater sections Dzhubga-Lazarevskoye-Sochi gas pipeline.

Keywords: risk tree, reliability, risk event, sensitivity analysis, monitoring system

I. Introduction

The preventive maintenance of equipment and predicting the operation risks of complex industrial systems is a key factor in ensuring the sustainability of the industry today. 82 % of companies have experienced unplanned downtime over the past three years. Analyst firm Aberdeen Research says that unplanned downtime can cost a company as much as $260,000 an hour. The problem of risks with application to industrial systems has recently received increased attention. Numerous studies are devoted to this both in printed publications [1, 2] and in Internet source [3].

The papers [4-7] propose a new approach to the investigation of risk phenomena. It contains the possibility to analyze and construct the most dangerous paths for the risk scenario development with respect to different criteria. Since the initial information about the emergence and development of a risk event and the damage it brings is usually very limited, it becomes important to analyze the sensitivity of risk characteristics to it. The proposed approach also allows to do this.

The aim of our paper is to present a risk tree based on an example of a real system of remote monitoring of underwater sections of the Dzhubga-Lazarevskoye-Sochi gas pipeline. The annual capacity of the gas pipeline is up to 3.78 billion cubic meters of gas. The approximate service time is 50 years. The total pipeline length is 171.6 km, the underwater part is about 90% of the total length [8]. The gas pipeline runs approximately 4.5 km from the waterfront. The sea depth reaches 80 m. The monitoring system evaluates the vertical position of the pipeline to identify places of insufficient backfilling, exposure, sagging, determines the condition of the anticorrosive insulation coating, classifies it as serviceable or requiring repair, or as marginal, that is, not allowing further operation. Monitoring is the basis for the safe operation of any complex system. Monitoring system failures can lead to serious risks of failure of the system itself, with possible catastrophic consequences.

We determine the most dangerous paths of the risk scenario development with respect to maximization of the failure probability criterion and analyze the sensitivity of results with respect to the shape of system components lifetime distributions and coefficient of variation. Although we limit ourselves to the analysis of the monitoring system, we are also ready for a deeper analysis of the entire pipeline system. However, this requires more detailed background information.

II. The problem statement

Consider the underwater pipeline monitoring system represented at the figure 1.

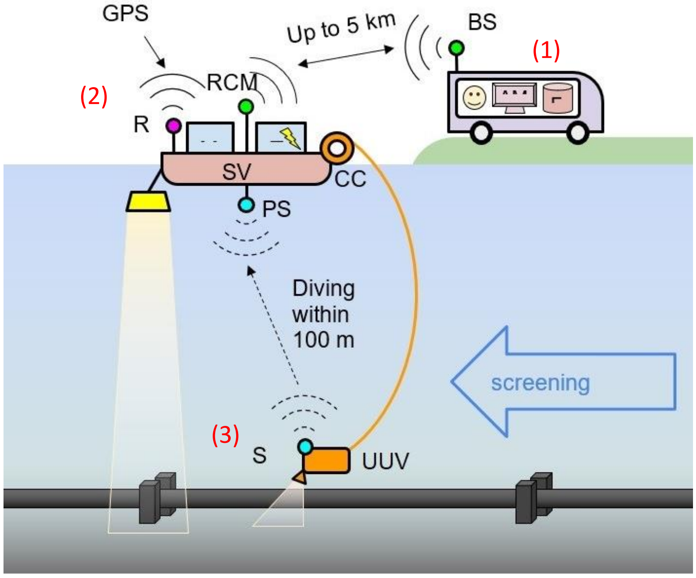

Figure 1: *The pipeline monitoring system*

Its hierarchical structure representation in the figure 2 with 3 main subsystems [1, 2, 9, 10]:
(1) – coast mobile operator center;
(2) – an accompanying surface vessel (SV), floating on the surface along the gas pipeline;
(3) –the remotely controlled unmanned underwater vehicle (UUV) "Vodyanoy-1".

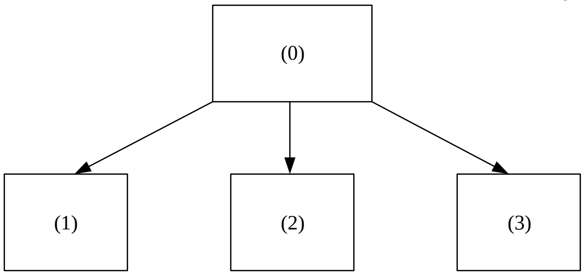

Figure 2: *A scheme of monitoring system*

Subsystems (1), (2) and (3) consist of lower-level subsystems.

The main segments associated with risky events for subsystem (1), are: (1,1) – control module/

operator's workplace; (1,1,1) – personal computer with a built–in DB; (1,1,2) – software analytics system; (1,1,3) – control tool/ joystick; (1,1,4) – radio system; (1,1,4,1) - network equipment; (1,1,4,2) –antenna; (1,2) – car.

In subsystem (2), the main elements that are significant in terms of the occurrence of risk events are: (2,1) – hydro echolocation system; (2,2) – control module; (2,2,1) – navigation system; (2,2,2) – local underwater positioning system; (2,2,3) – radio communication system; (2,2,4) – wire communication system for winch; (2,3) – power supply.

We define the following segments related to risk events in subsystem (3):

(3,1) – video system; (3,1,1) – camera; (3,1,2) – lamps; (3,2) – battery; (3,3) – tightness of the housing; (3,4) – control system; (3,5) – all sensors, such as a depth gauge, accelerometer, gyroscope; compass, voltage sensor; (3,6) – grab; (3,7) – motor drivers.

Based on expert assessments, we determine the initial information (the average service time) of the elements of the monitoring system in Table 1.

Table 1: *Initial information*

Elements of subsystem (1)	Mean lifetime, years	Elements of subsystem (2)	Mean lifetime, years	Elements of subsystem (3)	Mean lifetime, years
(1,1,1)	5	(2,1)	8	(3,1,1)	10
(1,1,2)	10	(2,2,1)	10	(3,1,2)	2
(1,1,3)	3	(2,2,2)	7	(3,2)	3
(1,1,4,1)	3	(2,2,3)	10	(3,3)	3
(1,1,4,2)	20	(2,2,4,1)	3	(3,4)	10
(1,2)	15	(2,2,4,2)	5	(3,5)	6
		(2,2,4,3)	6	(3,6)	10
		(2,3)	3	(3,7)	6

III. Risk tree

According to the methodology proposed in [4, 5], a scheme of the monitoring system has been developed and a risk tree has been constructed, taking into account the possibilities for the risk scenario.

Vector $\vec{i} = (i_1, i_2, ..., i_r)$ denotes an element of the tree, its components determine the sequence of numbers of risk events, starting from the main subsystem and ending with the elementary one. Here i_1 is the number of the first level event from k first level events. Then, i_2 - the number of the second level event that can be one of the reasons the uplevel event, etc, r is a hierarchy level of this event. Designation $\vec{i}_k = \left(i_{k,1}, i_{k,2}, ..., i_{k,n(\vec{i}_k)}\right)$ is used for the k level subsystem with the last element $n(\vec{i}_k)$, and j-th component of this subsystem is $j(\vec{i}_k)$. Let us divide the events into basic event (leaf) and other events. The round brackets for the leaf and square brackets for another event are used. For leaf events $A_{(\vec{i})}$ the average lifetime is given. The reliability of complex systems is investigated in terms of the reliability of elementary elements. Denote structural variable of an i-event by x_i, $1 \le i \le n$, x_i=1 if i-event occurs and x_i=0 otherwise. Corresponding structural function $\varphi(x_1, ..., x_n)$ can be calculated according to the rules of Boolean algebra, then $\varphi(x_1, ..., x_n) = 1$ if the system works, and $\varphi(x_1, ..., x_n) = 0$ otherwise [7].

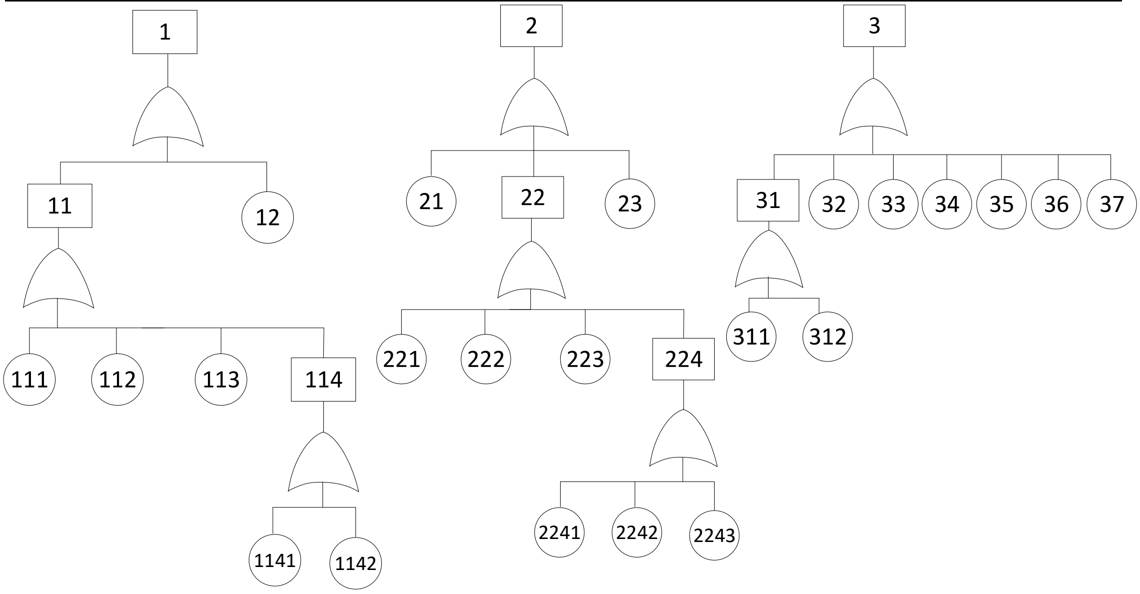

Figure 3: *Risk trees of subsystems (1), (2), (3).*

The main risk characteristics can be calculated with the help of structural functions, including the probability $q_{\vec{i}_k}(j)$ of $\vec{i}_k$ subsystem failure due to the failure of its j-component:

$$q_{\vec{i}_k}(j)=\int_0^\infty \left[\prod_{\substack{i_k=1\\ i_k\neq j}}^{n(\vec{i}_k)} R_{\overrightarrow{i_{k-1}},i_k}(u)\right] dF_{\overrightarrow{i_{k-1}},j}(u). \tag{1}$$

Using formula (2), we find the maximum failure probabilities $q^*_{\vec{i}_k}$ and the number of subsystem $j^*\left(\vec{i}_k\right)$ at which this maximum is reached.

$$q^*_{\vec{i}_k}=\max_{1\le j\le n(\vec{i}_k)} q_{\vec{i}_k}(j); \qquad j^*_q\left(\vec{i}_k\right)=\arg\max_{1\le j\le n(\vec{i}_k)} q_{\vec{i}_k}(j). \tag{2}$$

Collecting these values together, we find for any k the most dangerous path according to the maximum failure probability criterion, including path for the entire system with $k=1$:

$$\vec{i}^*_k(q)=j^*_q\left(\vec{i}_k\right), j^*_q\left(\overrightarrow{i^*_{k+1}}\right),\dots, j^*_q\left(\overrightarrow{i^*_{r-1}}\right), \qquad \overrightarrow{i^*_{k+l+1}}=\left(\overrightarrow{i^*_{k+l}}, j^*\left(\overrightarrow{i^*_{k+l}}\right)\right). \tag{3}$$

Let us analyze the sensitivity of the risk parameters to the accuracy of the initial information for different lifetime distribution functions and three different values of coefficient of variation ($\nu=0.5; 1; 2$).

IV. Numerical experiment

In numerical experiments, we use Gnedenko-Weibull distribution (GW) and Gamma distribution (Gamma) for the lifetime distributions of the leaf elements.

The risk tree analysis consists in calculating the probabilities of a system failure and in determining the most dangerous paths of a risky situation according to the maximum failure probability criterion.

For the first experiment (I), we estimate the failure probability $q_0(j)$ of system (0) due to the failure of subsystems (1), (2) and (3), each leaf element has a coefficient of variation $v = 0.5$. The distribution functions at the lower levels are Gamma, at the next up level – GW, then again we take Gamma, etc. System failure is more likely due to subsystem (3), the greatest failure probability is given in bold. The results are shown in row I of the Table 2.

Fort the second experiment (II), we change the lifetime distribution function for one element (311) and calculate again probabilities $q_0(j)$, the other elements do not change. The initial data of the I and II experiments are close to each other, we can conclude that the replacement of the distribution function for one element has little effect on the subsystems failure probabilities. The subsystem (3) is also unreliable in this case, the results are presented in row 2 of the Table 2.

In the third experiment (III), element (311) has the same distribution function as in (I), but the coefficient of variation is $v = 2$, the other elements coincide with experiment (I). Subsystem (1) has the highest failure probability now. We conclude that the initial data characteristics can greatly influence the technological risks prediction and the construction of risk paths.

Table 2: *Estimated probabilities for the system*

N	Description / Features	$q_0(1)$	$q_0(2)$	$q_0(3)$
I	DF at the lower levels are Gamma, at the next up level GW, then again Gamma, $v = 0.5$	0.2374	0.2387	**0.5239**
II	For one element (311), the lifetime distribution has been changed to GW	0.2541	0.2334	**0.5125**
III	For one element (311), the coefficient of variation has been changed $v = 2$	**0.6537**	0.1069	0.2394

V. Conclusion and the further research

Numerical experiments have shown a slight sensitivity of the risk parameters to the type of lifetime distribution function of the system elements, but their significant sensitivity to the value of the coefficient of variation of these random variables. The work shows the importance of preparing and analyzing the initial information concerning the reliability parameters of system elements. The risk analysis methodology developed by the authors makes it possible to estimate not only the failure parameters, but also the damage parameters for the entire system and each subsystem. Unfortunately, the lack of information necessary for this analysis did not allow us to conduct research in this direction and include them in this work. We intend to continue research in this field and invite interested organizations and researchers with the necessary background information to support these studies.

Acknowledgments

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References

[1] Rykov, V., Ivanova N. and Farhadov, M. (2022). On principles of risk analysis with a practical example. *RT&A*, Special Issue 3 (66), Volume 17.

[2] Rykov, V., Kochueva, O. and Farkhadov, M. Preventive Maintenance of a k-out-of-n System with Applications in Subsea Pipeline Monitoring. *J. Mar. Sci*. Eng. 2021, 9, 85.

[3] The Cost of Unplanned Downtime and the Rally for Digital Transformation. ServiceMax. 2017. Available online: https://www.servicemax.com/uk/fsd/2017/10/19/the-cost-of-unplanned-downtime-and-the-rally-for-digital-transformation (accessed on 01 July 2022).

[4] Rykov, V.V., Itkin, V.Yu (2016) Reliability of technical systems and technogenic risk. Textbook. INFRA-M, 214 p.

[5] Rykov, V (2018) Reliability of Engineering Systems and Technological Risks. Mathematics and Statistics Series. Stochastic Models in Survival Analysis and Reliability Set. ISTE, Willey.

[6] Henley, E.G., Kumamoto, H. (1981) Reliability engineering and risk assessment. Prentice-Hall, New Jersey, 07632. ISBN-0-13-772251-6.

[7] Rykov, V., Ivanova, N., Kozyrev, D. (2021) Risk tree as an assistant tool for the decision-maker. 109-114. DOI: 10.1109/ICUMT54235.2021.9631604.

[8] Gazprom. Dzhubga—Lazarevskoye—Sochi. The First Russia-Based Offshore Gas Pipeline. Available online: https://www. gazprom.com/projects/dls/ (accessed on 01 July 2022).

[9]. Rykov, V., Kochueva, O., Rykov, Ya. Preventive Maintenance of k-out-of-n System with Respect to Cost-Type Criterion. *Mathematics* 2021, 9, 2798.

[10]. Farkhadov, M.; Abramenkov, A.; Abdulov, A.; Eliseev, A. (2019) Portable Remotely Operated Underwater Smart Vehicle with a Camera and an Arm. *In Proceedings of the 2019 10th International Power Electronics Drive Systems and Technologies Conference* (PEDSTC) Shiraz, Iran. 178–183.

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TECHNICAL ASSET MANAGEMENT FOR RAILWAY TRANSPORT BASED ON RISK ASSESSMENT

Igor Shubinskiy

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Research, Design and Engineering Institute of Informatization, Automation and Communication on Railway Transport, Russia
igor-shubinsky@yandex.ru

Abstract

In the conditions of the stagnation of the global economy, the issues of finding the optimal strategy that would allow taking into account the balance of interests between costs, opportunities, performance of the company's technical assets and risks come to the forefront of the company's management. To this end, the URRAN system has been created, operated and developed in the Russian railway transport -a system for managing the reliability, safety, and resources of transport facilities based on risk assessment. Within the framework of this system, the tasks of operational collection, processing and analysis of the current state of reliability and safety of transport facilities, the activities of structural units are solved on the basis of risk assessment of maintenance management, assignments of major repairs, modernization and modification of transport facilities. The reliability and safety of transport facilities are managed within the framework of Big Data using artificial intelligence methods. Fire safety management is carried out using an automated fire risk management system, which is part of the URRAN system. It allows, based on the results of the fire risk forecast, to make a decision on the need for repair, replacement or maintenance of transport facilities and their fire safety system.

Keywords: risk, technical asset, reliability, safety, resource, railway transport facility, safety principle, risk matrix, integral risk, risk management, infrastructure, rolling stock

I. Introduction

Railway transport of the Russian Federation is mainly represented by JSC "Russian Railways", which, in turn, is the largest owner and explant of transport infrastructure facilities in the territory of the Russian Federation. Almost 335 thousand people work in the infrastructure complex of JSC "Russian Railways", they serve about 150 thousand kilometers of tracks, 30 thousand bridges and overpasses, 159 tunnels, more than 5 thousand stations and many other infrastructure facilities. At the same time, JSC "Russian Railways" is a major owner and operator of communication networks, operator of telephone and radio communications, including digital (DMR, Tetra, GSM-R). The total length of the communication lines of JSC "Russian Railways" is more than 330 thousand kilometers, the length of fiber-optic communication lines is more than 77 thousand kilometers. The railway infrastructure operates more than 500 thousand pieces of automation and telemechanics equipment, as well as more than 6 million different sensors, diagnostic equipment and telemetry.

Uninterrupted provision of the transportation process with electricity is carried out by 1,402 traction substations. 11,000 freight locomotives of direct or alternating current traction, 6,000 shunting locomotives, 1,600,000 freight cars of all types and owners, 24,000 long-distance passenger cars, more than 15,000 suburban train cars are used on the railway network of JSC "Russian Railways". Russian Railways Holding is the largest system-forming component of the

Russian economy, the most important link of its transport system, providing more than 44% of cargo turnover and more than 30% of passenger turnover of the entire transport system of the country, forming 1.7% of Russia's GDP, 1.5% of tax revenues to the country's budget system, up to 4% of total capital investments in Russia. JSC "Russian Railways" is among the TOP 5 largest companies in Russia, occupies a leading position in the world along with the highways of the USA and China, including in terms of traffic volumes. The share of the cost of fixed assets of the infrastructure of the Company "Russian Railways". The current situation in the world, associated with the introduction of widespread restrictions due to the COVID-19 coronavirus pandemic, has led to the stagnation of the world economy, in particular, in transport. The greatest blow fell on air transport, which practically stopped its activities, stopping flights in international traffic and reducing the number of flights in domestic traffic as much as possible. Railway transport, as a system-forming link of the state economy, did not cease its activities, but also faced a sharp drop in loading, a decrease in the activity of the population and, as a result, a decrease in revenue, which led to the rejection of strategic initiatives for the development of the infrastructure complex in favor of preserving the company's teams and ensuring current operational activities. So, according to RBC (www.rbc.ru) "Russian Railways" (RZD) recorded a failure of cargo turnover in March 2020 by 7.3%, and in the whole year about 5%. Passenger turnover in 2020 decreased by 56%. Things are not going well in the European Union. According to Global Railway Review (www.globalrailwayreview.com) rail transport indicators have decreased by 30% since the introduction of quarantine measures. All participants of the transport market also have to hastily revise their investment plans in favor of solving operational tasks.

II. Asset management system

The work model of a modern company in a simplified form consists in a constant search for ways to increase its profitability and reduce costs while meeting all regulatory requirements, by which we can mean requirements in the field of safety and reliability of train traffic, labor protection, environmental and fire safety, etc. Of course, it is impossible to endlessly reduce costs while achieving income growth. Therefore, the issues of finding the optimal strategy that would allow to comprehensively take into account the balance of interests between costs, opportunities, risks and asset performance come to the forefront of the company's management. An asset, in accordance with the ISO 55000 series of standards, should be understood here as an identifiable object, thing or object that has potential or actual value for the organization. [1,2]. Thus, the construction of a modern effective company management system is possible only on the basis of the principles.

Asset management focuses not directly on the asset itself, but on the value that the asset can provide to the organization. Asset management involves finding a balance between costs, prospects and risks, on the one hand, and ensuring the required performance of assets, on the other, to achieve the goals of the organization.

In the asset management system , the following become mandatory: - information (asset data); - assessment of the technical condition; - risk assessment; - RCM is a process where RCM (Reliability Centered Maintenance) is reliability-oriented maintenance); - life cycle cost analysis; - analysis of performance indicators, including the overall efficiency of equipment – OEE (Overall Equipment Effectiveness), etc.

III. URRAN system: the goals of the system and composite complexes

In JSC "Russian Railways". Since 2010, the project of reliability, security, and resource management based on risk assessment (URRAN) has been implemented [3-6]. The results of this project are the basis for the management system of technical assets in railway transport. They include methodology, information support, and regulatory framework. Currently, URRAN is a set of methodology, regulatory, methodological and information support, as well as software and hardware designed for integrated management of resources and processes in order to effectively provide railway transport services.

The object of application of the URRAN system is the means and systems of railway transport and the technological processes implemented by them.

The purpose of creating the URRAN system is Adaptive management of the technical content of the facility based on compliance with the criteria of reliability, safety and economic efficiency of functioning at the stages of the life cycle, taking into account risk assessment. Here, adaptive management (adaptive management) refers to the forms and methods of managing business structures, assuming the ability and ability of the management system to change the parameters and structure of the regulator and the control subsystem as a whole, depending on changes in the internal parameters of the control object or the external environment (disturbances), as well as changes in strategic goals. The functional purpose of the URRAN system is the effective management of technical assets.

The purpose of the introduction of the URRAN system on the railway network – Improving the efficiency of railway transport on the basis of adaptive management of technical content in conditions of resource constraints. Each complex of objects of JSC "Russian Railways" has specific features that are due to the purpose of this complex in the transportation process, the conditions for the implementation of this purpose, as well as the established links with other complexes. Therefore, the goals of the URRAN system implementation for each complex are specific

Track complex: Reducing the cost of the life cycle of the track infrastructure due to the redistribution of resources, provided that the required level of operational reliability and acceptable level of train safety is ensured.

The complex of automation and telemechanics facilities: Improving the operational reliability of railway automation and telemechanics systems while ensuring an acceptable level of train delay and a predictable life cycle cost based on the redistribution of resources..

Complex of Transenergo (electrification and power supply) facilities: Increasing the life cycle of electrification and power supply systems based on risk assessment, provided that the required level of operational reliability and acceptable level of train safety is ensured.

The complex of railway telecommunication facilities: Reducing the cost of the life cycle of railway telecommunication systems by increasing the efficiency of resource management based on improving the technology of operation of telecommunication networks while ensuring the required safety and reliability indicators in the provision of telecommunication services.

Locomotive complex: Reducing the cost of the life cycle of a locomotive by increasing the efficiency of resource use, provided that the required level of operational reliability and an acceptable level of train safety are ensured.

Motor car rolling stock (MVPS): Reducing the cost of the life cycle of the MVPS due to the efficient allocation of resources while ensuring an acceptable level of traffic safety and maintaining the requirements of passenger comfort.

Asset management involves finding a balance between costs, opportunities, risks and the required performance of assets. Violation of this balance leads to unjustified costs or unacceptable risks of violating the safety of the transportation process. Achieving this balance is realistic when implementing Asset Ownership Planning **(PSV)**. This is nothing more than Results-based Management **(RBM).** This maintenance and repair strategy is based on risk, revenue, and cost management at all stages of the asset lifecycle. At the same time, effective investment decisions on the long-term horizon, investments in the development of technical personnel and information systems are envisaged.

The URRAN system is conceived and implemented as a deeply layered PSV system at the level of complexes of facilities, directorates and structural divisions. It is complemented by adaptive control technology, which expands the ability and ability of the control system to change the parameters and even the structure of the regulator depending on changes in the conditions of the transportation process.

IV. Tasks of the URRAN system

To achieve the intended goals, the URRAN system is designed to solve the following tasks: - to assess and predict the reliability and safety indicators of infrastructure facilities and rolling stock in real time; - manage technical and technogenic risks;

- to assess the wear, residual resource and marginal condition of railway transpredict the state of infrastructure facilities. Predict dangerous failures of infrastructure and rolling stock; The task of predicting the condition of infrastructure facilities is one of the most costly and responsible tasks of managing their technical content. In the URRAN system, this task is solved both with the help of diagnostic complexes, and especially on the basis of Data Scensis technology with the help of artificial intelligence algorithms [7-12].
- to estimate the cost of the life cycle of railway transport facilities;
- evaluate the activities of the divisions of JSC "Russian Railways" taking into account their results of work to ensure the reliability and safety of operated facilities;
- manage resources aimed at technical maintenance; port facilities;
- on the basis of a single corporate platform **(*ECP) URRAN*** to provide support for management decisions. The task of providing support for management decisions based on the unified corporate platform of the *URRAN ECP* is a large-scale work on the informatization of the processes of collecting, analyzing, processing and investigating events and decision support **(***DSS***)** for the heads of enterprises, railways, Directorates, Management of JSC "Russian Railways". The *URRAN ECP* system is formed in the form of a four-layer architecture. The lower layer is data sources (automated systems of JSC "Russian Railways".). The second layer is the integration layer, which contains data integration modules. The third layer is data warehouses. It includes databases, aggregating functions and a computational pipeline for data aggregation. The fourth is the central layer. this is the analytics layer that implements the methodology of the URRAN system.

The task of risk management within the URRAN system is aimed at solving problems:

- ensuring the safety and reliability of the transportation process;
- ensuring the safety of professional activities related to the technical maintenance of railway transport facilities;
- ensuring fire safety;
- rational allocation of resources to ensure acceptable levels of safety of the transportation process and reliability of transport facilities

V. Principles of risk management and features of risk assessment in the management system of technical assets in railway transport

Principles of risk management. The task of risk management within the URRAN system also includes minimizing the risks of pedestrian injuries at pedestrian crossings. This report focuses on the conceptual provisions of risk management in the URRAN system. There are many accents in the definitions of risk [13]. Most of them concentrate either on taking into account the impact of uncertainty on goals (ISO 31000), or on a combination of probability and severity of consequences (harm) (IEC 62278). The definition of the IEC 62278 standard has been adopted in railway transport [14]. This circumstance predetermined the application of the principles of MEM, GAMAB, ALARP for risk management.

The principle of MEM (Minimum endogenous mortality) is as follows: *"the threat associated with the new system should not increase the minimum endogenous mortality rate for an individual*."

The principle of GAMAB (Globalement Au Moins Aussi Bon (France) is generally at least the same): "*All new managed transport systems should generally have a degree of risk at least the same as an equivalent existing system."* This formulation takes into account what has been achieved and implies the need to improve the designed system through the requirement "at least". It does not consider a certain type of risk, as indicated by the words "in general". Suppliers of infrastructure and rolling stock are free to choose between different types of risk inherent in the infrastructure and rolling stock, and apply the appropriate approach, i.e. qualitative or quantitative.

The principle of ALARP (As Low As Reasonably Practical: *"The risk is as low as it is practically reasonable"*) . An acceptable level of risk , according to the ALARP principle, is a level of risk for which the costs of achieving it are cost–effective. This principle is the basis for risk management in the URRAN system. The essence of the ALARP principle is as follows. In relation to individual risk, three zones are distinguished: 1. The zone of unacceptable risk, when the risk must be reduced for any cost - some risks are so great, and the consequences are so unacceptable that they are unacceptable and cannot be justified in any case. The upper bound defines the risk levels that are unacceptable. If the risk level cannot be lowered below this limit, then the risk should be excluded; 2. The zone of negligible risk - no risk reduction measures are required; 3. The ALARP zone - this zone between the upper and lower boundaries is called the ALARP area.

There are various ways to apply the ALARP principle. In some cases, it is sufficient to indicate that the best of the available modern standards and practical developments have been used. In the case of new types of activities or when the adequacy of modern standards and practical developments is in doubt, the concept of cost-benefit analysis is used. The content of this concept is as follows. If the risk of an object is located in the ALARP zone and its reduction is impossible, or the costs of reducing it are clearly not commensurate with the expected benefits, then such a risk is undesirable, but nevertheless allowed. Here the final word remains with the operating organization. The lower part of the ALARP area corresponds to a situation when the disparity between costs and benefits does not exceed the specified value for the risk reduction measure under consideration. In these cases, funds should be spent on risk reduction. This risk is commonly called acceptable. The results of cost-benefit analysis often depend on how the consequences of a dangerous event are assessed (for example, the value of human life or prevented mortality). A demonstration of the use of the ALARP principle is given by us in GOST 33433-2015 [15].

Risk management in the URRAN system is carried out according to the standard scheme of the following steps: 1.Stage of risk assessment: definition of the scope of risk analysis; identification of risk; assessment of the magnitude of risk; analysis of consequences; determination of the permissible level of risk. 2. Stage of risk assessment and processing (risk assessment (or comparison); risk processing :risk prevention, risk transfer, risk reduction, risk acceptance. 3. Stage of risk monitoring and revision: risk monitoring, risk revision.

The risk matrix. The presentation of the results of risk assessment is most often carried out using a risk matrix. The risk matrix is a modified form of the risk graph and allows you to display risk levels in the frequency-consequences coordinates, set both qualitatively and quantitatively. Since the risk level R is expressed by the product of the frequency f of the occurrence of an undesirable event and its specific damage C, the scales of the frequency scale and the scale of consequences on the risk graph should be logarithmic. This ensures that the hyperbolic dependencies $f = R/C$ (R = const) are displayed in the "frequency-consequences" coordinates in the form of straight lines and allows you to move from the risk graph to the risk matrix with the least significant loss of accuracy. If a straight line $f = R_{acceptable}/C$ is given, where $R_{acceptable}$ is the established acceptable risk level, then all points lying below this straight line will correspond to a risk level less than acceptable, and those above this straight line will correspond to a risk level more acceptable.

For practical use, as a rule, several interval ranges are set for risk assessment in several categories. The first task in constructing the risk matrix is to select the parameters of the risk scale. This problem was solved in [15-19 et al.]. Since quantitative risk assessment is of the greatest interest, such parameters will be: - the number of estimated intervals of the risk scale; - sensitivity of the risk scale, expressed by the relative step K of the risk scale; - binding value – the absolute value of the risk corresponding to a given point on the risk scale; usually the value of $R_{accrptable}$ is set at the point of the scale corresponding to the permissible level of risk. As a rule, the number of risk intervals (categories) is set for a wide range of risks and is not subject to change in the process of constructing risk matrices. For all the risks under consideration, a risk scale is adopted, which has 4 estimated intervals of risk values, colored in appropriate colors: *unacceptable* - ***red*** , *undesirable* - ***orange*** ; *acceptable* - ***yellow*** ; *not taken into account* - ***green***

The binding value is uniquely determined by the acceptable risk level, which is set for each type of risk, or by two ALARP levels (acceptable and negligible risk levels), which are also set for each type of risk. The choice of risk scale parameters, frequency scales and consequences is described in detail in [19].

Integral risk. A measure of the security of a system object can be the magnitude of its risk, which is based on the risks of the composite factors (elements) of the object. The need to determine the integral risk of the object and the system is as follows. Summing up the risks of all elements is not acceptable, because, for example, they may have different dimensions (the number of deaths over a certain time is a social risk or the cost of losses is an economic risk). We need another methodological tool that is able to transform various security measures of objects (elements) to some single integral measure of the system. Similar tasks arise in medicine, the food industry, transport, etc.[20] .

Let system A consist in the general case of a finite set of elements of different types $A=\{a_1, a_2,..., a_i,...a_j,..., a_k\}$. At the same time , the possibility of equivalence between the individual constituent elements is not excluded $a_i \Leftrightarrow a_j$. The safe operation of each element of the system is assessed by a certain amount of risk $a_i \rightarrow R_i$. Risks are formalized using the risk matrix tool. In general, the risk matrix contains m rows and n columns. Each line corresponds to a certain frequency of occurrence of a dangerous event $f_1, f_2,..., f_m$. The columns correspond to possible damages $c_1, c_2,..., c_n$. The extent of the damage depends on the object of the study. This may be the price (relative to economic, technical or man-made risks), the lethal outcome in relation to social risks, the number of negative events due to a dangerous event (relative to moral risks), etc. It is assumed that the frequency of occurrence of dangerous events and damages from them are estimated according to a posteriori data. This makes it possible to determine the security risks of all system elements at the intersection of the corresponding rows and columns.The risks of elements of different types are not equal to each other, for example $R_1 \neq R_i$ (equivalent elements have equal risks $R_i = R_j$). The task is to assess the risk level of the system based on the results of risk assessment of composite elements of different types. It is assumed that the risks of the system elements are mutually independent.

In many cases, the system under study consists of different types of objects that differ in damage scales and types of risks (for example, technological or social). Now it is impossible to summarize the risks of composite objects, as well as it is impossible to form a general scale of damage. To assess the risk of a system based on the totality of risks of composite elements of different types, it is necessary to have at least one common measure for all risks. If we consider the risks with respect to the measurement scales f and c, then this general measure is missing. The measure of damage may be different. This also applies to the frequency of occurrence of dangerous events, which elements and can vary many times. However, upon careful consideration of the constructed risk matrices of the system elements, we find a general measure of risk assessment, which, If we consider the risks relative to the measurement scales *f* and *c*, then this general measure is missing. The measure of damage may be different. This also applies to the frequency of occurrence of dangerous events, which elements a_i and a_j can vary many times. However, with careful consideration of the constructed risk matrices of the system elements. we find a general measure of risk assessment, which is contained in the decision-making levels. In accordance with the ALARP principle, there are four levels of risk hazards in total. The common field for combining the results is the decision colors (risk levels) for each of the objects. In order of increasing their importance, these levels are displayed in green, yellow, orange and, finally, red. The green color of the decision means that the risk is so insignificant that it may not be taken into account. The significance function in the green cells of the matrix should have small values (from zero to some insignificant value). At the same time, orange, especially red, means the highest degree of danger and the significance function in these matrix cells should have the highest possible values. There are three possible strategies for constructing the significance functions of the risk level decision in accordance with the accepted colors: 1. Linear 2. Power 3. Logarithmic. Strategy 2 corresponds to a responsible attitude to changing the significance of the color of the decision. Strategy 3 of constructing the significance function should be considered as an irresponsible attitude to the decision made about the level of risk of the object, since in this case the significance function levels the degree of danger of the red color, which reflects an unacceptable level of risk. Thus, it is advisable to use a power function to digitize the results of the risk assessment of objects expressed in one of the four specified colors. Step functions with a base $1 \leq a < 2$ do not provide high sensitivity to changes in the significance of the color of the solution, especially in the area of high risk levels. At the same time, based on $a > 2$, there is an unjustifiably high sensitivity to an undesirable and especially unacceptable level of risk and practically neglect of the significance of the permissible level of risk.

A compromise solution consists in choosing the basis of a 2-step function of the significance of the colors of decisions about the level of risk. The procedure for calculating the color weight and, on this basis, the integral risk assessment are given in [20]. Within the framework of the URRAN system, technical asset management tasks have been implemented based on risk assessment of infrastructure facilities and rolling stock complexes [21,22, etc.], a digital risk management platform has been created [23].

An example of calculating the integral risk and making decisions based on it can be the process of managing the technical content of a section of the track. The cost of maintenance costs for the facilities of the track complex reaches 80% of the cost of maintenance costs for all infrastructure facilities. For this reason, the implementation of rational management of the technical content of the facilities of the track complex is of great practical importance .based on a risk assessment.

VI. Example of managing the technical content of a section of track based on risk assessment

An example of calculating the integral risk and making decisions based on it can be the process of managing the technical content of a section of the track. The cost of maintenance costs for the facilities of the track complex reaches 80% of the cost of maintenance costs for all infrastructure facilities. For this reasons , the implementation of rational management of the technical content of the facilities of the track complex is of great practical importance .based on a risk assessment. The management process consists of the following procedures: 1. Choosing the distance of the path (IF) and the stage and dividing the stage into sections of the path. 2. Determination of the actual tonnage missed. 3. Comparison of the value of the actual missed tonnage with the standard value, then calculation of operational reliability indicators [24-27, etc.] and . calculation of technical indicators characterizing the residual resource based on the Sedyakin principle [28]. 4. Comparison of calculated values of indicators characterizing the residual resource, as well as calculation of indicators of operational reliability of the track object under the condition. when the operating time of the object before the required repair is less than or equal to the predicted time (all calculations are automatically done in the Unified Corporate Platform of the URRAN Track Complex (ECP URRAN P). 5. Comparison of indicators of operational reliability of the object under the condition of its overhaul (CR) or reconstruction. Calculation of economic indicators of the assessed object.6. Assessment of current repairs according to the criteria for making decisions on the appointment of repairs (.medium, lifting, planned preventive (alignment of the path)). 7 Integral assessment of the sections of the path according to the selected type of current repair. In accordance with the integral assessment, the preliminary ranking of the evaluated sections of the stage path within each of the types of repairs is carried out by priority. 8. Comparison of the values of economic indicators with normative ones. 9. Comparison of operational reliability indicators with normative ones. 10. Integral assessment (ranking) of sections of the road for capital repairs and reconstruction.

An example of ranking a section of the path based on an integral risk assessment is given in Table.1. On the basis of the constructed risk matrices, an integral risk matrix is formed for the list of plots and on the basis of an integral assessment, each plot is assigned priority for its inclusion in the title of the major repair of the track. In the example shown in the integral matrix of security risks in the plots of the put1.2,3....,M, the most priority is plot 2 (its integral risk is assessed as "unacceptable"). This section is ranked at number 1. The next in the ranking is determined by plot 1. Then plot 3, etc Similar management of the technical content of railway transport facilities .it is carried out in the locomotive complex, MVPS, in the complex of automation and telemechanics facilities, communications, electrification and power supply, etc.

Table 1: *Integral risk assessment of the section of the track.*

Risk factors	Plot 1	Plot 2	Plot 3 …	Plot M
Defectiveness of the roadbed	**0,13**	**0,53**	**0,13**	**0,07**
Single output of acutely defective rails	**0,53**	**0,13**	**0,13**	**0,07**
Output of defective rails	**0,07**	**0,27**	**0,07**	**0,13**
Number of defective fasteners , %	**0,13**	**0,27**	**0,27**	**0,07**
Number of sleepers with splashes , %	**0,27**	**0,53**	**0,13**	**0,07**
Number of unusable wooden sleepers , %	**0,27**	**0,13**	**0,07**	**0,07**
The given number of temporary recovery locations	**0,07**	**0,53**	**0,13**	**0,07**
total	**0,45**	**0,64**	**0,25**	**0,14**
Priority of the plot	**2**	**1**	**3**	**3**

VII. Fire risk management

Fire safety management of both stationary and mobile railway transport facilities covers all stages of the life cycle from design to decommissioning. At the same time, JSC "Russian Railways" must simultaneously provide fire safety for more than 14,000 locomotives, as well as hundreds of stationary facilities that employ more than 300 thousand people. This problem is solved with the help of an automated fire risk management system, which is part of the URRAN system. It allows, based on the results of the fire risk forecast, to make a decision on the need for repair, replacement or maintenance of transport facilities and their fire safety system.

Two blocks of methodological risk assessment tools have been identified. The first block operates with fire statistics. Its purpose is to assess the a posteriori probabilities of a fire on stationary and mobile transport facilities. The peculiarity of estimating the probability of fires (based on fire statistics) is that objects of each type are divided into groups on a regional basis. The operating conditions of the objects in the groups differ in such parameters as maximum and minimum ambient temperature, repair quality, traffic intensity, etc. All these factors can influence the sets of elementary outcomes that favor the "fire" event. There are questions about the belonging of samples (groups) to one general population and the need to assess the probability of a fire at transport facilities, taking into account the belonging of a particular group of objects. To answer these questions, hypotheses about the equality of sample characteristics are tested using well-known criteria, for example, Pearson or Kolmogorov-Smirnov. It is established that locomotives with similar design characteristics, but differing in performance, may belong to different general aggregates (for example, diesel locomotives 2TE10 and 3TE10).Based on the calculated values of fire probabilities and known levels of fire consequences, a risk matrix of transport facilities is built; groups of objects forming undesirable or unacceptable risk levels are identified.

The second data processing unit on fire safety conditions uses as initial information the results of diagnosing malfunctions of objects that lead to an increase in fire danger. For such objects, sequences of events leading to the appearance of a fire are simulated. The decision on the priority of measures to ensure the fire safety of facilities should be made on the basis of an assessment of the danger of the totality of the identified conditions. Indicators of fire danger are: the probability of a fire, the time before the appearance of a dangerous condition. To assess these indicators, a model is being built, with the help of which it is possible to imagine the process of getting into a state of fire danger of a transport object. The key characteristic of fire danger is the probability of a fire, i.e. the probability of falling from the actual non-dangerous state to the specified dangerous state of the model. The theoretical solution of this problem is given in [29]. For a priori assessment of this probability, it is provided to diagnose the actual state of serviceability of the object and assess the possibility of such a malfunction, as a result of which the object falls into a fire-hazardous state. This procedure is called a fire safety audit. In accordance with [30], fire safety audit is divided into the following types: declarative audit, repeated audit, supervisory audit. The declaration audit is the primary fire audit. In case of successful completion of the declarative audit, the declaration of fire safety of the object is carried out. A re-audit of the fire safety of the facility is carried out in case of failure or unsatisfactory results of passing the declarative audit of fire safety.

Based on statistical information about fires, fires, violations of fire safety requirements, scenarios of typical fire-hazardous events and the conditions of objects preceding them have been developed. According to these scenarios, classifiers of fire-hazardous conditions have been developed. The classification of fire-hazardous conditions also makes it possible to identify significant violations of fire safety requirements (SR) characteristic of objects. Using classifiers of SR violations and fire-hazardous conditions, experts diagnose fire-hazardous conditions (fire safety audit) of objects. The fire safety audit is based on the analysis of initial information about the fire hazard conditions of objects and the processing of expert opinions on the severity of possible consequences. The need for the work of experts is caused, among other things, by the fact that a significant part of the data on fire danger states is non-numeric. As a result of the audit, either a set of fire-hazardous conditions of the object is formed or a set of violations of fire safety requirements (the choice of approach depends on the complexity of the formation of one or another set). A set of states or events are sufficient information to estimate the a priori probability of a fire at an object.

When assessing fire risks at stationary facilities, in particular at railway stations, the consequences expressed in the minimum wage (minimum wage) are considered. In the table.2. an example of test calculations of individual and collective fire risks at railway stations in Russian cities of federal significance is given.

From the table.2 it follows that the most prosperous situation with fire safety is observed at the stations of Samara, Chelyabinsk, Saratov, etc. However, as the test calculations show, the levels of fire and collective risks at the Yaroslavl, Novosibirsk and Kiev railway stations in Moscow are two orders of magnitude higher than the risks at safe stations. This circumstance requires special attention to ensuring the fire safety of these stations.

Table 2: *Fire risks at railway stations in Russian cities*

Railway station	Fire risk	Collective (social) risk
Samara	10 -6	4*10 -6
Belarusian	10 -6	5.3*10 -6
Saratov	10 -6	4*10 -6
Kaliningrad - Yuzhny	10 -6	5.3*10 -6
Rostov – the main	4*10 -6	1.6*10 -5
Chelyabinsk	10 -6	4*10 -6
Yaroslav	10^{-4}	5.4*10 -4
Krasnoyarsk	5.5*10 -7	2.2*10 -6
Novosibirsk	1.1*10 -4	5.5*10 -4
Kiev	1.1*10 -4	4.4*10 -4
Moscow	5*10 -6	2.5*10 -5
Leningrad	5*10 -6	2.5*10 -5
Kazan	10 -6	5.2*10 -6

VIII. Conclusion

Risk assessment is a key element of managing technical assets at all stages of their life cycle. At the same time, efforts in railway transport are mainly focused on technical, technological, professional, fire and environmental risks. Since asset management includes their acquisition, maintenance, modification, modernization and disposal, insurance risks should also be taken into account. In general, the management of technical assets based on risk assessment makes it possible to find the most balanced solutions and significantly reduce the costs of maintenance of transport facilities while ensuring acceptable levels of their reliability and safety. It has been established that the quality of decision-making, and consequently the economic efficiency of its results, can be significantly improved by using artificial intelligence methods to predict, in particular, dangerous failures of infrastructure facilities and rolling stock.

The problem of asset management based on risk assessment is under development, it requires a lot of attention from scientists and practitioners.

References

[1] ISO 55001:2014. Asset management — Management systems — Requirements

[2] Iorsh V.I. Asset management in accordance with ISO standards // Quality management. – 2015. – № 5.

[3] Shubinsky I.B., Zamyshlyaev A.M. The main scientific and practical results of the development of the URRAN system// Railway transport No. 10, -2012. – pp.23-28

[4] Zamyshlyaev A.M., Shubinsky I.B. Development of the URRAN project – building a system for managing technical assets // Railway transport, - 2019. No. 12. – pp. 19-27.

[5] Shubinsky I.B., Zamyshlyaev A.M. Methods of managing technical assets of Russian railways. –M.: Ed. Russian Academy of Sciences, 2021, 233c.

[6] Shubinsky I.B. and ZamyshlaevA.M.: Technical Asset Management for Railway Transport.- London, publ.Springer, 2022, 226p 978-3-030-90028-1

[7] Serrada M. Diagnostics of malfunctions of cylindrical gears based on a genetic algorithm and a random forest / Serrada M., Zurita G., Cabrera D., Sanchez R.V., Artes M., Lee S. // Mechanics. System. Signaling process. . – V. 70-71. . – 2016. . – Pp. 87-103.

[8] Santur Yu. An approach to diagnostics based on a random forest for checking rail malfunctions on railways / Santur Yu., Karakose M., Akin E. // National Conference on Electrical Engineering, Electronics and Biomedical Engineering. – 2016. – pp. 714-719.

[9] Jiang Yu. Rapid classification of rail defect depths using a hybrid intelligent method / Jiang Yu., Wang H., Tian G., Yi K., Zhao J., Zhen K. // Optik (Stuttgart). – Vol. 180. – 2019. – pp. 455-468

[10] Shubinsky I.B., Zamyshlyaev A.M., Pronevich O.B., Ignatov A.N., Platonov E.N. Application of machine learning methods for predicting dangerous failures of railway track objects. //Reliability. 2020;20(2):43-53. https://doi.org/10.21683/1729-2646-2

[11] Zamyshlyaev A.M., Shubinsky I.B. Application of artificial intelligence algorithms in predicting dangerous events in the track complex //Rail transport.-2020.-No.12.-pp.38-44

[12] Shubinsky I.B., Pronevich O.B. Methods of data mining for predicting dangerous events//Rail transport.-2021.-No.12.-pp.57-60

[13] Madera A.G. Risks and chances: uncertainty, forecasting and evaluation. Moscow: URSS. 2014. 448 p. ISBN 978-5-396-00952-3.

[14] IEC 62278:2002 Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS).

[15] GOST 33433-2015 Functional safety. Risk management in railway transport

[16] Cox L. A. Jr., Huber W. Optimal design of qualitative risk matrices to classify binary quantitative risks [abstract] // Proceedings of the Annual Meeting of the Society of Risk Analysis. Boston, December 7-10, 2008.

[17] Pickering A., Cowley S.P. Risk matrices: implied accuracy and false assumptions // Journal of Health & Safety Research & Practice. - Volume 2, issue 1. October 2010.

[18] Gapanovich V.A., Shubinsky I.B., Zamyshlyaev A.M. Construction and use of risk matrices in the risk management system in railway transport // Reliability, - 2011. - No. 4. – pp.56-68.

[19] Novozhilov E.O. The principle of building risk matrices// Reliability. -2015.No.3.-pp.73-86. https://doi.org/10.21683/1729-2646-2015-0-3-73-86

[20] In Gapanovich.A., And Shubinsky.B., And Zamyshlyaev.M. Method of risk assessment of a system of different types of elements, //Reliability. 2016;16(2):https://doi.org/10.21683/1729-2646-2016-16-2-49-53 49-53

[21] Gapanovich V.A., I. B. Shubinsky, I. N. Rosenberg and A.M. Zamyshlyaev Risk assessment related to the functioning of railway telecommunications // International Journal of System Engineering and Management, Springer- 2019. pp. 1-10, DOI 10.1007/s 13198-019-00909-3

[22] Shubinsky I.B., Zamyshlyaev A.M., Ignatov A.N., Kibzun A.I., Novozhilov E.O. Methodology for determining zones of (not) permissible values of factors to reduce the risk of derailment of freight train cars due to a side frame fracture, //Reliability.2019;19(3):40-46. https://doi.org/10.21683/1729-2646-2019-19-3-40-46

[23] Shubinsky I.B., Zamyshlyaev A.M. Digital risk management platform for traffic safety//Automation, communications, computer science.-2021,- No. 2.-p.10-15

[24] Reliability of technical systems: Handbook [Text] / Yu.K.Belyaev [et al.]; edited by I.A. Ushakov. – M.: Radio and Communications, 1985. – 608p.

[25] Kumar, S. Reliability Analysis and Cost Modeling of Degrading Systems, Division of Operation and Maintenance Engineering, Luleå University of Technology, 2008.

[26] Shubinsky I.B. Structural reliability of information systems. Methods of analysis [Text] / I.B. Shubinsky.- M.: Journal Reliability, 2012. 212p.

[27] Shubinsky I.B., Novozhilov E.O. Method of rationing reliability indicators of railway transport facilities // Reliability, 2019, 19(4), pp.16-23

[28] Sedyakin N.M. On one physical principle of the theory of reliability and some of its applications. L.: LVIKA named after A.F. Mozhaisky, 1965. 41 p.

[29] Shubinsky I.B., Zamyshlyaev A.M., Pronevich O.B. Graph method of industrial safety assessment at railway transport facilities. //Reliability. 2017; 17(1): 40-45. https://doi.org/10.21683/1729-2646-2017-17-1-40-45

[30] Pronevich O.B., Shubinsky I.B. Automated system for predicting fire safety of railway transport facilities based on risk assessment, // Reliability. 2019; 19(1): 48-54. https://doi.org/

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ENTROPHY APPROACH TO ASSESSING REDUCTION OF LIFE EXPECTANCY AT BIRTH DUE TO THE IMPACT OF NEGATIVE ENVIRONMENTAL FACTORS

Anna Bushinskaya[1,2], Sviatoslav Timashev[1,2]

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[1] Science and Engineering Center "Reliability and Safety of Large Systems and Machines", Ural Branch, Russian Academy of Sciences, Russia

[2] Ural Federal University, Russia

bushinskaya@gmail.com

timashevs@gmail.com

Abstract

The paper presents a method for estimating the population entropy, which assesses the impact of an increase in the intensity of mortality (caused by negative environmental factors or sudden death of people in a man-made accident or catastrophe) on the average life expectancy (ALE) at birth. The method is based on the use of the Gompertz-Makeham law.

Keywords: Keyfitz entropy, population entropy, life expectancy, mortality rate, mortality intensity, ecological risk.

I. Introduction

Life expectancy of the population is an indicator of the quality of health care system, *and* also *of* the conditions of human life. The authorities of the constituent entities were tasked according to the Decree of the President of the Russian Federation of May 7, 2018 No. 204, with achieving the following targets by 2024: increasing the life expectancy of the population to 78 years; reducing mortality rates due to health problems of the circulatory system (down to 450 cases per 100 thousand of the population), and neoplasms, including malignant ones (down to 185 cases per 100 thousand of the population).

An analysis of the dynamics of the population of the Sverdlovsk Oblast affected by negative environmental factors (soil, water, and atmospheric pollution) has revealed an alarming trend of its decline in recent years [1].

The assimilation potential of the environment - its ability to level the negative impacts of economic activity, especially in urban subjects with a high population density and expanding transportation system is decreasing over time [2]. When exposed to a complex of chemical factors of atmospheric air pollution, traffic noise, negative lifestyle factors, an unacceptable risk to human health is formed by the age of 47 years, and a high risk - by the age of 58 [3]. This is primarily due to the age-related decrease in body's ability to adapt to changing environmental conditions [4]. The report of the World Health Organization concluded that environmental risks cause the greatest damage to young children under five years of age and the elderly at age 50-75 years [5].

According to the analysis [1], the total influence of the environmental factors explains 87% of the variation in the average life expectancy ALE of the population.

II. Loading model of ecological risk

The aggravation of the ecological situation, due to the increasing scale of environmental pollution, has long put forward the priority task of developing reliable methods for predicting possible consequences of the impact of various physical and chemical factors on humans and wildlife. Its relevance came to light with force after major environmental disasters of recent times, and especially after the accident at the Chernobyl nuclear power plant.

In experiments on the dynamics of mortality in mammals, as a rule, three statistical biometric functions are measured [4]: the probability of lifespan (the survival function) $S(t)$, the probability density of lifespan $f(t)$, and the mortality rate (intensity) MR $\lambda(t)$. The latter function is also called the intensity or strength of mortality. The function $S(t)$ determines the ratio of the number of individuals $n(t)$, who survived to the age t , to their initial number N : $S(t)=n(t)/N$. The biometric function $f(t)$ characterizes the rate of decrease in the number of individuals because of death at age t, related to their initial number: $f(t)=-\frac{dn(t)}{dt}\Big/N$. Function $\lambda(t)$ describes the rate of decrease in the number of individuals as a result of death at age t, divided by the number of individuals that survived to age t : $\lambda(t)=-\frac{dn(t)}{dt}\Big/n(t)$. The biometric functions probability density $f(t)$ and probability $S(t)$ of lifespan are related to the mortality rate MR function $\lambda(t)$ by the following relations:

$$\lambda(t)=\frac{f(t)}{S(t)},\qquad S(t)=\exp\left(-\int_0^t\lambda(u)\,du\right). \tag{1}$$

By definition, the MR $\lambda(x)$ (synonym to the mortality intensity MI) is the probability of death occurring during an infinitely small interval at age x , divided by the duration of this interval

$$\lambda(t)=-\frac{1}{S(t)}\frac{dS}{dt}, \tag{2}$$

The main pattern revealed by published data on animal and human deaths is the exponential or close to it increase of $\lambda(x)$ with age in sexually mature individuals. This pattern, first noticed by B. Gomperz in the study of the human lifespan [5], was subsequently confirmed in many biological species that differ greatly in anatomic and physiological characteristics, conditions and lifespan. Gomperz's law of mortality

$$\lambda(t)=\lambda(t_0)e^{\alpha_0(t-t_0)}, \tag{3}$$

where $\lambda(t)$ is the mortality intensity MI at age t; $\lambda(t_0)$ is the initial mortality rate (its inverse value $\lambda^{-1}(t_0)$ characterizes the initial level of "viability"); α_0 is the rate of increase in mortality with age or the intensity of deterioration of viability (in other words, the rate of aging, which reflects the rate of increase in mortality with age).

B. Gompertz considered mortality as an inverse value to viability - the ability to withstand the totality of destructive processes.

Gompertz also suggested that the rate of decline in vitality over time decreases in proportion to itself. For mortality (the inverse of viability), this assumption corresponds to an exponential increase with age. He also assumed that along with mortality, which grows exponentially with age, there is a component of mortality that does not depend on age, that is, death is a consequence of two causes [6]: 1) random - without a previous predisposition to death or physical wear and tear; 2) wear or increased inability to resist fracture.

In other words, along with an exponentially growing component of mortality due to aging, there must be an age-independent component associated with extreme situations.

In 1860, W. Makeham-- another specialist in life insurance, added an age-independent term [7] to the Gompertz formula, which was called the Makeham parameter. Thus, the Gompertz-Makeham law (G-M) appeared:

$$\lambda(t) = M + \lambda(t_0) e^{\alpha_0 (t-t_0)}, \tag{4}$$

where M is the Makeham's coefficient characterizing the contribution to mortality of exposures, the effect of which does not depend on age (accidental mortality).

Makeham's law is most suitable for studying the process of human mortality, since it takes into account that for small ages accidents play a predominant role in mortality, and with increasing age their role weakens. The model best describes the dynamics of human mortality in the age range of 20–80 years. In the older age domain, mortality does not increase as rapidly as this law of mortality provides. Historically, human mortality prior to the 1950s was largely due to the time-independent component of the law of mortality (the Makeham's parameter), while the age-dependent component (Gompertz) remained almost unchanged. After the 1950s, the picture changed, leading to a decline in late-life mortality and a flattening of the survival curve.

In protected environments where there are no external causes of death (in laboratory conditions, in zoos, or for people in developed countries), the age-independent component often becomes small, and formula (4) simplifies to the Gompertz function (3).

Below is a mathematical load model of radiation risk, originally developed and used to calculate and normalize the radiation risk during space flights [8-12]. This model, in fact, is not specifically about radiation, *it is based on general assumptions that do not impose fundamental restrictions on either the type of influencing factor, the mode and intensity of exposure, or the biological species.* Therefore, it can be extended to other chemicals and physical factors present in the environment, in addition to the radiation load [4].

It seems very problematic to establish a direct quantitative dependence of the probability of death of an individual on indicators of the state of body systems and tissues under the influence of adverse environmental factors at a level admissible according to modern standards. Therefore, it is necessary to have a nonspecific (with respect to ionizing radiation) connection between the mathematical model of the age dependence of the MI and mathematical models of negative environmental effects (including radiobiological ones). This connection is carried out with the help of an auxiliary function - the load intensity [9, 11, 12].

Consider a homogeneous population of adults under certain given conditions. Factors of the external and internal environment form the load on a living organism, which manifests itself in the form of local or generalized deviations from the norm of the anatomic and physiological indicators of the organism state. As a result, some damage (defects) occur that reduce the reliability (viability) of the organism. Obviously, the aging of an organism with time (mortality rate) under the influence of adverse environmental factors (i.e., the accumulation of damage (defects) that reduce the organism viability) will depend only on the exponential component of the MR, since in this case the Makeham coefficient $M=0$.

The initial value through which the environmental risk and reduction of life expectancy are calculated, is the mortality intensity (MI). It is believed that at any age, the MI depends on both the load on the body and the state of the body itself. To describe the reliability of the body systems (the body state), a value $\rho(t)$ is introduced, as the probability of not overcoming a unitary load at age t under the influence of a harmful factor. It is assumed that the MI, i.e. the probability of dying per unit time at age *t*, having lived to this age, is equal to the product of the load $h(t)$ experienced by the body and the probability $\rho(t)$ that the body dies as a result of not overcoming the unit load [9, 11, 12]

$$\lambda(t) = h(t)\rho(t). \tag{5}$$

The generally recognized fundamental nature of the exponential (or almost exponential) growth of MI, applicable to all animals (of course, with their specific values of α_0), makes it appropriate to analyze the slope of the graph $\lambda(t)$ on a logarithmic scale, i.e., analyze the value:

$$\alpha(t) = \frac{d}{dt}\ln\lambda(t). \tag{6}$$

and dictates the need to model its dependence on the impact of harmful factors on human body.

In the proposed model, it is assumed that for weak impacts [12]

$$\alpha(t) = \alpha_0\frac{h(t)}{h(t_0)}, \tag{7}$$

If the load $h(t)$ is constant, i.e. $h(t) = h(t_0)$, we get the Gompertz model. When analyzing the role of a separate technogenic load (e.g.,, radiation), it is considered as additional and is designated as $\Delta h(x)$ (additional load component due to the impact of the considered harmful factor), i.e. the total load on the body $h(t) = h(t_0) + \Delta h(t)$. Then

$$\lambda(t,\Delta h) = \lambda(t_0)\exp\left(\alpha_0(t - t_0) + \alpha_0\int_{t_0}^{t}\frac{\Delta h(\tau)}{h(t_0)}d\tau\right), \tag{8}$$

i.e., MI increases by a factor of $\exp\left(\alpha_0\int_{t_0}^{t}\frac{\Delta h(\tau)}{h(t_0)}d\tau\right)$.

The value

$$\Delta t(t_0,t) = \int_{t_0}^{t}\frac{\Delta h(\tau)}{h(t_0)}d\tau\ , \tag{9}$$

is called *additional aging* due to the influence of the considered harmful factor. In this case, the result of exposure to some factor, such as ionizing radiation, is formally written as

$$\lambda(t,\Delta h) = \lambda(t_0)\exp\left(\alpha_0\left(t - t_0 + \Delta t(t_0,t)\right)\right). \tag{10}$$

The model proposed above gives an increase in MI, which is observed only with weak long-term impacts, while under acute impacts that cause partial death soon, MI sharply increases and then decreases. This issue is covered in detail in [9, 11, 12].

Next, consider how the change of MI parameters $\lambda(t_0)$, α_0 in the Gompertz model affects the ALE at birth. This problem is solved using the entropy approach.

III. Entropy approach in demography

Age at death is an undetermined random variable. In this context it is appropriate to quote Thomas Paine "*Nothing, they say is more certain than death, and nothing is more uncertain than the time of dying*". However, it is known that the risk of death depends on many factors: environment, age, gender, genetics, lifestyle, etc. This knowledge is obtained from the analysis of specific groups of people and the information obtained has to be presented in the form of life tables that give a complete description of mortality in the population under consideration. The statistics of mortality tables (survival) gives an idea of life expectancy depending on age-specific mortality rates.

However, the average person usually has no idea of the risk of death relative to her/his age, nor of the rate at which this risk increases as she/he grows older or the environment deteriorates. Various measures have been proposed to quantify the uncertainty of death, including the concept of entropy. The most common tool for this is the Keyfitz' entropy [13].

This entropy was proposed to measure the change in life expectancy, which is a normalized version of the Shannon entropy and can be interpreted as the "elasticity" of life expectancy with respect to changes in the MI.

The Keyfitz' entropy is used to quantify the impact of MRs on life expectancy. Higher entropy means that life expectancy is more sensitive to changes in MRs, and vice versa. This entropy is a measure of the sensitivity of life expectancy to changes in mortality.

Let the MI $\lambda(t)$ change (increase) proportionally for all ages by a constant value $\Delta > 0$, so that the *new mortality rate* $\lambda_\Delta(t) = (1+\Delta)\lambda(t) = \lambda(t) + \Delta\lambda(t)$. Then probability of survival at age t due to an increase in MI:

$$S_\Delta(t) = e^{-\int_0^t (1+\Delta)\lambda(u)du} = \left(e^{-\int_0^t \lambda(u)du} \right)^{(1+\Delta)} = S^{(1+\Delta)}(t). \quad (11)$$

The residual ALE at birth is determined by the formula

$$e_0 = \int_0^{+\infty} S(t)dt. \quad (12)$$

Then the ALE at birth $e_\Delta(0)$, due to an increase in the MI

$$e_0(\Delta) = \int_0^{+\infty} S^{1+\Delta}(t)dt. \quad (13)$$

Suppose that a relative increase in mortality causes a relative decrease in ALE at birth. Then, in order to measure this decrease , it is necessary to calculate

$$\frac{de_0(\Delta)}{d\Delta} = \int_0^{+\infty} \frac{dS^{1+\Delta}(t)}{d\Delta} dt = \int_0^{+\infty} S^{1+\Delta}(t) \ln S^{1+\Delta}(t) dt. \quad (14)$$

For sufficiently small Δ

$$\frac{de_0(\Delta)}{d\Delta} = \lim_{\Delta \to 0} \frac{e_0(\Delta) - e_0}{\Delta}. \quad (15)$$

Then

$$\frac{\Delta e_0}{e_0} \approx \Delta \left. \frac{de_0(\Delta)}{e_0 d\Delta} \right|_{\Delta=0} = \Delta \left(\frac{\int_0^{+\infty} S(t) \ln S(t) dt}{\int_0^{+\infty} S(t) dt} \right). \quad (16)$$

Since $0 \le S(t) \le 1$, the ratio in brackets in (16) is negative, which confirms the assumption that a relative increase in mortality should lead to a relative decrease in life expectancy.

Expression

$$H_K = \frac{-\int_0^{+\infty} S(t) \ln S(t) dt}{\int_0^{+\infty} S(t) dt} \quad (17)$$

is known as the *Keyfitz entropy or population entropy*.

In this way,

$$\frac{\Delta e_0}{e_0} \approx -H_K \Delta. \quad (18)$$

Expression (18) allows following interpretation for H_K [14]: a slight increase Δ in mortality in all age groups leads to a proportional decrease in life expectancy by about a H_K factor of Δ. For example, at $H_K = 0.5$ and when the MR in all age groups increases by 1%, life expectancy decreases by 0.5% [13]. Thus, H_K measures how a proportional change in the MI affects the relative change in the population life expectancy.

Consider the boundary values of the quantity H_K. If $H_K = 0$, then all mortality is concentrated at one age. If, for example, everyone lives to be 70 years old and then dies, then $S(t) = 1$ for all ages up to 70 years, and its logarithm will be zero. On the other hand, if mortality λ is the same for all ages, then

$$S(t) = e^{-\lambda t},\; e_0 = \frac{1}{\lambda}.$$

Hence

$$\frac{\Delta e_0}{e_0} \approx -\Delta,$$

i.e., $H = 1$ and a proportional change in the MI leads to the same quantitative change in life expectancy (but in the opposite direction). For example, at $H = 1$, when mortality in all age groups increases by 1%, life expectancy decreases by 1%. With $H = 0.5$, $S(t)$ will be a linear function.

On the other hand, having a change in ALE at birth, one can estimate the corresponding change Δ in the MI. Consider the relation [13]

$$g(\Delta) = \frac{e_0(\Delta)}{e_0} = \frac{\int_0^{+\infty} S^{1+\Delta}(t)\,dt}{\int_0^{+\infty} S(t)\,dt}, \tag{19}$$

as a function of Δ.

Expanding this ratio into a Taylor series,

$$g(\Delta) = g(0) + g'(0)\Delta, \tag{20}$$

and taking into account that $g'(0) = \frac{de_0(\Delta)}{e_0 d\Delta} = -H_K$, we get

$$\frac{e_0(\Delta)}{e_0} \approx 1 - H_K\Delta. \tag{21}$$

For example, if ALE at birth increases by 10%, and $H_K = 0.2$, then MR will decrease by 50%:

$$\frac{e_0(\Delta)}{e_0} = 1.10 = 1 - 0.2\Delta \;\Rightarrow\; \Delta = -0.50.$$

Thus, a population that has 10% more ALE at birth will have half the MR.

It should be noted that with a decrease in ALE at birth by 10%, the MI will increase by the same percentage, i.e. by 50%. Thus, with an increase or decrease in ALE, the MI will, respectively, decrease or increase by the same amount, but with the opposite sign.

Function

$$\Lambda(t) = -\ln S(t) = \int_0^t \lambda(u)\,du, \tag{22}$$

is called *the cumulative risk function* .

Now the Keyfitz entropy can be rewritten in terms of the cumulative risk function:

$$H_K = \frac{\int_0^{+\infty} S(t)\Lambda(t)dt}{\int_0^{+\infty} S(t)dt}. \tag{23}$$

The numerator $\int_0^{+\infty} S(t)\Delta(t)dt$ is equal *to the average number of years of life lost due to death.*

Rewrite the Gompertz-Makeham law model in the form:

$$\lambda(t) = M + \beta e^{\alpha t}. \tag{24}$$

It is not difficult to show that the Keyfitz entropy in this case [15]:

$$H_K = \frac{1}{\alpha}\left(\frac{1}{e_0} - (M+\beta)\right) + M\bar{t} = \frac{\bar{\lambda} - \lambda_0}{\alpha} + M\bar{t}, \tag{24}$$

where $\bar{\lambda} = \frac{1}{e_0}$ is the average MR of the stationary population; $\lambda_0 = M + \beta$ is the initial MR; $\bar{t}$ is the average age of the stationary population:

$$\bar{t} = \frac{1}{e_0}\int_0^{+\infty} tS(t)dt. \tag{25}$$

According to [16, 17], the Keifitz entropy can be represented as:

$$\begin{aligned} H_K &= \frac{-\int_0^{+\infty} S(t)\ln S(t)dt}{\int_0^{+\infty} S(t)dt} = \frac{-\int_0^{+\infty} \lambda(t)S(t)e(t)dt}{\int_0^{+\infty} S(t)dt} = \\ &= \frac{-\int_0^{+\infty} f(t)e(t)dt}{\int_0^{+\infty} S(t)dt} = -\frac{e^{\dagger}}{e_0}, \end{aligned} \tag{26}$$

where $e(t) = \frac{1}{S(t)}\int_t^{+\infty} S(\tau)d\tau$ is the ALE at age t.

Since $\int_0^{+\infty} f(t)dt = 1$, the value $e^{\dagger}$ can be considered as a weighted ALE at age t. In fact, it refers to the average number of years of future life lost due to observed deaths, or the average number of years that a person could live if he had a second chance at life. Considered as a measure of inequality in life expectancy.

IV. Impact of changes in mortality rates on life expectancy at birth

Consider a more general case. Assume that the MI $\lambda(t)$ at the age of t years increases due to the value Δ in such a way that following condition holds true:

$$\lim_{\Delta\to 0}\lambda(t,\Delta) = \lambda(t,0) = \lambda(t),\ \forall t. \tag{27}$$

where $\lambda(t,\Delta)$ is the new, perturbed MI.

As noted above, to calculate the relative decrease in ALE at birth, it is necessary to calculate

$$\frac{de_0(\Delta)}{d\Delta} = \lim_{\Delta\to 0}\frac{e_0(\Delta) - e_0}{\Delta}. \tag{28}$$

Expand the MR in a Taylor series using its first two terms:

$$\lambda(t,\Delta) \approx \lambda(t) + \Delta \frac{\partial \lambda}{\partial \Delta}(t,0). \tag{29}$$

Then

$$S(t,\Delta) \approx e^{-\int_0^t \lambda(u)du - \Delta \int_0^t \frac{\partial \lambda}{\partial \Delta}(u,0)du} = S(t) e^{-\Delta \int_0^t \frac{\partial \lambda}{\partial \Delta}(u,0)du}. \tag{30}$$

Applying the Taylor expansion to the exponent, we get

$$S(t,\Delta) \approx S(t)\left(1 - \Delta \int_0^t \frac{\partial \lambda}{\partial \Delta}(u,0)du\right). \tag{31}$$

Integrating this expression, we find a new ALE at birth

$$e_0(\Delta) \approx e_0 - \Delta \int_0^{+\infty} S(t) \int_0^t \frac{\partial \lambda}{\partial \Delta}(u,0)dudt. \tag{32}$$

Applying the method of integration by parts, we obtain

$$e_0(\Delta) \approx e_0 - \Delta \int_0^{+\infty} \frac{\partial \lambda}{\partial \Delta}(t,0)e(t)S(t)dt, \tag{33}$$

where following expressions were used: $\left(e(t)S(t)\right)' = -S(t)$; $\int_0^t \frac{\partial \lambda}{\partial \Delta}(u,0)du = \frac{\partial \lambda}{\partial \Delta}(t,0)$.

Then from (33) it follows that

$$\frac{de_0(\Delta)}{d\Delta} = \lim_{\Delta \to 0} \frac{e_0(\Delta) - e_0}{\Delta} = -\int_0^{+\infty} \frac{\partial \lambda}{\partial \Delta}(t,0)e(t)S(t)dt. \tag{3 4}$$

Consider how the value $\frac{de_0(\Delta)}{d\Delta}$ will change for various types of perturbations in the MI [18].

1. Additive growth: $\lambda(t,\Delta) = \lambda(t) + \Delta$. Then

$$\frac{de_0(\Delta)}{d\Delta} = -\int_0^{+\infty} e(t)S(t)dt = -\int_0^{+\infty} tS(t)dt = -\bar{t}e_0, \tag{35}$$

where $\bar{t}$ is the average age of the stationary population (see formula (25)); expression (35) is obtained by the method of integration by parts using equation $\left(e(t)S(t)\right)' = -S(t)$.

Thus, with an additive change in the intensity of mortality, the relative change in life expectancy at birth depends on two average values: the average age of the living (in a stationary population), and the unperturbed life expectancy, which is equivalent to the average age at death.

2. Proportional growth: $\lambda(t,\Delta) = (1+\Delta)\lambda(t)$. This case was considered above when describing the Keyfitz entropy, i.e.

$$\frac{de_0(\Delta)}{d\Delta} = -\int_0^{+\infty} \lambda(t)S(t)e(t)dt = -\int_0^{+\infty} f(t)e(t)dt = -e^{\dagger}. \tag{36}$$

Thus, if the perturbed MI at each age increases in proportion to the unperturbed intensity, then the relative change in life expectancy is associated with inequality in life expectancy, which is measured by the average number of years of future life $e^{\dagger}$ lost due to observed deaths.

3. Linear growth: $\lambda(t,\Delta) = \lambda(t) + \Delta t$. In this case:

$$\frac{de_0(\Delta)}{d\Delta} = -\int_0^{+\infty} tS(t)e(t)dt = -e_0\left(Cov_S(t,e) + \bar{t}^2\right), \tag{37}$$

where $\bar{t}$ is the mean age of the stationary population and the covariance

$$Cov_w(u,v)=\frac{\int_0^{+\infty}u(t)v(t)w(t)dt}{\int_0^{+\infty}w(t)dt}-\frac{\int_0^{+\infty}u(t)w(t)dt}{\int_0^{+\infty}w(t)dt}\cdot\frac{\int_0^{+\infty}v(t)w(t)dt}{\int_0^{+\infty}w(t)dt}.$$

Since linear growth, in contrast to additive growth, has a different effect on mortality at each age, the change in life expectancy depends not only on the value $\overline{t}$ (as with additive growth), but also on covariance, which reflects the age heterogeneity of the perturbed MR.

4. Exponential growth: $\lambda(t,\Delta)=\lambda(t)e^{\Delta t}$, which corresponds to the load model discussed above. In this case:

$$\frac{de_0(\Delta)}{d\Delta}=-\int_0^{+\infty}td(t)e(t)dt=-\left(Cov_d(t,e)+e_0e^{\dagger}\right). \tag{38}$$

Note that this case is equivalent to a perturbation of the form $\lambda(t,\Delta)=(1+\Delta t)\lambda(t)$, because $e^{\Delta t}\approx 1+\Delta t$. Thus, the exponential change in the MI is, in a sense, a variant of proportional growth, but affecting each age differently, so the resulting relative change in life expectancy consists of two terms covering different aspects of the change in mortality.

Consider the foregoing on the example of the Gompertz-Makeham law of mortality. Let us analyze the effect of an additive change in the parameters of the law M,α,β on ALE at birth.

1. Change in initial MR: $\beta(\Delta)=\beta+\Delta$. Then

$$\begin{aligned}&\lambda(t,\Delta)=M+\beta e^{\alpha x}+\Delta e^{\alpha x}=\lambda(t)+\Delta e^{\alpha t}=\lambda(t)+\Delta\left(\frac{\lambda(t)-M}{\beta}\right),\\&\frac{d\lambda}{d\Delta}(t,0)=\frac{\lambda(t)-M}{\beta}.\end{aligned} \tag{39}$$

Therefore, at $\beta\neq 0$ we have:

$$\frac{de_0(\Delta)}{d\Delta}=-\frac{1}{\beta}\left[\int_0^{+\infty}\lambda(t)e(t)S(t)dt-M\int_0^{+\infty}e(t)S(t)dt\right]=\frac{1}{\beta}\left[M\overline{t}e_0-e^{\dagger}\right]. \tag{40}$$

In the general case the change in life expectancy due to the additive increase in the initial mortality of the Gompertz-Makeham model is a linear combination of proportional and additive changes in the MI.

2. Change in MR: $\alpha(\Delta)=\alpha+\Delta$. Then

$$\begin{aligned}&\lambda(t,\Delta)=M+\beta e^{\alpha t}e^{\Delta t}=\lambda(x)+\Delta e^{\alpha t}=\left(\lambda(t)-M\right)e^{\Delta t}+M,\\&\frac{d\lambda}{d\Delta}(t,0)=t\left(\lambda(t)-M\right).\end{aligned} \tag{41}$$

On the other hand

$$\lambda'(t)=\lambda(t,\Delta)=\alpha\beta e^{\alpha t}=\alpha\left(\lambda(t)-M\right)\Rightarrow\lambda(t)-M=\frac{\lambda'(t)}{\alpha}.$$

Therefore, at $\alpha\neq 0$ we have:

$$\begin{aligned}&\frac{d\lambda}{d\Delta}(t,0)=t\frac{\lambda'(t)}{\alpha}\\&\frac{de_0(\Delta)}{d\Delta}=-\frac{1}{\alpha}\int_0^{+\infty}t\lambda'(t)e(t)S(t)dt=-\frac{1}{\alpha}\left[\int_0^{+\infty}td(t)dt-\int_0^{+\infty}e(t)d(t)dt\right]=\\&=\frac{1}{\alpha}\left(e^{\dagger}-e_0\right).\end{aligned} \tag{42}$$

This expression was obtained by integration by parts using the equation $\left(te(t)S(t)\right)'=\left(e(t)-t\right)S(t)$.

This ratio is a special case of the result obtained by changing the MR of the species $\lambda(t,\Delta)=\lambda((1+\Delta)t)$, which in the case of the Gompertz-Makeham law corresponds to an additive change in the parameter α.

3. Change in the age-independent parameter M characterizing death from accidental causes: $M(\Delta)=M+\Delta$. Since M is just an additive term independent of age, this is a case of an additive increase in MR:

$$\frac{de_0(\Delta)}{d\Delta}=-\bar{t}e_0. \tag{43}$$

V. Analysis of changes in life expectancy on the example of the Sverdlovsk region of Russia

To calculate the population entropy, it is necessary to have a mortality law that allows to determine the type of MI. Suppose that mortality in the Sverdlovsk region changes according to the Gompertz-Makeham law. Based on the analyzed table of mortality for 2020 of the urban population of the Sverdlovsk region, the estimates of parameters of this law:

$$M=4.78\cdot10^{-4},\ \alpha=2.65\cdot10^{-4},\ \beta=7.06\cdot10^{-2}.$$

According to (24), the Keifitz entropy for the Gompertz-Makeham mortality law, for our example will be equal to:

$$H_K=\frac{\bar{\lambda}-\lambda_0}{\alpha}+M\bar{t}\approx-0.21,$$

Where the average *mortality rate of the* stationary population $\bar{\lambda}=\frac{1}{e_0}=\frac{1}{69.95}=0.014$; initial mortality rate $\lambda_0=M+\beta=7.44\cdot10^{-4}$; average age of the stationary population: $\bar{t}=\frac{1}{e_0}\int_0^{+\infty}tS(t)\,dt\approx37.48$.

Thus, it was found that when the MI in all age groups increases by 1%, life expectancy decreases by 0.21%. Or, when the MI in all age groups increases by 10%, life expectancy decreases by 2.1%.

Let us consider how the intensity of mortality will change with a change (decrease and increase) in ALE at birth. To do this, plot the function $\Delta=\frac{1-\frac{e_0(\Delta)}{e_0}}{H_K}=\frac{1-\frac{e_0(\Delta)}{e_0}}{0.21}$. The Fig. 1 shows the percentage increase (decrease) of Δ depending on the percentage decrease (increase) of ALE at birth.

In Sverdlovsk Region ALE at birth is $69.95\approx70$ years. Thus, if ALE at birth increases by 10% (7 years), then the MI will decrease by almost half (47.65%). The same will happen with a decrease of ALE - the MI will increase by almost half (by 47.65%). With an increase (decrease) of ALE by 50% (that is, the population will live on average to 105 (35) years), the MR will decrease (increase) by 238.27%.

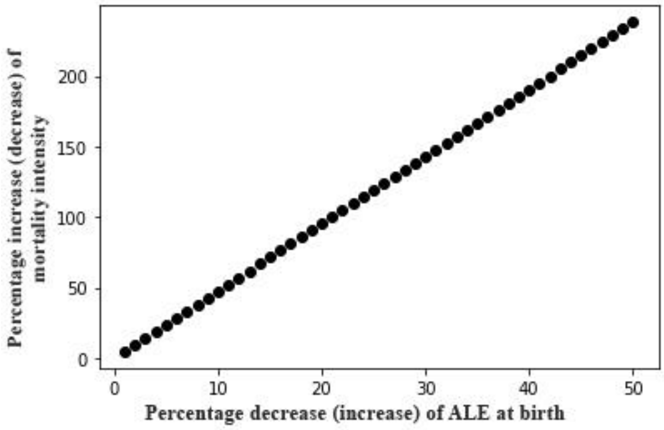

Figure 1: *Percentage increase (decrease) of* Δ *depending on the percentage decrease (increase) of ALE at birth*

Consider how the percentage increase of the Gompertz-Makeham law parameters will affect on ALE at birth.

1. Change in the level of initial MR: $\beta(\Delta) = \beta + \Delta.$

In this case

$$g'(0) = \frac{de_0(\Delta)}{e_0 d\Delta} = \frac{1}{\beta}\left[M\bar{t} - \frac{e^{\dagger}}{e_0}\right] = \frac{1}{\beta}\left[M\bar{t} - H_K\right].$$

Then

$$\frac{e_0(\Delta)}{e_0} = 1 + \frac{1}{\beta}\left[M\bar{t} - H_K\right]\Delta .$$

In our case $\Delta = k\beta$, where k changes from 0.01 (1%) to 1 (100%). Then

$$\frac{e_0(\Delta)}{e_0} = 1 + \left[M\bar{t} - H_K\right]k$$

A graph of the function of the percentage decrease of ALE at birth, depending on the percentage increase of initial mortality, is shown in Fig. 2.

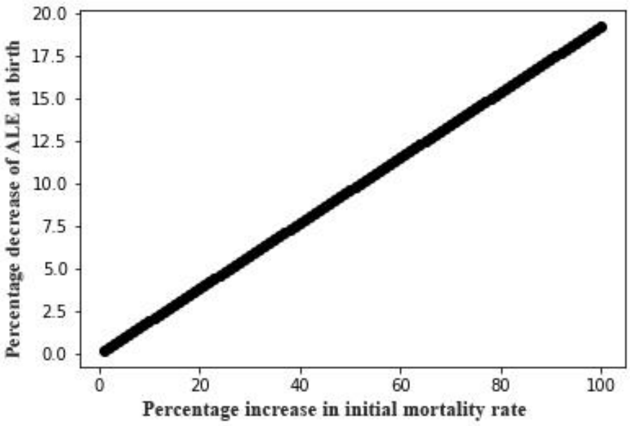

Figure 2: *Percentage reduction of ALE at birth depending on the percentage increase in initial mortality rate*

Thus, with an increase in the level of age-related mortality β by 1%, ALE at birth will decrease by 0.19% (0.13 years); with a twofold increase of β (by 100%), ALE will decrease by 19.19% (13.5 years).

2. Change in the rate of increase in mortality with age: $\alpha(\Delta) = \alpha + \Delta.$

In this case

$$g'(0)=\frac{de_0(\Delta)}{e_0 d\Delta}=\frac{1}{\alpha}\left(\frac{e^\dagger}{e_0}-1\right)=\frac{1}{\alpha}(H_K-1).$$

Then

$$\frac{e_0(\Delta)}{e_0}=1+\frac{1}{\alpha}(H_K-1)\Delta$$

In our case $\Delta=k\alpha$, where k changes from 0.01 (1%) to 1 (100%). Then

$$\frac{e_0(\Delta)}{e_0}=1+(H_K-1)k\ .$$

A graph of the function of the percentage decrease of ALE at birth, depending on the percentage increase in the rate of increase in mortality with age, is shown in Fig. 3.

Thus, with an increase in the MR α per 1% the ALE at birth will decrease by 0.79% (0.55 years); with a twofold increase of α (by 100%), the ALE will decrease by 79.01% (55.27 years).

3. Change in the age-independent parameter M characterizing death from accidental causes: $M(\Delta)=M+\Delta$.

In this case

$$g'(0)=\frac{de_0(\Delta)}{e_0 d\Delta}=-\bar{t}\,.$$

Then

$$\frac{e_0(\Delta)}{e_0}=1-\bar{t}\,\Delta$$

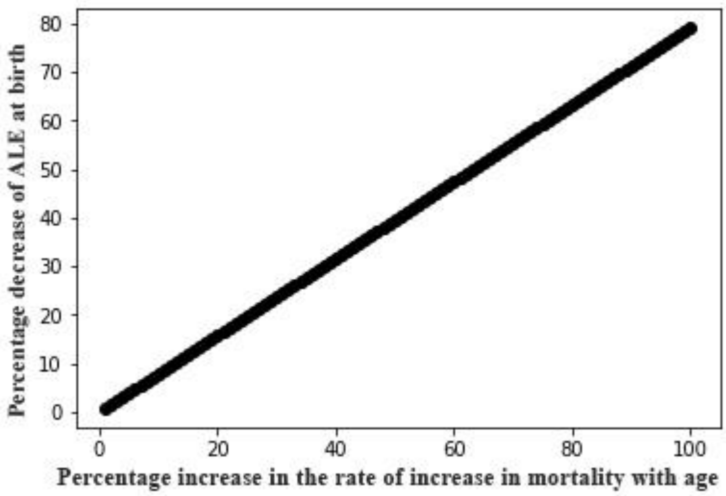

Figure 3: *Percentage reduction in ALE at birth depending on the percentage increase in the rate of increase in mortality with age*

In our case $\Delta=kM$, where k changes from 0.01 (1%) to 1 (100%). Then

$$\frac{e_0(\Delta)}{e_0}=1-\bar{t}kM\ .$$

A graph of the function of the percentage decrease in ALE at birth, depending on the percentage increase in the Makeham parameter M, is shown in Fig. 4.

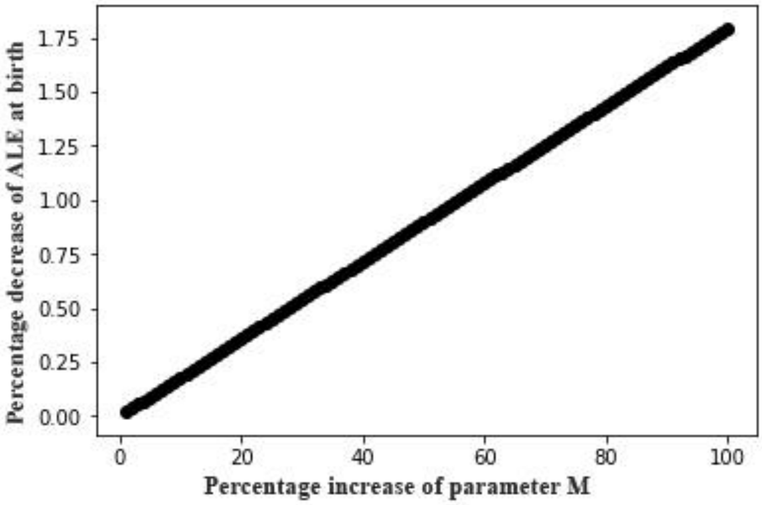

Figure 4: *Percentage reduction in ALE at birth depending on the percentage increase of parameter M*

Thus, with an increase in the parameter *M* by 1%, ALE at birth will decrease by 0.01% (0.01 years); with a twofold increase in *M* (by 100%), ALE will decrease by 1.79% (1.25 years).

According to the analysis, the greatest decrease in ALE at birth occurs with an increase in the MR (parameter α), followed by parameter β (initial MR), an increase in which causes a smaller decrease in ALE, and, finally, an increase in the parameter *M*, which characterizes death from random reasons.

VI. Conclusion

The paper presents an entropy approach to assessing the reduction in life expectancy from the impact of negative environmental factors, which is expressed as an increase in the MI, which is the initial value through which the environmental risk and reduction in life expectancy are determined.

Using the presented approach, an analysis was conducted of the increase in the MI, described by various mathematical forms of its change, as well as of the impact of such a change on the ALE at birth.

The results of the described research open the door to consistent assessing of the total damage inflicted on the society (in terms of biological, cognitive and social dimension) by different technogenic and environmental factors that evolve in time. This, in its term, permits optimizing expenditures needed for mitigating and minimizing collective risk.

References

[1[Kozlova O.A., Shelomentsev A.G., Trushkova E.A. Influence of environmental factors on the indicators of life expectancy of the population of the Sverdlovsk region. Social aspects of public health [network publication]. 2018;64(6):12. URL : http :// vestnik . mednet . ru / content / view /1034/30/ lang , ru . https :// doi . org /10.21045/2071-5021-2018-64-6-12.

[2] Kozlova O.A., Tukhtarova E.Kh., Ilinbaeva E.A. Methodological issues of assessing the resilience of the working-age population to negative environmental impacts. Economic and social changes: facts, trends, forecast 2017; (4): 212-227.

[3] Zaitseva N.V., Trusov P.V., Shur P.Z., Kiryanov D.A., Chivgintsev V.M., Tsinker M.Yu.

Methodological approaches to risk assessment of the impact of heterogeneous environmental factors on public health based on evolutionary models. Health Risk Analysis 2013; (1): 15-23.

[4] Sakovich V.A., Smirnova O. A. Mathematical modeling of the effect of radiation on the life span of mammals // Physics of elementary particles and the atomic nucleus, 2003, v. 134, c. 6, p. 1436–1484

[5] Gompertz . B. On the nature of the function expressive of the law of human mortality and on a new mode of determining life contingencies // Philos. Trans. Roy. soc. London. A. 1825. Vol. 115. P. 513-585.

[6] Gavrilov L.A., Gavrilova N.S. The biology of longevity. Resp. ed. V. P. Skulachev. 2nd ed., revised, and additional M.: Nauka , 1991. 280 p.

[7] Makeham W.M. On the law of mortality and the construction of annuity tables // J. Inst. actuaries. 1860 Vol. 8. P. 301-310.

[8] GOST 25645. 205-83. Radiation safety of the spacecraft crew in space flight. Method **of** calcula**ting** radiation risk . M.: Gosstandart of the USSR, 1984.

[9] Gubin, A.T. et al., Mathematical model of animal mortality rate under radiation exposure, Tr. XVIII council . socialist countries in space biology and medicine. M., 1985. S.227-278.

[10] GOST 25645. 215-85. Radiation safety of the spacecraft crew in space flight. Safety standards for a flight duration of up to three years. M.: Gosstandart of the USSR, 1986.

[11] Gubin A.T. Kovalev E. E. Sakovich V. A. A model for describing the probability of a lethal outcome under the influence of radiation and other harmful factors // AE. 1992. Vol. 72, no . 6. S. 604-512.

[12] Gubin A.T. Sakovich V.A. Mathematical model of the intensity of radiation mortality during irradiation in childhood // AE. 1999. Vol. 87, no . 2. S. 159-161.

[13] Keyfitz N, Caswell H, 2005. Applied Mathematical Demography. Springer, New York, USA.

[14] Goldman N, Lord G, 1986. A new look at entropy and the life table. Demography 23, 275–282.

[15] Wrycza T.F.. Entropy of the Gompertz-Makeham mortality model // Demographic research, 30, 13971404 (2014).

[16] Vaupel J.W., Canudas Romo V, 2003. Decomposing change in life expectancy: A bouquet of formulas in honor of Nathan Keyfitz's 90th birthday. Demography 40, 201–216.

[17] Zhang Z, 2009. The age separating early deaths from late deaths. demogr . Res 20, 721–730

[18] Tomasz Wrycza & Annette Baudisch, 2012. How life expectancy varies with perturbations in age-specific mortality, Demographic Research, Max Planck Institute for Demographic Research, Rostock, Germany, vol. 27(13), pages 365-376.

EXPERIMENTAL STUDIES OF SEISMIC RESISTANCE OF TRANSLUCENT FACADE STRUCTURES

Arkadiy Granovskiy[1,2], Alexandra Demina[1,2]

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[1]Moscow State University of Civil Engineering
[2]National Research University, Science Research of Experimental Mechanics
arcgran@list.ru

Abstract

The results of experimental studies on the assessment of seismic resistance of hinged facade translucent systems, glass windows and glass panels are presented. The tests were carried out on special stands. When assessing the seismic resistance of facade translucent systems, a two-component pendulum-type vibration platform was used. During dynamic tests of glass windows and glass panels, a stand was used, for the excitation of vibrations of which a system consisting of dynamic hydraulic jacks was used. During the tests, the amplitude-frequency characteristics of dynamic effects varied in the range from 1.0 to 25.0 Hz with the amplitude of vibrations of the vibration platform up to 70 mm in the horizontal direction and 12.8 mm in the vertical direction. The values of accelerations of the vibration platform and dynamic jacks at the specified amplitude-frequency characteristics varied in the range from 0.2 to 5.0 m/s² in the horizontal direction and from 0.1 to 2.0 m/s² in the vertical direction. The behavior of glass panels under dynamic impact is modeled. It has been established that the use of glass partitions wall made of tempered Triplex glass with a thickness of at least t = 18 mm using a strengthening film of the TROSIFOL brand makes it possible to exclude the collapse of the structure of glass panels during the destruction of glass. The analysis of the results of experimental studies on the assessment of seismic resistance and injury safety of glass panels under dynamic loads simulating seismic impacts with an intensity of 7-9 points on the MSK-64 scale is carried out. The necessity of developing special regulatory documents is indicated.

Keywords: translucent structures, dynamic tests, vibration platform.

I. Introduction

The dynamic development of the building materials industry and socio-cultural traditions of the twentieth century contributed to the creation of a new type of respectable buildings with visually weightless, partially or completely transparent facade envelopes. There are many problems that give rise to disagreements among professionals all over the world regarding the design and architecture of glass facades, as well as the physical, mechanical and strength characteristics of the glass used and the fencing system as a whole. There was a need to develop methods for calculating and designing light spatial outer shells made of glass, which are fundamentally different from the previously used standard enclosing facade structures. The American idea of a light facade glazing suspended from the outside of the supporting frame of the building radically changed not only the general technological trends in the production of enclosing structures, but also laid the foundation for a new theory of designing translucent building systems. The results of research by foreign experts have shown that the low reliability of glass exterior enclosing structures in terms of ensuring their reliable trouble-free operation is associated with the perception of both the wind load, its pulsating component and the resulting shock effects from various external elements during a hurricane, and the high amplitude of vibrations of the upper floors of the building during earthquakes. In the Norms of the USA, Canada, Australia, China and Hong Kong, the wind load on the glazing of buildings with a height of 18 to 500 m is considered as the main destructive factor arising from the cyclic application of the load. In Russia, the methodology for determining the magnitude of the design loads on glass facades is based on the instructions of the Norms [1]. In Europe, strength calculations of translucent structures are carried out according to DIN Standards [2,3]. In Russia, recommendations are currently used in the design of hinged translucent facade structures [4,5].

The situation on the Russian market of translucent facade aluminum structures and the forecast of the general situation of the development of this market are set out in [6]. According to these studies, the market volume of facade translucent aluminum structures in 2017 amounted to 56999 tons.

The use of facade translucent aluminum structures in seismic areas is hindered by the lack of experimental studies. The analysis of the state of the regulatory framework for facade systems in Russia and abroad was carried out in the work of St. Petersburg scientists [7].

The methodology of testing translucent facade structures for the action of static and dynamic loads is currently not worked out, which does not allow us to evaluate the results of tests of various systems performed in different research centers from one position. In Russia, the design systems of the vibration platform are conservative harmonic oscillators, with the help of which only a simple harmonic (sinusoidal) oscillation can be realized. A correct dynamic test simulating a particular seismic impact is possible only if a specific accelerogram necessary for the researcher is set during the testing process.

II. Experimental setup and realization of the test

1. Experimental studies of glass facades

Let's analyze the existing methods in Russia and Europe for determining the calculated values of wind load. According to SP [1], the normative value of the average component of the main wind load is determined by the formula:

$$W_m = W_0 \times \kappa(Z) \times c$$

According to DIN [2,3], the magnitude of the hurricane wind pressure $q_{hu.}$ (analogous to W_m) and the velocity $V_{hu.}$ determined by the formula:

$$q_{hu.}(Z) = 2.6 \times q_{ref}\ (Z/10)^{0.19};$$
$$V_{hu.}(Z) = 1.61 \times V_{ref}\ (Z/10)^{0.095},$$

where:

q_{ref} (kN/m^2) is the standard value of wind pressure, analogous to W_m;

V_{ref} (m/s) – wind speed at a height of 10 m from the earth's surface.

The calculation analysis shows that in Russian Standards, the value of the normative value of wind pressure when calculating glass windows is underestimated in comparison with foreign Standards.

At the first stage of dynamic testing of translucent facades for the effect of loads simulating seismic impacts with an intensity of 7-9 points on the MSK-64 scale [8] were carried out on a two-component pendulum-type vibration platform (Figure 1).

In accordance with the Test Program, an enclosing translucent structure designed to provide thermal insulation of premises and their natural illumination was tested. A system in the form of an anti-aircraft lamp was used for the coating (Figure 2).

For the glazing of anti-aircraft lanterns, a 32 mm thick laminated glass мulti – layered block SGLam was used consisting of two (triplex) glasses bonded together and a 6 mm thick SGTempM1 tempered glass covered with a tape. In case of destruction of double-glazed windows during an earthquake, glass fragments remain glued to the tape, which prevents injury to people. Double-glazed windows without triplex with two tempered glasses of the SGTempM1 brand were used on the facade panels. The supporting elements of the glass-transparent structures were made of aluminum alloy. During the tests, 33 modes of dynamic loading of the vibration platform with different amplitude-frequency parameters were performed. According to vibration tests, the amplitude-frequency characteristics of the tested fragments were determined for specific loading levels.

Fig. 1: *Pendulum type vibration platform*

Fig. 2: *Glass facade mounted on a vibration platform*

2. Experimental studies of stained glass and glass partitions wall

At the second stage of the tests, experimental studies of the seismic resistance of the construction of fragments of glass windows and glass walls were carried out. The following elements were used as glass panels for stained glass windows and glass partitions wall:

- all-glass partitions made of tempered non-traumatic glass with a thickness of 10 mm (system 1 - figure 3);
- fire-fighting glass partitions of the EIW(S)90 brand (system 3 - Figure 3);
- glass partitions wall on a spider system and a 10 mm thick tempered glass clamping profile (system 2 - figure 3);
- stained glass systems made of tempered glass with a thickness of 8 mm (system 6 - figure 3);

- office partitions wall systems with double or single tempered non-traumatic glass (system 4 - figure 4);
- stained glass systems with a tempered glass block with a thickness of no more than 68 mm (system 5 - figure 4);
- glass partitions wall on a spider system made of triplex glass with a thickness of at least 18 mm (tempered glass with a thickness of 8 mm + 4 layers of a strengthening tape of the TROSIFOL brand (or equivalent) + tempered glass with a thickness of 8 mm (system 7 - figure 4).

Fig. 3: *Fragments of the stand (systems 1, 3, 2, 6)*

Fig. 4: *Fragments of the stand (systems 4, 5, 7)*

Special dynamic equipment and measuring instruments were used to conduct dynamic tests of stained glass and glass panels. The test stand included the following elements:

- metal stand for fixing glass windows and glass panels;
- rolling supports with a load capacity of 60 kN;
- dynamic hydraulic cylinders of the MTS brand (Figure 5), designed to create a dynamic impact with different acceleration at each stage of loading from 0.2 m/s^2 to 4

m/s² with a frequency from 1 to 50 Hz. The amplitude of the displacement of the hydraulic cylinder rod varied from ± 50 to ± 250 mm, the maximum force under dynamic action was ± 800 kN. The rod movement was monitored using an LVDT type displacement sensor;

- 2 steel stops that are not connected to the power frame and ensure the transfer of dynamic load from hydraulic cylinders to a metal stand (Figure 6);
- measuring equipment:
  - accelerometers are single- and triaxial, allowing to determine the magnitude of accelerations with a data acquisition frequency of up to 4000 Hz;
  - NI PXIe-1082 equipment package with NI PXI-4496 modules (for recording accelerometer data) and NI PXIE-4330 (for register and recording data from strain gages);
  - digital controller MT Flux Test 60, designed to control dynamic hydraulic cylinders with the ability to control and change the parameters of their operation during the testing process.

The level of dynamic impact was set in accordance with the Test Program and included the following stages with acceleration values: $a_1 = 1.0$ m/s², $a_2 = 2.0$ m/s² and $a_3 = 4.0$ m/s².

Fig. 5: *Location of hydraulic cylinders relative to the stand*

At each stage of the tests, the frequency spectrum of the effects varied in the range from 0.5 to 22.63 Hz. The duration of the test at each loading step was up to 40-50 s. The tests were performed at fixed frequencies corresponding to the average geometric frequencies of 1/6-octave bands, in the range up to 22.63 Hz.

Fig. 6: *Steel stops for hydraulic cylinders*

In the process of laboratory dynamic tests of the hinged facade system in the form of glass panel, the following was established.

1. The acceleration of the vibration platform varied in the range from 0.2 to 4.9 m/s² in the horizontal direction and from 0.1 to 1.9 m/s² in the vertical direction.
2. The magnitude of the accelerations installed on the vertical stained-glass windows varied from 0.3 to 5.0 m/s² in the horizontal direction and from 0.1 to 3.3 m/s² in the vertical direction.
3. At the level of the zenith lantern, the acceleration values during dynamic loading of the system varied horizontally in the range from 0.3 to 13.6 m/s².
4. The coefficient of dynamism calculated on the basis of processing the results of dynamic tests was $\beta = 2.8$. The forced vibration frequency of the vibration platform varied during the tests from 1.5 to 10.0 Hz, the maximum amplitude of the vibrations was 68.4 mm in the horizontal direction and 12.8 mm in the vertical direction. The maximum oscillation amplitude according to the sensors installed on the zenith lantern was 100.1 mm in the horizontal direction and 20.8 mm in the vertical direction. Figure 7 shows the spectra of peak acceleration values at various points along the height of the system in one of the loading modes. At a frequency of 5 Hz, a resonance was detected.

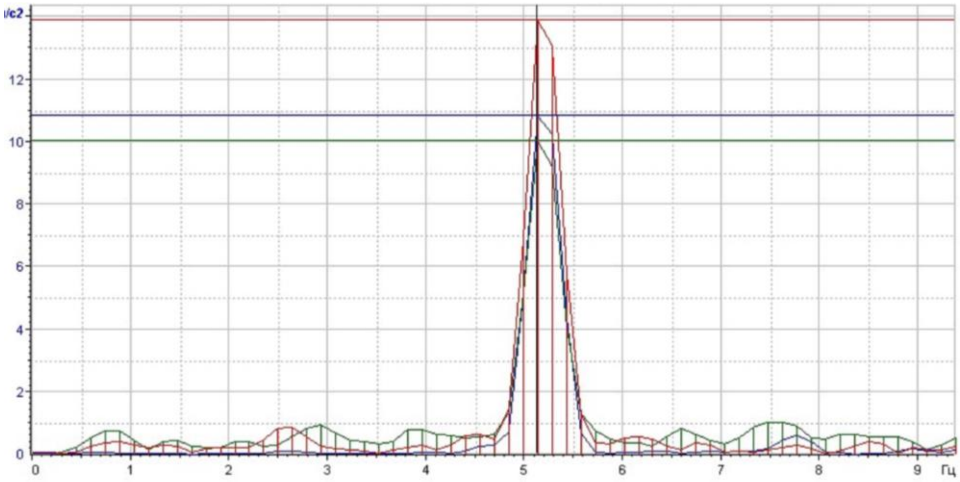

Fig. 7: *Graph of the acceleration spectrum with a frequency change from 0.5 to 9.5 Hz*

III. Analysis of test results

In the process of testing glass windows and glass partitions wall, the following has been established.

1. With a given input dynamic effect corresponding to the acceleration of the base **– 1 m / s² (7 points)**, the maximum value of the acceleration values in the lower and upper zones of the stand was: at the bottom of the stand - 1.98 m/ s², at the top - 6.93 m/s². The maximum coefficient of dynamism under dynamic influences with a change in the frequency spectrum from 0.5 to 22.63 Hz , depending on the type of glass panels , was: for single-chamber partition wall glass - 4.72 at a frequency of 6.35 Hz; for two-chamber stained glass - 3.25 at a frequency of 6.35 Hz; for a fire partition wall - 14.45 at a frequency of 7.13 Hz; for a single-chamber glass partition using a spider fastening of a double-glazed window - 11.77 at a frequency of 7.13 Hz. The resonance effect was established at the frequency of exposure in the range from 2.83 to 5.66 Hz.
2. With a given input dynamic effect corresponding to the acceleration of the base **– 2 m /s² (8 points)**, the maximum value of the acceleration values in the lower and upper zones of the

stand was: at the bottom of the stand – 2.51 m/s^2, at the top level – 11.74 m/s^2. The maximum coefficient of dynamism under dynamic influences with a change in the frequency spectrum from 0.5 to 22.63 Hz, depending on the type of glass panels, was: for a single–chamber glass fence - 2.63 at a frequency of 7.13 Hz; for a two-chamber glass screen - 2.7 at a frequency of 7.13 Hz; for a fire partition wall - 19.0 at a frequency of 7.13 Hz; for a single-chamber glass partition wall using a spider fastening of a double-glazed window - 10.3 at a frequency of 8.98 Hz. The resonance effect was established at a frequency of exposure in the range from 2.83 to 5.66 Hz.

3. With a given input dynamic effect corresponding to the acceleration of the base – **4 m /s^2 (9 points)**, the maximum value of the acceleration values in the lower and upper zones of the stand was: at the bottom of the stand – 4.84 m /s^2, at the top level – 15.46 m/s^2. The maximum coefficient of dynamism under dynamic influences with a change in the frequency spectrum from 0.5 to 22.63 Hz, depending on the type of glass panels, was: for a single–chamber glass fence - 2.15 at a frequency of 7.13 Hz; for a two-chamber glass screen - 2.15 at a frequency of 7.13 Hz; for a fire partition - 23.43 at a frequency of 7.13 Hz; for a single-chamber glass fence using a spider fastening of a double-glazed window - 12.87 at a frequency of 4.49 Hz. The resonance effect was established at the frequency of exposure in the range from 2.83 to 5.66 Hz.

In the process of conducting dynamic tests with an impact value corresponding to 9 points, the conditions under which the dynamic impact of the double-glass unit of system 7 on the metal beams of the stand took place were simulated. In the process of repeated dynamic impact, the glass was destroyed without collapsing. The reason for this is the presence of a laminating tape between the layers of the double-glass unit. Figures 8-10 show the process of changing the amplitude of the oscillation of a double-glazed window (over 18 cm) at the moment of impact.

Fig. 8: *Changing the geometry of the glass panel under dynamic influence*

IV. Conclusions

Based on the analysis of the performed dynamic studies and test results with an assessment of the seismic resistance of hinged facade translucent structures, as well as glass windows and glass partitions wall, the following can be noted.

1. During the tests, when the facades of glass windows and glass partitions wall fluctuate, multiple collisions of facing panels with structural elements occur. Due to the high sampling rate and the absence of averaging, peak values of the oscillation amplitudes are recorded at the time of these collisions. These values can reach significant values. The appearance of peak values is due to the peculiarity of the vibration platform and measuring equipment, which should be taken into account when processing test results.
2. It is necessary to develop a regulatory document on the design of translucent structures in earthquake-prone regions. Such a document will allow designers to competently approach the design of translucent systems, taking into account the features of their design solution and a given degree of reliability.

References

[1] SP 20.13330.2011. Loads and impacts (updated revision of SNiP 2.01.07-85*.)

[2] DIN EN 12210. Fenster und Turen. Widerstandsfahigkeit bei Windlast – Klassifiziering.

[3] DIN 1055-4:2005-03 Lastaunahmen für Bauten.

[4] SP 426.1325800.2018. Facade translucent structures of buildings and structures. Design rules.

[5] Recommendations on the construction of hinged translucent enclosing structures / «КТБ ЖБ» LLC. M. 2008, p. 36.

[6] The market of translucent aluminum facade structures 2015-2017. Forecast for 2018-2020. Monitoring market research of translucent aluminum facade structures / Fenster Web. 2018.

[7] Sychev S.A., Rocheva V.M. Analysis of modern normative base of facade systems of buildings in Russia and abroad // Young Scientist. № 18 (204), pp. 92-94.

[8] The scale of seismic intensity MSK. 1964.

FORECAST OF NATURAL EMERGENCY SITUATIONS WITH MODERN METHODS

Valery Akimov, Maxim Bedilo, Olga Derendiaeva, Ekaterina Ivanova, Irina Oltyan

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"All-Russian Research Institute for Civil Defense and Emergency Situations of the Emergencies Ministry of Russia" (Federal Center for Science and High Technologies)

akimov@vniigochs.ru
vniigochs@vniigochs.ru
irenaoltyan@mail.ru

Abstract

The article discusses the verbal and mathematical base for the forecast modeling of the most catastrophic natural emergencies, the sources of which are: hazardous hydrological phenomena; hazardous meteorological phenomena; hazardous geophysical phenomena; large natural fires.

Keywords: natural emergency situations, hazardous hydrological phenomena, hazardous meteorological phenomena, dangerous geophysical phenomena, large natural fires, modeling methods.

I. Introduction

According to the degrees of catastrophicity in the Russian Federation, the following natural emergence can be distinguished [1,2]: "Hazardous hydrological phenomena, hazardous meteorological phenomena, dangerous geophysical phenomena, large natural fires."

II. Methods

Hazardous hydrological phenomena [3].

"Sources of natural emergencies are hazardous hydrological phenomena and processes such as floods, tsunami, avalanche. Among them are the most catastrophic (by the number of deaths, affected people and material damage) are floods"[4].

Floods caused by various reasons [5].

"Russia is affected by spring floods caused by the melting of snow cover, accumulated during the cold winter period. The spring floods on the rivers (which current from the south to the north) are often accompanied by the ice. All these aggravate the disaster dimensions. Such floods include a catastrophic flooding of Lensk, which happened on the River Lena in 2001.

Floods can be a result of the fallout of intensive rain or the passage of typhoons and monsions, covering significant waterborne areas and forming rain floors in Russia. Some of the latest examples of this dangerous phenomenon are floods at the Kuban basin in 2002 and at the Amur Basin in 2013.

Another problem is a flood of man-made character. These include floodings caused by unreasonable discharge through the structures of water consumption hydraulosles, superior to the bandwidth of the river bed. The threat of flooding the territories of settlements under the protection of dams requires increased attention to the structures of engineering protection. There are about 180 cities and large settlements in Russia which are in danger due to these disasters. An example of this disaster is the flood in Tulun on the River Jia during 2019. The insufficiency of territorial planning activities was accompanied by poor quality design and construction of the city engineering system.

The threat of flooding as a result of the cooler and burial phenomena is essential for Russia. The ice constrains cross-section of the river and leads to an increase in water level on the over-site and flooding adjacent territories. Ice burrow - a phenomenon similar to the ice traffic, which is a cluster of shugs in the river bed, accompanied by a clogging of some part of its living section and leads to the increase in the water level above this cluster."

There are two approaches to mathematical modeling of complex phenomena [6]. "When deterministic modeling, the variables are entered in such a way to obtain a discrete result, operate with numerically pronounced specific values of the parameters. Stochastic modeling uses the sample and probability to receive answers. It is used a deterministic model for floods. The deterministic approach has the advantages of rapid calculation and fairly accurate results, which plays a special role for the effectiveness of alert and response measures. An additional advantage is the limited amount of input data required for modeling."

The key flood striking factor is the flood zone. To calculate the flood exposure zone, the characteristic of the river flow is required, including the forecast of the depth of the flow, the flow rate and the extent of the flood. Hydraulic models use control equations of the flow in motion (storing the principles of mass and pulse) to predict the flow characteristics. However, the solution of such equations may be expensive depending on their spatial expansion. Moreover, the simulation of a two-or three-dimensional river runoff using high-resolution topographic data for large-scale regions is almost impossible.

The large number of models of flow forming and dynamics of the flow - flooding streams, the most common in domestic practice is the Ecomag model [7].

In [8], Bayesian classifiers are used as a mathematical framework for flood modeling.

The maximum allowable medium-quality level of water lifting in the observed river target (Z np, M) for a period of at least 5 years is determined by the equation:

$$Z^{np} = \varepsilon_{\text{cc}} + k_f + \sum_1^y (\varepsilon_{\text{cc}} - \varepsilon_{\text{т}}), \tag{1}$$

where:

$\varepsilon_{\text{т}}$ — The current level of water lifting in the observed river, m;

ε_{cc} — The average seasonal level of water lifting in the observed river, determined by the historical number of observations, m;

k_f — The estimated coefficient equal to 1/3 of the average seasonal level of water lifting in the observed river to the mark "adverse phenomenon", m;

y — The number of analyzed daily observations, according to which an assessment is made from the beginning of the period of the ice drift (period of increased water level) to the date of recorded observation, units.

After determining the maximum permissible medium-sized level of water lifting, the observed river is monitored by incoming monitoring data for the identification of signs of flooding or catastrophic flooding of the area.

The population that has fallen into the flood zone ($N_{flooded}^{np}$, people) should be determined by the equation:

$$N_{flooded}^{np} = \sum_1^i \frac{S_{\text{building}}^{flooded} h_{\text{зд}}}{\rho_{\text{p/zh}}^{flooded}} \partial_t^i, \tag{2}$$

where:

$S_{building}^{flooded}$ — Square of flooded building, m2;

$h_{building}$ — the number of floors and structures, m;
i — Residential, socially significant, administrative and industrial buildings;
$\rho_{\text{p/zh}}^{flooded}$ — a parameter characterizing an exemplary calculation area per victim in the flood zone, m2 / person;
t — time of day, h;
∂_t^i — The proportion of the population residing depending on the time of day in the respective buildings and facilities.

The procedure for determining the calculated hydromorphological parameters characterizing the water system is presented in [8].

Hazardous meteorological phenomena [9]

"Sources of natural emergencies are dangerous meteorological phenomena and processes, such as a strong wind, whirlwind, hurricane, cyclone, typhoon, storm, tornado, flurry, long rain, thunderstorm, shower, hail, heavy snowfall, ice rain, ice, strong blizzard, fog, dust storm, warm waves or cold waves, drought [10]. Among them are the most catastrophic (by the number of deaths, affected people and material damage) are heavy snowfall and strong wind "[4].

The main prognostic tool of dangerous meteorological phenomena (OA) is the numerical atmospheric models - they successfully reproduce many phenomena of the atmosphere and are becoming increasingly popular. The predictive atmosphere model is a complex software package that solves a system of equations describing the evolution of the atmosphere, i.e. calculates temperature, humidity, wind and other parameters at different heights and different points of the globe. The models take into account the processes of thermohydrodynamics, moisture transformations, radiation-cloud interactions, complex processes in the atmosphere border layer and on the border with its underlying surface, etc.

The problem of predictability began to be realized after the first numerical experiments on modeling the evolution of the atmosphere for a long time. Back in the 1950s, it was shown that how small errors of the task of initial data for calculating the forecast over time are transformed into large errors (the Attractor E. Lorenz, the "Butterfly Effect") "[11].

"In general purpose weather forecasts include information on the following weather phenomena: thunderstorm, hail, flurry, fog, ice, hoarfrost, sticking wet snow on wires and trees, blizzard, dusty (sandy) storm, ice drill, frost, severe heat, severe frost, abnormally hot (cold) weather" [12].

A typical list and criteria for meteorological hazardous phenomena, designed to meet the recommendations of WMO [13], is given in the table.

Table 1: *Typical list of meteorological OA and their criteria*

Name of OA	Characteristics and criteria of OA
A.1 Very strong wind	Wind with a maximum speed of 25 m / s or more, on coasts of the seas and in mountainous areas 35 m / s and more
A.2 Hurricane wind	Wind speed of 33 m / s and more
A.3 Squall	Sharp short-term (within a few minutes, but not less than 1 min) wind increasing to 25 m / s and more
A.4 Tornado	Strong small-scale vortex in the form of a pillar (funnels) directed from the cloud to the surface
A.5 Very heavy rain	Rain and mixed sediments with 50 mm and more, in mountainous areas with 30 mm and more for a period of time not more than 12 hours
A.6 Heavy rain	Strong rain with the amount of precipitation 30 mm and more for a period of no more than 1 hour
A.7 Long heavy rain	Rain with precipitation of at least 100 mm and more (in mountainous areas with precipitation 60 mm or more for a period of time 48 hours; and less than or 120 mm and for more than 48 hours)

A.8 Very heavy snow	Snow (snowfall) 20 mm and more for a period of 12 hours and less
A.9 Large hail	Hail with a diameter of 20 mm and more
A.10 Strong blizzard	Transferring snow from the surface, often accompanied by the strong (with an average rate of at least 15 m / s) wind and with a meteorological range of not more than 500 m duration of at least 12 hours
A.11 Strong dusty (sandy) storm	Transfer of dust (sand) strong (with an average rate of at least 15 m / s) wind and with meteorological visibility range of not more than 500 m duration of at least 12 hours
A.12 Strong fog	Strong air clouds due to the accumulation of the smallest water particles (dust, combustion products), with a meteorological range of visibility not more than 50 m duration of at least 12 hours
A.13 Strong iceed - hoarfish deposition	The diameter of the deposit on the wires of the ice alloy: ice is not less than 20 mm; complex sediment or wet (freezing) snow - at least 35 mm; frost - at least 50 mm
A.14 Strong frost	In the period from November to March, the value of the minimum air temperature reaches the dangerous value established for this territory or below it
A.15 Heatwave	In the period from May to August, the value of the air temperature reaches the average maximum or above its
A.16 Very cold weather	In the period from October to March for 5 days and the magnification of the average daily air temperature below the climatic rate is 7 ° C and more
A.17 Very hot weather	In the period from April to September for 5 days and the magnification of the average daily air temperature above the climatic rate is 7 ° C and more
A.18 Freeze	Lowering air temperature and / or soil surfaces (herbage) to values below 0 ° C, when the positive average daily air temperatures during periods of active vegetation of crops or harvesting, leading to their damage and / or partial crop death
A.19 Emergency fire danger	Fifth grade of fire hazard indicator (10 000 ° C and more) calculated by Nesterov's equation)
A.20 Skiming avalanche	Large avalanches can make significant damage to economic objects or create the danger of settlements

Dangerous geophysical phenomena [14].

"Sources of natural emergencies are dangerous geophysical phenomena and processes such as earthquake, volcano, landslide" [10]. Among them are the most catastrophic (by the number of deaths, affected people and material damage) are earthquakes [4].

"In the Russian Federation, seismic zones cover extensive areas of the Far East, Transbaikalia, the North Caucasus, where the intensity of earthquakes can reach nine points" [15, 16].

"Agrowing factors for earthquakes are the mechanical effects of oscillations of the earth's surface and crack. The soil movement is extremely rarely can caused human victims. The main causes of accidents and deaths of people are secondary earthquake factors: damage and destruction of buildings and structures, broken windows, the fall of electrical conductors, explosions and fires associated with gas leakage from damaged pipes, as well as uncontrollable actions of people caused by fright and panic [17, 18].

Successful prediction of catastrophic earthquakes implies a sequential step-by-step definition, which allows to narrow the time interval, a location area and a range of a magnitude of an earthquake. In [19], for predicting such emergency, methods of statistical data processing were proposed based on the Bayes Theorem. A draft relevant national standard has been developed [20], which contains a description of the processes for the formation of a priori information for forecasting earthquakes on a controlled territory.

Earthquake (M) is determined by tool data obtained from surface waves (M_S) based on the conditions:

$$M = \begin{cases} M_s\,, \ with\ h \leq 70 \\ M_s + 0{,}8\,, \ with\ h > 70\,' \end{cases} \tag{3}$$

where:

h — depth of the epicenter of the earthquake, km;

M_s — Earthquake Magnid on Richter scale.

For calculating the parameters of the seismic effects of the earthquake, it is necessary to devide the territories of settlements in the form of a regular grid of the seismicone. The coordinate values of the platforms are accepted with equal values of the coordinates of their centers. (x, y).

Then the likelihood of incoming the random value of intensity I on the (I_{min}, I_{max}) is determined by the equation:

$$P(I_{min} < I < I_{max}) = \int_{I_{min}}^{I_{max}} f(I)dI. \tag{4}$$

The function of the distribution of a random variable $F(x, y, I)$ should be calculated by the equation:

$$F(x, y, I) = \int_{-\infty}^{I} f(x, y, I)dI. \tag{5}$$

The resulting intensity parameter (I) for each site (cell of the regular mesh matrix) with coordinates (x, y) is subject to evaluation in the medium-term forecasting of earthquakes [14]. The procedure for determining seismic impact parameters is presented in [20].

Large natural fires

Natural fires, uncontrolled combustion processes, spontaneously emerging and spreading in natura (forest, steppe and peat). At the same time, forest fires are applied to the most important damage in the Russian Federation.

"The problem of predicting forest fire parameters and evaluating their consequences did not receive its satisfactory decision, despite its importance for various sectors of the national economy of Russia. The difficulties of solving this problem are due to: the complex nature and variability of the behavior of fires, and even more so multi-day forest fires that develop on a large area in changing natural and weather conditions; insufficiency or inaccuracy of information on the characteristics of the forest, topography of the area, local meteorla; not always reliable reporting information coming from the fire places "[21].

In [22], Bayesian classifiers were offered as a mathematical framework for modeling forest fires.

In this case, the forest fire area (S_{ff}, ha) after the time corresponding to the forecasting step is recommended to determine by the equation:

$$S_{ff} = n_1 \cdot S_{ff}^{1\text{B}} + m_1 \cdot S_{ff}^{1medium}, \tag{6}$$

where:

$S_{ff}^{1\text{B}}$ — Cell area of the matrix of a regular grid with a high level of threat of hypothesis No. 1, ha;

$S_{ff}^{1medium}$ — Cell area of the regular grid matrix with an average level of threat of hypothesis No. 1, ha;

n_1 — number of cells of the matrix of a regular grid with a high level of threat of hypothesis No. 1, units;

m_1 — Number of cells of the matrix of a regular grid with an average level of threat of hypothesis No. 1, units.

Hypothesis No. 1 means the likelihood of spreading a forest fire on a controlled territory during the day every 3 hours.

Determination of the length of the edge of the forest fire (D_{edge}, м), after the time corresponding to the forecasting step, should be determined by the equation:

$$D_{edge} = 0{,}5 \cdot \sqrt{S \cdot 10000}, m. \tag{7}$$

where:

S — Forest fire square, ha.

The proportion of the controlled territory with a high level of threat is the possibility of the occurrence and distribution of forest fire (P_{B}) is determined by the equation:

$$P_{\text{B}} = n_3 \, \frac{S_{ff}^{3\text{B}}}{S_{kt}}, \tag{8}$$

where:

$S_{ff}^{3\text{B}}$ — Cell area of the matrix of a regular grid with a high level of threat of hypothesis No. 3, ha;

S_{kt} — The total area of the regular grid for KT, ha;

n_3 — Number of cells of the matrix of a regular grid with a high level of threat of hypothesis No. 3, units.

Hypothesis No. 3 means the possibility of the emergence and spread of a forest fire on a controlled territory over the next 10 days.

III. Results

Thus, this article presents the verbal and mathematical foundations of the forecast modeling of the most catastrophic natural emergencies, the sources of which are: hazardous hydrological phenomena; hazardous meteorological phenomena; dangerous geophysical phenomena; large natural fires.

IV. Discussion

The discussion of the verbal and mathematical foundations of the forecast modeling of the most catastrophic emergencies of a natural nature is quite actively occurring in the scientific literature [1, 5, 6, 7, 11, 17-19, 21], in particular, on the pages of the scientific and technical journal "Civil Security Technologies» [2, 3, 9, 14].

References

[1] Akimov V.A., Bedilo M.V., S. S. S. Study of emergency situations of natural, technogenic and biological and social nature by modern scientific methods: monograph. M.: FSBI VNII GOCC (FC), 2021. 180 p.

[2] Akimov V.A. Applications of the general theory of security to the study of emergency situations of natural, technogenic and biological and social character // Scientific and Technical Journal of Civil Security Technologies, Volume 18, 2021 (Special Education) -PP. 12 - 27.

[3] Akimov V.A., Bedilo M.V., Dangerous hydrological phenomena and processes as sources of emergencies of natural nature: verbal model // Scientific and Technical Journal of Civil Security Technologies, No. 4 (70), 2021. - PP. 4-8.

[4] State reports on the state of protection of the population and territories of the Russian Federation from natural and technogenic emergencies in 2010 - 2019. M.: EMERCOM of Russia. 2011 - 2020 years.

[5] Natural dangers of Russia. Volume 6. Evaluation and management of natural risks. M.: Krook, 2003. - 320 p.

[6] Remark of R & D "Development of uniform standards, functional, technical requirements and projected-analytical solutions of the hardware and software complex" Safe City "with the required regulatory and methodological support." Formation of the scientific and technological basis for the subject area of the agro-industrial complex "Safe City" on the topic: Forecast and analytical models for the main types of threats described in the concept - 2 queue. Book 6. Description of the methodology of the forecast and analytical model "Flooding within the framework of the territory of the municipality" // NCI LLC, 2021. - 338 p.

[7] Motovilov Yu.G., Gelphan A.N. Models of flow formation in river pool hydrology tasks. IVP RAS, Moscow, 2018, 300 p.

[8] GOST R 22.1.Hh-202x. Safety in emergency situations. Safe city. Flood forecasting. General requirements.

[9] Akimov V.A., Bedilo M.V., S. S.P. Hazardous meteorological phenomena and processes as sources of emergencies of natural nature: verbal model // Scientific and Technical Journal of Civil Security Technologies, No. 4 (70), 2021. - p. 14-18.

[10] GOST R 22.0.03 - 2020. Safety in emergency situations. Natural emergencies. Terms and Definitions.

[11] Akimov V.A., Didenko S.L., Olyan I.Yu. Nonlinear science for researching accidents, disasters and natural disasters. M.: FSBI VNII GOCC (FC), 2020, 134 p.

[12] RD 52.27.724-2019. Guidance on short-term general purpose weather forecasts (approved by Roshydromet 11.04.2019).

[13] WMO No. 834. Guidelines for the practice of meteorological services for the population. Second edition. - Geneva-Switzerland: Secretariat of the World Meteorological Organization, 2000.

[14] Akimov V.A., Bedilo M.V., Ivanova E.O. Hazardous geophysical phenomena and processes as sources of emergency situations of a natural nature: a model of medium-term forecasting of earthquakes // Scientific and Technical Journal of Civil Security Technologies, No. 1 (71), 2022. - p. 4-8.

[15] Russia in the fight against disasters. Book 1. IX - XIX century. - M.: Business Express, 2007. – 288 p.

[16] Russia in the fight against catastrophes. Book 2. XX - early XXI century. - M.: Business Express, 2007. – 272p.

[17] Akimov V.A., Didenko S.L., Smirnov A.S. Scientific basis of the overall theory of life safety / ed. A.P. Chupriyan / EMERCOM of Russia. M.: FSBI VNII GOCHS (FC), 2019. - 252 p.

[18] Arsenyev S.A. Earthquake from the point of view of the theory of disasters // Trigger effects in geosystems, 2017. PP. 52-59.

[19] Report on R & D "Development of uniform standards, functional, technical requirements and projected-analytical solutions of the hardware and software complex" Safe City "with the required regulatory and legal and methodological support." Formation of the scientific and technological basis for the subject area of the agro-industrial complex "Safe City" on the topic: Forecast and analytical models for the main types of threats described in the concept - 2 queue. Book 4. General description of a typical forecast and analytical model // NCI LLC, 2021. – 66p.

[20] GOST R 22.1.Hh - 202x. Safety in emergency situations. Safe city. Forecasting earthquakes. General requirements.

[21] Kuleshov, A.A. Mathematical models of forest fires // Mathematical modeling, 2002, vol. 14, No. 11, PP. 33-42.

[22] GOST R 22.1.HX - 202X. Safety in emergency situations. Safe city. Forecasting forest fires. General requirements.

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ELECTRODRILLING AND NEW PROSPECTS IN THE OIL & GAS WELL CONSTRUCTION RISK REDUCTION

Mikhail Gelfgat[1], Alexander Geraskin[1], Oleg Perelman[1], Alexander Fadeykin[2]

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[1]Gubkin University, Russia;
[2]Novobur, LLC, Russia
mikhailgelfgat@gmail.com; geraskin.as96@gmail.com
perelman@novomet.ru; fadeikin.as@novobur.com

Abstract

Electrodrilling technology represents an alternative to commonly used hydraulic downhole motors. Drill bit driving with the advanced permanent magnet motor (PMM) provide wide range of rpm and constant torque, the ideal parameters for rock destruction. Most importantly, these parameters are not dependent on the type and amount of the agent pumping into the borehole for pressure balance and bottomhole cleaning. The additional advantage is high-speed communication capability between the bottomhole and surface, because of power cable line installed in the drill string. This paper purpose is to show that such drilling system can provide more reliable technology for operation in complicated geological conditions with high risk of problems, such as formation fluid influx, mud losses, borehole walls instability etc. The most critical components of electrodrilling technology are connections of power cable. Paper presented recently completed modeling of connections, which proof potential of electrodrilling for wells construction. The reliability of electrical drive using PMM is proven by vast worldwide experience of the ESP with PMM application. On the top of that electrodrilling technology is naturally compatible with the managed pressure drilling methods, known as the best practice tool for drilling hazards elimination and risks reduction.

Keywords: well construction, drilling problem, electrodrilling, permanent magnet motor, power cable, connections, risks

I. Introduction

Oil and Gas industry is considered as the high-risk enterprise. Biggest risks facing Oil & Gas Companies are: cyber, financial, supply and demand, environmental, safety, risks from the Internet of Things, risks from the employees, and other. In the well construction segment of this industry the key factor influencing risks is the selection of technology. We are dealing here with the "Mother Nature" and despite using all available experience the careful and comprehensive assessment of wellbore conditions, mainly pressure balance during the each of processes is needed.

The hazards associated with a kick are considered as critical, so the well control procedures have always been and are the most critical factor for risks mitigation. When using conventional "open loop circulation" drilling technology, well control situations usually require extra time for kick management, which lead to increase non-productive time (NPT) and consequently cost of well construction. The average NPT today considered as 20-25 %. The reason is different complications related to geology, technology and human factor. During the last 20 years managed pressure drilling (MPD) technology has been implemented to improve well construction process in the "narrow pressure margin" conditions, which appeared in the most of new developing oil and gas fields. This is "closed loop circulation" system with the ability to automate the process of borehole pressure stabilization.[1]

Automatic control has been widely used in most industries for many decades. The motivation factors for the introduction of automatic control were costs reduction and improving the efficiency (for example cars production), where expensive manual labor has been replaced by robotic complexes. Another motivation is improved accuracy and safety as example in aviation and nuclear power plants. In the oil and gas industry, process control is widely used at refineries, were, hundreds or thousands of variables such as pressure, temperature, level, and flow are controlled automatically by feedback control loops consisting of controllers and remotely actuated valves and pumps. In drilling, however, the process runs almost 100% manually with no or very little help from automatic control, like drill bit feed regulation when using downhole motors. The driller operates the rig pump, the drawworks, and much more. A team of service engineers control bottom-hole assembly (BHA) performance and mud system, all parameters from the surface and downhole sensors are monitoring and collecting by different systems, generally called Geological and engineering survey, or Advanced mud logging stations. These data processing with certain algorithms provides ability for NPT and so-called idle NPT recognition and advises for process improvement. The goal is to drill the well into the reservoir in a safe way as fast as possible. The downhole pressure must be kept sufficiently high to avoid hydrocarbons flowing into the borehole (kick) and below the fracture pressure to avoid mud loss or damages to the reservoir near the borehole. Using MPD helps reaching this goal, but the key factor here is the accuracy of downhole measurements and speed of the bottomhole - surface communication.

Despite the rapid development of hydraulic telemetry systems and data compression techniques, existing limitations of traditional approach are expressed in a narrow permissible range of mud flow rate; low resistance of components to erosive wear; signal quality dependency on parameters and the type of circulating agent as well as on pump work. The additional limitations are: shortage of up-to-date information on downhole parameters in real time; inability to obtain and record data without circulation; deficiency in the concentration of lost circulating agent in drilling fluid. These restrictions are often not considered as limiting factors and impede the search for state-of-the-art technical and technological solutions to improve the well construction process.[2]

The known solution is wired drill string (WDS), which is slowly implementing in the up-to-date construction of high-tech wells – long horizontal, extended reach, multilateral etc.

Success and further progress in increasing drilling rates, drilling quality, as well as risk reduction during well construction will result from real-time data transmission technologies. Given the advantages of the latest generation of WDS in providing two-way communication between downhole and surface equipment, it must be taken into account that this technology requires certain technical solutions aimed to improve the signal quality. There are subs along the length of the string, amplifying the signal and limited in time by batteries or power-down capabilities through the communication channel (no more than 500W - Reelwell, 300W - TDE Group), the main part of which is for powering downhole tools. The difficulties in wiring through the downhole motor including the option of using it together with the RSS should be considered also. Nevertheless, existing WDS concept proof the idea of high-speed telemetry and distributed sensors application for improving drilling process performance characteristics and in particular with MPD.

Combination of WDS and MPD provides much better opportunities for drilling complication/incidents prediction at the early phase of their development. This solution has been presented in work [3]. Possible downhole drilling problems are illustrating on Figure 1. Early detection and isolation of drilling problems may be difficult or impossible to determine based on manual sensor reading. The model-based diagnosis system which uses a simple hydraulics model and statistical change detection for drilling problem diagnosis was developed and successfully tested. Determining the type of incident, and in some cases also its position, was successfully done for such problems as drillstring washout, lost circulation, gas influx, bit nozzle plugging. These incidents are automatically detected by the method at a very early stage.

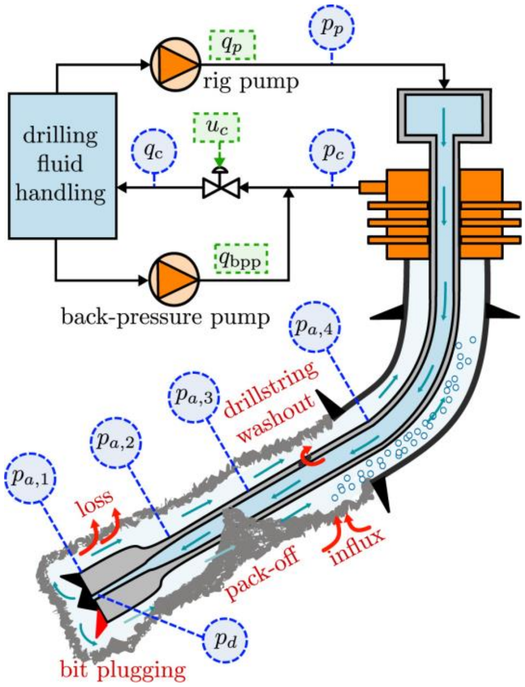

Figure 1: *Managed pressure drilling with wired pipe sensors. The different possible problems of influx, lost circulation, drillstring washout, bit nozzle plugging and pack-off are shown. Available sensors are shown in blue and possible actuation shown in green. Downhole pressure sensors pa,i measure the pressure in the well, while pd measures the pressure in the bottom of the drillstring.*

II. Electrodrilling [2]

The next logical step towards well construction process improvement could be implementation of electrodrilling technology (Figure 2).

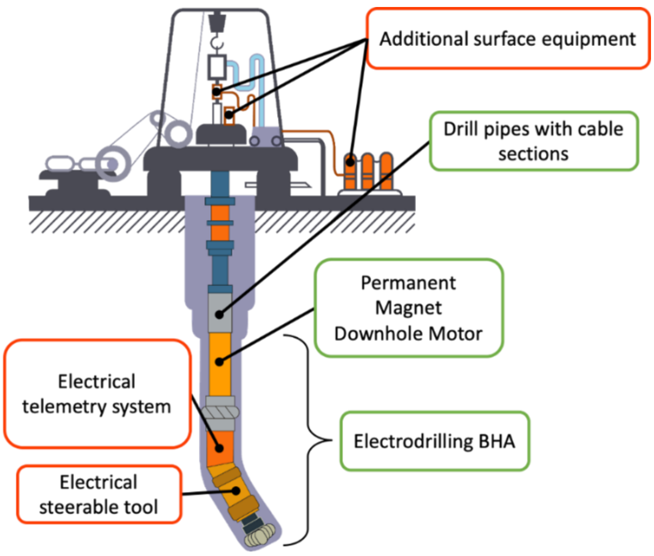

Figure 2: *Electrodrilling complex concept*

Electrodrilling technology has certain advantages over hydraulic downhole motors and rotary drilling:

- The energy transmitted to the motor is independent of flow rate and drilling fluid parameters. This provides complete control over shaft's output rotational speed regardless of weight on the bit, flow rate and torque on the bit within a defined range;
- The communication channel via electric wire provides ultra-high-speed two-way data transmission related to drilling parameters, including borehole direction, characteristics of rocks, distribution of pressure and temperature along the wellbore, downhole dynamics and mechanics data; also, there are capabilities to use seismic while drilling technology, 3D and 4D caliper technology over the drilling process; all of that is possible due to the transfer of the required amount of electrical energy to the motor, BHA elements, as well as sensors located along the length of the string;
- Constant motor characteristic, independent of circulation hours since the motor design does not have a wearing elastomer as PDM's stator;
- Ability to transfer computing capability from the complex downhole equipment to the surface and monitor equipment from the surface. Reducing complex and high-tech electronics in downhole equipment will simplify the applied circuits in RSS and M/LWD tools, reduce the risk of malfunctions while working under conditions of high bottomhole pressures, temperatures and dynamic loads.

Using an electrical downhole motor and capability of electrical communication channel to monitor and optimize drilling parameters can provide the following benefits:

- The energy used to destroy the rock is immediately reflected in the value of the consumed current, which makes it possible to:
  - Control the load on the bit through an ammeter;
  - Determine the bit performance at different regimes and select the optimal parameters for a specific lithology and bit design;
  - Determine the wear of the bit and prevent from its critical wear;
  - Carry out detailed geology and lithology identification at the bit;
  - Determine the causes and interpret the mechanisms of downhole dynamic processes: vibrations and shocks.
- More accurate input parameters (bit rotation speed, torque, WOB) for monitoring drilling performance indicators (specific mechanical energy, depth-of-cut, drilling strength) in real time;
- The ability to automate the process of selecting the optimum drilling parameters to improve efficiency of rock destruction, approximate the actual profile to the planned one and adjust it, mitigate vibrations, predict and mitigate accidents.

During the industrial use of electrodrilling technology in 1960-2009 more than 7.5 million meters were drilled in Bashkortostan at 2500 wells with a cumulative 12.5 million meters drilled in all countries of the former Soviet Union. The technical and economic analysis of electrodrilling system based on the induction type submersible motors carried out in the 1980s showed that, in comparison with rotary and turbine drilling with roller cone bits, when drilling directional and horizontal wells, the use of electrodrill ensured reduction the cost of 1 meter drilled by 10-25 % on average, increase bit run footage and ROP by an average of 16-18%.

The telemetry system was the most important element in the electric drilling complex (EDC), as it provided new opportunities for monitoring and control of downhole equipment due to 2-way transmission of information in real time. Energy was supplied through a cable placed at the center of drill pipes along the whole drill string. At the surface, energy was supplied through the slip rings, which allowed to transmit power, ensure communication and to rotate drill string as needed.

Despite the obvious advantages of electrodrilling in comparison with existing drilling technologies, electrodrill has not become the predominant type of downhole motor. One of the main reasons was the constant shortage of electric drilling equipment, spare parts and assemblies, as the equipment was much more sophisticated then turbodrill, or positive displacement motor. Also, the surface set of control equipment is specifically needed for electrodrilling. Another important reason was related to reliability of electric drilling equipment. The weakest element in EDC, from the point of view of reliability, was electric power cable connections. The average durability of roller cone drill bits was low, lifetime measured by 10ths of hours. These days PDC-type drill bits lifetime is measured by 100s hours. The number of roundtrips, means making up and breaking down connections was much more than required at the present time, which led to a decrease in hydraulic tightness and a reduction in their service life.

In addition, induction electrical motors had starting up currents 6-7 times higher than the operating currents, which sharply increased the probability of electrical breakdown in the cable section connections even with a slight decrease in their tightness, especially when drilling at great depths in high-pressure conditions.

In the late 80s and 90s, horizontal drilling became an increasingly relevant topic and discussions about electrodrilling application resumed. The shortcomings of the method were analyzed together with the actual drilling results, and evaluated by experts; conclusions were drawn about potential prospects using new electrical motor design - permanent magnet motors (PMM), which would provide smooth start, rotational control and better efficiency in compare with the induction motors.

By the mid-90s, several foreign companies have shown interest in electrodrilling technology assessment, since they considered this method as one of the possibilities for improving the horizontal and multilateral wells technical and economic indicators. The focus was on the experience of operating a power cable line for the bottomhole - wellhead communication. By the same time the combination of electrodrilling and coiled tubing technology attracted particular interest in the USA and Canada. One of the most important works [4] described a project to create an "electro-BHA" for directional drilling on coiled tubing with a borehole diameter of 3.75" (95 mm), BHA diameter 3-1/8" (79.3 mm). The advantages of the system were formulated as follows:

- the motor power does not depend on the fluid flow rate;
- high tolerance to drilling fluid parameters (air, nitrogen, foam, standard and heavy mud can be used) are ideal for underbalanced drilling - these days for MPD technology;
- high temperatures operational environment (no elastomers in motor design);
- flexible power management with instant feedback for closed-loop drilling (means drilling automation) and optimization of drilling efficiency,
- motor operations are scalable; the same motor can be used for auxiliary operations, such as orientation, movement of the BHA along the well, formation testing;
- data transmission to the surface in real time;
- increased motor life;
- reduced vibrations (affects the location of the gyroscope, the reliability of other equipment, such as NMR magnets),
- reverse rotation of the engine (passive or active traction capabilities).

Advances in artificial lift technology have enabled a new type of electrical submersible pump (ESP) installation on coiled tubing. New system presumes a high-capacity power cable installation within the coiled tubing for protection against the downhole environment. This concept was transferred to coiled tubing drilling and a joint industry project was formed to produce a cost-effective electric coiled tubing drilling (Eni Agip, Amerada Hess, Amoco Corporation E&P Technology, BP, Elf, Enterprise Oil, Shell Expro and Texaco Britain were project sponsors). "An ESP motor was combined with a planetary gearbox and electromechanical coiled tubing connector. The motor was controlled from surface via a laptop computer connected to a variable speed drive (VSD). A command-and-control software package was developed which interrogated the drive to acquire and record real-time drilling data from the motor" [4]. Unfortunately, this project has never been forwarded until the commercial prototype. The similar concept is going to be realized in Russia now, almost 20 years later, when the successful application of ESP using PMM (in fact similar type of motor proposed in that project), has been verified all over the World.

It is noteworthy that since 2012, the volume of PMM implementation as part of ESP has been steadily growing (according to Novomet-Perm JSC, Figure 3).

At the same time, the use of PMM increases the average operating time of ESP, which reaches more than 450 days [5]. This indicates not only the high reliability of the PMM, but also the sophistication of the design of the electric motor as a whole. The use of already proven design solutions in the permanent magnet drilling motor (PMDM) will significantly increase the probability of trouble-free operation in comparison with existing hydraulic downhole motors.

Since 2017, Novobur Company commenced electrodrilling technology development both on conventional drill pipes with the power cable sections and coiled tubing option. Currently available standard size range of PMMs, widely used for driving modern ESP, corresponds to the size of the BHA for drilling, including coiled tubing, that ensures effective use already proven and reliable equipment in further operations.

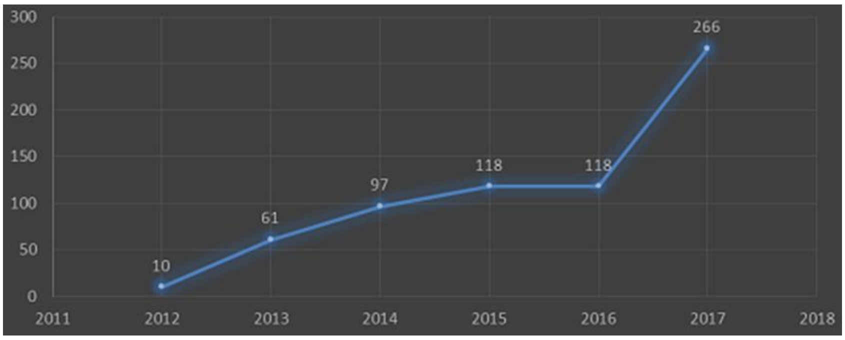

Figure 3: *Number of PMMs working outside the Russian Federation as part of ESP*

III. R&D work results

The main area of new EDC application is directional drilling of exploration and production wells with complex trajectories, with long horizontal section, extended-reach and deep wells. EDC significantly differs from conventional systems, both in the composition of surface equipment and the downhole one (see fig. 2). The typical composition of the EDC is indicated in Table 1.

Table 1: *Components of Novobur's Electrical Drilling Complex*

№	Element of Electrical Drilling Complex
1	Surface equipment for bit feed regulator
2	Control unit (working place of M/LWD engineer)
3	PMDM control station
4	Current lead
5	Contacts cleaning device
6	Drill pipes with cable sections
7	Jar and drill collars with cable sections
8	Float valve with cable sections
9	Hydraulic insulation of downhole motor
10	PMDM with hydraulic insulation
11	Gearbox and spindle with cable sections
12	Controllable downhole deflector with M/LWD modules

When talking about additional risks, the most critical element in EDC would certainly be drill pipes with power cable and connections. Here is the brief review of the recent study [6]. The considered structure uses a method of transferring energy using electric cables passing inside the drill pipes. It is necessary to provide a sufficiently low electrical resistance at the contact points (<0.001 Ohm) for ensuring the reliable and efficient transmission of electricity to the BHA. Joining the cable sections is carried out using rubber-metal joints. The estimation of this type of joint is nontrivial due to the nonlinearity of the properties of rubber bonded to metal components. The purpose was numerical modeling of the process of joining the power cable sections, as well as an approbation of methods for transferring the stress-strain state (SSS) of the structure between design cases. The listed tasks belong to the class of problems of the sealing joints behavior. Measured parameters are contact pressure and SSS of structural parts. The main feature of this study is using the structure SSS after joining as the initial conditions for further virtual tests of the structure under the action of operational loads.

Figure 4 represent connection design under study.

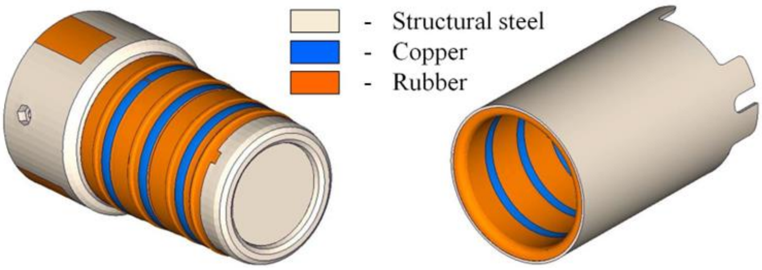

Figure 4: *Structure and material distribution of the pin and box modules*

A highly adequate digital model of the power cable section contains:

- Full-scale geometric (CAD) and finite element (CAE) section models;
- Properties of the materials: elastic-plastic characteristics of metals, taking into account the dependence on the rate of deformation, as well as the results of field tests of rubber samples for uniaxial tension;
- Information on operating conditions:
  - the value of the internal hydrostatic pressure - 75 MPa;
  - vibration (axial / radial) - acceleration amplitude 30g, frequency 300 Hz;
  - shock impact (axial / radial) - acceleration amplitude 15g, pulse duration 12 ms;
  - the curvature of the pipe axis of the drilling equipment section - 30 mm / m.
- Targets and limitations: for joining - value of interference is not more than 3 mm during joining, the contact resistance is not more than 0.001 Ohm; for mechanical tests - no destruction of parts.

All calculation models were prepared for the LS-DYNA finite element analysis system.

The results of numerical simulations of cable sections joining show that SSS of structural parts meet the strength conditions. Besides, the structure provides required level of the electrical conductivity in terms of the interaction of contact rings, which is confirmed by full-scale tests of the structure operability after assembly. The operability of the applied method of transferring the stress-strain state of a rubber-metal structure between virtual tests was confirmed in the course of the test design evaluation of the structure under the action of axial vibration.

Several types of calculations were carried out: the simulation of mechanical docking of electrical contacts; the impact of vibrations and shocks on a docked pair of electrical contacts with simultaneous exposure to hydrostatic pressure.

The most important result of dynamic structural analyses (operational load) is the reproduction of the level of contact pressures at the first steps of the estimation, achieved during joining. Vibrations that could be encountered while drilling process were studied, modeled and compared with actual results. Subsequently, the contact pressures, which ensured reliable power transmission, increased because of the internal pressure acting on the structure (see figure 5).

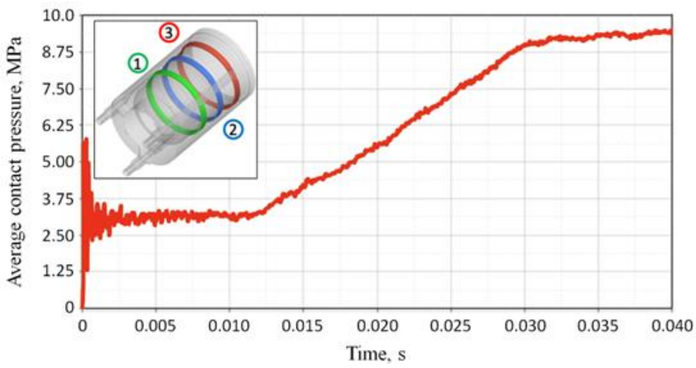

Figure 5: *The contact pressure of the third ring during virtual axial vibration test*

Performed studies showed the potential of new generation EDC critical component – drill pipes with electrical power cable inside, which become much more reliable in comparison with the previous generation system. The assessment of the quantitative characteristics of the structural SSS and the degree of test results compliance with reality will be done after full-scale tests.

IV. Conclusion

1. Electrodrilling with PMDM combines certain advantages of modern rotary drilling and mud motors drilling method: wide range of rotation speeds at the optimum torque on the bit; independence from the energy transmitted to the bit by drilling fluid; use of various circulating agents; directional and horizontal drilling capability.
2. EDC is naturally matching with MPD technology providing huge potential for NPT and risks reduction when constructing wells in difficult geological conditions, drilling through fractures and faults, depleted formations with total losses, HPHT conditions, geothermal drilling, exploratory wells.
3. Electrodrilling is promising technology in coiled tubing applications with integrated electrical wire (inside CT) for directional, horizontal and multilateral wells drilling, small diameter sidetracks.
4. Integrating EDC with drilling rig systems and digital platform will ensure achieving closed-loop control system and ultimately autonomous drilling with minimum human intervention.

All the above is shown the capabilities of the new generation EDC for different well types drilling in diverse and challenging conditions as a method for effective, economic, reliable and low risk well construction process.

References

[1] Gelfgat M., Oganov A., Sledkov V. Well construction technologies for prediction of complications and risk mitigation, Abstracts of The Second Eurasian RISK-2020 Conference and Symposium (RISK-2020) 12 – 19 April 2020, AIJR Publisher, Dhaurahra, Balrampur, India 271604, pp.165-166.

[2] Gelfgat M., Geraskin A., Fadeikin A., Perelman O. Prospects of Electric Drilling for the Development of Well Construction Technologies, SPE-206463-MS, SPE Russian Petroleum Technology Conference online 12 - 15 October 2021,

[3] Willersrud A., Imsland L., Blanke M., Pavlov A. Early Detection and Localization of Downhole Incidents in Managed Pressure Drilling, SPE/IADC-173816-MS, SPE/IADC Managed Pressure Drilling and Underbalanced Operations Conference & Exhibition held in Dubai, UAE, 13–14 April 2015.

[4] Turner, D.R., Harris, T.W.R., Slater, M., Yuratich, M.A., and P.F. Head. (1999). "Electric Coiled Tubing Drilling: A Smarter CT Drilling System." Paper presented at the SPE/IADC Drilling Conference, Amsterdam, Netherlands. doi: https://doi.org/10.2118/52791-MS

[5] Peshcherenko S., Slepchenko S., “NOVOMET: full-spectrum approach to ESP systems operation in Kazakhstan” Oil & Gas Vertical, #17/2008

[6] Sergeeva T.V., Monahovskiy G.V., Kharaldin N.A., Klyavin O.I., Kraev A.A., Knyazeva O.V. (2021) Development of Approaches to Modeling the Processes of Joining Sections and Operation of Drilling Equipment. In: Zheng L., Sun C., Goh KL. (eds) Proceedings of MEACM 2020. MEACM 2020. Mechanisms and Machine Science, vol 99. Springer, Cham. https: //doi.org/10.1007/978-3-030-67958-3_37

CARBON POLYGONS AS A TOOL FOR IDENTIFICATION, ANALYSIS AND ASSESSMENT OF VARIOUS TYPES OF NATURAL AND ANTHROPOGENIC HAZARDS

Rustam Gakaev, Magomed-Sadyk Bakhaev, Masud Israilov

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Chechen State University named after A.A. Kadyrov, Russia
rustam.geofak@yandex.ru
salamova_chgu@mail.ru

Abstract

Environmental issues, including those related to the reduction of anthropogenic greenhouse gas emissions and climate conservation, occupy an important place on the agenda of most world powers, including the Russian Federation (RF), which was documented by the adoption of the Paris Agreement. The countries of the European Union (EU) have historically been the most active supporters of environmental initiatives and have long adapted various fiscal instruments (taxes and quotas) to stimulate enterprises to reduce carbon dioxide and other greenhouse gas emissions. One of the latest steps towards such a policy was the introduction of a proposal to introduce cross-border taxes on carbon dioxide in relation to a number of goods imported into the EU countries. And although this project is currently under development, and the legal and methodological details of its implementation are unknown, experts are confident that the new tax will be introduced and entail significant financial losses for the Russian Federation. Taking into account the fact that more than 40% of Russian exports go to the EU, of which more than 70% are "environmentally dirty": oil, coal, gas and metal, due to the new tax, the Russian economy will lose from three to five billion dollars annually already from 2022, and by 2030 these costs will amount to more than eight billion a year.

Keywords: Carbon polygons, greenhouse, gas emissions, environmental problems, environmental protection, carbon dioxide

I. Introduction

The main hypothesis is that the creation of a network of carbon polygons will make it possible to form a domestic method for calculating the ability of carbon dioxide absorption by the environment. Dedicated reference areas are used to calibrate satellite and drone data, and the results obtained can be extrapolated to the rest of the country to obtain accurate data on the absorption capacity of different types of landscapes without the use of laborious and time-consuming ground studies. The stated principles of analysis are: the use of satellite images of the surface from space, surveys from a drone and ground-based measurements [1]. Ground measurements are used as data markup (for training machine learning algorithms) received from the drone and satellite. In the future, this should make it possible to assess the absorbing capacity of territories using drone/satellite data, without using ground-based measurement data. For native spectral analysis, satellite and radar data are used. The selected area is analyzed using various unmanned systems for the layout of "hyperspectral cubes" (different spectral signatures make it possible to determine the type of the earth's surface). Thus, the polygon is used to calibrate satellite data and drone data, with the subsequent extrapolation of the results to the rest of the territory. To ensure the operation of this approach in different types of territory, it is necessary to collect data on the absorption capacity of different types of landscapes (news sources say about 80 polygons), including spectroscopy data (no information) [2].

The main goal of creating a wide network of carbon polygons throughout the country is to fully take into account climatic features in various parts of the Russian Federation, which is necessary to determine the territorial correction factors in the developed model for calculating the carbon balance. The global federal program (10-15 years) related to greenhouse gases and the economic consequences of their control can be divided into three major stages [3-4]: 1. Development and certification at the international level of a unified methodology for calculating and accounting for the absorption and emission of greenhouse gases; 2. Development of technologies for changing the carbon balance (reducing emissions and increasing sequestration); 3. Linking the carbon balance to economic systems (quotas). After all, this market, which may be formed after the entry into force of the Kyoto Protocol, provides for taking into account not only emissions, but also absorption (sequestration) and conservation of carbon, which allows Russia to enter it as a supplier of carbon units. At the same time, all the listed stages can be additionally divided into two more blocks: - related to natural phenomena; - associated with the results of technogenic activities. Today, there is no unequivocal confirmed method for calculating the carbon balance of natural systems specifically, in particular in terms of absorption (in contrast to emissions based on the results of technogenic activities, which, in accordance with some recognized methods, are calculated mathematically).

The carbon polygon is a geographically distributed research platform designed to solve three main tasks: - developing a model for calculating the carbon balance of the area, taking into account the absorption and emission of the local ecosystem; - development of a method for using aerospace data to track emitted and retained greenhouse gases within specific biogeocenoses; - training of highly qualified personnel in the field of the latest methods of environmental control, promising technologies for the low-carbon industry, agriculture and municipal economy.

II. Methods

Let's take a look at different methods of implementing landfills around the world. Restoring and rewetting peatlands As the world's largest natural carbon store on land, peatlands play a key role in combating climate change. Intact peatlands play an important role in the carbon cycle, climate change mitigation and the provision of ecosystem services due to their role as a permanent water-locked carbon store and permanent sink. However, years of unsustainable land management practices have degraded peatlands, limiting their ability to provide effective climate management services. Currently, degraded peatlands emit 2 Gt CO_2 per year and account for almost 5% of global anthropogenic CO_2 emissions [7]. Only due to the drainage of peatlands, about 220 million tons of CO_2eq. are emitted into the EU per year. Therefore, restoration, rewetting and conservation of peatlands is an urgent priority in climate change mitigation, as well as in providing other ecosystem services. Impact on climate: mainly avoidance of emissions from drainage, in addition, peatlands actively sequester a large amount of carbon, but this is a slow process with low annual carbon growth. Monitoring, Reporting and Verification (MRV): It is not possible to continuously monitor primary data in situ. Therefore, mechanisms should rely on performance monitoring (eg GEST method). Project-level internal reporting and third-party verification by experts approved by the mechanism. Verification data is transmitted for verification. Overall conclusion: avoiding emissions from peatland drainage is an important mitigation option with significant co-benefits for the provision of ecosystem services. The development and operation of a carbon-based peatland mechanism is a promising and feasible way to incentivize government, authorities and farmers to take effective and efficient climate action in the EU. The study and use of already existing sub-national and national mechanisms and programs of peat payments based on results in the EU can contribute to the development of mechanisms and their scaling up in the EU. Agroforestry 11 Agroforestry is the practice of deliberately combining woody vegetation (trees or shrubs) with crop and/or livestock systems on the same piece of land. Traditional agroforestry systems are very diverse and adapted to local soils, climatic conditions and farming systems. Examples include the large deesa and montadón drylands in Spain and Portugal, perennial crop and pasture systems in southeastern Europe, and woodland pastures and bocage (hedge) landscapes in northern Member States. More recently, new agroforestry systems have been established on both arable and pastoral farms, but it is clear that the potential of agroforestry is not being tapped and existing long-established systems are under threat. Compared to traditional production systems, agroforestry contributes significantly to carbon sequestration, increasing. a range of regulating ecosystem services and enhances biodiversity.

Recent studies estimate that the introduction of agroforestry in croplands and rangelands where multiple environmental pressures already exist could lead to sequestration between 2.1 and 63.9 Mt C a − 1 (7.78 and 234.85 Mt CO2eqa - 1). The type of agroforestry adopted will affect both the sequestration potential and the contribution of agroforestry to creating other environmental pressures (Kay et al, 2019). However, as IPCC (2019) notes, agroforestry may take longer to realize greenhouse gas emissions benefits than other measures and cannot continue to capture carbon indefinitely. Agroforestry systems are also at risk of re-emissions associated with poor management and natural disasters. Climate impact: any action that maintains/improves or introduces wood components integrated into agricultural production to increase long-term carbon stocks and sequestration potential in biomass and soils without increasing emissions in the short term. Monitoring, Reporting and Verification (MRV): Only indirect methods to determine home garden carbon savings associated with aboveground biomass and actual values will depend on the agroforestry system, end-of-life wood use and local definitions of the baseline for the assessment. SOC methodologies are not yet considered fully tested or validated for results-based agroforestry mechanisms. Overall conclusion: Existing extensively managed agroforestry systems are under threat and their agricultural intensification risks increasing greenhouse gas emissions, so ongoing supportive management is a priority. The introduction of new agroforestry within traditional farming systems offers the potential for additional climate benefits (both mitigation and adaptation) as well as a range of other ecosystem and biodiversity services. However, achieving these cost-effectiveness requires careful selection of locally appropriate systems and the provision of other environmental public goods, not just reductions in greenhouse gas emissions. Significant advisory, technical and upfront investment support will be needed to overcome farmers' resistance in many parts of the EU. Results-based mechanisms have not yet been developed and tested for agroforestry and should take into account the time frame required to realize the full benefits of the woody element.

Preservation and increase of organic carbon content in mineral soils. Soil organic carbon (SOC) has proven beneficial to soil quality, agricultural productivity, and climate change mitigation and adaptation. The potential for SOC sequestration in the EU is estimated at 9 Mt to 58 Mt CO2-eq per year. In addition, maintaining existing SOC levels is critical given that many mineral soils continue to lose SOC, i.e. Estimated annual EU emissions from mineral soils under arable land are 27 MtCO2eq and from grasslands 41 MtCO2eq (2016 report; EC 2019). Research and existing SOC initiatives show that farmers can apply a range of management practices to improve SOC levels, including growing cover crops, improving crop rotations, agroforestry, avoiding conversion to arable land, and converting to pasture. Many of these methods are cost effective. However, soil heterogeneity, climatic conditions, existing SOC levels, and management practices mean that the likelihood of uptake can vary significantly at the farm and plot level. Climate impact: any action that maintains and increases SOC levels and benefits soil health [6].

III. Results

The carbon polygon is a geographically distributed research platform designed to solve two main tasks: developing a model for calculating the carbon balance of the area, taking into account the absorption and emission of the local ecosystem, and developing a method for using aerospace data to track greenhouse gases emitted and retained within specific biogeocenoses. This is a somewhat narrower definition as it does not include a number of experimental aspects of the landfill operation, such as studies of the absorptive capacity of specific plant species or the study of the effectiveness of various carbon farming methods. However, a full-scale polygon requires significant financial and time resources, and carrying out additional experimental work is characterized by diminishing returns on the potential value of the information obtained as the number of polygons increases. In other words, if paulownia is planted in the conditional region N on the polygon (taking into account the long-term forecast - for a period of 7+ years - depending on the productive age of the plant) and it turns out that this tree is the optimal carbon sequester, then it seems inappropriate to plant the same paulownia on polygon of another region, for example, KO. Climate, soil, and other components of the environment are different, but not so much that the results obtained have a fundamental difference. A different approach seems to be more correct: large polygons are created, where all planting and farming are studied, then the obtained data are extrapolated to CR, or not used, depending on the climatic conditions of the productivity of certain plants. But since the main purpose of the landfill is accounting (taxes on exports, etc.), we will focus on "compact landfills". The exact parameters of the model plots where research is planned will be specified based on the results of consultations with bioecological specialists. First, these should be territories that are characteristic representatives of the main types of ecosystems: meadow, swamp, forest. And if the definition of the list of terrain types studied is a flexible variable and may vary depending on expert advice and/or availability. appropriate territories for scientific work, then the condition of "modeling" is strict - if the site does not have the necessary representativeness (for example, in terms of species or age composition of trees), then it will not be possible to create a reliable statistical model based on it. Second, the study areas should be spaced apart to take into account the heterogeneity of climatic conditions and differences in soil composition, which can potentially manifest themselves at the scale of the CR. Thirdly, the size of each site should be, on the one hand, large enough to be considered a full-fledged ecosystem, and on the other hand, relatively compact in order to reduce the dispersion of measurements for identical objects within the site and reduce the cost of experimental work. The corresponding review article [7] was used as a reference material on modern methods for calculating the carbon balance. From which it follows that the reference in terms of measurement accuracy are field, subdivided into destructive and without interference in the natural biocycle. Based on the specifics of the polygon, the last type of measurements performed using allometric equations is of interest. In fact, this is the same statistical model that makes it possible to estimate the level of carbon sequestration by trees using indirect measurements: height, trunk diameter, crown size, etc. To determine the coefficients of allometric equations, it is necessary to first examine several samples of tree species using destructive methods: cut down, divide into separate parts and study them in the laboratory. Soil allometric equations are derived in a similar way: the coefficients derived from the detailed biochemical analysis are used to estimate measurements for more general parameters in the future. For the polygon being created, it is proposed to use internationally recognized calculation methods from the recommendations of the Intergovernmental Panel on Climate Change (IPCC) [10]. This not only simplifies the subsequent certification of the obtained allometric equations, but also reduces the range of possible errors in the course of experiments to measurement errors.

Conducting ground-based measurements is a resource-intensive process and has low scalability, and for some hard-to-reach areas it is not possible at all. The main modern trend in solving this problem is the use of air and space sounding systems. In such systems, various types of sensors are used (optical, thermal, radio frequency, etc.), and they themselves have different spatial (from a few to hundreds of meters) and temporal (from several hours to a couple of weeks) resolution, they differ in the area covered territory (from units to thousands of kilometers). The variety of available options and the advantages and disadvantages inherent in each of them make the choice of a specific method (or combination of them) of aerospace sounding one of the most important in the research protocol of the carbon test site being created. Given the combination of qualitative characteristics and parameters (given in the reference article), it is proposed to use a combination of hyperspectral sensors (for example, one of the following: AISA Eagle, HYDICE, ALOS) placed on an unmanned aerial vehicle (drone) and lidar sensors (for example, as in the Carbon project). 3D [4]) on board the satellite. Such a solution is distinguished by the maximum completeness of the collected information, is relatively resistant to weather fluctuations, and makes it possible to achieve an accuracy of about 0.9 from reference ground-based measurements (0.83 for hyperspectral sensors and 0.89 for lidar - combining data improves accuracy). The disadvantage of this approach is the high cost and technical complexity of the survey methods used, however, within the framework of the research site, this seems to be a rational compromise.

IV. Discussion

In contrast to field work, there are no ready-made methodologies for organizing research for aerospace sensing, therefore, when moving from the concept (this document) to the implementation of a carbon test site in KO, it will be necessary to develop an appropriate protocol. It is recommended to include the following points in it: all sounding data will have to be compared with field measurements, the temporal resolution of the survey should compensate for weather fluctuations, the spatial resolution should correspond to the size of the minimum measurable unit (this is not necessarily a separate tree, it may be more rational to take into account the carbon balance for a small group of plants, which will reduce the error of discrete measurements), the satellite acquisition band should completely cover the model area, aerial photography over selected areas should be available, etc. If the relevant protocol is properly implemented and all surveys are carried out according to its letter, aerospace sounding data and the results of field studies can be used to develop algorithms for estimating carbon balance without ground-based measurements. Turning again to the experience should be said that the creation of software solutions responsible for mathematical modeling and processing of aerospace sounding images is the most difficult part of the entire carbon test site project [5]. However, in the absence of real data, it is not possible to give any recommendations regarding promising areas in the field of machine learning, which would be more suitable for solving the tasks set.

Tasks to be solved using the landfill [8-9]: 1. Development and evaluation of the effectiveness of methods for monitoring current levels (as well as emissions) of greenhouse gases. 2. Studies of the carbon balance of ecosystems characteristic. 3. Research on the carbon sequestration potential of various plant species at different stages of their life cycle. 4. Studies to evaluate the effectiveness of possible measures and practices aimed at reducing greenhouse gas emissions by ecosystems.

Drawing on world experience, the most relevant approaches in this area are:

● Restoring and rewetting peatlands to limit greenhouse gas emissions Peatlands, the world's largest natural carbon store on land, play a key role in combating climate change. In addition, peatlands sequester carbon, but the rate of this process is low. Unsustainable land use leads to the degradation of peatlands, which limits their ability to positively influence the climate. Currently, degraded peatlands emit 2 Gt CO_2 per year and account for almost 5% of global anthropogenic CO_2 emissions. Restoration, rewetting and conservation of peatlands is an effective approach in climate change mitigation.

• Agroforestry technologies for carbon sequestration Agroforestry refers to the practice of deliberately combining woody vegetation (trees or shrubs) with crop and livestock systems on the same piece of land. Specific technologies within this area are diverse, due to the need to adapt to specific soils, climatic conditions and agricultural systems. The introduction of agroforestry within traditional farming systems contributes to carbon sequestration in the long term without increasing emissions in the short term, and also has a positive effect on biodiversity.

● Maintaining and increasing soil organic carbon levels Maintaining and increasing soil organic carbon levels can be done by growing cover crops, improving crop rotations, introducing agroforestry, preventing plowing, organizing pastures. At the same time, the effectiveness of specific measures can vary significantly depending on climatic conditions, soil structure, and the current level of soil organic carbon. High monitoring costs, and such uncertainty in efficiency even at the site level, creates an obstacle to the actual implementation of sequestration projects of this type.

● Process optimization in agriculture and livestock production On the one hand, grasslands and pastures occupy a large area of agricultural land, which allows them to naturally sequester a significant amount of carbon. On the other hand, ongoing agricultural activities (for example, in the case of conversion of land to arable land) can lead to significant emissions. At the same time, in addition to the impact on the climate, it is necessary to take into account the problems of preserving biodiversity and increasing soil productivity and pasture productivity. Livestock such as meat, dairy, sheep and pig farms make a significant contribution to the total greenhouse gas emissions into the atmosphere. The introduction of technologies to combat climate change on farms (for example, the selection of special feeds, the treatment and processing of waste, etc.) can reduce greenhouse gas emissions. Thus, the polygon should contain on its territory the main types of ecosystems - meadow, swamp and forest - on which the research will be directly carried out. At the same time, it is possible to organize a polygon on the basis of several sites spaced apart in space, if such a need arises. The area of each such area should not be large enough to obtain reliable results. According to world and Russian experience, the landfill area can vary from tenths to units of square kilometers.

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References

[1] Zhuravleva V. V., Kazazaev V. V. On modeling plant photosynthesis under global climate change. No. 4 (96), 2020, pp. 104-107.

[2] Pinyavina E.A. Creation of forest carbon (carbon) landfills: economic component // Actual directions of scientific research of the XXI century: theory and practice. 2021. No. 1. p.26-34.

[3] Porfiriev B.N. An effective strategy for action on climate change and its consequences for the Russian economy, 2019. No. 3 (174). pp. 3-16.

[4] Gakaev R.A., Bayrakov I.A., Bagasheva M.I. Ecological foundations of the optimal structure of forest landscapes in the Chechen Republic. In the collection: Environmental problems. A look into the future. Proceedings of the III scientific-practical conference. Executive editor Yu.A. Fedorov. 2006.S. 50-52.

[5] Hallding, K.; G. Han and M. Olsson, China's Climate- and Energy-security Dilemma: Shaping a NewPath of Economic Growth. Journal of Current Chinese Affairs, 2020, 83(3), pp. 119-134.

[6] Hansen, J.; M. Sato; R. Ruedy; K. Lo; D. W. Lea and M. M. Elizade, Global Temperature Change, PNAS, 2020, 103(39), pp. 14288–14293.

[7] Leggett, J. A.; J. Logan and A. Mockey, China's Greenhouse Gas Emissions and Mitigation Policies, CRS Report for Congress 2008.

[8] Verfaillie, H., and R. Bidwell, Measuring Eco-efficiency: A Guide to Reporting Company Performance, World Business Council for Sustainable Development, Geneva, 2020.

[9] Kantyukov R R., Kolybanov K. Yu, Ravikovich V I Information technologies for preparing control decisions in automated systems of environmental monitoring, 2019.

[10] Kampschreur MJ, Temmink H, Kleerebezem R, Jettena MSM, van Loosdrecht MCM. Nitrous oxide emission during wastewater treatment. Water Res. 2019, pp.4093–4103.

BOUNDARY DELINEATION OF AGRICULTURAL FIELDS BY APPLYING FUZZY OBJECT-BASED IMAGE ANALYSIS

Aliakbar Rasouli[1], Matanat Asgarova[2]

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[1] Department of Remote Sensing & GIS, Faculty of Planning and Environment Sciences, University of Tabriz, East Azerbaijan, Iran
rasouli@tabrizu.ac.ir
[2] Faculty of History and Geography, Azerbaijan State Pedagogical University, Azerbaijan,
matanat_askerova@mail.ru

Abstract

Expected climate change can disrupt food availability, reduce access to food, and treat human beings and large living creatures in many agricultural operations worldwide, including our homeland Azerbaijan. The boundaries of agricultural fields are, therefore, important components necessary for defining the location, shape, and spatial extent of farming units commonly used to summarize production statistics at the field level. Accordingly, the current paper delineated the agricultural field boundaries from which we acquired Sentinel-2 satellite images dated 2021/06/17 inside the eCognition Developer, Version 9.5, over a small part northeast of Ganja Dashkasan and northwest Central Aran economics regions the Republic of Azerbaijan. Then, the examination was followed by applying a few Fuzzy Object-Based Image Analysis (F-OBIA) techniques inside eCognition Software. In addition, we covered edge detection approaches, watershed segmentation algorithms, and a few rule-based applications to reach the study's targeted aims. Finally, we combined edge detection features and segmented image objects with knowledge-based methods to trace agricultural fields with various Normalized Differences in Vegetation Indices. At the regional and local scales, the current methodology and associated models could be used in many agricultural operational types of research by processing high-resolution satellite imagery. The field data gave satisfactory results. Researchers could apply the proposed methodology in other Azerbaijan regions to access accurate information leading to sustainable agricultural operations.

Keywords: Fuzzy Object-Based Image Analysis, eCognition Developer, Knowledge-Based Methods, Boundary Delineation of Agricultural Fields

I. Introduction

Under climate change, climatic hazards have a higher probability of occurrence, and crop insurance has become more critical to growers. To have reasonable insurance premiums, the growers and the crop insurance agencies need precise measurements of the cropped field area and boundaries [1]. Global Navigation Satellite System (GNSS)-based on site surveys can determine field areas and boundaries, but they are costly in time and effort. The main purpose of the current article is to identify agriculture farms - examples of traditional agricultural and modern irrigation fields - based on Sentinel-2 satellite imagery. Field boundary information is often available for individual farms, but it isn't easy to collate and maintain this uniform across a region containing thousands of farms [2]. Also, physical fence lines are not the only interesting feature: several different crops are sometimes grown inside a single field. Since the final aim is to classify these crop parcels separately, subareas must also be segmented. Rydberg and Borgefors 2001 defined field boundaries as being at locations "where a change in crop type takes place or where two similar crops are separated by a natural disruption in the landscape, like a ditch or a road." To this, we add any significant differences in crop management. In practice, any boundary mapping method must be able to work across large areas, such as whole districts or full satellite scenes. It must also be easy to quickly regenerate the field boundary map from new image sequences so that we can keep up the result to date. Changes in farm type often give rise to new field layouts, and subareas of the crop within fields vary from year to year. Existing approaches for segmenting imagery include:

a) edge detection methods [3]; these accurately locate significant boundaries but do not guarantee closed polygons;

b) region-based methods involving merging adjacent areas that have similar spectral properties (bottom-up, region growing); splitting areas that have different spectral properties (top-down); or clustering spectrally similar pixels around a set of k-means [4]—all produce closed polygons, but the boundaries are not always located at the natural/visible edges of the highest gradient or linearity;

c) integrated methods that combine the advantages of edge and spectral approaches and, more recently [5]. We can combine these techniques with other metrics on potential object segments, such as shape and size. Commercial toolkits such as eCognition are available for developing segmentation and object classification algorithms [6].

According to the main aims of the current study, we applied a few simple Object-Based Image Analysis (OBIA) techniques inside eCognition Developer Software, such as covered edge detection approaches, watershed segmentation algorithm, and rule-based applications [7]. We combined edge detection features and segmented image objects with knowledge-based methods to successfully delineate agricultural fields with various normalized differences in vegetation indices. The current methodology and associated models could be used in many agricultural operational types of research by combining high-resolution satellite imagery, for example, Azer Cosmos imagery, and filed data with the aim of easy operation of agricultural methods and finally suitable agricultural products in other regions of Azerbaijan.

The Study Area:

Azerbaijan is a country located in South-Western Asia, bordering the Caspian Sea and lying on two continents: Asia and, by a small part in the north of the Caucasus range, Europe. Agriculture has been an important activity for Azerbaijan throughout its history [8]. After the rapid development in the base sectors, the contribution of agro-food businesses to the national economy has proportionally decreased. 29.5% of the population of Ganja-Dashkesan Economic Region, 58.9% of the population of the Central Aran Economic Region live in rural areas, and most of them are engaged in agriculture. Today, agriculture is the major sector providing employment and contributing to food security unless there are higher figures for other sectors. The central Aran and the low-lying areas of the Ganja-Gazakh Economic Region are highly productive areas specializing in cotton and fruit cultivation. The mountainous regions of the Ganja-Gazakh economic Region are famous for viticulture, potato growing, grain and honey production. While Central Aran are well-known for crop production, salinity is the major problem in Aran valley [9]. With this assumption, of the economic regions Nakhichevan, Central Aran and low-lying areas of the Ganja-Dashkasan seem to have relative advantages regarding cereals and dried pulses.

The pilot project is being implemented in the economic districts of Ganja-Dashkesan and Central Aran in order to test the existing concepts of the OBIA research methodology. The study is limited to the north-eastern part of Samukh, the northern part of Goranboy and the north-western part of Yevlakh districts, which are located on the right bank of the Migechaur reservoir. In these regions of Azerbaijan, as is known, traditional and modern methods of farming are used. The

Mingachevir Dam is also considered to irrigation the lands in the north of the selected pilot area. By focusing on the Sentinel-2 satellite images, it is clear that the agricultural lands are mostly managed in traditional and irrigated ways [10]. Figure 1 illustrates the pilot area's location and a map overlaid on a combined RGB Sentinel-2 image.

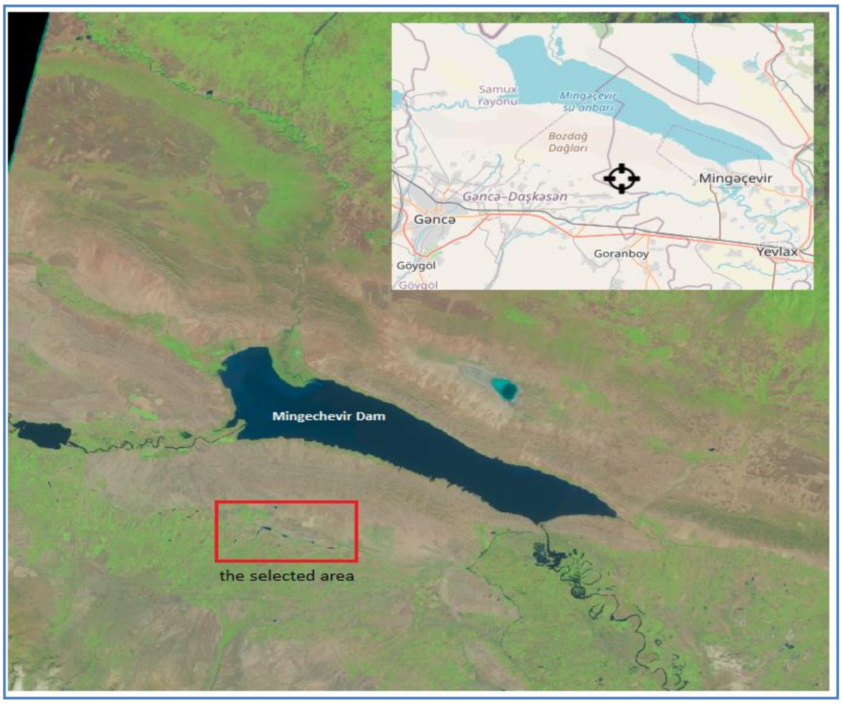


Figure 1: *The location of the selected agricultural site*

Data Analyzed:

The source of optical imagery is Sentinel-2, which is a wide-swathe, high-resolution, multispectral imaging tool that supports Copernicus land monitoring studies, including the monitoring of vegetation, soil, and water cover, as well as the observation of agricultural areas. Sentinel-2 imagery is available at various levels, level-1B and level-1C, from different sites [11]. Each tile consisted of 13 compressed JPEG-2000 images, each image representing one single band. The 13 bands had three resolutions (10, 20, and 60 m)—Notice Figure 1 for more details on the Sentinel-2 imagery. Since 2001, GloVis has been used to view easily, order, and download remotely sensed data. The current paper utilized the USGS EROS Registration System (ERS) hub to obtain the basic data. Sentinel-2 carries an innovative wide swath high-resolution multispectral imager with 13 spectral bands for a new perspective of our land and vegetation. The combination of high resolution, novel spectral capabilities, a swath width of 290 km, and frequent revisit times provides unprecedented views of Earth. The spectral and spatial resolution of Sentinel 2A, with 13 bands in total, is listed in Table 1. Four spectral bands have a 10-meter resolution, six bands have a 20-meter resolution, and the remaining 3 have a spatial resolution of 60 meters [12].

Table 1: *Sentinel 2 Spectral Bands*

Band	Description	Central Wavelength (μm)	Resolution (m)
B1	Ultra Blue	0.443	60
B2	Blue	0.490	10
B3	Green	0.560	10
B4	Red	0.665	10
B5	Visible and Near Infrared (VNIR)	0.705	20

B6	Visible and Near Infrared (VNIR)	0.740	20
B7	Visible and Near Infrared (VNIR)	0.783	20
B8	Visible and Near Infrared (VNIR)	0.842	10
B8a	Visible and Near Infrared (VNIR)	0.865	20
B9	Short Wave Infrared (SWIR)	0.940	60
B10	Short Wave Infrared (SWIR)	1.375	60
B11	Short Wave Infrared (SWIR)	1.610	20
B12	Short Wave Infrared (SWIR)	2.190	20

Also, Figure 2 illustrates the Sentinel-2 band's spectral graphical characteristics.

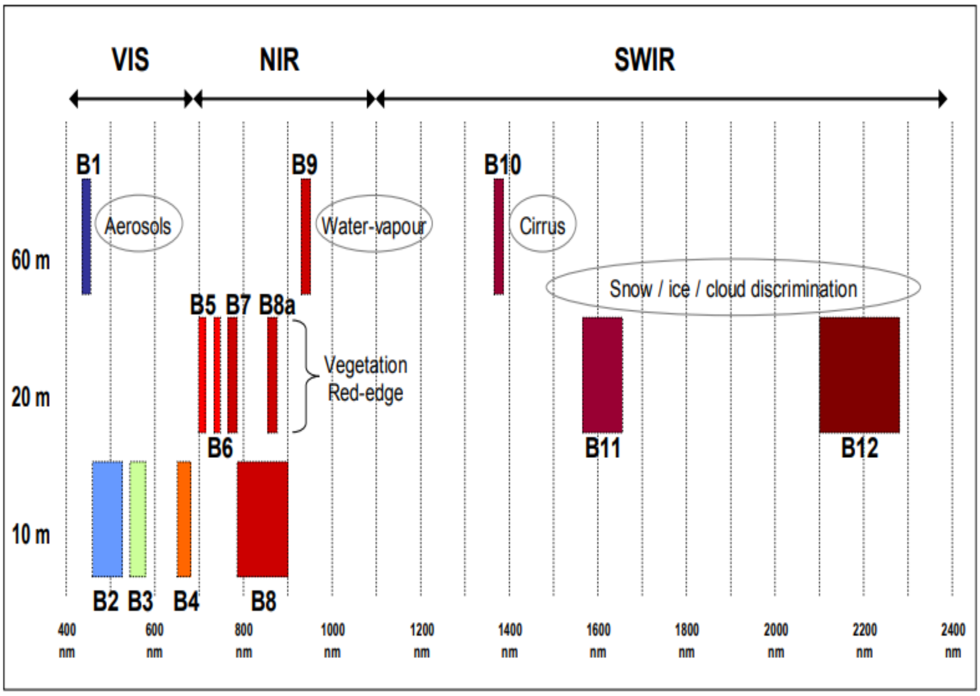


Figure 2: ***Sentinel-2 bands and spectral characteristics***

Every single satellite revisit-time is ten days. Because there are two satellites (Sentinel 2A and 2B), it has a combined constellation revisit of 5 days. To well-perform the Sentinel-2 images well, we paid attention to the following points:

- ✓ Usually, the Sentinel-2 images are in jp2 format and need to be converted to Geo-TIF format in SNAP or ArcGIS software.
- ✓ For the present exercise, we selected image bands 2, 3, 4, and 8 due to their high spatial resolution.
- ✓ In the current paper, the selected area is the small part of the agricultural area located southwest of Mingachevir reservoir in northwest Azerbaijan (Figure 2).

II. Methods

At a simple glance, aiming at the agricultural field boundary delineation, we applied a set of fuzzy object-based Sentinel-2 image analyses inside the eCognition software version 9.5. In the first step, we followed the main functionality of the eCognition by creating a new project inside the eCognition and setting the desired bands, such as blue, Green, Red, and NIR bands [6]. It was preferable to start with a small subsetted area from the main imagery, as you can notice in Figure

1. In step two, an Edge Extraction method based on Canny's Algorithm was applied [13]. In practice, the Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect a wide range of image edges. It could be a technique to extract useful structural information from different vision objects and dramatically reduce the amount of data to be processed. It must be mentioned that the Edge Extraction Canny enhances or extracts feature boundaries using Canny's algorithm [3].

We could use Edge extraction filters to enhance or extract feature boundaries. The resulting layer typically shows high pixel values where there is a specific change of pixel values in the original image layer. The Supported Domains are Pixel Level, Image Object Level, Current Image Object, Neighbor Image Object, Super Objects, Sub Objects, and Linked Objects. In step third, a Watershed Segmentation algorithm was applied to the data, a region-based segmentation algorithm that segments a single image layer of a scene. This algorithm is an alternative to the Multiresolution Segmentation algorithm and supports, at the moment, only small images [14]. In step fourth, a basic reshaping algorithm was applied. This technique modifies the shape of existing image objects. For example, the Remove Objects algorithm executes operations such as merging image objects and splitting them into sub-objects. Each image object is merged into the neighbor image object with the largest common border, which is especially helpful for clutter removal [15]. During step sixth, we applied two basics of spectral such as NDWI and NDVI indices. Normally, inside the eCognition software, a layer calculation algorithm inserts a new image layer by calculating any spectral indexes such as NDWI and NDVI indices [16]. These indices are numerical indicators that use spectral bands; highly associated with water and vegetation contents. The basic formula is given in Table 2, which was adjusted to the Sentinel-2 images inside the eCognition software.

Table 2: *The basic formula for different indices*

Index Name	**Abbreviation**	**Formula**
Normalized Difference Vegetation Index	NDVI	(NIR-Red)/(NIR+Red)
Normalized Difference Water Index	NDWI	(Green-NIR)/(Green+NIR)

We introduced a rule-based algorithm to the NDVI ranges in the last stage. Once we had the vegetation layer of the area in NDVI mode, we explicitly classified it by applying different thresholds and knowledge-based rule sets.

III. Results

We subsetted a small area from the main Sentinel-2 imagery. Figure 3 shows a combined image illustrating Sentinel2 blue, green, red, and NIR bands.

By applying such a simple method inside the eCognition software, the differences among different land use, such as traditional agricultural and modern farms, easily could be distinguished, even among those who have not been in the farming process. The results of a default Canny algorithm, with the single Edge-Canny (a) and Sentinel-2, combined color bands (b), are shown in Figure 4.

In most cases, after applying the Canny edging technique, some noisy object features remain on the output map. You can use one basic object reshaping algorithm to eliminate these disproportionate objects. After finishing the remove objects algorithm, you notice the results. Using this function eliminates a lot of additional objects, as shown in Figure 5.

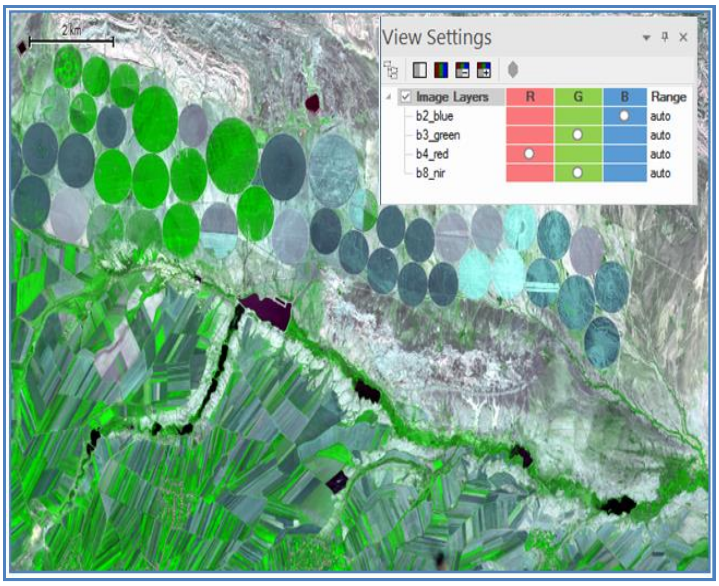


Figure 3: *A combined image illustrating Sentinel-2 blue, green, red, and NIR bands*

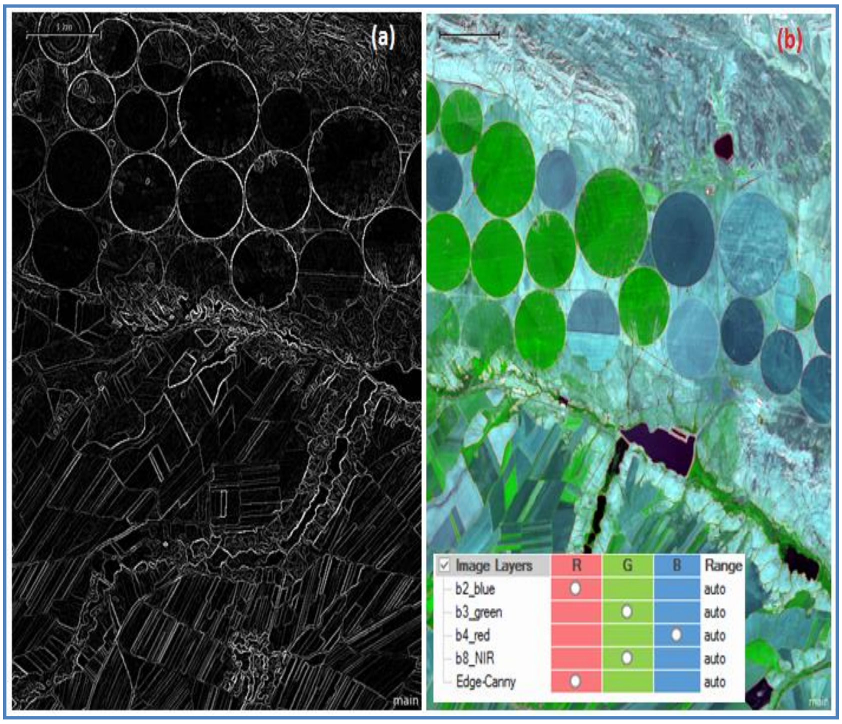


Figure 4: *The results of a default Canny algorithm, with the single Edge-Canny (a) and Sentinel-2, combined color bands (b)*

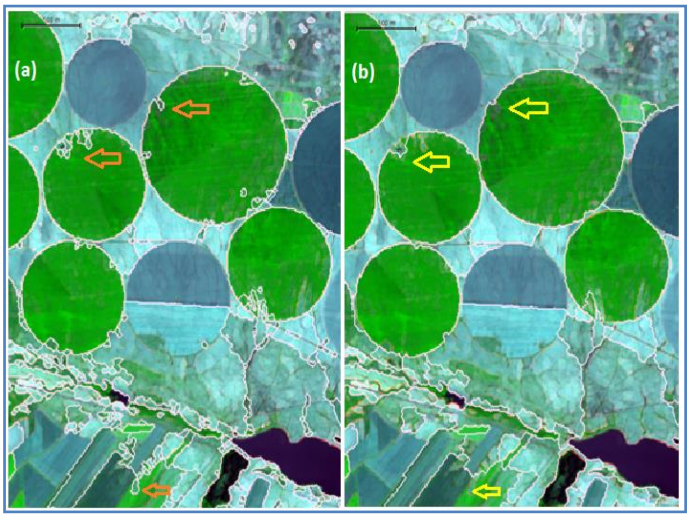


Figure 5: *The result (a) before and (b) after applying the Remove Objects algorithm*

In the implementation stage of the Watershed Segmentation algorithm, we cited the information contained in Table 3.

Table 3: *The Watershed Segmentation algorithm, the information contained in can be cited*

Stage	**Parameter**	**Function**
1	Algorithm	
2	Level	Available only if the domain is pixel-level. Select an existing level or enter a name.
3	Layer	Select the input image layer.
4	Invert layer	Specify whether to invert the image layer. The default setting is *No*. If set to *No*, dark pixels will be used as seeds; if set to *Yes*, bright pixels will be used as seeds.
5	Neighborhood	You may select option 4 - or 8 - pixel connectivity. The default setting is *8 - connected*. Specify whether seeds can grow into the four neighboring pixels (left, right, top, bottom) or into 8 neighboring pixels (i.e., they can grow diagonally). In the latter case, you can decide whether the final objects will be converted to connected objects (8- connected) or not (8-disconnected).
6	Seed criterion	With the default behavior, each initial seed (i.e., each local intensity minimum) will correspond to an object of the final segmentation. However, we can define certain criteria under which we will merge two initially distinct seeds. The criterion is always evaluated when two objects first "touch" each other, i.e., they start having a common border. Select the "l Ovfl. Height" option so that it would merge seeds with maximum intensity below the criterion into neighboring objects/seeds.
7	Threshold	Select a threshold for the seed criterion.
8	Extra seed riterion	Up to three seed criteria can be selected and combined.

9	Fuse super objects	Specify whether to fuse super object. The default setting is *No*.
10	Supported Domain	Pixel Level; Image Object Level; Current Image Object; Neighbor Image Object; Super Object; Sub-Objects; Linked Objects
11	Execute	Run the algorithm

By executing the Watershed Segmentation algorithm, you will see Figure 6.

The NDVI is a numerical indicator that uses the red and near-infrared spectral bands; highly associated with vegetation content. Higher NDVI values correspond to areas that reflect more in the near-infrared spectrum and correspond to denser and healthier vegetation. In Figure 7, orange and red colors indicate vegetation covers. Also, the blue color indicates the water surface in the area.

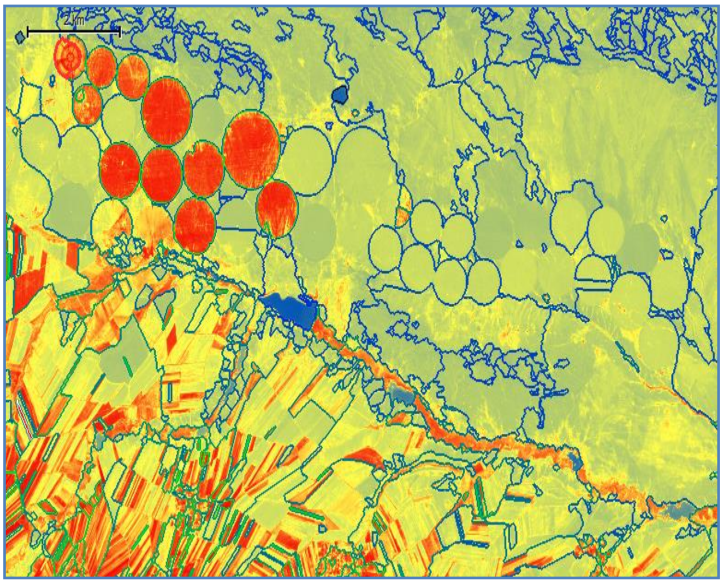


Figure 6: *The result of the Watershed Segmentation algorithm*

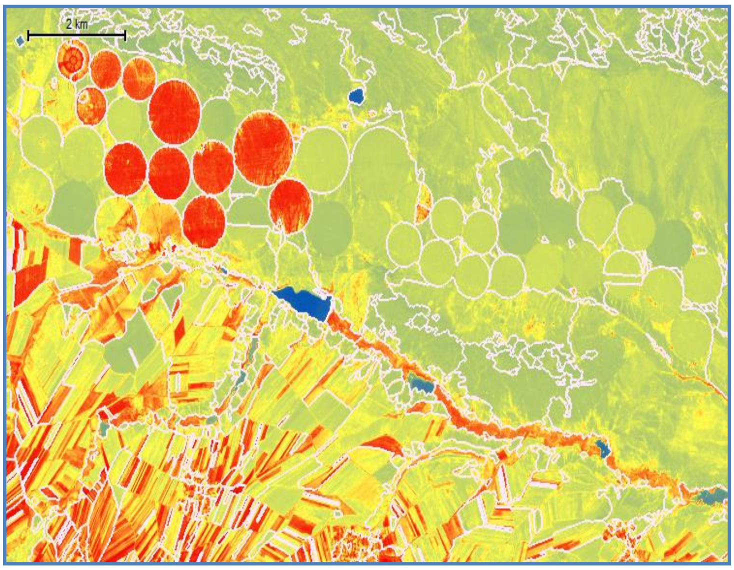


Figure 7: *The NDVI map; the higher reddish color indicates intense vegetation cover*

The vegetation cover in the modern agricultural area seems thicker than the classic cultivated areas. Meanwhile, many modern cultivated fields appeared with less or no vegetation covers. Once we created the vegetation layer of the area in NDVI mode, we classified it by applying different thresholds and knowledge-based rule sets. For this, we needed to check image object-related features inside the Image Object Information box. At the same time, we optimized the NDVI ranges indicated by the Feature View box (Figure 8).

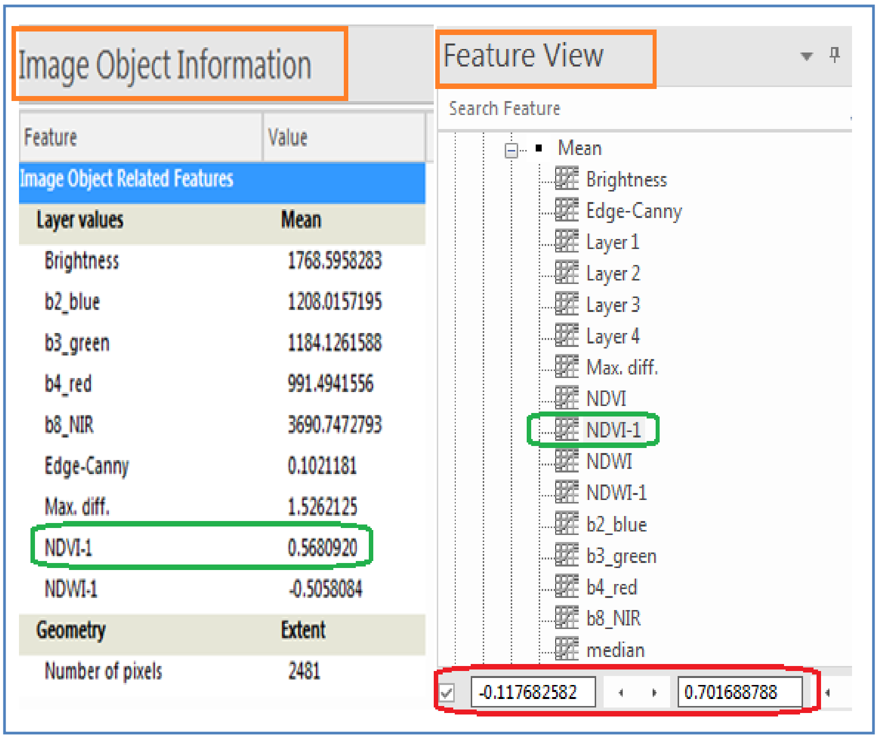


Figure 8: *Information for features is indicated by the Image Object Information and the Feature View boxes*

The results of thresholds and knowledge-based rule sets on NDVI layer information are indicated as a range of algorithms on the Process Tree (Figure 9).

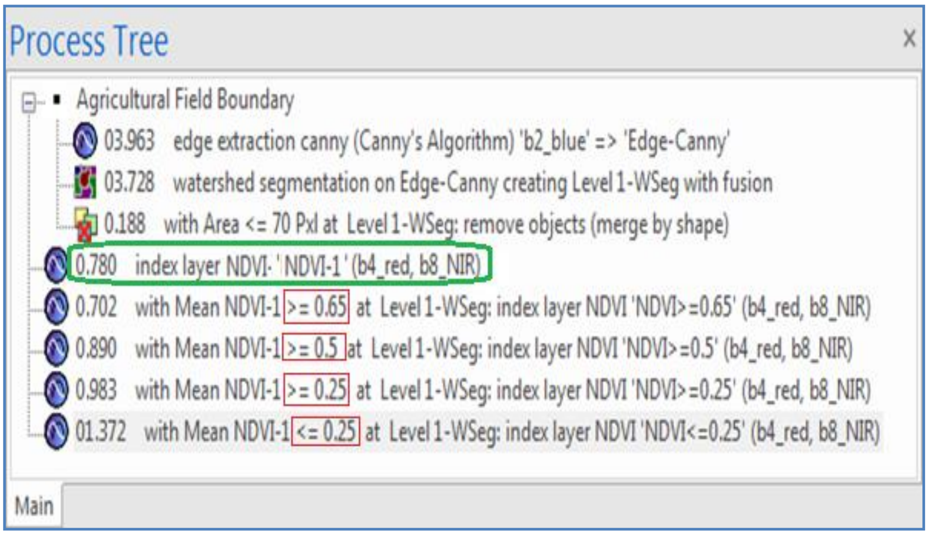
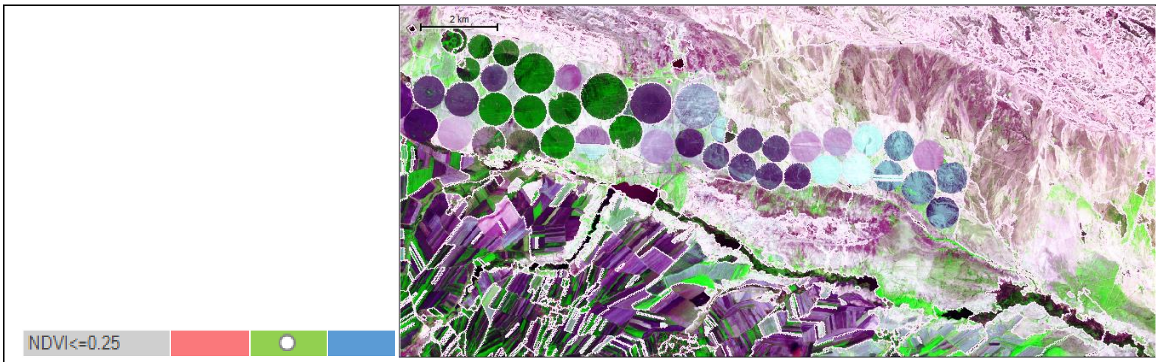
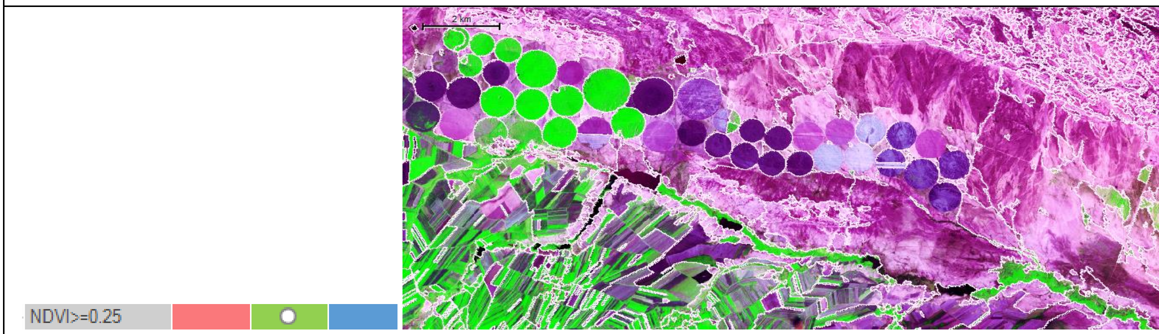


Figure 9: *Process Tree; main appended and inserted child algorithms*

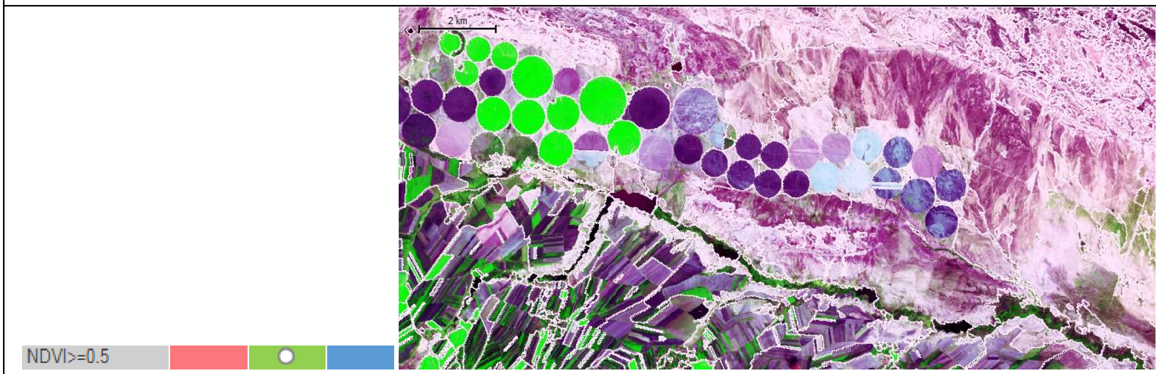
Remember that we had to modify the "Edit Process dialog box content," with the threshold condition as NDVI> =0.65 value.



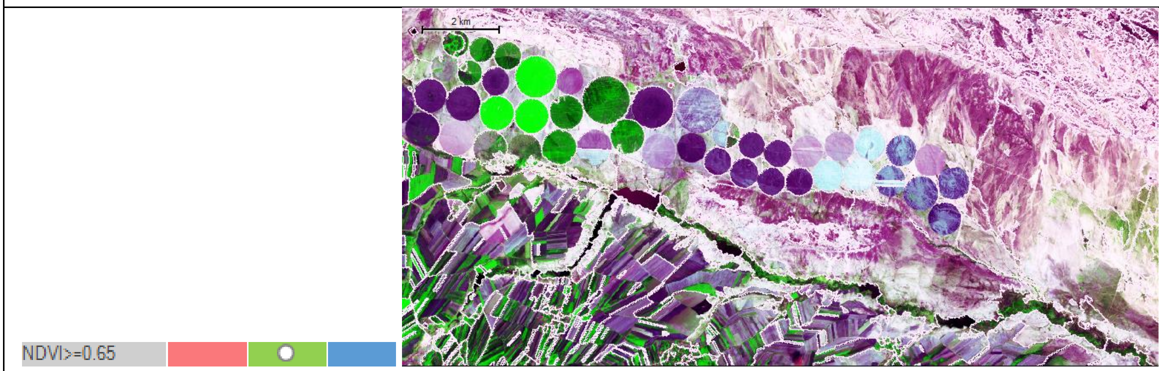
with Mean NDVI-1 <= 0.25



with Mean NDVI-1> =0.25



with Mean NDVI-1> =0.5



with Mean NDVI-1> = 0.65

Figure 10: *Final classified NDVI values for different threshold ranges, green colors indicate the associated NDVI values*

Above-mentioned threshold has to be repeated three times more: with conditions Mean NDVI> = 0.5;> = 0.25; and <= 0.25 values. Final classified NDVI values for different thresholds are shown in Figure 10, and greenish colors indicate the associated NDVI values for each NDVI category. Note that describing and interpreting the results of the current paper would be different depending on the image processing data and distinguished purposes.

IV. Discussion

Small-scale farms generally do not use modern technology to improve the product's quality (hygiene, cooling, storage, etc.) and increase production (productivity-enhancing methods using modern equipment, fertilizers, seeds, etc.). They cannot afford the investment in these inputs. For bulk production and low-value agricultural commodities, present farming methods may be appropriate. Yet, as demand for high-value food commodities increases, driven by rising income, urbanization, and changing preferences, a transition towards using more up-to-date quality-enhancing technologies is necessary. In the current paper, we used a few simple OBIA techniques inside eCognition 9.5, such as covered edge detection approaches, watershed segmentation algorithm, and rule-based applications to successfully delineate agricultural fields with various NDVI values [17]. Agricultural land use maps are more informative per field than per-pixel. It requires up-to-date field boundary maps potentially covering large areas containing thousands of farms, especially in remote areas where land access is very difficult. Although this kind of map is usually difficult to obtain, you have learned to develop a set of combined edge detection and image-segmented object methods to some extent. Meanwhile, by deriving sets of closed polygons around traditional and modern agricultural fields by processing Sentinel-2 imagery, the NDVI indices will be needed [7,18]. In more detailed research, you may compare the greenery obtained from traditional and modern patrol methods during the growing season to estimate the ultimate agricultural harvested products.

We have developed a segmentation method that is tailored to identify fields in an agricultural landscape [4]. The method has enabled regional-scale analysis of farming patterns by producing field polygons. This technique allows for classifying fields as whole objects, which is more accurate than classifying individual pixels. The area that can be segmented is essentially unlimited because the imagery is tiled for processing. The locational accuracy of boundary line work is approximately half the pixel size of imagery used to produce it. Comparison with hand-drawn reference boundaries has shown a high degree of segmentation correctness, meaning that the segments seldom merge two different land uses [19]. These observations mean that the resulting field boundaries are suitable for input into a land-use classification process. Comparison against two existing segmentation methods shows straighter, cleaner linework and results in agricultural lands not being disrupted by data gaps [5]. The researchers could adjust the current paper methods to other Azerbaijan agricultural fields. We used the same parameters in all cases, showing that our method is robust in the context of the medium-resolution satellite imagery we typically use for field-scale mapping. The conclusion is that the Canny edge detector provides finer edges than others. In addition, a watershed segmentation outperforms multi-resolution and multi-threshold segmentation for field boundary delineation. Due to the dynamic nature of field crops, a multi-temporal NDVI is essential for accurate agricultural information [20]. Finally, more information delineates agricultural farms by processing different topographies and satellite sensors.

References

[1] Willer H. and Lernoud, J. eds. (2016), The World of Organic Agriculture. Statistics and Emerging Trends 2016, Research Institute of Organic Agriculture (FIBL), Frick and IFOAM-Organics International, Bonn.

[2] Yan, L. and Roy D. P. (2014), Automated crop field extraction from multitemporal web-enabled Landsat data. Remote Sens. Environ., vol. 144, pp. 42–64.

[3] Canny, J. (1986), A computational approach to edge detection. IEEE Trans. Pattern Anal. Mach. Intell., vol. PAMI-8, no. 6, pp. 679–698.

[4] Pal, S. K. and Mitra, P. (2002), Multispectral image segmentation using the roughest initialized EM algorithm. IEEE Trans. Geosci. Remote Sens., vol. 40, no. 11, pp. 2495–2501.

[5] Graesser, J., and Ramankutty, N. (2017), Detection of cropland field parcels from Landsat imagery. Remote Sens. Environ., vol. 201, pp. 165–180.

[6] Trimble, eCognition Developer 9.5 (2019), Reference Book. Trimble Company, Munich, Germany.

[7] Rasouli, A.A., Asgarova, M.M., Safarov, S.H. (2021), Mapping of LC/LU Changes Inside the Agdam District of Karabakh Region Applying Object-Based Satellite Image Analysis//Journal of Life Science and Biomedicine, Baku, 13p.

[8] Khalilov, H., Shalbuzov, N., Huseyn, R. (2015), Country Report: Azerbaijan. Research Institute of Agricultural Economics, Azerbaijan.

[9] Ministry of Economic Development of Azerbaijan Republic, Economic Development Scientific Research Institute (2016), Reports.

[10] ESA's Sentinel-2 Team (2015), Color Vision for Copernicus, The story of Sentinel-2. ESA Bulletin No 161, May 11, 2015, pp. 2–9.

[11] Copernicus, Sentinel-2 (2020), Satellite Missions – eoPortal Directory. eoportal.org, It retrieved it on March 5.

[12] Rasouli, A.A.; Mammadov, R.; Safarov, E.; Mohammadzadeh, K. (2018c), Fuzzy Object-Based Landcover/Use Mapping of The Karabagh Region by Processing of Sentinel Satellite Imageries. Eurasian GIS 2019 Congress 04–07 September 2018 – Baku/Azerbaijan.

[13] Hu, Y.; Chen, J.; Pan, D. and Hao, Z. (2016), Edge-guided image object detection in multi-scale segmentation for high-resolution remotely sensed imagery. IEEE Trans. Geosci. Remote Sens., vol. 54, no. 8, pp. 4702–4711.

[14] Woodcock, C., and Harward, J. (1992), Nested-hierarchical scene models and image segmentation. Int. J. Remote Sens., vol. 13, no. 16, pp. 3167–3187.

[15] North, H.C; IEEE, M.; Pairman, D.; and Belliss, S. E. (2019), Boundary Delineation of Agricultural Fields in Multitemporal Satellite Imagery, IEEE Journal of Selected Topics in Applied Earth Observation and Remote Sensing. VOL. 12, NO. 1.

[16] Dobrowski, S.Z., Safford, H.D., Cheng, Y. Ben, & Ustin, S.L. (2008), Mapping Mountain vegetation using species distribution modeling, image-based texture analysis, and object-based classification. Applied Vegetation Science 11: 499–508.

[17] Rydberg, A. and G. Borgefors, (2001), Integrated method for boundary delineation of agricultural fields in multispectral satellite images. IEEE Trans. Geosci. Remote Sens., vol. 39, no. 11, pp. 2514–2520.

[18] Asgarova, M.M. Application of GIS technologies in soil fertility management. 3rd International November 24 Head Teacher Education and Innovative Sciences Symposium, Baku, Azerbaijan. May24-25 2021, P.58-63, www.24kasim.org

[19] Trimble, eCognition Developer 10.2 (2021), Detection of cropland field parcels from Landsat imagery. Remote Sens. Environ., vol. 201, pp. 165–180.

[20] Benz, U. C.; Hofmann, P.; Willhauck, G.; Lingenfelder, I.; and Heynen, M. (2004), Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. ISPRS J. Photograms. Remote Sens., vol. 58, pp. 239–258.

ALGORITHM FOR BUILDING A HYBRID MODEL OF THE EXISTING RISK MODEL

Vugar Aliyev[1], Zurab Gasitashvili[2], Merab Pkhovelishvili[3], Natela Archvadze[4]

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[1]AMIR Technical Services Company, Azerbaijan
prof.vugar.aliyev@gmail.com
[2]Georgian Technical University, Georgia
zur_gas@gtu.ge
[3]Muskhelishvili Institute of Computational Mathematics, Georgian Technical University
merab5@list.ru
[4]Ivane Javakhishvili Tbilisi State University, Georgia
natela.archvadze@tsu.ge

Abstract

Putting risk theory and risk modeling into practice is high on the agenda. We introduce a forecasting algorithm that can be used to forecast "predictive events" - such as forecasting the risk of natural processes, as well as forecasting the risk of various processes of human activity. The article considers an algorithm for choosing the best pairs from event risk forecast models, which, using the precursors of these pairs, significantly reduces the risk of occurring of an event. For a given predictive event, the existing precursors of events are studied, on the basis of which a hybrid model is built.

Keywords: risk management, parallel data, prediction models, model improvement algorithm

I. Introduction

Risk, as an integral element of the economic, political and social life of society, necessarily accompanies all areas and spheres of public life. Basic scientific research in the field of safety theory and risks is very important in order to apply it in practice to reduce actual risks.

We have considered an algorithm for predicting events, which, by using parallel data, gave a sufficiently high forecast reliability, which makes it possible to reduce risks or avoid them altogether [1,2]. In this paper, we will review risk prediction models and the issues of building a new hybrid model based on them. A hybrid model is built based on the study of precursors for a given predicted event.

The conditions and factors of risk occurrence are of natural, man-made and social origin, if we consider them by genesis. Risks can be divided into predictable and unpredictable risks. Unpredictable risks for the evaluation of events may arise in force majeure situations. In this cases, timely identification of these hazards and threats is important to reduce the negative impacts they cause.

Recently, models have been used for non-force majeure risk situations in order to avoid or reduce negative consequences through timely and correct actions. Models should also be developed for force majeure situations (wars, emergency disasters, Tectogenic disasters). When considering the risks of economic tasks, models are developed for individual groups. There is a risk management model for service sector organizations, also decision-making models under conditions of uncertainty, as well as a model for taking into account risks in investment projects, and others are considered [3].

We need to identify risks before we consider risk prediction issues. For this one should:

- identify the possible consequences of the action of risk factors;
- identify existing hidden obstacles to achieving goals;
- in case of unsuccessful or undesirable development of events, new backup capabilities should be used, that is, if something unexpected happens, the model should be expanded.

The result of forecasting the risk of a certain event is to determine when, where the event will occur and what (what kind of) characteristics it will have. In risk forecasting, nonparametric methods are often used, such as, for example, the least squares method, which estimates the accuracy of the forecast. Adaptive methods, autoregressive methods and others are also used. It is also important to use expert forecasting methods, including those based on non-numerical data.

Particularly relevant is the development of forecasting methods under risk conditions, which are based on the use of combined economic-mathematical and econometric (both statistical and expert) methods in forecasting models.

Precursors in risk forecasting [4] - is what precedes the predictive event and on the basis of which the forecasting model of this event is developed.

If we consider the problem of forecasting an actual risk of any natural phenomenon, then the precursor is basically a certain geophysical phenomenon that precedes the occurrence of a natural event. Geophysical precursors (phenomena) include, for example, seismic, hydro-geodynamic, deformational, geochemical, thermal, gravitational, and electromagnetic events. As well as the results of observations obtained by remote monitoring using recently developed satellite technologies, etc.

Forecasting a specific natural phenomenon means determining a sequence of actions aimed at identifying the characteristic features of an event or anomalous variations in various geological and geophysical fields, their joint consideration and analysis in order to determine, for example, in the case of an earthquake forecast, its location, time and strength.

That is, the results of earthquake forecasting are the location of the earthquake, the time of the event and its strength [5].

II. Hybrid Approach to Risk Forecasting

To predict natural phenomena, a hybrid model is considered [5], according to which, out of the models developed on the basis on the necessary precursors, should be selected pairs, triplets, etc. of such models that have a minimum number of coincidences of forecasts. As a result, the forecast is significantly improved, which means that the indicator of forecast accuracy increases. [5] describes this forecasting model for earthquake problems.

Let us describe a forecasting model that is based on a hybrid approach specifically for risks. In this case, we have different models, developed for the same events, which calculate the risks of the event under consideration, using certain indicators of this event. Let's take the construction of high-rise buildings in Racha (a high mountainous region of Georgia) as an event, having calculated the values of the risks. Let the first model A1 be, for example, a model that calculates the risk if the building is built of brick (brick quality is a precursor), the model predicts that the risk of building collapse in Racha in case of an earthquake of a certain magnitude (for example, magnitude 5) is 28%. Let the second model A2 be based, for example, on the A1 cement brand. If, for example, the brand type is M500, then the risk of the building collapsing is 20%. It is necessary to consider the magnitude of the risk when using these two models together. That is, if you use these two risk models simultaneously for the construction works in the same region, then the risk of building collapse will certainly decrease. It is intuitively clear that the combination of two, three, four or more models reduces the risk, but increases the calculations of considering precursors.

Various models of building high-rise buildings in Racha, building houses in Kamchatka, which use the first, second, third, fourth methods. Models may consider variables such as what material to use for the foundation, etc. for the construction of a nuclear power plant, the construction of a conventional hydroelectric power plant. If we found those in which the requirements of each model match, then together, these requirements give much less result, but this should be measurable as well. The model that initially identified the 30% risk. Where did this percentage come from? How much is being built, and calculated, what is the probability of how much should be used - 70% depends on the thickness of the bricks, it would be 80% , if one put two blocks, how much for a hollow core slab, etc.

Second, on the contrary, depends on the concrete - what degree of adhesion the concrete should have, depending on concrete adhesion qualities, the risk percentage value will decrease if adhesion is high.

Thus, we use intersection of these various models, as we did before. We select pairs of models and calculate how much is risk (which is clearly reduced) when both of these conditions are met. The risk may even be reduced to zero. For example, if the brick is good, the concrete is good, the builders are good too, the site is well chosen, then the risk can be practically reduced to zero. This is the main idea.

Suppose we have the following models: $Mod_{1,}Mod_{2,}\ \dots, Mod_n$. What each model represents and on the basis of what precursors it makes predictions is not essential in our case.
For each model, it is necessary to calculate the number of forecasts made, the number of correct and false forecasts, and also calculate the probability of correct prediction for each model. It is clear that the sum of correct and false predictions is the total number of predictions made. As for the probability of correct prediction [4], it is calculated for each model and determines how many times an earthquake was predicted and how many times an earthquake actually happened. Suppose that probabilities of correct prediction are calculated for 5 models in total (%), and accordingly these values are as follows: 6.00; 6.32; 7.06; 6.12; 7.59.

When forecasting earthquakes, the author of each model claims that their model is the best and explains this by the fact that his model predicted all earthquakes that occurred. Neither of them gives the number of false predictions and therefore does not calculate the probabilities of true predictions, which are fairly small numbers. The probability of the correct prediction of a model may be quite low, but it is possible to pair this model with another model and thus ensure the best correct prediction probability outcome. We will demonstrate the correctness of the above said with our example.

As the next step of the algorithm, we need to consider pairs of models. There will be 10 pairs in total: M1, M2,…,M10, where M1=$Mod_1 \cap Mod_2$; M2= $Mod_1 \cap Mod_3$; M3= $Mod_1 \cap Mod_4$; M4=$Mod_1 \cap Mod_5$; M5= $Mod_2 \cap Mod_3$; M6= $Mod_2 \cap Mod_4$; M7= $Mod_2 \cap Mod_5$; M8= $Mod_3 \cap Mod_4$; M9= $Mod_3 \cap Mod_5$; M10= $Mod_4 \cap Mod_5$. For each model, it is necessary to calculate the number of forecasts made, the number of correct and false forecasts, and also calculate the probabilities of correct predictions for each pair (see Table 1).

Table 1: *The "necessary models" for pairs*

Models	Number of prediction	Failed number of prediction	Successful number of prediction	Probability of success in %
$Mod_1 \cap Mod_2$	17	6	11	35.29
$Mod_1 \cap Mod_3$	20	6	14	30
$Mod_1 \cap Mod_4$	15	6	9	40
$Mod_1 \cap Mod_5$	13	6	7	46.15
$Mod_2 \cap Mod_3$	15	6	9	40

$Mod_2 \cap Mod_4$;	10	6	4	60
$Mod_2 \cap Mod_5$	16	6	10	37.5
$Mod_3 \cap Mod_4$	17	6	11	35.29
$Mod_3 \cap Mod_5$	8	6	2	75
$Mod_4 \cap Mod_5$	18	6	12	33.33

Let us analyze the constructed chart according to the corresponding diagram (see **Fig. 1**), which demonstrates that the best result gives M9 which is obtained by a combination of two models - Mod_3 and Mod_3 . The probability of their joint correct prediction has already increased to 75%. Although these models individually, compared to others, have much less correct prediction indices - 7.06% and 7.59%. In the example under discussion, two pairs of models can give the same result. At this stage, it is up to the expert to decide which ones to use.

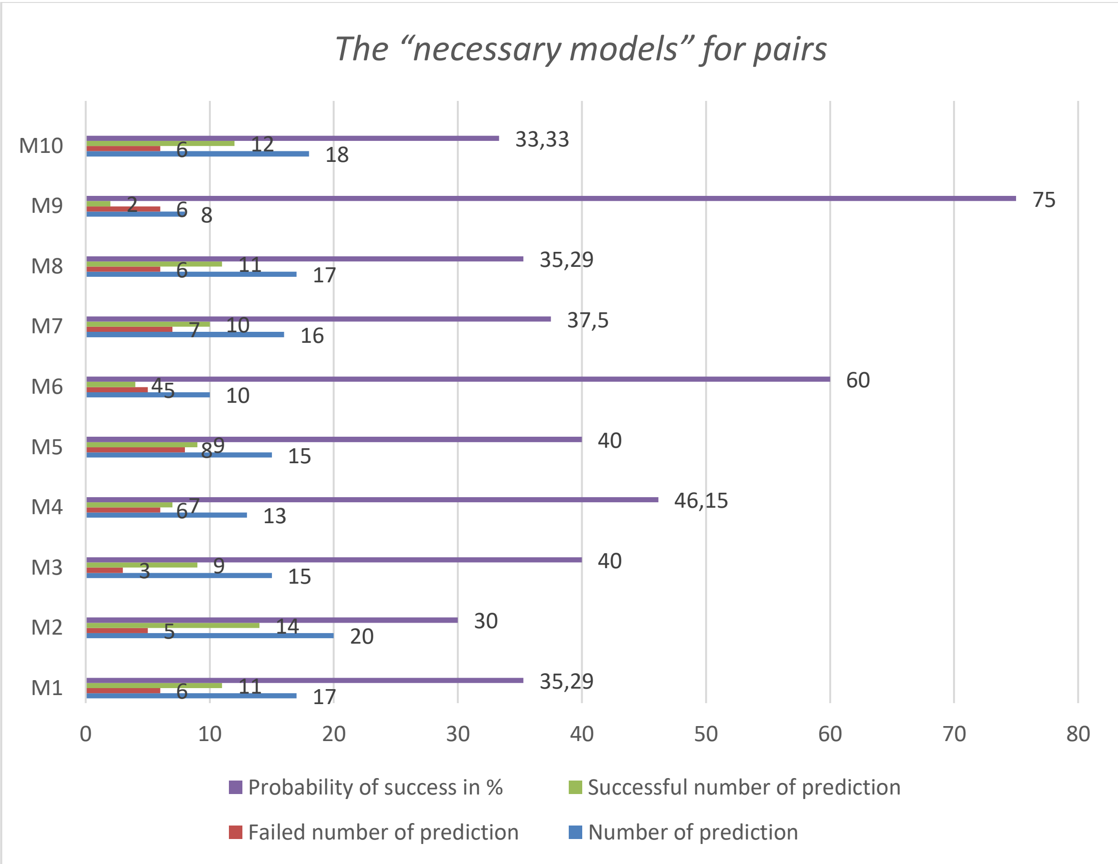

Figure 1: *The characteristics of the "necessary models" for pairs*

Obviously, this applies not only to risk forecasting, but also to forecasting any other event, both static (most often, these are the tasks of forecasting natural disasters) and dynamic forecasting, for example, economic fields.

III. Results

It is clear that the greater the number of the intersected predictive models from which we choose the best one, the better is the result, in contrast to choosing from a smaller number intersection.

However, it should be taken into account that more models require a large volume of data (precursors), the acquisition of which is also associated with high consumption of material resources. Collecting and analyzing large volume of data is an insurmountable problem for relatively small poor states. It is in such cases that it is advisable, theoretically, to choose two or three forecasting models, the intersection of the forecasts of which gives the best results. Information collection will be required only for these selected models, which will drastically reduce the cost of information processing.

References

[1] Gasitashvili, Z., Pkhovelishvili, M., Archvadze, N., Jorjiashvili N. An Algorithm of Improved Prediction from Existing Risk Predictions. / Published by AIJR Publisher in "Abstracts of The Second Eurasian RISK-2020 Conference and Symposium" April 12- 19, 2020, Tbilisi, Georgia. DOI: 10.21467/abstracts.93 pp. 31. 2020.

[2] Zurab Gasitashvili, Merab Pkhovelishvili, Natela Archvadze. REDUCING RISKS THROUGH IMPROVEMENT OF PREDICTION MODELS . „Reliability: Theory and applications". RT&A, Special Issue No 3 (66) Volume 17, January 2022. ISSN 1932-2321 pp.197-202

[3] Dimitrov, B. ON THE CONCEPTS MEANING, THEIR MEASUREMENTS AND USE IN PRACTICE OF RISK ASSESSMENT. Reliability: Theory and Applications, 2022, 17, pp. 15–37.

[4] Prangishvili, A., Gasitashvili, Z., Pkhovelishvili, M., Archvadze, N. Predicting Events by Analyzing the Results of the Work of Predictive Models. Communications in Computer and Information Science, 2022, 1562 CCIS, pp. 64–78

[5] Gasitashvili, Z., Pkhovelishvili, M., Archvadze, N. Prediction of events means of data parallelism. Proceedings - Mathematics and Computers in Science and Engineering, MACISE 2019, 2019, pp. 32–35, 8944725

[6] https://www.gse.com.ge/sw/static/file/egx-ajameTi-riskebis-analizi.pdf

[7] A Rasouli, R Mammadov, V Aliyev. Detection of Caspian Sea Coastline Changes by Fuzzy-based Object-Oriented Image Analysis. AIJR Abstracts, 120-122, 2020.

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MODELING OF REGIMES WITH SUDDEN CHANGE

Islam Mustafayev, Aminagha Sadigov
•
Azerbaijan University of Architecture and Construction
imustafayev@mail.ru aminaga.sadigov@gmail.com

Abstract

The existing concepts of risk and uncertainty for regimes with sudden changes are described. Analyzed what opportunities can be identified and used as possible risks of uncertainty. The main objective of the work is to strengthen the capacity in study of uncertainty impact on security of complex systems for which standard modeling methods are inadequate. The regimes with sudden, discontinuous changes that cause the instability have been modeling for a wide range of different complex systems from economics and ecology to sociology and biology

Keywords: modeling, complex systems, theory of catastrophes, sudden change, uncertainty, risk

I. Introduction

The 21st century was marked by the rapid development of new technologies, which is usually called the fourth industrial revolution. The process of digitalization is accelerating, which in a broad sense means the transition to a system of economic, social and cultural relations that based on the use of new ICT.

In recent years, one observes the dramatic increase of the frequency of rare events and their destructive power. There is a sharp increase in the number of natural and man-made disasters, financial and economic crises. The unique nature of rare events does not completely allow the correct use of probability theory to assess the risk posed by the crisis management system, reduces the time horizon of extreme events, especially related to the power-law probability density distribution of the damage that decreases more slowly than a Gaussian distribution law of probability.

Analysis of rare events shows that usually they are relating with a sudden change, resulting from continuous low impact on the system. Traditional methods of prediction of their behavior are not sufficiently efficient for the events of such kind. New risks require new research methods. Thus, the necessity on the work is relating with the appearance of new forms of global issues connected with a wide range of asymmetric threats, high sensitivity to initial conditions, and increase of the possibility that a small disturbance can lead to unpredictable ecological, economic, epidemiological, social and political consequences.

II. Modeling of Mechanisms of Instability of Complex Systems

Modeling methodology is based on a mathematical formalism for modeling of nonlinear systems whose behavior shows sudden, discontinuous changes or phase transitions, resulting from small continuous changes in variables that affect the system – on the theory of catastrophes (TC), which was applied to a wide range of various systems such as physical, engineering, biological, psychological and sociological systems. A small list of specific phenomena, which are analyzed and modeled using the TC includes quantum morphogenesis, the formation of caustics in the ray optics, the stability of black holes, morphogenesis, perceptual biostability [1].

The methodology of risk assessment for sudden transition from one steady state to another, based on the use of TC is considered in [2-5]. It allows the calculation of the bifurcation values, curves and surfaces of the control parameters. The transition probability was estimated as a measure of the approximation of values of control parameters to their bifurcation values, which characterize the system's transition from one stationary state (normal) to another (catastrophe).

Assume that a complex system satisfies all requirements of the potential system and can be described by a potential function $U(x, A_1, A_2,...A_N)$ of the behavioral variable x and the control parameters A_i. The dynamics of deterministic gradient system was described by the equation of the form

$$dx/dt = -\partial U/\partial x \tag{1}$$

Eq. (1) means that the variable was changed in the direction of decreasing of the potential at a rate proportional to the slope of the gradient of the potential field. Equilibrium manifold of the system is a set of variables x such that $dx/dt = -\partial U/\partial x = 0.$

For example, if

$$U(x, A_1, A_2, A_3, A_4, A_5) = 1/6x^6 + 1/4A_1x^4 + 1/3A_2x^3 + 1/2A_3x^2 + A_4x + A_5, \tag{2}$$

then, the system is in equilibrium when

$$x^5 + A_1x^3 + A_2x^2 + A_3x + A_4 = 0.$$

The function U has five stationary states: three of them are stable whereas 2 others are unstable. Moving the system from one stationary state to another or a change in the nature of the stationary state (for example, from a stable to an unstable) is a function of the control parameters A. These parameters control both the movement of the image point on the surface U and the transformation of this surface.

The number of stationary states of the system can be determined by analyzing a set of input data. Let's assume, this analysis shows that the investigated complex system has three stable stationary states. For simplicity, one can make the following assumptions. The first stable stationary state characterizes normal conditions. The level in this state is minimal. The second one characterizes the state with average x.

The third one describes the crisis with a high level x. Under these assumptions, the potential function U was described by eq. (2).

This case with three stable stationary states and the four control parameters corresponds to one of the universal deformation theory of catastrophes, which is called as "butterfly":

$$-\partial U(x, A)/\partial x = x^5 + A_1x^3 + A_2x^2 + A_3x + A_4 \tag{3}$$

In order to minimize the vulnerability of complex systems one can propose the methodology that includes the following stages: collection and analysis of initial information, definition of a function $U(x, A)$ on the basis of a set of experimental data, using the technology proposed in [5], mapping of set of source data to set of disaster management parameters with appropriate transformations, definition of indexes, which characterize the control parameters, based on a set of input data and appropriate mathematical models allowing us to determine the trajectory of the control parameters over time, calculation of the bifurcation surfaces, at the intersection of which the number or nature of the stationary states will be changed, the risk assessment of transition from one to another level of vulnerability in the degree of remoteness terms describing the current state of the bifurcation surfaces, which separate the different levels of security.

Shifts in the relation between A_i cause transitions from the norm to the pre-crisis or crisis states. Bifurcation values of these parameters can be calculated using the proposed mathematical methods. Achievement to these critical values sharply increases the probability of transition from one to another functional state. Thus, for a given system state, one can determine the range of parameters corresponding to the normal pre-crisis and crisis states.

The main advantage of the proposed methodology for modeling of appearance of instability in complex systems lies in the fact that it allows us to define the transformation of the vulnerability of a complex system as a function of dynamical variables.

III. Possible Studies of Instability in Complex Systems

The structuring of complex systems in a wide range of disciplines is carried out in [6-14]. Algorithmic realization of interrelations in these systems allows justification of the form of function $U(x, A)$ based on the analysis of entry data. In tables 1 and 2, the classification of the control parameters used for the study of a number of systems in ecology, biology, psychology and sociology is shown.

Table 1: *Classification of control parameters for systems in ecology, biology and psychology*

$\partial U / \partial x$	Control parameters	
	A_1	A_2
$x^3 + A_1 x + A_2$	Biological systems: calculation of the probability of appearance of pre-pathological and pathological states	
Type of disaster – "assembly"	Determined by reserves of the biological system	Determined by the strength of the regulatory mechanisms
	Environmental systems: calculation of critical levels of pollution and ecosystem reserves	
	Determined by reserves of the environmental system	Determined by the level of environmental pollution
	Psychological systems: formation of the position	
	Depends on the emotional assessment of the situation in terms of its importance	Depends on a rational assessment of the situation in terms of probabilities of gains and losses

Table 2: *Classification of control parameters for systems in sociology*

$\partial U / \partial x$	Control parameters		
$x^4 + A_1 x^2 +$ $+ A_2 x + A_3$	A_1	A_2	A_3
	Social systems: a study of the influence of physical, human and social capital to social security		
Type of disaster – "dovetail"	Depends on the index of sustainable development, which assesses the contribution of endogenous factors (economic, environmental and social) to the change in security	Determined by the index of globalization, which assesses the contribution of exogenous factors (shifts in the structure of relationships in a globalized world) to change the security	Determined by the index of social capital, assessing the degree of human corporations in society, allowing individuals to cooperate in the information society within a certain "radius of trust"

The classification of the control parameters used for the study of global changes, economical, biological (health, neuro-immune-endocrine network (NIEN), cellular energy trigger, metabolic and hormonal regulation), epidemiological (the forecast of dissemination of infectious diseases, control of epidemic process and ranking of risks) and political systems by accident of "butterfly" type (3) is shown in Table 3.

Table 3: *Classification of control parameters for global changes in a number of systems*

Control parameters			
A_1	A_2	A_3	A_4
Global systems			
Depends on the ability to prevent / minimize the consequences of accidents	Depends on stimulant abuse, mental disadaptation, epidemics and suicides	Depends on the factors causing natural disasters due to climatic changes	Depends on factors that increase the risk of industrial accidents and human pressure
Economical systems			
Depends on factors that characterize the labor market: the Gini index, unemployment, etc.	Depends on factors that characterize the financial market: loans, inflation, etc.	Depends on factors related to the securities market: business activity, etc.	Depends on factors related to market of goods and services: personal income, GDP, etc.
Biological systems			
Depends on the energy of cells and biologically active substances, hormones, NIEN	Depends on the balance of synthesis and energy expenditure, the adaptive capacity of cells	Depends on the psychic status of the body, forming a mental health	Depends on the genetic background (hereditary predisposition)
Epidemiological systems			
Depends on the speed of propagation of pathogens and their resistance to drugs, etc.	Depends on the resistance to viruses, reserves and immune status	Depends on the quality of epidemiological services, availability of vaccines and equipment	Depends on environmental influences on the body's resistance to infections
Political systems			
Depends on the network of ideas - beliefs, proofs, definitions	Depends on the network rules - regulations, norms, ideals, values	Depends on the network of action - the ordering of status, hierarchy, community dialogue	Depends on the network of interests - opportunities, chances and access to resources

Thus, the approach discussed above can be applied to various complex systems from ecology and economics to psychology and sociology, and can form the basis for the development of tools to extend the forecast horizon, develop a global strategy to prevent extreme and rare events, a lack of which is felt keenly today.

IV. Study of the Effect of Global Change on Water Resources

Let X is the level of globalization, defined by levels of technological development, economical integration, intensity of personal contacts between people and political commitments, Y is the level of available water resources, Z is the level of instability related with the struggle for water resources. It was shown that the interrelation between these variables is described by Lorenz model of a metastable chaos [4]

$$dX/dt = \sigma(Y - X), \quad dY/dt = rX - Y - XZ, \quad dZ/dt = XY - bZ. \tag{4}$$

Here, σ, b, r characterize speeds of processes. Parameter r is the function of current supplies and demands on level of globalization and water resources. Fluctuations of parameter r cause significant transformations of the system dynamics. There are intervals of demand-supply ratio, which correspond to different modes of functionality. At the boundaries of such intervals, fluctuations can lead to catastrophic consequences associated with the transition from stability to instability.

Chaotic oscillations ΔY obtained by the model (4) are shown in the figure a, where ΔY and time t are given in arbitrary units. As the results of observations show in [15, 16], since 1860 there is a significant change in the oscillations ΔT, so that the time interval marked by the rectangle in the figure b is an example of the bifurcation zone in which there was a loss of stability of operation.

V. Conclusion

Modern co-evolution of technology and society has positive and negative consequences. The positive ones are in the increase in human capabilities to influence the environment and its modernization in accordance with their requirements. The cost of obtaining new functionality of the human object environment is drastically reducing. Become available, mass production and consumption items with previously unattainable functional properties.

The negative consequences include insufficient understanding of emerging problems at the personal, natural, socio-economic levels. The result may be the emergence of new types of conflicts, the rapid development of weapons with new destructive capabilities, irreversible changes in the natural environment, etc.

This study involves the development of new modeling techniques to solve complex problems of adaptive control of behavior of systems in the unstable nonequilibrium medium with a strong dependence on initial conditions and strong information overloads. The proposed approach provides an approach to solving a number of fundamental issues related to the crisis of modern systems of control: to minimize the delay between the beginning of catastrophic changes and the moment of their detection; to transform the priorities from the response to the consequences (the tactics of "planning yesterday") to control the risk of events; to determine the optimal redistribution of resources and effective actions (controls), which minimize damage from natural and manmade disasters, as well as from terror actions; to rank the different types of threats, to identify weak links in a complex system, to assess its adaptability to a rapidly changing world.

Some projects face a broad array of uncertainties which have the potential to affect achievement of their objectives and outcomes. But some of these uncertainties would give benefits if they occurred. Risk management can give an important contribution and benefits to effective project management. We try to identify opportunities as well as threats early enough, take appropriate action to exploit them.

References

[1] Kryukovskiy A. S. et al. Catastrophe theory and its applications to the description of focusing, diffraction and propagation of wave fields. Proceedings of the Moscow Institute of Physics and Technology (State University). Moscow, 2009, Volume 1, № 2. https://mipt.ru/upload/8fa/f_ee44-arphcxl1tgs.pdf

[2] Kodaneva S. I. Society and Technology: Opportunities and Risks of Co-Evolutionary Development (Review). Social Novelties and Social Sciences. Moscow, INION RAN, 2021, № 1, 179–203 pp. DOI: 10.31249/snsn/2021.01.14. https://cyberleninka.ru/article/n/obschestvo-i-tehnologii-vozmozhnosti-i-riski-koevolyutsionnogo-razvitiya

[3] Sadigov A. B., Zeynalov R. M. Robust solutions to minimize risks. The Reports of National Academy of Sciences of Azerbaijan. 2020, Valume LXXVI, № 3-4, p. 16-21. http://www.maruazalar.az/

[4] Sadigov A.B. Methods of risks assessment of life activity in environment, 1st International Turkish World Engineering and Science Congress in Antalya, December 7-10, 2017, s.28-38
https://www.tdx.cat/bitstream/handle/10803/666490/TXCR1de1.pdf?sequence=1&isAllowed=y

[5] Sadigov A. B., Zeynalov R. M. Mathematical Modeling of Environmental Processes at Military Facilities. Informatics and Control Problems, Vol. 40, Issue 2 (2020), pp. 31-37.
https://icp.az/index.php?newsid=291

[6] Xavier C. R. Ecosystem modelling in the Eastern Mediterranean Sea: the cumulative impact of alien species, fishing and climate change on the Israeli marine ecosystem. PhD Thesis. 2019, 335 p.

[7] Atoyev K. L., Pepelyayev V. A., Sadigov A. B. Mathematical Model of Water Resources Management for the Adaptation of the Agricultural Complex to Climate Change. Computer Mathematics. Kiev, 2012, № 1, pp. 23-30. (in Russian)
http://dspace.nbuv.gov.ua/handle/123456789/84684

[8] Makhutov N.A., Gadenin M. M., Yudina O. N. The Scientific Analysis of Risks in Life-Support of a Person, a Society and the State. // Issues of Risk Analysis. Vol. 16. 2019. №. 2. pp. 70—86. https://doi.org/10.32686/1812-5220-2019-16-2-70-86

[9] Plyatsuk L. D., Chernysh E. Yu. Synergetics: Non-Linear Processes in Ecology. 2016, 229 p. (in Russian). https://core.ac.uk/download/pdf/324216193.pdf

[10] Bekefi T., Epstein M., Yuthas K. Managing Opportunities and Risks. Management Accounting Guideline. 2008, 39 p. The Society of Management Accountants of Canada. AICPA, CIMA.
https://www.cimaglobal.com/Documents/ImportedDocuments/cid_mag_managing_opportunities_and_risk_march08.pdf.pdf

[11] Atoyev K. L. Mathematical modeling of metabolic and hormonal regulation: risk assessment of environmental and radiation influence on various links of endocrine system. HAIT Journal of Science and Engineering. Series B: Applied Sciences and Engineering. Volume 2, Issues 1-2, pp. 31-53. http://www.magniel.com/jse/B/vol0201B/p31.html

[12] World Development Report 2014: Risk and Opportunity — Managing Risk for Development. Washington, DC, 363 p. https://openknowledge.worldbank.org/handle/10986/16092

[13]. Atoyev K. L. Optimal control by normalization of cell's energetic balance // Theory of Optimal Solutions, 2006, № 5, pp. 76- 84. http://dspace.nbuv.gov.ua/handle/123456789/84957

[14] Estimation of HIV/AIDS Escalation in Ukraine. Information Technology for Management of Epidemics and Risk Ranking.
https://www.researchgate.net/publication/344441623_Estimation_of_HIVAIDS_Escalation_in_Ukraine_Information_Technology_for_Management_of_Epidemics_and_Risk_Ranking

[15] Climate Change 2022: Impacts, Adaptation, and Vulnerability. Summary for Policymakers IPCC WGIISixth Assessment Report (2022). 2022, 3676 p. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FinalDraft_FullReport.pdf

[16] World Development Report 2021: Data for Better Lives. A World Bank Group Flagship Report. Washington, 2021. 349 p. https://openknowledge.worldbank.org/handle/10986/35218

A COMPARATIVE ANALYSIS OF MESTA-NESTOS RIVER RUNOFF MODULUS ON BULGARIAN AND GREEK TERRITORY

Emil Bournaski, Ivan Ivanov
•
Climate, Atmosphere and Water Research Institute at Bulgarian Academy of Sciences, Sofia, Bulgaria
bournaski@aim.com
ivan.ivanov@aim.com

Abstract

The River Basin Management Plans and relevant Integrated Water Management of the transboundary river Mesta-Nestos between Bulgaria and Greece require sufficiently complete information about the water resources in the watershed and natural risk of expected climate change. The present study aims to present the surface runoff modulus (specific discharge as a characteristic of water resources) in the watershed based on measurements from 3 hydrometric stations on Bulgarian territory for the period 1935 - 2019 and 2 on Greek territory for the hydrological years 1965–1966 to 1989–1990. An attempt has been made for assessment of Climate Change impact on the Mesta-Nestos river runoff for years 2025, 2050 and 2100 based on two different scenarios HadCM2 and ECHM4. The results show an decrease in yearly specific discharge, both in the near future and in the longer time horizon compared to the reference period 1961-1990.

Keywords: Balkans, transboundary river, surface runoff, risk

I. Introduction

The Mesta-Nestos River basin of Mediterranean watershed is located in the Balkan peninsula, in South Eastern Europe and is shared between Bulgaria and Greece (known in Greece as Nestos). The river flows some 255 km and its catchment area covers 6,218 km^2 (the catchment of Dospat river included), and is almost equally divided between Bulgaria and Greece. It flows from the North, where the headwaters are located in the Rila mountain of Bulgaria, to the South East, where the river ends in a delta situated on the coast of the Aegean sea in Northern Greece. The Bulgarian territory of the catchment is located over 388 m above sea level and twenty-five percent of the territory is more than 1500 m above sea level (average level 1310 m a.s.l.). The Mesta river forms 6.5% of the river outflow of the country, while the area is only 2.49% of the entire area of Bulgaria [1]. It is characterised with very high specific water-power potential in comparison with the other Bulgarian rivers [1]. Beautiful mountains are popular and attractive destinations for international tourism, including winter sports. Part of the river waters are also used for electricity generation in a neighboring river catchment, while in Greek territory they are mainly used for electricity generation and irrigated agriculture. Currently, three hydroelectric power plants are located in the mountainous part of the Nestos basin in Greece: the Thissavros plant, with a reservoir capacity of 565 millions m^3 (construction completed in 1997), and further downstream the Platanovryssi dam (completed in 1990), with a reservoir capacity of 11 millions m^3 [2, 3, 4].

Both dams were designed to operate in pump-storage mode for electricity generation. The third dam, namely Toxotes, which is mainly a regulatory dam, is located in the delta's neck in order to divert the water to the plains of Kavala (western part of the delta) and Xanthi (eastern part of the delta) through two main channels [3]. The construction of a further fourth Temenos dam downstream of the Platanovryssi dam (6 millions m^3) was recently completed financed exclusively by private funds [3]. Situated downstream of the upper two dams, it is designed for electricity production, irrigation regulation and should contribute to increasing the total amount of power produced by the existing Greek complex.

The river water is of vital importance for the life and economic activity of the population in the Bulgarian and Greek territory. The river basin management plans and the implementation of the Bulgarian-Greek Integrated Water Management of the transboundary river need an assessment of water resources and natural risk of expected Climate Change, which is presented here through an analysis of the surface runoff modulus for the two territories.

II. Methods

The river runoff in the catchment is formed and fed by the surface runoff of rainwater (rainy and snowy) and by the drainage of the groundwater accumulated in the aquifers. Therefore, river runoff consists of these two components, and both components have the same primary genesis – precipitation. Surface water runoff forms the unsustainable component of total river runoff, and groundwater maintains its steady inflow - its sustainable component. There are also karst areas in the the catchment of the Mesta-Nestos river. Rainwater in karst areas is more quickly transformed into underground water.

Average annual and multi-year average water quantities are the main characteristics for evaluating the water resource of the river. In the case of assessing the water resource on the Bulgarian territory of the Mesta River, data from the monitoring in characteristic hydrometric stations - Yakoruda (functioning since 1948), Momina Kula (functioning since 1927 for water levels and from 1935-36 for water quantities) and Hadjidimovo (functioning since 1953) are used [1] (Fig. 1). Time series of undisturbed (natural) and disturbed (actually measured) water quantities for different time periods are used. Data from hydrometric stations Delta (operational since 1979, closed 1989), Papades (operational since 1965, closed 1990) and Temenos (operational since 1965) are used to assess the water resource of the Greek territory of the Nestos River [4] (Fig. 1). The aim is to reveal the trends in the nature of the change in the average annual water quantities of the main river over time and what the consequences of these trends over time may be.

The average water quantities along the river are used to determine the runoff modulus. The runoff modulus M is a hydrological characteristic expressing the water content of the river at a certain point along its length. It is determined by the formula

$$M = \frac{Q}{F}, \text{ m}^3/\text{s.km}^2 \quad \text{or} \quad M = 1000\frac{Q}{F}, \text{ l/s.km}^2 \qquad (1)$$

where Q is the average annual or multi-year average water quantity of the river at the point with the catchment area to the point F. The standard observation data as temperature, precipitation and river discharge are the source of information for analysis of the Climate Change risk. The historical temperature and precipitation information were taken from two Bulgarian meteorological stations: Bansko – 918 m a.s.l. and Gotze Delchev – 510 m a.s.l.

III. Results

The annual precipitation amounts and the runoff coefficient as a function of altitude for the mountainous parts of the Mesta watershed are shown in Table 1 (with some territories outside

Mesta).

The assessment of river discharge and water volume is based on measurement data from the Hadjidimovo gauging station closest to the Geek border, independent of water consumption in the basin and the volume of diverted water to other river basins (so called natural discharge). The basin runoff (discharge) modulus at the Hadjidimovo station for the period 1935/36 – 1974/75 and 1955 - 1983 is 14.30 l/s.km² and 13.582 l/s.km² respectively [1], Table 2.

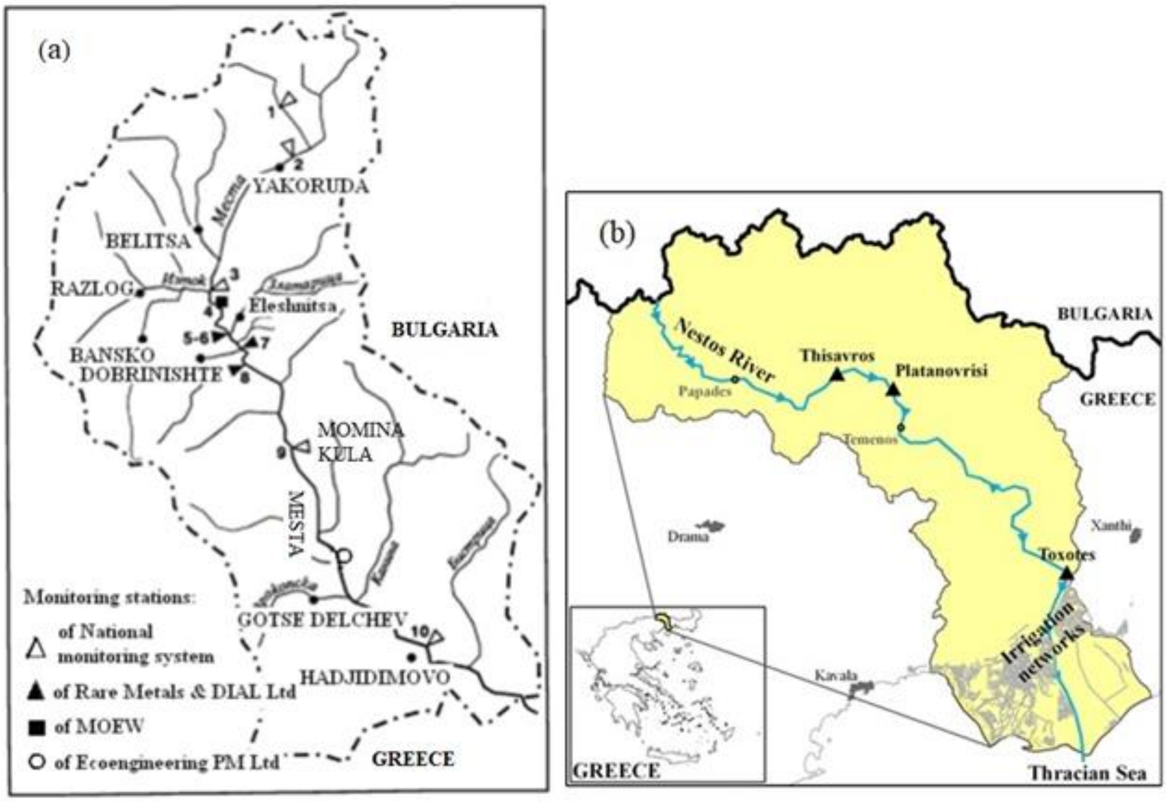

Figure 1: *Hydrometric stations on Mesta-Nestos River basin: (a) in Bulgarian territory [5], (b) in Greek territory [6].*

Table 1: *Water resources by Bulgarian mountain belts according to data from [7]*

mountain belt	Height, m a.s.l	Area, km²	Average water saturation, mm	Water resource, 10^6 m³	Annual rainfall, mm	Runoff coefficient,%
Rilo-Pirinsky	above 1600	1582	810	1280	950	85
	600 – 1600	3184	260	830	750	35
	300 – 600	659	80	50	600	14
	total:	5425	400	2160	790	51
Western Rhodope	above 1600	764	550	420	900	61
	600 – 1600	4471	280	1250	700	40
	300 – 600	490	180	90	600	30
	total:	5725	300	1760	720	41

Table 2: *Hydrological characteristics of the natural discharge of the Mesta River at the Hadjidimovo gauging station for different periods*

Time period	1935/36 – 1974/75	1955 - 1983
average Q, m^3/s	32.32	30.695
W, 10^6 m^3	1019.24	967.997
$M = 1000 \frac{Q}{F}$, $l/s.km^2$	14.30	13.58

The measurements at the Greek rain gauge stations were taken for the years 1965/66 to 1989/90 for Papades, 1965/66 to 1994/95 at Temenos and 1979/80 to 1989/90 at Delta [4]. The runoff measurements at the Greek station Delta, excludes the runoff of Dospat, because Dospat outflows to Nestos downstream of Delta and upstream of station Papades. The annual runoff at Temenos minus the annual runoff at Papades (estimated area between these two stations 1116 km^2) for the years 1965 to 1990 is about 388 × 10^6 m^3 and the average discharge is 12.3 m^3/s. The specific discharge in this region according Eq. (1) is 12.3 × 1000/1116 = 11 $l/s.km^2$ [4]. Due to the absence of measurements, it was assumed that the specific discharge 11 l/ $s.km^2$ was also valid for the region of the Greek catchment from the Bulgarian border to Papades (area 406 km^2) and for the region Temenos-Toxotes (area 584 km^2). Therefore it was found that the mean annual discharge due exclusively to the subcatchment from the Bulgarian border up to Papades was 11 × 406/1000 = 4.47 m^3/s and therefore the contribution to average annual runoff was 140.9 × 10^6 m^3. Similarly, the mean annual discharge due exclusively to the subcatchment from Temenos to Toxotes was 11 × 584/1000 = 6.42 m^3/s and its contribution to the mean annual runoff was 202 × 10^6 m^3. From Toxotes to the Nestos outlet to the Aegean Sea (area about 420 km2) there is no essential contribution to the river runoff due to the constructed level of the river, and to the fact, that a great part of this area is flat estuary. The average total physical runoff from the Rila mountain up to the Nestos estuary is 2076 × 10^6 m^3 and the average discharge about 66.4 m^3/s, based on data of the hydrological years 1965/66 to 1989/90 [4].

IV. Discussion

To calculate climate changes, two scenarios HadCM2 and ECHM4 are used. The same scenarios with monthly data of weather stations Bansko and Gotze Delchev were used by V. Alexandrov and M. Genev [8, 9]. Here we use the results obtained for years 2025, 2050 and 2100 from literature [9], where 30 years base period (1961 – 1990) was used for calibration of the HBV model (a semi-distributed conceptual model) with runoff data at station Hadjidimovo, Table 3. The available monthly data for precipitation and temperature of the weather stations are first corrected with the values of different climate change scenarios and after that the model was applied for the assessment of climate change impacts on the elements of hydrological cycle [9]. The model was not applied to the Greek catchment of the river due to a lack of precipitation and temperature data for a long period, assuming that climate changes are similar to those calculated for the Bulgarian catchment. The results for the hydrological parameters Q, annual volume and M are shown in Table 3 for stations Hadajidimovo and Temenos for 3 future periods.

The increase in mean monthly temperature results in an increase of the potential evapotranspiration and together with the predicted decrease in precipitation, they lead to a decrease in the river runoff, respectively the surface runoff modulus, Table 3. Both catchment areas are experiencing reductions in river modulus. And other studies of the same catchment indicate a decrease in the long-term annual mean runoff in comparison with the standard (baseline) period [10].

Table 3: *Calculated results for two different climate change scenarios and different years.*

			Mesta, Hadjidimovo, area 2260 km^2		Nestos, between Papades and Temenos, area 1116 km^2		
Year	scenarios	*Q*, m^3/s	annual volume, mm	*M*, l/s.km^2	Q, m^3/s	annual volume, mm	*M*, l/s.km^2
1961 – 1990 Base period		27.27	372.66	11.817	12,3	347.67	11,024
2025	HadCM2	23.98	327.73	10.392	10.82	305.75	9.695
	ECHM4	24.15	330.08	10.467	10.89	307.94	9.765
2050	HadCM2	21.38	292.20	9.266	9.64	272.61	8.644
	ECHM4	21.71	296.61	9.405	9.79	276.72	8.774
2100	HadCM2	16.21	221.47	7.023	7.31	206.62	6.552
	ECHM4	16.94	231.44	7.339	7.64	215.92	6.847

The results presented here are not a forecast, but an attempt to assess the possible future risk of changes in the Mesta-Nestos river flow, which could serve in making decisions related to the use and management of water resources. As we know primary sector plays an important role both to regional and national economy in the Balkans Peninsula, thus the coverage of irrigation demands on water is highly prioritized. For the fertile and agriculturally developed territory of the Nestos river delta such kind climate scenarios and climatic models indicate the existing difficulty in fully meeting the needs of irrigated agriculture. Difficulties may also arise in hydropower. Also in case of decreased streamflows, as predicted here, the maintenance of the environmental flow is bound to not be met.

In practice a hydrological model of the catchment areas coupled with a sequence of models such as irrigation models, reservoir simulation models, etc. and economic evaluation (based on priorities) enable a realistic assessment of the sustainability of the human activity in the water sector under various hypotheses of climate change.

Acknowledgements

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References

[1] Ivanov I., E.Bournaski, (2004). Water problems of the Mesta/ Nestos transboundary river in the Bulgarian territory. *Journal of Environmental Protection and Ecology,* (*BENA*), 5, No.4, 2004, pp.926-934.

[2] Skoulikaris, Ch., J. Ganoulis and J.M. Monget (2009) Integrated modelling of a new dam: a case study from the "HELP" Mesta/Nestos River., *18th World IMACS / MODSIM Congress, Cairns, Australia* 13-17 July 2009.

[3] Skoulikaris, Ch., J. Ganoulis and J.M. Monget (2011) Climate Change Impacts on Dams Projects in Transboundary River Basins. The Case of Mesta/Nestos River Basin, Greece., *Transboundary Water Resources Management: A Multidisciplinary Approach,* Eds: J.Ganoulis, A.Aureli, J.Fried, WILEY-VCH, Edition: 978-3-527-33014-0

[4] Mimides, Th., N.Kotsovinos, S.Rizos, C.Soulis, P.Karakatsoulis, D.Stavropoulos, (2007) Integrated Runoff and Balance Analysis Concerning Greek-Bulgarian Transboundary

Hydrological Basin of River Nestos/Mesta., *Desalination* 213 (2007) 174-181.

[5] Ivanov I., E Bournaski, (2021) Sources of pollution and water quality of the Mesta river in Bulgarian territory., *Journal of Environmental Protection and Ecology,* Book 6, ISSN 1311-5065

[6] Doulgeris, Charalampos & Georgiou, P. & Papadimos, Dimitris & Papamichail, D.. (2015). Water allocation under deficit irrigation using MIKE BASIN model for the mitigation of climate change. *Irrigation Science*. 33. 469-482. 10.1007/s00271-015-0482-4.

[7] Mandajiev D. (1989) "The natural and economic potential of the mountains in Bulgaria", vol. 1, 1989 (in Bulgarian).

[8] Alexandrov, V. & Genev M. (2002): Water Resources in Bulgaria under Climate Variability and Change. *Proceedings of the XXI Conference of the Danubian Countries on the Hydrological Forecasting and Hydrological Bases of Water Management*, Bucharest, Romania (CD version).

[9] Stanev K. (2008) The climate change impact on the Mesta river basin runoff. *XXIV-th Conference of the Danubian countries on the hydrological forecasting and hydrological bases of water management*, 2–4 June 2008, Bled, Slovenia.

[10] Kolokytha E., Skoulikaris Ch. (2019) Dependencies in transboundary water management in Greece in the face of climate change., *E-proceedings of the 38th IAHR World Congress,* September 1-6, 2019, Panama City, Panama doi:10.3850/38WC092019-0939

INFORMATION SYSTEM FOR MONITORING AND MANAGING THE RISKS OF DEVELOPMENT OF SIBERIA AND THE ARCTIC REGIONS

Vladimir Moskvichev[1,2], Ulyana Postnikova[2,3], Olga Taseiko[2,3]

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[1]Siberian Federal University
mlf@akadem.ru
[2]Krasnoyarsk Branch of the Federal Research Center for Information and Computational Technologies
ulyana-ivanova@inbox.ru
[3]Reshetnev Siberian State University of Science and Technology
taseiko@gmail.com

Abstract

The territorial risks of the development of Siberia and the Arctic should be considered within the framework of a closed social-natural-technogenic system (S-P-T system), which includes elements of the technosphere, ecosphere and sociosphere and is characterized by strategic development risks, taking into account the territorial factor, scale, composition and level socio-economic development. In SPT systems (subject of the Russian Federation, region, industrial agglomeration, municipality) man-made, natural, environmental, technological, social and other risk groups are implemented. The priority task is to monitor and organize an information system for managing territorial risks and ensure, on this basis, an integrated natural and technogenic safety of territories. This work presents various methods for assessing industrial safety for the northern territories.

Keywords: sustainable development, risk assessment, monitoring, safety expertise

I. Introduction

The regions of Siberia and the Arctic zone of the Russian Federation are becoming a strategic resource base not only for the near future, but also for the long-term development of the country. "Practically all aspects of national security are concentrated in the Arctic zone - military-political, economic, technological, environmental and others." In accordance with this statement (V.V. Putin, 2013), the most important strategic documents in the field of state policy for the development of the Russian Federation, Siberia and the Arctic have been adopted in the country in the last decade:

- “On the National Security Strategy of the Russian Federation” Decree of the Russian Federation President July 2, 2021 No. 400;
- "On the strategy of scientific and technological development of the Russian Federation" Decree of the of the Russian Federation President 1.12.2016 No. 642;
- "On the strategy of environmental security of the Russian Federation for the period up to 2025" Decree of the Russian Federation President April 19, 2017 No. 176;
- State program of the Russian Federation "Socio-economic development of the Arctic zone of the Russian Federation". Government Decree dated March 30, 2021
- Action plan for the implementation of the Fundamentals of the State Policy of the Russian

Federation in the field of industrial safety for the period up to 2025 and beyond. Decree of the Government of the Russian Federation of September 17, 2018 No. 1952-r.

In order to ensure the safe operation of technosphere facilities, including in the conditions of Siberia, the North and the Arctic, through Rostekhnadzor, the Russian Emergencies Ministry, Rosprirodnadzor and other departments, a system has been created in the country for the implementation of state policy in the field of industrial safety, protection of the population, the natural environment and territories from Natural and man-made emergencies, including the relevant legislative and regulatory framework.

However, the high rates of technosphere development have led to the emergence and growth of previously non-existent potential and real threats to man, society, and the natural environment from the objects of the technosphere. To localize modern man-made threats, deep fundamental research is required in the field of creating monitoring systems, diagnostics, computational analysis of reliability, residual life, security and safety of technical systems.

Current conditions and fundamental principles for the development of the Arctic zone:

1. Dilemma of contradictions:
- the need for industrial development and development of new territories;
- requirements for ensuring natural-technogenic, environmental and energy security.

2. The need to ensure the sustainability of socio-natural-technogenic systems, closed ecosystems and their adaptation to an increase in anthropogenic pressure, while development risks must be manageable and acceptable.

3. Low technical level of the existing systems of energy, heat, water supply, technological water treatment and waste disposal.

4. The promotion of modern technosphere objects in the northern and Arctic regions should be provided with appropriate scientific and technological support at the stages of their creation, production and operation.

5. The mass use of machines, structures and equipment, the construction of unique engineering structures, critical and dangerous industrial facilities in the implementation of investment projects is possible only with the widespread use of innovative equipment and technologies.

Territorial risks of the development of Siberia and the Arctic should be considered within the framework of a closed social-natural-technogenic system (S-N-T system), including elements of the technosphere, ecosphere and sociosphere (Fig. 1), characterized by strategic development risks, taking into account the territorial factor, scale, composition and level of socio-economic development. In SPT systems (subject of the Russian Federation, region, industrial agglomeration, municipality) man-made, natural, environmental, technological, social and other risk groups are implemented. The priority task is to monitor SPT systems, organize a territorial risk management system and ensure, on this basis, the integrated natural and technogenic safety of territories and technosphere objects. Monitoring of the elements state of SPT systems is provided by federal and regional structures and includes a significant set of different types: monitoring of technosphere objects, state environmental monitoring, socio-hygienic, industrial environmental, biospheric, aerospace (remote sensing), monitoring of the natural environment, which have received regulatory registration in the form of laws and GOSTs. The main problem is the difficulty of centralized collection, presentation, processing and analysis of the results of monitoring information due to the lack of interagency cooperation, especially at the regional level.

Below there are a number of research results in the field of natural and technogenic safety of the territories of Siberia and the Arctic zone [1-6].

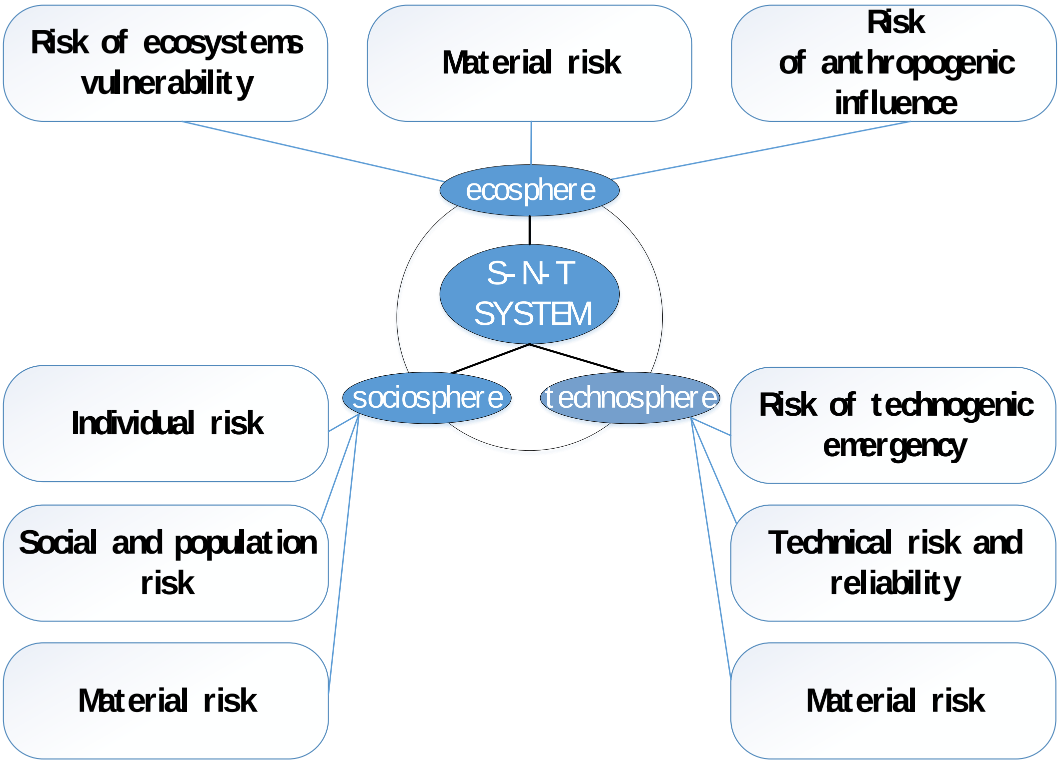

Figure 1: *The main elements and risks of the socio-natural-technogenic system (S-P-T system)*

II. Assessment of technogenic risk in Siberian regions

Figure 2 presents the results of individual technogenic risk calculations for a number of subjects of the Siberian Federal District. In some years, calculated risk indicators exceed the normative values. The calculation was carried out according to the state reports of the EMERCOM of Russia according to the formula (1):

$$R = N_p / N_n , \tag{1}$$

where N_p is the number of deaths per year with a certain type of emergency in a given territory; N_n is the number of people in a given territory.

Analysis of material risk, performed according to the formula: (2):

$$R_d = \sum_{i=1}^{K} g_i p_i , \tag{2}$$

where g_i is the value of the amount of material damage in the implementation of the i-th scenario of the emergency, which can be carried out with a probability p_i equal to conditionally acceptable, elevated and unacceptable.

Based on the results of the analysis of territorial risks of the subjects of the Siberian Federal District and municipalities of the Krasnoyarsk Region, the Irkutsk Region and the Republic of Sakha (Yakutia), was developed a regulatory and technical document (NTD) "Guidelines for assessing the territorial risks of the development of socio-natural-technogenic systems (municipalities)".

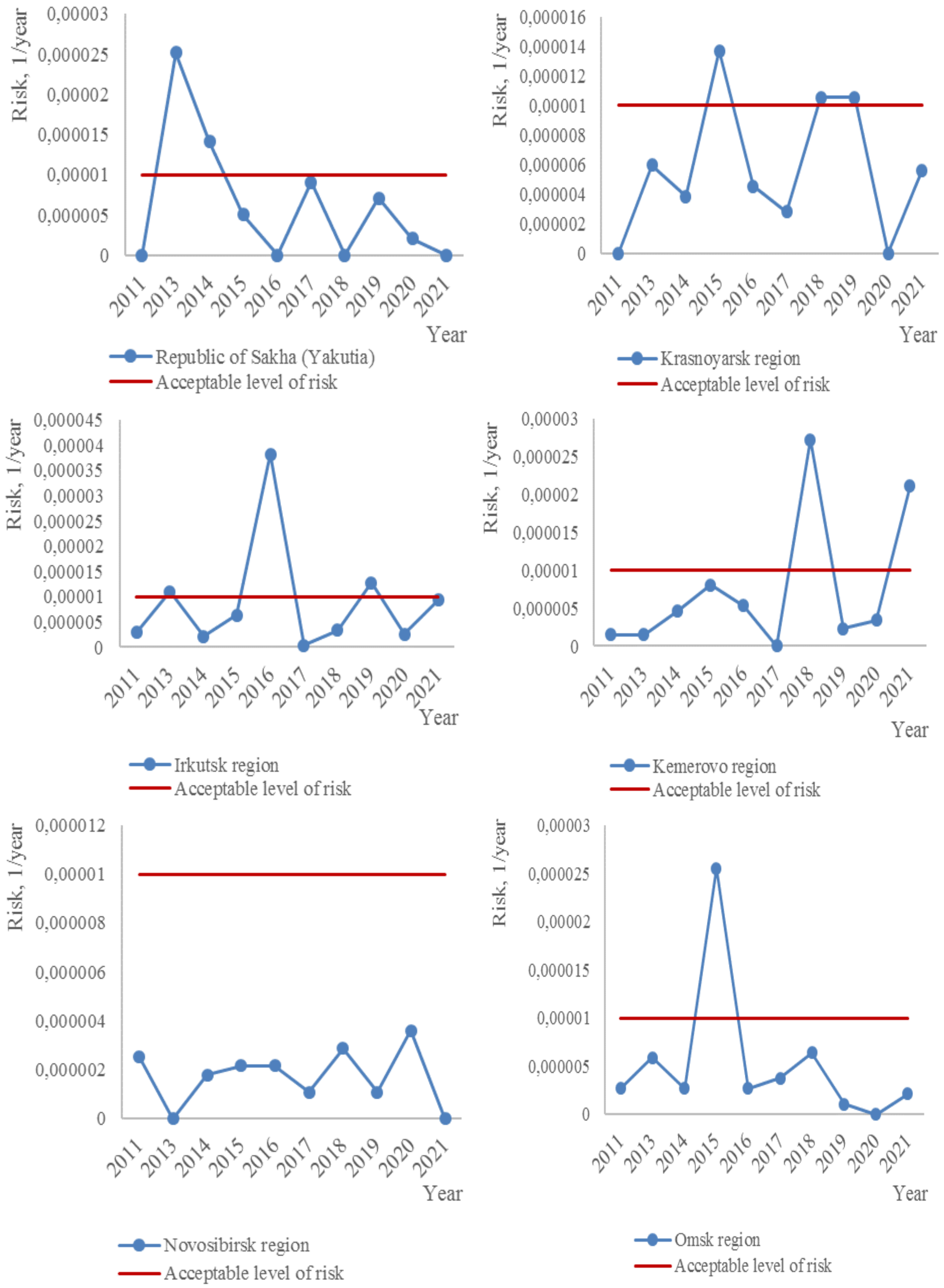

Figure 2: *Assessment of the individual risk of technogenic emergencies in the Siberia regions and the Arctic*

The NTD was prepared as part of the state assignment of the FRC ICT for the project "Development of a new generation of information systems for monitoring and assessing the risks of developing S-P-T systems for managing industrial regions of the country" and in accordance with the Action Plan of the Russian Scientific Society for Risk Analysis for the implementation of the Sendai Framework Program for disaster risk reduction for 2015-2030 "Building the resilience of nations and communities to natural disasters" (adopted at the Third World Conference in Sendai, Japan on March 18, 2015).

Table 1: *Assessment of the material risk of man-made emergencies in Siberia and the Arctic*

	Probability of a man-made emergency				
Region name	2017 year	2018 year	2019 year	2020 year	2021 year
Republic of Sakha (Yakutia)	0,008219178	0,002739726	0,005479452	0,005479452	0
Krasnoyarsk region	0,005479452	0,016438356	0,021917808	0,01369863	0,008219178
Irkutsk region	0,016438356	0,008219178	0,019178082	0,016438356	0,019178082
Kemerovo region	0,002739726	0,008219178	0,005479452	0,008219178	0,005479452
Novosibirsk region	0,005479452	0,008219178	0,005479452	0,016438356	0
Omsk region	0,008219178	0,01369863	0,002739726	0,002739726	0,002739726
	Material damage, million rubles				
	2017 year	2018 year	2019 year	2020 year	2021 year
Republic of Sakha (Yakutia)	0	369,5	0	11,2	0
Krasnoyarsk region	722,2	0,9	33,9	148179	0,42
Irkutsk region	337,4	533	5	103,9	195,5
Kemerovo region	150	1,3	15,6	7,8	30
Novosibirsk region	0	0	0	23,6	0
Omsk region	329,9	5,2	0	24,3	250
	Level of material risk				
	2017 year	2018 year	2019 year	2020 year	2021 year
Republic of Sakha (Yakutia)	Conditionally Acceptable	Increased	Conditionally Acceptable	Increased	Acceptable
Krasnoyarsk region	Unacceptable	Increased	Increased	Unacceptable	Conditionally Acceptable
Irkutsk region	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Kemerovo region	Increased	Increased	Increased	Increased	Increased
Novosibirsk region	Conditionally Acceptable	Conditionally Acceptable	Conditionally Acceptable	Increased	Acceptable
Omsk region	Increased	Increased	Conditionally Acceptable	Increased	Increased

The guide is a system of interrelated methodological materials that define the procedure for assessing the risks of developing SPT systems (individual risks, material risks, risk of emergencies, collective risk, individual and population carcinogenic risks, non-carcinogenic risk, relative risk of mortality). There are three main stages in the assessment of territorial risks. During the first stage: general target information is formed; possible dangers for the territories are determined; initial data are determined; the main sections on the risks of possible emergencies are being developed. The second stage is the calculation of risk indicators, mapping and comparison with acceptable risk levels. At the third stage, recommendations are developed for risk management at the level of municipalities.

III. Safety review of facilities of the Norilsk industrial agglomeration

Over a ten-year period (2005-2014), about 500 industrial safety reviews of various types of technical systems and technological equipment were carried out on the territory of the Norilsk industrial agglomeration, including: lifting and transport equipment (48 units), technological vessels (45 units), pressure vessels. (27 units), vertical welded tanks (32 units), boiler plants (51 units), technological pipelines (91 units), tanks and containers (86 units). A feature of the operation of machinery and equipment is low temperatures (up to −60 °C), the presence of permafrost (more than 60% of the entire territory of the Russian Federation), a sharply continental climate, which causes the problem of cold resistance of materials, machines and structures. An analysis of the cause-and-effect complex of failures and destruction revealed the following reasons: design errors - 25%; inconsistency of the materials used (10-15%), manufacturing defects (up to 30%), imperfection of standards - up to 10%. The main types of destruction: brittle, quasi-brittle, ductile, buckling, development of welding defects, corrosion phenomena. The human factor, which manifests itself at the stages of design, production and operation, is up to 60%. The latter circumstance is of dominant importance in the causal analysis of the destruction of the vertical steel tank RVS-30000, which occurred on June 22, 2020 in JSC Norilsk-Taimyr Energy Company.

IV. Safety review of facilities of the Norilsk industrial agglomeration

For the effective management of territorial entities on the basis of the Federal Research Center for Information and Computing Technologies, an information system for territorial risk and security management (ISTU RB) has been developed. The purpose of the information system is to reduce territorial risks to acceptable scientifically substantiated levels. The system allows integrating the accumulated experience of network monitoring of the state of the environment and the technosphere, technologies for analyzing large volumes of information and modeling, the theory of security and risk, mechanisms of territorial administration, and methods for predicting socio-economic development [7] (Figure 3).

The information system allows solving the following tasks:

- analysis of the quantitative assessment of environmental, technological, individual and social risks;
- development of standards characterizing the permissible impact on subsystems, taking into account regional geoecological features and the specifics of anthropogenic impact;
- assessment of the complex characteristics of the state of safety of the territory under consideration;
- formation of recommendations based on a risk-based approach for the effective management of territorial entities.

The ISTU RB receives statistical data characterizing the SPT system (territory). ISTU RB consists of two subsystems:

1) information subsystem "Monitoring". In this subsystem, information flows of systems are collected and systematized, followed by processing, analysis and organization of storage of initial and processed data.

2) information subsystem "Risk-analysis". This subsystem has three blocks: crisis databases of the S-P-T system; a cartographic base of a geographic information system and a block that includes models and computational technologies for analyzing basic development risks. In this subsystem, the risk is identified (identification, classification, evaluation and determination of the acceptable

level).

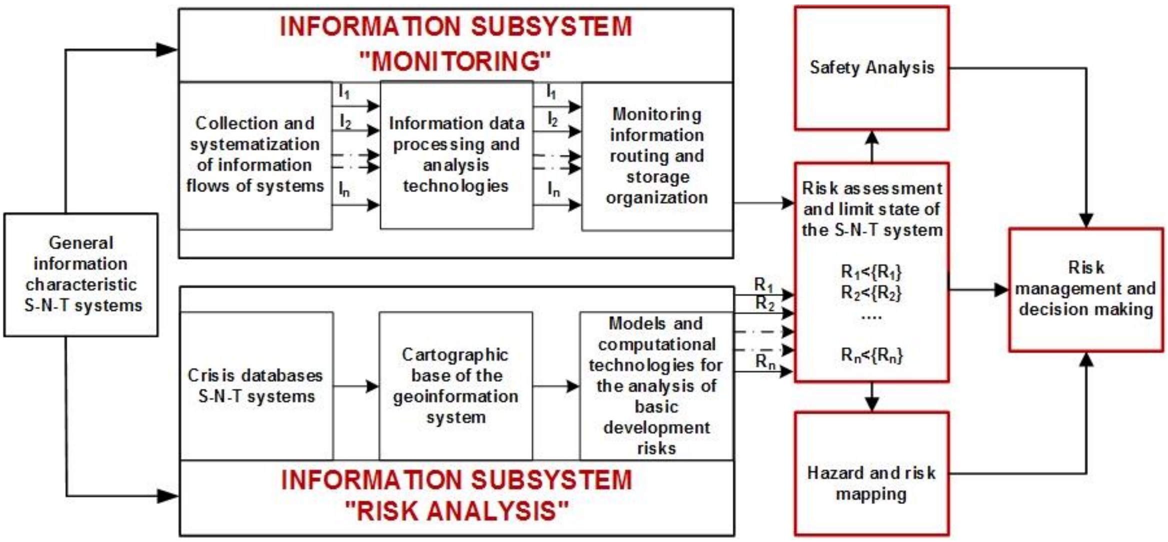

Figure 3: *Block diagram of the information system for territorial risk and security management*

The system provides for risk assessment in three modules - "Ecosphere", "Sociosphere" and "Technosphere".

Quantitative risk assessment requires taking into account and analyzing a significant amount of initial data provided by the results of monitoring the main elements of the system:

- ecosphere (natural environment): frequency of dangerous meteorological, hydrological and geodynamic situations, atmospheric air quality, state of surface waters, land and forest resources;
- technosphere: the state of technical systems, the risk of loss of life and health at production facilities;
- sociosphere: morbidity and mortality of the population of the region by main groups of diseases, life expectancy, income level, education, health care.

V. Conclusion

The accelerated development of Siberia, the Far North, the Arctic, including the coast and shelf of the Arctic seas, aimed at strengthening the economic potential of Russia, means the accelerated development of basic industries (mining, oil, gas) and mechanical engineering (machine tool building, robotics, transport and metallurgical engineering, shipbuilding, construction industry equipment, construction, lifting and transport, road construction, mining and transport equipment, etc.), while taking into account extreme climatic, complex mining and geological, transport and logistics, energy and extremely unfavorable socio-economic conditions for development industrial production.

The technosphere development in the northern regions against the backdrop of infrastructure development, economic growth and an increase in the living standards of the population leads to environmental problems for the natural environment and an increase in the risk of man-made accidents and disasters. The priority task is to ensure the technogenic, environmental and energy security of the strategically important objects, critical facilities, hazardous production facilities, objects of technical regulation and the territories of cold climate regions.

The contradictions between the requirements of industrial development and the development of new territories and the need to ensure natural, technogenic and environmental safety can only be resolved with an integrated approach to planning and managing development risks based on interdisciplinary research.

Thus, the main tasks that need to be solved in the near future are: organizing a system of territorial management of the risk of catastrophic situations at hazardous industrial facilities based on an integrated interdisciplinary approach; development of means for diagnosing the technical condition, organization of technical and environmental monitoring; development of methods for estimating the residual life of CTS during their operation in cold climate regions..

References

[1] Safety and risks of sustainable development of territories / Moskvichev V.V., Nicheporchuk V.V., Shokin Yu.I. and others. Krasnoyarsk: Sib. Feder. Un-ty, 2014. 224 p.

[2] Mechanical engineering in Russia: the technique of Siberia, the North and the Arctic / Fortov V.E., Makhutov N.A., Moskvichev V.V., Fomin V.M. Krasnoyarsk: Sib. Feder. Un-ty, 2018. 178 p.

[3] Moskvichev V.V., Bychkov I.V., Potapov V.P., Taseiko O.V., Shokin YU. I. Information system for territorial risk and safety management development // Herald of the Russian Academy of Sciences. – 2017. – №8. – p. 696–705.

[4] Moskvichev V.V., Taseiko O.V., Ivanova U.S., Chernykh D.A. Basic regional risks of territorial development for Siberian federal district // Computational Technologies. – 2018. Vol 23. – №4. – p. 95–109.

[5] Moskvichev V.V., Taseiko O.V., Ivanova U.S., Chernykh D.A. Basic risks of natural and technogenic safety of the Krasnoyarsk industrial agglomeration. // Problems of risk analysis. - 2018. - No. 1. - p. 42-47

[6] Moskvichev V.V., Prokhorov V.A., Ivanova U.S. Technogenic and environmental risks: Krasnoyarsk territory, Republic of Sakha (Yakutia) // Ecology and Industry of Russia. – 2020. - №4. - p. 53-59.

[7] Certificate of state registration of the computer program No. 2020661041 Russian Federation. Information and computing system "Risks" : No. 2020660032 : application 04.09.2020 : publ. 17.09.2020 / S. E. Popov, V. P. Potapov, R. Y. Zamaraev [et al.] ; applicant Federal State Budgetary Scientific Institution "Federal Research Center for Information and Computing Technologies" (FRC ICT). – EDN DHXBEP.

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PROTECTION CIVILIAN INFRASTRUCTURE AGAINST HIGH ALTITUDE ELECTROMAGNETIC PULSE (HEMP): THE PROBLEMS AND STRATEGY

Vladimir Gurevich
•
Israel Electric Corp.
vladimir.gurevich@outlook.com

Abstract

Since the devastating effect of HEMP on electronics in the military field has been known for a long time, all military systems are equipped with efficient protection against the impact of HEMP. However, HEMP is equally dangerous for all civil electronics used in almost every section of today's most important infrastructure of any country, for instance the power industry. Therefore, the opinion that all technical problems have long been solved by the military and you just need to use their solutions and their experience in the civilian sector can be heard often. It is a very common and very dangerous illusion in the author opinion. The article describes the problems associated with the use of military technology in the civilian sector and proposes an author's strategy for protecting the civilian infrastructure.

Keywords: HEMP, electromagnetic pulse, electronic equipment, infrastructure protection, power industry, protection strategy

I. Introduction

The ability of the powerful electromagnetic pulse, generated upon the nuclear explosion at high altitude (HEMP) to destroy all electronics, has been known to nuclear physicists since the first nuclear explosion was performed in 1945 on the Alamogordo range, New Mexico (project Trinity). Upon the explosion, all apparatus that was meant to monitor the explosion parameters became inoperative. Upon all further test explosions performed in all countries, that electromagnetic pulse was registered precisely and was followed with the analysis and study of the parameters. Beginning in the 1970s (50 years ago), that subject has been unclassified. At that time, dozens of Western scientific and technical reports, prepared by numerous military and civilian organizations (working at the military request), were devoted to different aspects of HEMP impact on electrical equipment and electronics. Since then, the electromagnetic pulse had been officially recognized as one of the damage effects of nuclear weapons, along with the detonation wave, the temperature, the light and the radioactive emission. This has been mentioned in all open sources, including booklets and recommendations on protection against the massive weapon distributed amongst the population during the "cold war" between the USA and the USSR. However, at that time only a few people understood. Not only average people, but also engineers and technicians working in power generation, electrical engineering and electronics, and even military specialists who are not experts in nuclear physics were not aware of the problem. Unfortunately, the situation has not changed a lot despite hundreds of reports, presentations, articles and books, as well as dozens of open military and civilian standards on this subject. At least in the USA this subject is in the spotlight of many dozens of organizations listed in [1], including numerous Congress Panels created especially for this. Many years have been spent researching this subject which has been funded prevalently by the government. However, civil engineers working in the field of electrical power supply, water supply, sewage systems, telecommunication, banking, etc., are bewildered about this massive data so far.

But why?

II. The Problems

The problem is that all such numerous organizations which are fed on massaging the HEMP issue and periodically frightening the laymen with the fatal disaster resulting from the HEMP impact are not interested in an early solution to this issue and are discontinuing. Conversely, all of them are interested in keeping this problem afloat and continuation of prolonged funding. And the proposed specific technical solutions for protecting civilian infrastructure elements against HEMP encounter reluctance to even discuss these solutions, since, supposedly, all technical problems have long been resolved.

The opinion that all technical problems have long been solved by the military and you just need to use their solutions and their experience in the civilian sector can be heard often. Here is what Dr. George H. Baker, Prof. Emeritus James Madison University, Director Foundation for Resilient Societies says in his testimony before the Senate Homeland Security Committeein of Congress [2]:

> *"The U.S. military already has EMP protection approaches that are practical, affordable, tested and well understood that can be translated directly to electric power grid control facilities and supervisory control and data acquisition electronics and networks."*

In his numerous publications Dr. Peter Vincent Pry, Executive Director of the Task Force on National and Homeland Security, has said the same thing many times:

> *"The problem is not the technology. We know how to protect against it. It's not the money, it doesn't cost that much. The problem is the politics. It always seems to be the politics that gets in the way".*

The same idea, but in different words, is repeated by Ambassador Henry F. Cooper, Chairman of High Frontier, and an acknowledged expert on strategic and space national security issues [3]:

> *"Moreover, I emphasized that we have the technical know-how to accomplish this objective; actually, have known how for decades but have not done so for political — not technical or financial reasons".*

Unfortunately, this is a very common and very dangerous illusion that is replicated by people who are very far from the real technical problems of the civil infrastructure sector. Instead of involving technical experts for solving technical problems, such statements only replicate empty talks and delay the practical solutions of the problem. It is clear that the more such empty talk and the fewer specific technical solutions suitable for the civilian sector, the longer the problem will remain afloat and the more money can be obtained for this problem.

Why military HEMP protection means are not suitable for the civilian sector?

There are several very important problems and here are some of them:

Problem 1. Unlike the civilian systems, over the last few decades, all critical military systems vulnerable to HEMP have been designed with HEMP protection. It is much easier and cheaper to include HEMP protection means in the design stage than try to protect the existing critical civilian equipment, such as digital protection relay cabinets used in the power generation industry. Such cabinets, sometimes overstuffed with apparatus, have dozens of inputs and output multicore cables and each separate core requires protection. Who will do it?

Problem 2. Internal electrical wiring of military systems (tanks, airplanes, ships, missiles) are made with preassembled wire harnesses or with separate wires in strict adherence to drawings and sizes. Thus, the electrical characteristics of such wiring at high frequencies (HEMP frequencies) are identical to the equipment of the same type. It means that it is enough to test the HEMP immunity of one finished typical sample in order to be sure that all other units will have the same characteristics. In the power generation industry, it is hardly possible to find two identical cabinets with electronics having absolutely identical internal wiring. Since at HEMP frequencies range (100 kHz to 100 MHz) the minor change of wire length, even to 20 cm - 30 cm, or in its placement inside the cabinet, results in a dramatic change of cabinet internal apparatus vulnerability to HEMP (Gurevich, V., 2021), a typical test model does not exist. Thus, the results of testing any individual cabinet for very short electromagnetic pulse impact cannot be extrapolated over other cabinets, i.e., in practice, there is no “typical” cabinet for such tests. Based on conclusions made in [1] and [4] it is not feasible to conduct such tests for this type of equipment. The data presented in [1] regarding the resilience of computers and computer networks, also confirm an extremely large scattering of test results, depending on the influence of a very large number of almost unpredictable factors and the inability to transfer the results of single tests of specific devices and systems to other devices and systems.

Problem 3. The military apparatus is protected within the electromagnetic range both from HEMP and Intentional Electromagnetic Interferences (IEMI), as well as from data leak through the electromagnetic fields (TEMPEST). The higher frequency range of IEMI and TEMPEST is far beyond the HEMP range (20 GHz–40 GHz). According to MIL-STD -188-125-1 such means must ensure at least 80 dB attenuation of an electromagnetic interference in the frequency range up to 1 GHz. Many manufacturers want to be holier than the Pope and offer on the market HEMP filters with parameters that exceed the requirements of this standard. For example, the typical attenuation features of HEMP filters described in ETS-Lindgren’s promotion materials reach 100 dB in the frequency range up to 40 GHz, and this despite the fact that 96% of the total HEMP energy is released in the frequency range up to 100 MHz (in accordance with the standard IEC 61000-2-9). It is clear why a such low power filter (for example LRX-2005-52 type, for a current of 5A) of this company has dimensions of 940 x 229 x 127 mm and a weight of more than 27 kg. Similar parameters are available for filters from other manufacturers. The costs $US 1,500-2,500 worsen the situation. Does anyone really believe that civil power engineering can use the same filters simulating the ones used in the underground military bunker? The answer to this question can be obtained from the results of a study carried out by the National Coordinating Center for Communications (USA) (*Electromagnetic Pulse (EMP) Protection and Resilience Guidelines*, 2019). From the presented data, one can see the inexpediency of applying the requirements of military standards to the means of protecting civil equipment. It appears that it is quite enough to attenuate HEMP by 20 - 30 dB only. This significantly changes the attitude towards the problem of protecting civilian equipment.

Such conclusion is also confirmed in [5], where it is shown that even for military equipment, the requirements of the basic standard MIL-STD-188-125 should not be applied directly to military facilities of all echelons:

> *“If shielding facilities applying the MIL-STD-188-125 standard are installed in all national infrastructures, it is estimated that a huge budget will be required. MIL-STD-188-125 does not consider the blocking and attenuation characteristics of regular buildings or underground facilities in terms of EMP protection. Furthermore, it requires the use of a huge amount of concrete, rebar, and steel plates in heavyweight structures to disallow even a single failure in mission-critical facilities. Hence, there is no need to apply MIL-STD-188-125 to military facilities of all echelons… Therefore, it was confirmed that EMP protection measures could be changed from the current shielding room-oriented, fixed-type protection facilities to mobile lightweight protection facilities using shielding fabrics, shielding racks, redundant equipment, spare equipment, and failure recovery.”*

So, what to say about civilian equipment?!

Problem 4. This problem is related to the test benches simulating HEMP.

Within such a test bench like the guided-wave type HEMP simulator that has been primarily developed for testing pieces of military equipment), the bottom part of the antenna is embedded into a concrete base and has ground potential. It is not a problem for tanks, airplanes, missiles, or other military equipment. However, in the case of civilian equipment, such as cabinets with digital protective relays with grounded internal electronic circuit (i.e. connected directly to the antenna bottom part), the test bench pulse impact on such a cabinet will differ from the real HEMP, since it will not be related to Earth potential in any way.

One another problem of the HEMP simulators. Electronics cabinets used in the power generation industry have dozens of input and output cables, tens and hundreds of meters long. The cables act as antennas absorbing electromagnetic energy over the large area and delivering it directly to the sensitive electronics inside the cabinets. How can such long cables be modeled on a compact test bench (the above image on Fig. 1.4 shows one of the very big benches not available in every country)?

As shown in [1], [4] most existing test benches are of little help for testing cabinet-type equipment, which is used in the civil power industry and the results of these tests are illogical.

Problem 5. Despite a large number of civil and military standards, including the still classified standard [6], describing the parameters of HEMP that affect equipment, the real values of these parameters remain completely unpredictable due to objective reasons.

For example, all HEMP-related standards define a field strength of 50 kV/m as a factor affecting equipment. But in fact, this field strength can be completely different, both much more (100 kV/m for Super-EMP) and much less (5 – 10 kV/m for some environmental).

Table 1: *Electric field peak value distributed on the ground from a 100 km height of burst (HOB), 1Mt yield burst [7].*

Location on the ground (projection point on the ground from the explosion center)	Peak electric field, V/m
50 km to the north	2866
26 to the north	11447
ground zero	20777
57.7 km to the south	35494
100 km to the south	40042
173 km to the south	40227
247 km to the south	37071
290 km to the south	34802
514 km to the south	30796

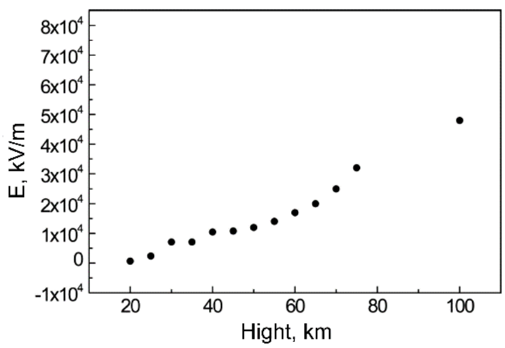

Figure 1: *Changes of the electric field intensity at different heights of burst over the explosion center for 1Mt yield [7].*

In Table. 1 in Fig. 1. shows only some of the possible variations of the HEMP field strength depending on external conditions, which cannot be predetermined.

There is also a nonlinear relationship between the power of the nuclear charge and the strength of the electric field:

> *"The power of the 100 kT explosion is 10 times less than that of the 1 MT nuclear explosion, with the electric field intensity peak down by 2.5 times; the power of 500 kT explosion is two times less than that of the 1 MT nuclear explosion, with the field intensity peak down by 15% only"* [7].

As can be seen, unpredictable variations in the intensity of HEMP exposure to equipment are possible over a very wide range.

Problem 6. The inability to consider the specific conditions in which thousands of specific types of equipment are located: types of buildings; the location of rooms with equipment inside them; the presence of windows; cables, their length, depth in the soil; specific soil properties (which, moreover, change significantly depending on weather conditions), etc. That is, the inability to consider the weakening properties of the environment surrounding the equipment in order to assess what additional protective equipment and with what properties are needed. There are thousands of options here.

This raises a very important question regarding assessment of efficiency of applied protection measures and protection means. In this situation I rely on three rationales:

- it is fundamentally impossible to formulate clear technical requirements for HEMP protection of equipment that would be universal for all types of civilian equipment;
- it is impossible to ensure absolute protection for every piece of electronic equipment employed at power facilities;
- any level of protection which can attenuate (at least partially) HEMP impact on electronic equipment is useful.

Based on this, the general strategy should be based on ***maximum use of maximum amount of known protection means with restrictions to be determined by technical and economic capabilities of specific power system only.***

This approach makes testing of complete protected equipment on simulation test benches absolutely senseless, even if we forget about downsides of guided wave-type simulators. Nevertheless, some tests are necessary and important. They include testing of specific means (elements) selected for protection, such as varistors, filters, cabinets, cables, etc. The purpose of these tests is to check parameters declared by the manufacturer and to select the most efficient protection elements from the diversity offered in the market. These tests can be performed using generally accessible instruments, manufactured by companies described in [1].

All these problems have been detailed in my previous books on this subject [1], [4].

But what is the status in terms of drawing the government's and society's attention to this problem? Just as bad as in terms of technical problems! US bureaucrats and officials have managed to convert the renowned Directive of former President D. Trump "Executive Order on Coordinating National Resilience to Electromagnetic Pulses" into another example of bureaucratic sophistry and verbosity. It was detailed in my previous book [1]. As a consequence, nothing essential was made in this regard, and "*the current state of EMP protection is random, disoriented and uncoordinated*", - according to Dr. George H. Baker, Prof. Emeritus James Madison University. Regarding that situation, there is a big range of views amongst different specialists in this field, including the very opposite ones [1]. For example, Dr. Peter Vincent Pry, Executive Director of the Task Force on National and Homeland Security mentions: "*The problem is not the technology. We know how to protect against it. It's not the money, it doesn't cost that much. The problem is the politics. It always seems to be the politics that gets in the way*". However, other experts take great issue with it. "*I don't think we have an illusion we will prevent it. That's really the government's job*", - says Mike

Bryson, Vice president of operations for the Valley Forge, Pennsylvania-based operator. His words are echoed by another representative of the US electrical energy sector, Richard Mroz, President of the New Jersey Board of Public Utilities: "*Managing that kind of threat right now — no one really has the resources to do that*" [1]. General M. V. Hayden, Ex-Director of the National Security Agency (NSA), Ex-Director of the Central Intelligence Agency (CIA) sums up: "*I don't mean to be so flippant, but there really aren't any solutions to THIS, so I would just leave it at that*" [1].

"*…leave it at that*"? So, let us forget and do nothing... Brilliant strategy, isn't it? Nonetheless, the developers of the new weaponry from all countries clearly understand the chosen strategy and the present situation and relentlessly work on the new electromagnetic weapon types, including a super-EMP bomb – nuclear explosive with a manifold magnification of pulsed electromagnetic radiation, while understanding that there is no protection against it and it will not be available in the near future.

It should be noted here that opponents to any measures on protection of infrastructure against HEMP often say that such protection does not make sense, since any nuclear explosion initiated by any side will immediately result in a massive attack with all nuclear weaponry and a single electromagnetic pulse will be meaningless. In fact, this is not true. Recently, nuclear weapon strategy and tactics have evolved. It is not just a strategic deterrent weapon anymore. For example, there are programs on creating new tiny nuclear warheads for tactical cannon shots actively developed in many countries. Here it should be noted that in order to generate a powerful EMP, the nuclear warhead must be activated at a high altitude (more than 30 km), therefore such a warhead is not a mass lethal weapon. This fact should be deemed as an important motivation to apply such weapons. If the weapon will cause no direct human losses, the opponent will hardly initiate the regular overland nuclear attack resulting in millions of deaths. The response will likely be symmetric. That is why it is very important to protect the infrastructure against HEMP, and this problem will evolve over time.

Digital protective relays and automatic control systems built on microprocessors, distributed power generation controlled with the artificial intelligence devices, digital substations, etc., all these great and most advanced systems are particularly vulnerable to HEMP. A very dangerous modern phenomenon in the electrical power industry called "digital substation" should be mentioned here. No, of course, it is not dangerous in itself, but in the way it is "implanted" into the power electrical industry. However, no threats stop the digital substation apologists. The development and implementation of artificial intelligence systems in the electric power industry continues without any limitations and without regard to the increasing significantly vulnerability of the electric power industry to HEMP with such development trends. Thus, the modern electrical power industry's development tendency is accompanied by its increasing vulnerability. Is it progress? There is rather a strange situation – while everyone is concerned with the cyber security of today's civil electrical power industry, no one thinks about its protection against HEMP. This position of the leading power engineering experts, and all-around appeals to fasten the power engineering sector digitalization by any and all means, without any consideration of the problem or intention to simultaneously develop measures on protection of all those digital technologies against HEMP, are hair-raising.

However, this does not eliminate the need to search for and select the most effective means of protection of the civilian infrastructure from those offered on the market, which have the best price-performance ratio.

Despite the seemingly routine and simplicity of the problem, for a number of reasons this becomes a very difficult task in this specific field of technology. One of the problems is that civilian sectors of the economy have not yet started real work anywhere in the world to protect civilian infrastructure from HEMP, and therefore these sectors are not consumers of protective equipment. For this reason, manufacturers of this protective equipment are primarily focused on military orders and produce products according to military standards that meet the requirements of the military. As a result, the means of protection offered on the market today have parameters that are excessively high for the needs of civilian infrastructure and, accordingly, a high cost that is completely unacceptable for civilian needs. Specifically, even if in some country, in some sector of the economy, they decide to deal with the problem of protection against HEMP, they will not find anything suitable on the market.

In this regard, the only solution may be to conduct research and development of protective equipment specifically designed for civilian infrastructure with the new strategies and methods for their application. It can be stated that today these tasks have not yet been solved, and numerous reports and recommendations published by dozens of organizations are too vague, not specific, and do not help to solve the problem of protecting civilian infrastructure. They create only a background noise and the illusion that all technical problems have already been resolved and it is only a matter of government decisions.

It is a pity that the authors of the report do not understand that the most important for protection against HEMP parameters of "*thousands of diverse infrastructure installations*"[8], are not determined in fact and any "*EMP-related intelligence gathering*" not will help here.

III. The Strategy

From the foregoing, we can conclude that military strategies, means and technologies for protecting against HEMP are too expensive for the civilian sector, and suitable strategies and technologies for the civilian sector simply do not exist now. Therefore, a new absolute different strategy and means are required for the protection of the civilian infrastructure.

The main principles of this strategy:

- It is impossible to ensure protection of any and all types of electronic equipment in the power systems.
- It is impossible to ensure absolute protection even for the most important types of equipment being used.
- The cost of protection devices budgeted during the design stage (in case of new equipment and facilities) will be much lower compared to upgrading the existing equipment.
- Instead of protecting specific types of employed electronic equipment, it is sometimes feasible to use back-up equipment of the same type stored in a metal container directly at the facility being protected.
- Existing HEMP-simulating test benches provide insufficient information at immunity testing of power system's electronic equipment and thus testing such equipment (e.g. each cabinet with electronic equipment) on such test-benches is not feasible.
- Due to technical and economic reasons, protection should only be provided to the most important (critical) types of electronic equipment installed at critical facilities of the power industry, rather than to any and all types of equipment employed at the power industry.
- Critical types may include equipment which is directly involved in electrical energy generation and transmission, as well as main types of relay protection, control and automation systems, AC and DC power supply systems.
- Consequently, measuring systems, communication (but not telecommunications used by digital relay protection devices), remote control and remote signaling systems do not belong to equipment without which temporary generation and distribution of electrical energy will be hampered in emergency situations.
- HEMP protection of equipment is multi-layered:

- *The first (top) layer* includes protected buildings and structures.
- *The second layer* includes protected rooms (halls) where equipment is installed.
- *The third layer* includes protected cabinets with electronic equipment.
- *The fourth layer* includes protection input and output terminals of the equipment itself placed into control cabinets

- *Some additional "layers"* of protection may include means for attenuation electromagnetic interferences penetrating into the equipment through the input and output cables (grounding, control and power).
- However, the use of all these "layers" in any situation is not feasible. In some cases, it is feasible to use just some of the "layers" in various combinations.

In other words, the **general strategy should be based on maximum use of maximum amount of known nonmilitary protection means (selected based on the above-mentioned strategy), with restrictions to be determined by technical and economic capabilities of a specific power system, only because any level of protection which can attenuate (at least partially) HEMP impact on electronic equipment is useful.**

References

[1] Gurevich V. Protecting Electrical Equipment: GOOD Practices for Preventing High Altitude Electromagnetic Pulse Impacts. DeGruyter, Berlin, 2019, 386 pp.

[2] Testimony of Dr. George H. Baker before the Senate Homeland Security Committee. *Senate Committee on Homeland Security and Governmental Affairs, February* 27, 2019.

[3] Cooper H. F. Will Biden Improve Trump's Cyber and EMP Initiatives? – *NewsMax*, 29 January 2021.

[4] Gurevich V. "Protecting Electrical Equipment: NEW Practices for Preventing High Altitude Electromagnetic Pulse Impacts. DeGruyter, Berlin, 2021, 204 pp.

[5] Kukjoo, K, at al, 2021. "Development of Decision-Making Factors to Determine EMP Protection Level: A Case Study of a Brigade-Level EMP Protection Facility". *Applied Science,* No. 11, 2921. MDPI.

[6] MIL-STD-2169B, 2012. High Altitude Electromagnetic Pulse (HEMP) Environmental.

[7] Cui, M., 2013. "Numerical Simulation of the HEMP Environmental". *IEEE Transactions on Electromagnetic Compatibility, Vol. 55, No. 3, June 2013.*

[8] Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment. National Cybersecurity and Communications Integration Center, Arlington, Virginia, 2019.

STUDY OF THE STABILITY AND SAFETY OF THE DAM ON LAKE BOYUK-SHOR IN BAKU

Fakhreddin Gabibov[1], Vugar Aliyev[2], Emil Gafarov[3], Aytan Akhmedova[3], Sabina Magerramova[3]

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[1]Azerbaijan Scientific Research Institute of Construction and Architecture
farchad@yandex.ru
[2]AMIR Technical Services LLC, Azerbaijan
prof.vugar.aliyev@gmail.com
[3]Azerbaijan University of Architecture and Civil Engineering
emilqafarov@inbox.ru
aytenaxmedova@mail.ru
sabinamaharramova@mail.ru

Abstract

The embankment dam on Lake Boyuk-Shor is designed for a highway and divides the lake into two parts. Engineering and geological studies have revealed a complex structure of the soil base of the dam and high seismicity. Studies of the stability of the dam slopes under the PLAXIS 2D program have shown their reliable stability. Studies of the sediment of the body of the dam and its soil base according to the PLAXIS 2D program have shown that the sediment of both the dam and its soil base is acceptable for this class of structures.

Keywords: dam, stability, soil foundation, expensive, sediment, lake, slope.

I. Introduction

Lake Boyuk-Shor is one of the largest lakes in Azerbaijan. It is located on the Apsheron Peninsula on the territory of the Binagadi, Sabunchi and Narimanov districts of Baku. The lake has a relict origin [1]. Figure 1 shows an aerial photo of Lake Boyuk-Shor.

In 1866, the first oil storage tank in Azerbaijan was built near the lake. In 1929, oil industry waste flowed into the lake through the Keshl Canal. Since the 70s of the last century, household and industrial waste has been thrown into the lake. In 2011-2015, the Baku Olympic Stadium was built on the eastern shore of the lake.

According to international experts, Lake Boyuk-Shor is considered one of the most polluted lakes. In 2014, in connection with the construction of the Olympic stadium, the lake was cleaned as part of a project to restore and improve the ecological condition of the lakes of the Apsheron Peninsula. The project of ecological restoration of the lake consisted of two stages. The first was carried out in 2014-2015, during which the restoration of an area of 300 hectares was carried out, separation and isolation using a dam of the northern part of the lake contaminated with oil. The second stage of restoration and improvement of the state of the OSNR began in 2015 and lasted until 2020. In December 2018, a new Balakhany-Binagadi road was opened, which runs along the dam and has a length of 1570 m.

The construction of multi-purpose bulk dams is a complex engineering process, the basics of which are described in the monographs K.Terzghi [2], J.L.Sherard, R.J.Woodword, S.F.Gizienski, W.A.Clevenger [3], G.V.Jeleznyakov, Y.A.Ibad-zade, P.L.Ivanov and others [4], A.L.Goldin, L.N.Rasskazov [5], W.F.Van Impe, R.D.Verastegui Flores [6] and others. Figure 2 shows a photo of the dam construction process on Lake Boyuk-Shor.

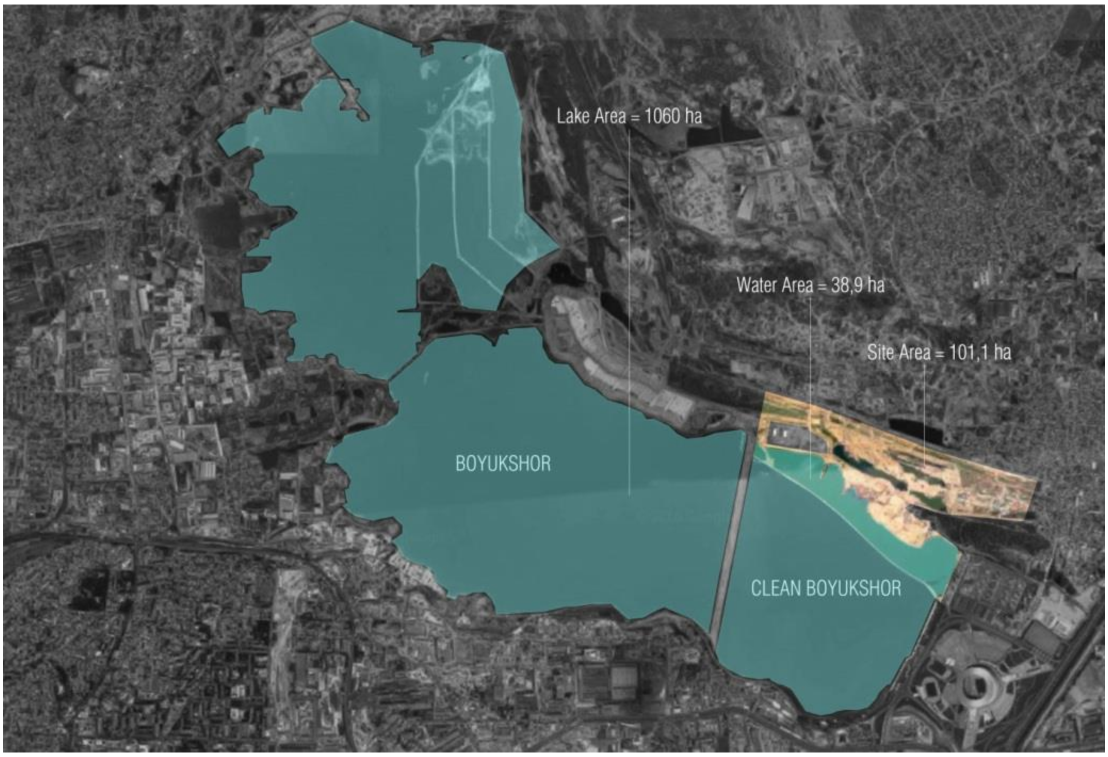

Figure 1: *Aerial photo of Lake Boyuk-Shor*

Figure 2: *Photo of the dam construction process on Lake Boyuk-Shor*

II. Selection of design sections and determination of design parameters of the dam

Along the projected route of the road located on the dam, 16 engineering and geological wells were drilled every 20 m. Based on the information received, two cross-sections of the dam with the foundation soils were selected, which differ from each other. In the selected section 1-1, the soil base is represented by the following layers: refractory clay – 5.35 m; plastic sandy loam – 1.5 m; semi–solid loam – 2.45 m; weak limestone - 0.55 m; dusty, moist sand – 5.0. In section 2-2, the soil base is represented by the following layers: semi–solid loam - 1.3 m; dusty, moist sand – 8.5 m; semi–solid loam - 4.5 m.

The physical and mechanical characteristics of the soils of the dam base are as follows. Clay is refractory: density – γ = 1.92 g/cm^3; angle of internal friction – φ = 13º; adhesion force - C = 27 kPa; modulus of deformation – E = 14 MPa; porosity – e = 0.877. Semi-solid loam: density – γ = 2.06 g/cm^3; angle of internal friction – φ = 21 °; adhesion force - C = 21 kPa; modulus of deformation – E = 24.5 MPa; porosity – e = 0.60. Sandy loam plastic: density – γ = 2.05 g/cm^3; internal friction angle – φ = 22 °; adhesion force - C = 9 kPa; modulus of deformation – E = 21 MPa; porosity – e = 0.588. The sand is dusty, moist: density – γ = 2.01 g/cm^3; internal friction angle – φ = 27 °; adhesion force - C = 3 kPa; modulus of deformation – E = 18 MPa; porosity – e = 0.658.

The physical and mechanical characteristics of the dam soils are as follows. Dam body: density – γ = 2.4 g/cm^3; internal friction angle – φ = 34º; adhesion force - C = 0 kPa; deformation modulus – E = 100 MPa. Dam prisms: density – γ = 2.4 g/cm^3; internal friction angle – φ = 36º; adhesion force - C = 0 kPa; modulus of deformation – E = 100 MPa. Dam loading prisms: density – γ = 2.4 g/cm^3; internal friction angle – φ = 40º; adhesion force - C = 2 kPa; deformation modulus – E = 100 MPa.

Two highways run along the crest of the dam. A traffic load acts on the dam from this road. According to the NK-100 standard, two loads from 12.5 tons wheels act on each side of the road.

III. Determination of the stability of dam slopes

The stability coefficients of the Ks dam slopes were calculated using mathematical modeling of the stress-strain state of the soil massif by the finite element method using the PLAXIS 2D computer program in a two-dimensional formulation of the problem. The seismic impact was modeled in a quasi-static formulation. The seismic force Q_s was determined as a fraction of the weight of the soil mass P:

$$Q_s = \mu P \tag{1}$$

where μ is the coefficient of dynamic seismicity (for seismicity 8 points μ = 0.05.

According to the building codes, the following limiting coefficients of stability of the dam slopes were selected: for a normal combination of loads – 1.3; for a special combination of loads (taking into account seismics) – 1.1. The calculation results showed the following. According to the calculated cross section 1-1: with a normal combination of loads K_s = 2.05; with a special combination of loads K_s = 1.616. According to the calculated cross section 2-2: with a normal combination of loads K_s = 2.085; with a special combination of loads K_s = 1.74.

Stability coefficients were calculated for the right slope of the dam. Stability calculations were not carried out for the left slope, since the problem is axisymmetric and the calculation results coincide with the results of calculations of the stability of the right slope.

The least stability of the dam slopes is observed with a special combination of loads. Figures 3 and 4 show the results of calculations of the stability of the right slopes. As can be seen in both calculated sections, the sliding lines pass from the place of application of the transport load, enters and crosses the upper layers of the soil base and comes to the surface at the very bottom of the slope. The stability of the dam slopes in all cases is provided with a margin.

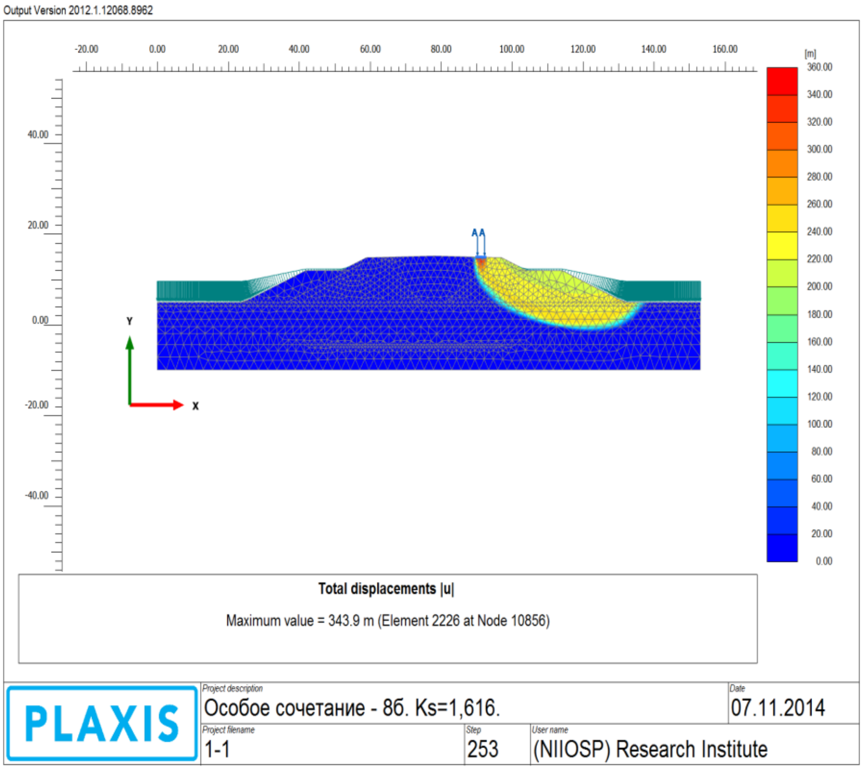

Figure 3: *The result of calculating the stability of the dam slope (section 1-1) under seismicity conditions*

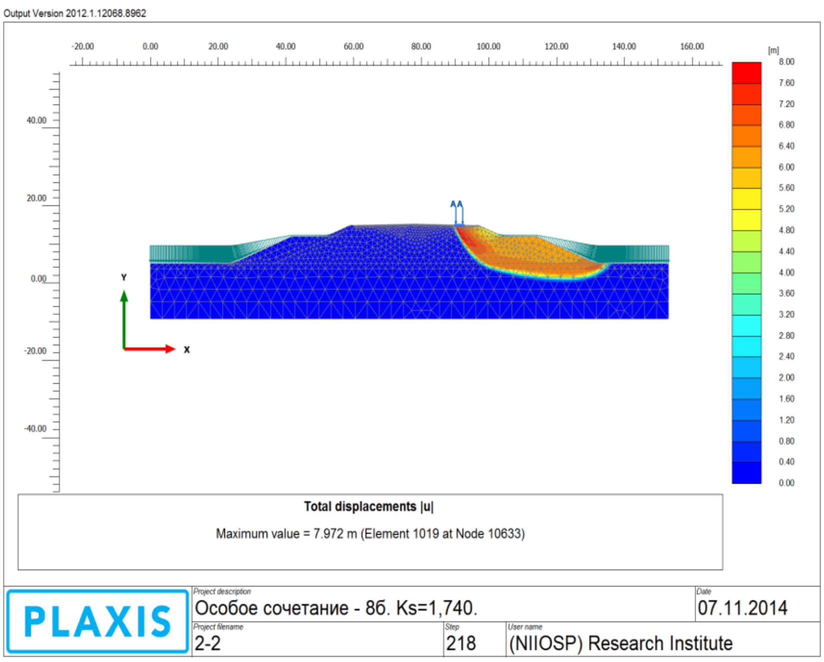

Figure 4: *The result of calculating the stability of the dam slope (section 2-2) under seismicity conditions*

IV. Determination of dam sediment

The calculation of the sediment of the dam itself and its soil base was carried out using the computer geotechnical program PLAXIS 2D. Two types of calculations were performed: determination of the sediment of the body of the dam; determination of the sediment of the soil base of the dam. To be able to perform calculations and assign the height of the calculated area, the compressible thickness H was determined. The compressible thickness of the soil base was determined according to the requirements of building codes by the formula:

$$\sigma_{zp} = 0.5\ \sigma_{zq} \tag{2}$$

where σ_{zp} are vertical stresses in the soil from an external load; σ_{zq} are vertical stresses from the soil's own weight, taking into account the weighing action of water.

Compressible thickness of the soil base is determined for a dam with a width of B = 107 m with a load on the soil $\sigma_{zp,0}$ = 17.2 t/m².Compressible thickness H = 32.1 m. Further, the resulting compressible thickness (calculated area) was set in the program, according to the calculation results of which the sediment of the dam was obtained. Figure 5 shows the isolines of vertical displacements in the array at the level of the dam crest along the 1-1 section (U_y = 25.5 cm). The movement of the soil base at the level of the bottom of the dam is 23.2 cm. Thus, the sediment of the dam body is ΔU_y = 2.3 cm. Figure 6 shows the isolines of vertical displacements in the massif at the level of the dam crest along the section 2-2 (U_y = 22.5 cm). The movement of the soil base at the level of the bottom of the dam is 20.3 cm. Thus, the sediment of the dam body is ΔU_y = 2.2 cm.

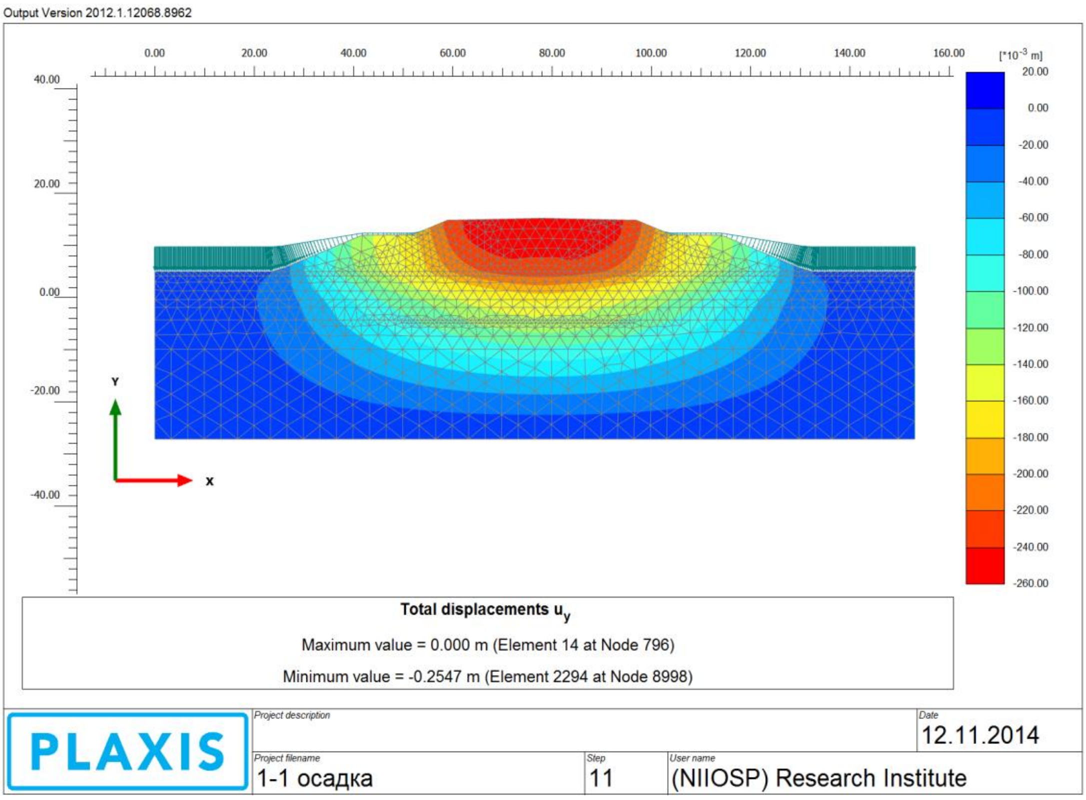

Figure 5: *Isolines of vertical movements during landing in the dam array and its base (section 1-1)*

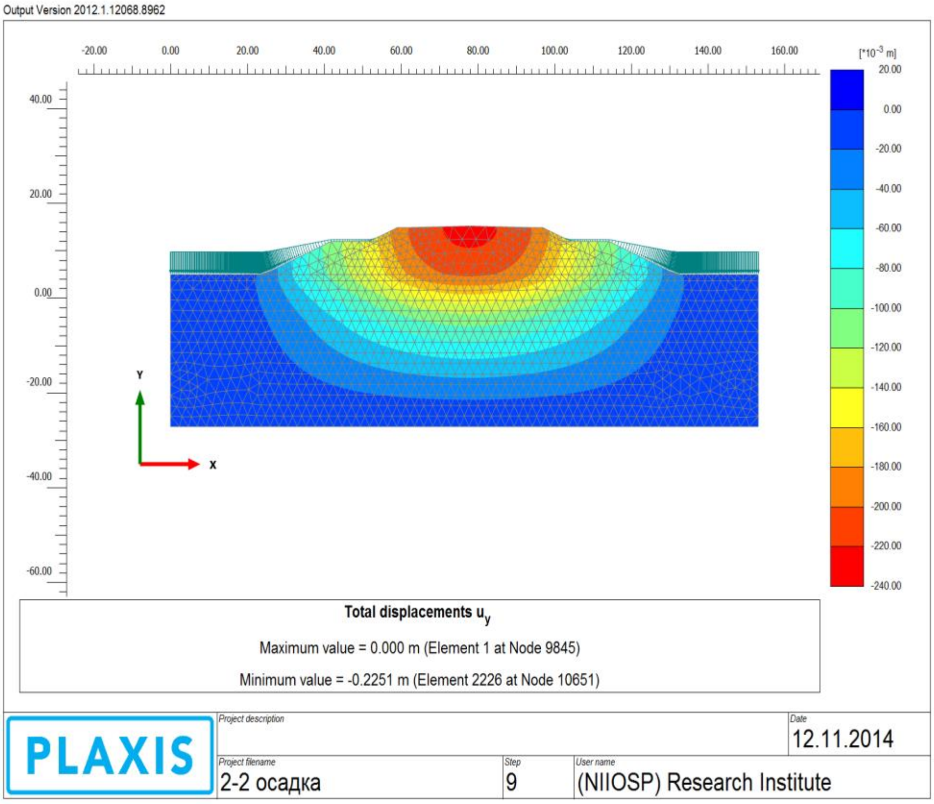

Figure 6: *Isolines of vertical movements during landing in the dam array and its base (section 2-2)*

V. Conclusions

1. The bulk dam on Lake Boyuk-Shor is designed to solve engineering, environmental and transport problems;
2. The dam is located in difficult engineering-geological and seismic conditions;
3. Studies have shown that the stability of the dam slopes is provided in any conditions with a margin;
4. The sedimentation of the dam and its soil base is permissible for this class of structures.

References

[1] Aliyev, G.A. (editor). Natural conditions and resources of Apsheron. Baku: ELM, 1979, 180 p.

[2] Terzaghi, K., Peck, R.B., Messi, G. Soil Mechanics and Engineering. John Wiley & Sons, Inc., 549 p.

[3] Shepard, J.L., Woodward, R.J., Gizienski, S.F., Clevenger, W.A. Earth and Earth-rock Dams. New York, 1967, 725 p.

[4] Zheleznyakov, G.V., Ibad-zade, Y.A., Ivanov, P.L. et al. Hydraulic structures. Designer's Handbook. Moscow: Stroyizdat, 1983, 543 p.

[5] Goldin, A.L., Rasskazov, L.N. Design of ground dams. Moscow: Energoatomizdat, 1987, 304 p.

[6] Van Impe, W.F., Verastegui Flores, R.D. On the Design, Construction and Monitoring of Embankments on Soft Soil in Underwater Conditions. Sankt-Peterburg: NPO “Georekonstruksiya-Fundamentproyekt”, 2007, 168 p.

RISK MANAGEMENT IN THE DEVELOPMENT OF UNDERGROUND SPACE IN RUSSIAN CITIES

Lebedev Mikhail, Romanevich Kirill

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OJSC Scientific research, design and survey institute "Lenmetrogiprotrans",
Saint-Petersburg, Russia
mail@lmgt.ru
romanevichkirill@gmail.com

Abstract

The article briefly discusses the experience of large cities in the integrated development of underground space together with ground construction. This document lists the major cities of Russia in which underground systems operate or are being designed. Based on the existing classification of geological and construction risks of megacities – Moscow and St. Petersburg, the necessity of continuous monitoring and risk management in the development of underground space is shown. The existing latest methodological documents are considered, on the basis of which, construction risks are managed, as well as geotechnical monitoring during the construction and operation of underground structures. Promising directions in developing means and methods of scientific and technical support of underground construction are shown.

Keywords: risk management, geotechnical monitoring, underground structures, geological hazards, underground space, construction and operation

I. Introduction

The experience of large cities around the world indicates the need for integrated development of underground space together with ground construction. The ever-increasing population concentration in megacities and the continuous growth of the car fleets give rise to territorial, transport, environmental and energy problems that hinder the sustainable development of modern Russian cities [1].

Progressive countries of the East and West have long been turning to underground space as a tool for creating a comfortable, environmentally friendly and safe space. Taking into account the experience of developed countries, we can say that the best option for the harmonious development of transport infrastructure is the development of an integrated ground-underground transport system.

One of the key components necessary for the integrated development of the transport infrastructure of cities is a developed underground network. The underground is the basis around which and together with which the intensive development of urban areas and all the processes taking place in them is carried out. The world practice of underground development shows the tendency to create underground complexes combining an underground station, transfer stations for various types of transport and business, cultural, historical and shopping centers, in order to unload the daytime surface of cities and ensure the comfort of moving city residents between them.

There are currently eight active underground networks in Russia in cities with a population of more than 1 million people: Samara, Yekaterinburg, Novosibirsk, Kazan, Volgograd (a high-speed tram with underground elements), Nizhny Novgorod, St. Petersburg and Moscow. In addition, the list of planned underground systems includes Chelyabinsk, Krasnoyarsk, Omsk, Perm, Rostov and Ufa.

The undisputed leaders in construction in Russia are St. Petersburg and Moscow, therefore, for these megacities, the territory according to geological and construction risk has been zoned in sufficient detail. At the same time, during the construction of underground structures, specific risks of underground space arise with a special character of natural and man-made factors caused by the interaction of elements of the natural and technical geosystem "rock mass – construction technology – underground structure – environment" [2,3]. In this regard, continuous refinement and risk management in the development of underground space is an extremely urgent task.

II. Geological and construction risks in Moscow

Moscow differs from other regions of the country in unprecedented large-scale construction and operation of underground transport and utility facilities.

Construction is carried out at various depths by almost all modern methods. If necessary, special methods are used to stabilize and strengthen the soils of strengthening structures (freezing, water reduction).

At the same time, in practice, it is often necessary to solve issues related to the elimination of abnormal, and in some cases, emergency situations in the form of excessive, up to destruction, deformations of facilities on the surface and underground, flooding and collapse of workings, provoking landslides, fire, etc. Damage can be tens of times higher than the funds "saved" in case of refusal to implement the necessary protective measures.

The risks of abnormal situations during underground construction in Moscow are caused, first of all, by specifically very complex engineering, geological, hydro-geological and urban planning conditions of the facilities location, which include such as:

- presence of a powerful layer of man-made soils, karst soils, high activity of groundwater and water-logging of underground construction sites, etc.;
- significant man-made loads on the engineering and geological environment of the city, which, provoking negative fast-flowing geological processes, worsen the conditions of the construction and operation of underground facilities;
- presence of dense urban development and the need to work on underground construction in cramped conditions, where many other facilities fall into the zone of influence, in addition to those under construction.

These conditions have been supplemented in the last decade by the risks associated with the actual scale of underground development in the Russian capital and the involvement of a large number of non-core specialists and organisations.

The listed risk factors and the possibility of their action in an unfavorable combination determine the need for their identification and accounting during the entire life cycle of an underground structure (during design, construction and operation). This is designed to optimize the choice of the facility location (tunnel route) and the appropriate protective measures, the cost of which largely depends on the degree of geological hazard for various conditions of the workings location conditions.

Fig. 1 shows a map of Moscow territory zoning by geological risk [4].

In the modern practice of construction and operation of critical underground facilities in the city of Moscow, many tasks of prevention of emergency situations, and in case of their manifestation – elimination of consequences, are solved by the organization of scientific and technical support at all life cycle stages of the structure. At the same time, the main importance is attached to solving geotechnical issues, for example, such as assessing the possible negative impact of new construction on the natural and urban environment, changing the conditions of static operation of structures under construction over time, determining the category of geotechnical complexity of construction.

For this purpose, a complex of additional surveys, calculations using modern geotechnical software and computing complexes such as PLAXIS, Z_Soil, MIDAS, etc., the stress-strain state of the system "soil body-structure" is monitored. Based on the results of these operations, adjustments are made to design and process solutions and to methods to ensure the operational reliability of facilities under construction and operating. However, the effectiveness of taking into account the features of a particular geotechnical situation for risk mitigation is still largely determined by the qualifications and experience of organizations that design, build or operate the facility. The regulatory and methodological framework available concerning this issue, including the Guidelines of the International Tunnel Association [5], is mainly general in nature.

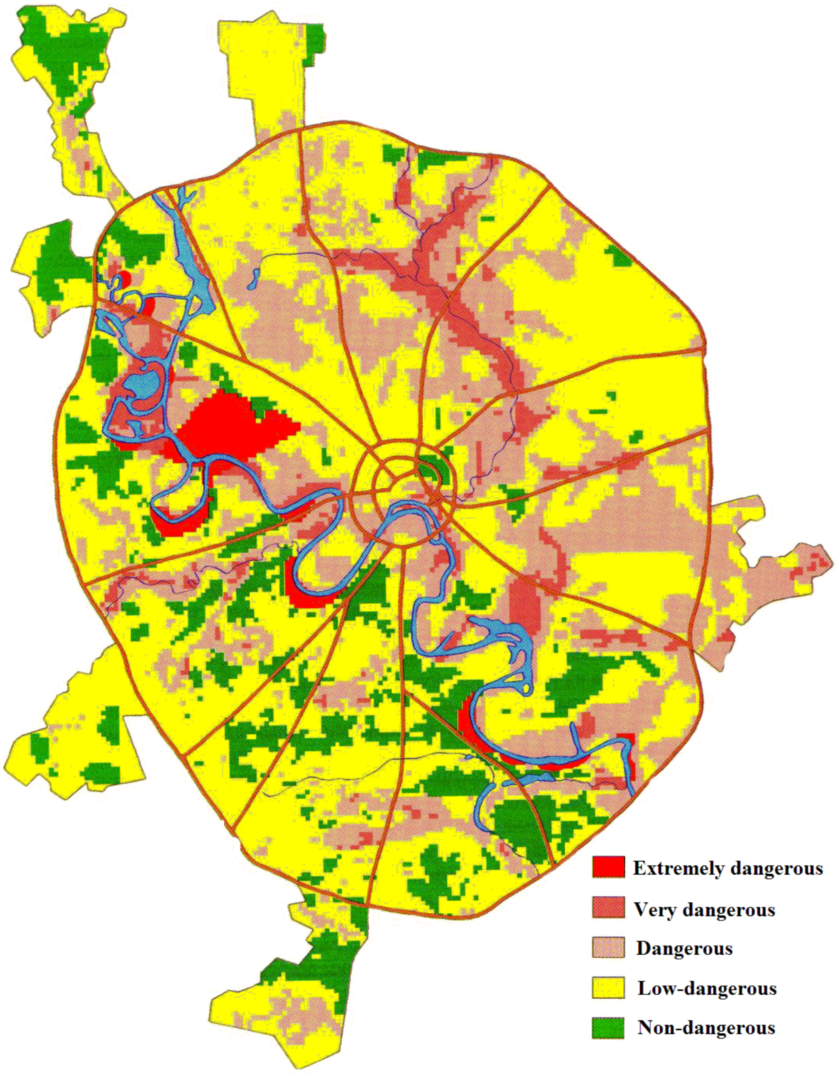

Figure 1: *Map of Moscow territory zoning by geological risk [4]. Extremely dangerous areas for geological risk (2% of the territory), very dangerous (2% of the territory) and dangerous (26% of the territory) are highlighted in red gradations, low-risk areas for geological risk (54% of the territory) are highlighted in yellow and non-hazardous areas for geological risk (12% of the territory) are highlighted in green*

The Reference manual for assessing and accounting for risks in the development of underground space in the city of Moscow [6] was developed in addition and in order to specify certain provisions of regulatory documents on ensuring the structures reliability and risk management in relation to underground facilities under construction and operated in engineering-geological and urban conditions of the city of Moscow. At the same time, the underground facility and the inclosing soil body are considered as a multi-factorial natural and technical geosystem, and an emergency situation in this system is considered as a probabilistic event, an adequate assessment of which will optimize protective measures.

Using the Reference manual for assessing and accounting for risks in the development of underground space in the city of Moscow [6], it is possible to adequately assess the possible risks of a natural and process nature at the stages of the life cycle of an underground structure and propose the most effective strategy for managing them to prevent emergency situations or to minimize damage in the event of their manifestation, for example, through appropriate protective measures. Based on the experience of eliminating the consequences of accidents at such facilities as the underground, we can talk about hundreds of millions of rubles and more than six months of downtime.

The document [6] includes, based on the data analysis on the state of the regulatory and methodological framework in force in Russia and abroad and practical experience in risk management in construction, adapted to the engineering-geological and urban planning conditions of the city of Moscow, "Methodology for assessing and managing risks of the impact of hazardous geotechnical processes and negative structural and process factors on the reliability of and operated underground structures".

The document [6] also contains a list and characteristics of special protective measures recommended for use to ensure the safety of underground structures under construction and operated in areas of potential danger. Using examples from domestic and foreign practice, it is indicated in which situations, i.e. from which dangers (risks) and with what effect an event can be implemented.

The determination of the probability of various risk realization during the construction and operation of underground structures is illustrated by examples of calculations performed both without taking into account possible protective measures and for cases of their application. To assess the effectiveness of the proposed engineering solutions to eliminate the event cause or to reduce possible damage, an appropriate methodology is proposed. Guided by the provisions of this Methodology, it is possible to optimize the choice of protective measures on linear and spatial construction facilities with open and closed methods of work.

Reference manual for assessing and accounting for risks in the development of underground space in the city of Moscow [6] includes:

- requirements for the initial information for assessing the level of danger of the development of negative manifestations and processes at underground urban infrastructure facilities;

- a methodology for quantifying the risks of the development of hazardous geological processes and their impact on the safety of underground structures under construction and in operation;

- criteria for assessing the reliability of structures and the effectiveness of measures to ensure the safety of underground structures under construction and in operation;

- characteristics of systems of constructive, process, organizational and technical measures to prevent abnormal, including emergency situations and methods for assessing their socio-economic efficiency;

- examples indicating proven in practice possible ways of implementing the proposed technical solutions in the development of projects and construction of underground facilities in the city of Moscow.

The design provisions, requirements for materials, equipment, algorithm of actions and control during the production of works contained in the Reference manual for assessing and accounting for risks in the development of underground space in the city of Moscow [6] have been tested during the construction and operation of the underground, transport and utility tunnels in Moscow and a number of other regions.

III. Geological and construction risks of St. Petersburg

The main negative natural features of the territory of the city of St. Petersburg are:

- powerful, sometimes up to 30 m, heterogeneous thickness of weak, slowly compacting, including thixotropic soils, in most areas of the city;
- high groundwater level;
- presence of blocked soils and buried peat layers. The layers of lake-sea sediments contain lenses and interlayers of peat and frozen soils of different composition. These soils have a relatively high and irregular compressibility. The presence of buried bogs and peated soils, which, even with low power, have a negative impact on the underlying clay soils. Under buried bogs, sands are usually enriched with organic compounds of biotic and abiotic nature and have all the signs of quicksand, while the clay ones are characterized as weak thixotropic differences. The presence of bogs presupposes the existence of a sharply reducing environment in the underground space and its pronounced corrosive properties. Stagnant hydrodynamic regime of groundwater due to the presence of impermeable sheet pile fences and embankments, which leads to the accumulation of pollutants, activation of microbiological activity and biochemical gas formation [7];
- hydrodynamic processes associated with the impact of surface and groundwater causing water-logging, mechanical and chemical suffusion of soil, quicksand phenomena;
- processes associated with freezing-thawing of soils (frost heaving, subsidence during thawing);

Additionally, natural risks for artificial underground structures during their construction and operation in St. Petersburg are:

- aquifers in the context of the underground space of St. Petersburg;
- underground watercourses and aggressiveness of underground waters;
- possible breakthroughs of water and quicksand soils from "pockets" in glacial moraine deposits;
- removal of soil due to tunnel lining;
- capacity of the residual whole of clays between the bottom of the workings and the roof of a high-pressure aquifer (the pressure value can currently exceed 100 m);
- presence of paleodolines (buried paleodolines are laid along tectonic faults and determine the underground relief of bedrock – in the structure of buried valleys, slope areas, terraces and thalweg zones are distinguished. Thalweg is the deepest part of the buried valley, which is the bed of an ancient river filled with quaternary sediments);
- degree of fracturing of the sedimentary cover bedrock;
- aggressive biochemical processes;
- geological hazards in the coastal zone of St. Petersburg water bodies;
- manifestations of karst formation processes in the southern part of the city;
- seismic risk on the territory of St. Petersburg and the Leningrad Region;
- processes of natural gas formation (biogas) in the soils of St. Petersburg;
- gas dynamic processes in the underground space of the city;

- radon hazard and deep radon emanations;
- rheological properties of rocks (heaving, creep);
- ice formation on the structures of artificial structures of the underground;
- especially dangerous weather phenomena;
- floods in St. Petersburg;
- negative transformation of sand-clay rocks of both quaternary and pre-quaternary age with changes in physico-chemical and biochemical conditions.

Fig. 2 shows a map of the zoning of the territory of Moscow for integrated construction risk [8]:

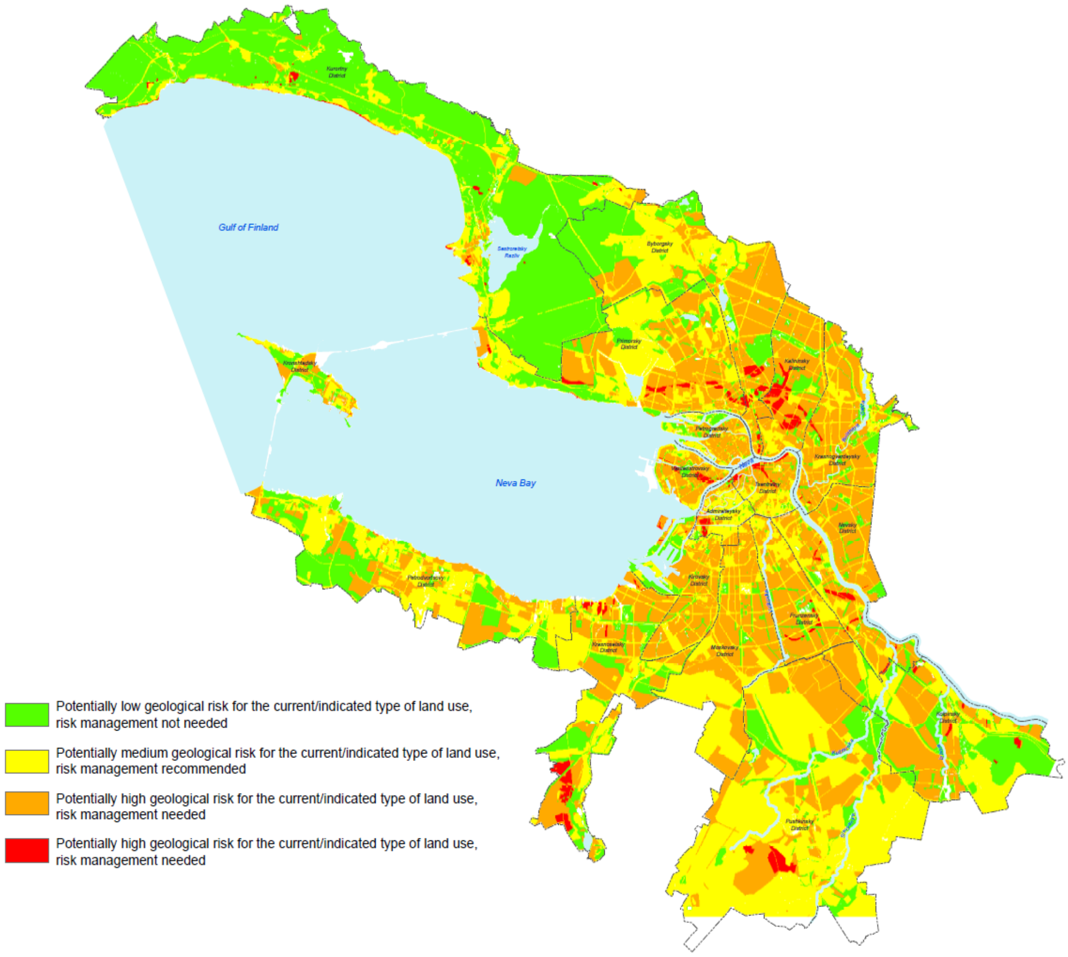

Figure 2: *Map of St. Petersburg zoning by geological risk [8]. Low geological risk zones are shown in green, medium geological risk zones — in yellow, high geological risk zones — in orange, and extremely high geological risk zones — in red*

In addition, negative man-made features of the territory of the city of St. Petersburg can be additionally highlighted:

- presence of alluvial, bulk territories along the banks of rivers and the bay;
- high level of underground waters of man-made origin;
- presence of existing buildings with defects caused by uneven precipitation, including due to lowering of the groundwater level (temporary or permanent);
- utility accidents;
- construction and other types of work (major repairs, reconstruction, dismantling, etc.) near artificial underground structures;

- man-made hydrodynamics;
- landfills and burials of various kinds, etc.
- accumulated powerful layer of various man-made formations in the urban coastal zone;
- disjunctive tectonics on the territory of St. Petersburg in the aggregate of man-made impact;
- poor quality construction and repair work of structures;
- uneven thawing of the rock mass after the commissioning of artificial underground structures built with the use of pre-freezing of soils;
- electrocorrosion;
- heat-generating effects.

All the listed risk elements for underground structures in the city of St. Petersburg should be considered in the complex of natural and man-made causes of potential accidents and emergency situations.

IV. Risk level control by means of geotechnical monitoring at various stages of the existence of underground structures

The risk level is not a constant value, but a variable, so it is not enough to simply state the presence of potentially dangerous sites and processes and assess the risk. It is necessary to constantly monitor the risk level that may change during the construction/existence of an underground structure.

The creation and use of automated geotechnical monitoring systems is one of the most important aspects of risk assessment and management in the development of underground space. When conducting geotechnical monitoring, a dynamic (iterative) and risk-oriented approach is implemented (when the main control efforts are directed to the most dangerous (suspicious) processes detected during geotechnical monitoring, and the remaining processes and intervals are observed in the background).

Geotechnical monitoring is carried out, among other things, to update forecasts and estimates made at previous stages of observations. The model (or risk map) for a particular underground structure should not be a static image (frame), but rather a set of such images that change over time – animation frames.

To date, the most comprehensive methodological guide for integrated geotechnical (mining and environmental) monitoring during the construction and operation of underground structures (transport tunnels) is the "Methodological guide for integrated mining and environmental monitoring during the construction and operation of transport tunnels" [9]. It sets out the main provisions applied in the design, construction, commissioning, operation, reconstruction, restoration, conservation and liquidation of transport tunnels as part of measures to ensure their safety. The system of geotechnical monitoring for the control of dangerous geodynamic processes and phenomena of a natural and man-made nature is presented, which provides for the development of scenarios for the development of a possible accident when each of the criteria indicators dangerous for an underground structure is manifested.

For example, for the purposes of mapping geological risk, various methods of engineering geophysics in the areal version are often used (magnetic exploration, electrical profiling, microseism registration, etc.). The survey is carried out over a network of profiles with a uniform measurement step. During processing, a matrix is formed from all the obtained measurement points, according to which the isolines of the recorded parameter or its derivatives are built.

One of the methods of operational control of the modern geotechnical situation at large-area facilities is the EMR registration method, used both at the survey stage and in monitoring mode [10].

The method is based on the registration of abnormal electromagnetic radiation of rocks during their deformation, for example, during precipitation of the Earth's surface or during landslide processes. The obtained absolute EMR values during processing are normalized to the average value over the entire observation area to obtain the normalized Anorm parameter. An increase of this parameter by 4-6 relative units indicates geodynamic activity associated with intensive deformation of existing inhomogeneities in the studied rock mass. At Anorm > 6, accelerated development of microdefects in the rock mass is recorded [11].

Fig. 3 shows the result of constructing a distribution map of the Anorm parameter when registering EMR in the territory affected by landslide processes. The shoreline is shown at the bottom of the figure, with dark outlines above showing landslide bodies identified during the geological survey and drilling. It can be seen that the increased values of the EMR level correspond to the spatial position of the landslide bodies, and the maximum values of the Apogm parameter fix the places of the landslide process activation.

EMR registration in this area was carried out by us during the updating of engineering and geological surveys during the railway tunnel design. The data shown as part of a complex of engineering and geophysical methods are valuable information when choosing the location of the tunnel portal and construction site. Similar work is being carried out by us to assess the geodynamic activity of rock bodies and to map tectonic disturbances.

The disadvantage of the EMR registration method is the strong dependence of the EMR level on the number of sources of industrial interference, therefore, application in the city is extremely difficult.

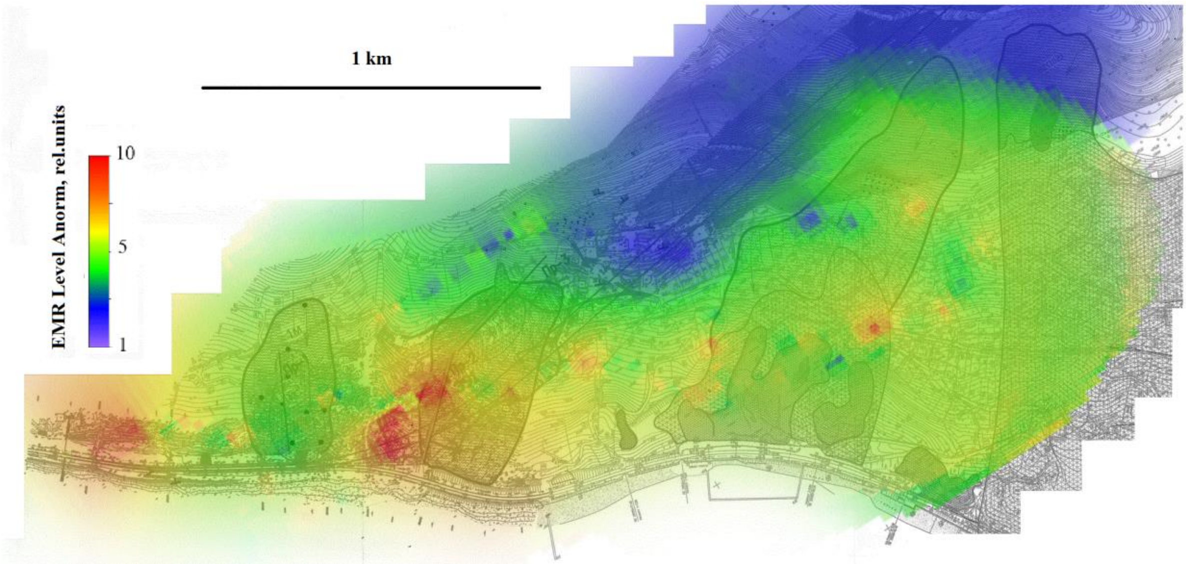

Figure 3: *Map of the EMR level in the coastal area affected by landslide processes. The shoreline is shown at the bottom of the figure, with dark outlines above showing landslide bodies identified during the geological survey and drilling*

V. Geotechnical monitoring system for the development of underground space

The theory and practice of underground construction emphasizes the importance of regular supervision of the technical condition of tunnel structures and facilities, as well as special surveys of tunnel structures, professional analysis of the survey results and adequate measures to prevent emergencies. The level of safety of underground structures should be increased within the framework of a preventive safety strategy. Currently, the most advanced means is geotechnical monitoring.

The basic purpose of geotechnical monitoring is to study in full-scale conditions of the static operation of temporary support and permanent lining of underground structures with the determination of deformations, stresses, temperatures, geodynamic parameters in the lining and the inclosing rock body, as well as with the prediction of loads from mountain pressure and other environmental influences. As a result, scientific information necessary for the development of proposals and recommendations for improving tunnel structures and construction technologies in reducing labor and material intensity, cost, and improving the quality of structures should be obtained. Such information should be used as a basis for clarifying the existing regulatory documents on the construction (reconstruction and operation) of underground structures. Research should be carried out both during construction and subsequent operation. Therefore, information and measurement systems created at underground facilities should be remote and designed for a long service life.

VI. Geotechnical monitoring at the stage of construction of underground structures

Geotechnical monitoring during the construction of underground structures solves geotechnical and geoecological tasks, the main purpose of which is the integrated safety of mining operations and reducing the negative impact on the environment, both during construction and operation.

The main methods of observations using the geotechnical monitoring system during the construction of underground structures:

- geodetic and surveying observations, including using satellite imagery;
- seismological observations;
- geophysical observations;
- geomechanical observations;
- hydrogeological observations;
- environmental monitoring system (including control of aggressive chemical and biological environmental influences).

Direct and indirect methods for determining controlled parameters allow to:

- predict engineering and geological conditions ahead of tunnel faces with sufficient accuracy;
- determine qualitative and quantitative indicators of the stress-strain state of the "lining - body" system;
- determine the actual deformation and strength properties of the inclosing body;
- determine the deformations of the inclosing body from the contour of the tunnel to the day surface;
- determine the maximum permissible concentrations of pollutants in the air, water and dumps.

The results obtained in the course of conducting geotechnical monitoring make it possible, during the construction, to determine the impact of work on the activation of hazardous processes and adjust the process parameters of mining operations, and develop recommendations to reduce the negative impact on the environment.

Work on the Geotechnical Monitoring Project is carried out during the construction of the underground structure until the facility commissioning. With their help, the parameters of the applied support structures and linings, as well as the technology of their construction, are adjusted.

Relatively young in world practice, and at the same time effective both in the construction and operation of underground structures, are the methods of XRS interferometry (XRS radar with synthesized aperture – InSAR abbreviation used in the international literature) are widely used in solving various problems related to surface displacements: in the study of displacements at landslide slopes, soil subsidence over underground structures, including in conditions of dense urban development, when monitoring deformations of pipelines and overpasses, displacements of the earth's surface as a result of earthquakes, volcanic and other natural processes [12-14].

XRS interferometry methods make it possible to identify areas of active deformations of the Earth's surface and infrastructure facilities associated with many natural and man-made processes with a high degree of detail.

Short-wave images of Terra-SAR and COSMO-SkyMed satellites are particularly effective for monitoring urban areas. The images of these satellites (Fig. 4) have a small resolution element, but are more sensitive to atmospheric interference.

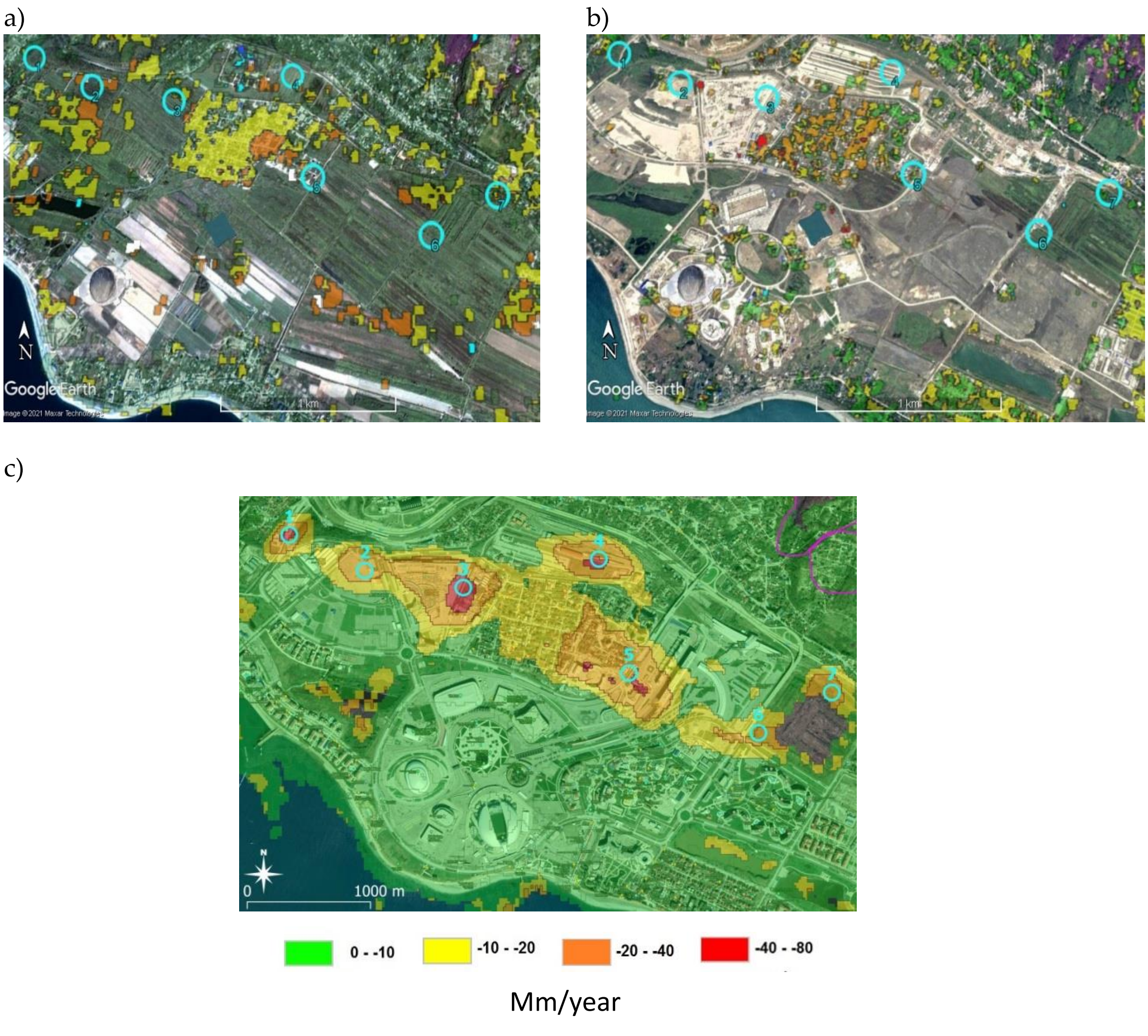

Figure 4: *Maps of average vertical displacement velocities on the territory of St. Petersburg based on satellite images: a) ALOS 2007-2010 track 588A; b) Envisat 2010-2012 track 35D; c) S-1A 2015-2020 track 43A in Google Earth images for 2007 (a), 2010 (b) and Google Maps for 2020 (c)*

The satellite XRS interferometry method do not require large financial costs, and the results can be interpreted together with ground geodesy data, as well as with field geological research materials, which makes it possible to significantly increase the efficiency of existing monitoring systems.

The latter is especially important when developing underground space on the territory of large cities in order to preserve historically significant buildings and structures.

VII. Geotechnical monitoring at the operation stage of underground structures

In accordance with the requirements of the Federal Laws of Russia, the safety of structures during operation shall be ensured by maintaining the established parameters at the required level.

Supervision of operated underground structures, as a system of inspections, surveys and observations, has historically been the main organizational event carried out during the maintenance of underground system and other underground structures. The concept of "supervision" includes a system of visual and instrumental observations, periodic and special surveys aimed at early detection of defects, primarily of basic structures and arrangements, and analysis of the causes of these defects.

With obvious disadvantages of visual inspection of the inner surface of the lining of underground structures to assess their technical condition, there is an alternative method: use of control and measuring equipment placed in the lining during construction as part of geotechnical monitoring.

The lining and lining equipment shall be fitted in accordance with the geotechnical monitoring project included in the project documentation.

The geotechnical monitoring system informs about changes and predicts changes in the stress-strain state of structures. The results of field studies play an important role in the selection of methods for calculating supports and linings.

For the safe operation of underground structures and the forecast of the state of the "lining - inclosing body" system, it is advisable to create an analytical center for processing and analyzing the database of geotechnical monitoring performed on operated underground structures in order to improve and optimize methodological and technical means.

Different modes of operation of underground structures can also negatively affect the activation of hazardous processes and phenomena in high-risk areas. Uncontrolled development of geotechnical processes in such zones is potentially dangerous for traffic and, accordingly, people. Therefore, the list of works to ensure the operation of functional tunnel systems must necessarily include a complex of geotechnical monitoring to control the level of geotechnical risks as part of an automated process control system (automated process control system).

To measure the thermodynamic parameters of the air environment (temperature, relative humidity and air velocity) and the surface temperature of the concrete lining, as well as static pressure, it is preferable to use autonomous sensors with the possibility of accumulating the measured information for a given period of time. Information from these sensors can be read by connecting them to secondary storage systems after a specified measurement period has elapsed.

The geotechnical monitoring system at all stages of the existence of an underground structure seems to be an absolutely necessary element of accident prevention, prediction of the technical condition of structures and safe operation.

Risk level control with the help of a well-established geotechnical monitoring system allows you to plan in advance measures to restore and eliminate the consequences of accidents at any stage of the existence of an underground structure.

The geotechnical monitoring system is a source of new geotechnical information about the work of linings and bodies. The obtained results of geotechnical monitoring make it possible to determine the impact of work on the activation of hazardous processes during construction and adjust the process parameters of mining operations, develop recommendations to reduce the negative impact on the environment. With the help of data from the geotechnical monitoring system, the parameters of the applied support structures and linings, as well as the technology of their construction, are adjusted.

During the operation of an underground structure, the automated GEM system in online mode provides operational services with information necessary and sufficient to determine the impact of the operating mode and climatic anomalies on the activation of dangerous geodynamic processes in order to select the safest process operating modes, assign visual and instrumental surveys, as well as strengthening measures.

During the inspections of monitoring systems in controlled facilities, a search is carried out for new risk factors that, with appropriate justification, can be included in the control scheme by the geotechnical monitoring system.

A large volume of geotechnical data obtained from geotechnical monitoring systems can later be used in the development of unified approaches to monitoring and forecasting the level of risk using digital geomechanics tools, mathematical modeling of natural and man-made processes, deep learning techniques based on neural networks. Automated geotechnical monitoring systems can be included in algorithms for assessing the technical condition of underground structures using BIM technology. In any case, the initial information here is full-scale studies of the stress-strain state of structures and inclosing bodies as part of the integrated geotechnical monitoring system, which is a physical tool for assessing, controlling and predicting the level of geotechnical risks in the most potentially dangerous intervals of the structure.

Geotechnical monitoring systems during the construction and operation of underground structures can be upgraded with new technical means of control, which are currently being developed and implemented both in Russia and abroad for the purposes of safe integrated development of underground space [15].

As an example, the following promising areas of developing means and methods of scientific and technical support of underground construction can be given:

- spatial geometric parameters of the supports and linings of railway tunnels during construction and operation are measured using laser scanning according to the specified regulations. This makes it possible to compare actual three-dimensional models of structures and sections of exposed inclosing soil bodies. The data obtained at different time periods of observations allow us to determine the displacement of unmarked points of temporary support, as well as changes in the shape of the tunnel walls and arch. Due to the high scanning density, this method makes it possible to remotely detect relatively small areas of changes in the body structure and the support state;
- Comprehensive integrated solutions that allow you to manage various modules, such as access control and tracking operators, communication in the tunnel, closed-circuit video surveillance systems, environmental sensing and emergency management and alarms. The solution is based on the identification and control of the presence of personnel, as well as the detection and storage of the number and location of operators in real time. Maximum automation is achieved for more efficient and timely management of emergency and evacuation processes;
- High-speed video recording and image recognition technologies that make it possible to warn about a collapse 0.1 seconds after detecting the movements of falling objects;
- Determination of displacements of the Earth's surface by radar satellite interferometry;
- Technologies based on augmented reality and virtual reality, etc.

VIII. Conclusion

The integrated development of the underground space of large megacities puts forward a number of requirements that shall be taken into account when planning, designing and building, since underground structures under construction and operated are high-risk zones and in the event of an accident, pose a serious danger to people in them. The purpose of risk management in the construction and operation of underground structures in megacities is to ensure the successful functioning of urban systems in the conditions of risk and uncertainty. To do this, it is necessary first of all to understand the dangers that the underground space puts forward, classify these dangers and control them in the most effective ways.

Conducting geotechnical monitoring during the construction and operation of underground structures is an absolutely necessary type of work. For this purpose, on the basis of international documents, special methods and reference manuals are being developed in Russia to assess and account for risks in the development of the underground space of megacities. As a result of applying these techniques in the practice of underground construction, they should be tested and validated, after which the most effective of them, of course, should be included in the guiding regulatory and technical documents.

References

[1] Alpatov S.N. (2018). The concept of underground space development to improve the quality of the urban environment. *URL: undergroundexpert.info/issledovaniya-itehnologii/nauchnye-stati/razvitiye-podzemnogo-prostranstva-gorodov*. (In Russian).

[2] Kulikova E. Yu. and Balovtsev S. V. (2020). Risk control system for the construction of urban underground structures IOP Conference Series: Materials Science and Engineering, Volume 962, International Conference on Construction, Architecture and Technosphere Safety (ICCATS 2020) 6-12 September 2020, Sochi, Russia.

[3] Kulikova E. Yu. (2019). Risk Assessment of Dangerous Natural Processes and Phenomena in Mining Operations Springer Proceedings in Earth and Environmental Sciences book series (SPEES) (Springer, Cham), p. 21–33.

[4] Osipov V.I., Medvedev O.P. (1997). Moscow: Geology and the City – Moscow. Publisher: Moscow textbooks and cartolithography, 1997. – 400 p. (In Russian).

[5] Eskesen S.D., Tengborg P., Kampmann J., Veicherts T.H. (2004). Guidelines for Tunnelling Risk Management. 2004. International Tunnel Association Working Group No. 2 // Tunnelling and Underground Space Technology. – Vol. 19, No. 3. 2004. – Pp. 217-237. – URL: https://doi.org/10.1016/j.tust.2004.01.001.

[6] Reference manual for assessing and accounting for risks in the development of underground space in the city of Moscow / Government of Moscow. Complex of urban planning policy and construction of the city of Moscow. Publisher: Infra-Engineering, 2021. – 260 p. (In Russian).

[7] Dashko, R.E., Alekseev, I.V. (2019). Main features of engineering-geological and geotechnical research of microbiota influence on hard rocks in the urban underground space. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 2019, 19(1.2), pp. 369–376.

[8] Project Climate Proof Living Environment (CliPLivE), 2012. *http://cliplive.infoeco.ru.*

[9] Methodological guide for integrated mining and environmental monitoring during the construction and operation of transport tunnels. – Moscow.: Publisher: URAN IP-KON, 2009. – 75 p. (In Russian).

[10] Romanevich, K.V., Lebedev, M.O., Andrianov, S.V., Mulev, S.N. (2022). Integrated Interpretation of the Results of Long-Term Geotechnical Monitoring in Underground Tunnels Using the Electromagnetic Radiation Method. Foundations 2022, 2, 561–580.

https://doi.org/10.3390/ foundations2030038.

[11] Romanevich, K.V. (2015). Development of Criteria and Method for Identifying Geodynamic Processes by Electromagnetic Radiation Near Shallow Mines. Ph.D. Thesis. Institute of Comprehensive Exploitation of Mineral Resources, Russian Academy of Sciences, Moscow, Russia, 2015; 156p. (In Russian).

[12] Mikhailov V. O., Kiseleva E. A., Smol'yaninova E. I., Dmitriev P. N., Golubev V. I., Isaev Yu. S., Dorokhin K. A., Timoshkina E. P. and Khairetdinov S. A. (2014). Some Problems of Landslide Monitoring Using Satellite Radar Imagery with Different Wavelengths: Case Study of Two Landslides in the Region of Greater Sochi. Published in Fizika Zemli, 2014, No. 4, pp. 120–130. (In Russian).

[13] Berardino P., Fornaro G., Lanari R., Sansosti E. (2002). A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms // IEEE Transactions on geoscience and remote sensing. 2002. V.40. N11. P.2375-2383.

[14] Carlà T., Intrieri E., Raspini F., Bardi F., Farina P., Ferretti A., Colombo D., Novali F., Casagli N. (2019). Perspectives on the prediction of catastrophic slope failures from satellite InSAR // Scientific Reports. 2019. V.9. N1.P.1-9. https://doi.org/10.1038/s41598-019-50792-y.

[15] Merkin V. E., Zertsalov M. G., Petrova E. N. (2020). Underground structures for transport purposes: a textbook. – Moscow: Infra-Engineering Publishing House, 2020. – 432 p. (In Russian).

THE INFLUENCE OF CLIMATIC CHANGES ON THE INTENSITY OF EROSION PROCESSES IN THE ARID ZONE OF THE CHECHEN REPUBLIC

Idris Bayrakov
•
Chechen State University named after A.A. Kadyrov, Russia
idris-54@mail.ru

Abstract

Arid ecosystems of the Chechen Republic change their appearance under the influence of various conditions and especially climatic ones. Sometimes such changes are formed only on the increase or, conversely, the decrease of one or another association of herbs or cereals in associations without causing a radical change of vegetation cover. However, often the impact of changed climatic conditions is so strong that a sharp change of associations takes place: the grasshopper ecosystem turns into a white–field ecosystem or, conversely, white-field-type associations become completely typical. The speed of such processes varies, as does the duration of ongoing climatic changes: sometimes they are temporary, and after a few years the original picture is restored, but often they turn out to be permanent. Therefore, the purpose of these studies is to show how the vegetation cover changes under the influence of climatic changes. Vegetation changes under the influence of temperature fluctuations and changes in the intensity of precipitation are shown. The results of the work will be useful in the development of agroforestry measures in the arid zone of the Chechen Republic.

Keywords: Chechen Republic, arid zone, climatic conditions, vegetation, dry winds, climate variability

I. Introduction

The arid zone of the Chechen Republic is located in the south–west of the Tersk–Kum lowland, dominated mainly by semi-desert landscapes, and is characterized by a high degree of variability of climatic conditions. The increase in the continentality of the climate has been occurring since the middle of the twentieth century. This leads to a change of plant associations, the processes of desertification are activated. Currently, this process has intensified, climatic conditions contribute to the expansion of the area of arid landscape complexes with appropriate vegetation cover. Therefore, the assessment of vegetation changes in arid landscapes under the influence of climatic conditions is not only of theoretical, but also of practical interest.

The development of the vegetation cover of the arid zone of the Chechen Republic occurs in climatic conditions characterized by a very small amount of precipitation less than 300 mm per year, and a significantly high temperature regime (more than +260 C average values for the summer period), high values of solar radiation and a number of marine transgressions of the Caspian Sea, in connection with which plant associations have formed on saline soils.

The currently available information and significant material about the nature and distribution of vegetation has accumulated as a result of research by a number of botanists. Of these, P.V. Novopokrovsky (1922, 1925-1926), S.A. Vinogradov, G.A. Tolchin (1932), S.E. Rozhenets-Kucherovskaya (1925), A.D. Gozhev (1930), S.M. Borisov (1946) should be noted.

II. Methods

The object of our field research was the vegetation cover of the arid zone of the Chechen Republic. Semi-desert landscape complexes occupy a ridge marine accumulative plain with a slight slope to the northeast with heights of 5-100 m above sea level. Large arrays of open sands are located in the central and north-eastern part.

Our own research on the degradation of vegetation cover and the changes of their associations under the influence of climate change was carried out near the Baklazan tract (5 key sites). Field studies were conducted mainly by the route method. When studying the vegetation cover, we used generally accepted geobotanical techniques.

Geobotanical descriptions of plant communities and their characteristic shifts were carried out at each site on five sites measuring 100 m2. To determine the phytomas, 8 experimental sites were randomly laid at each site. Studies have shown that the main degradation process developing in arid ecosystems is climatic emptying, which leads to a decrease in the productivity of vegetation cover, an increase in the area of exposed sands, significantly reduces the reproducible functions of natural components of ecosystems of the arid zone.

III. Results

The climatic conditions of the arid zone of the Chechen Republic are characterized by significant continentality, which is expressed primarily in the sharp temperature differences of individual months and seasons. If in winter the average monthly temperatures can decrease in Naurskaya to – 100 and below, with an absolute minimum to -400 , and summer temperatures here can reach + 270 in July, at the same time in the Pritersky sand massif, summer temperature maxima can reach more than 300 with an absolute maximum of +430. [1, 2]

Summer heats cause evaporation in large volumes, further increased by frequent dry winds, and winter periods with little or no snow in recent years, with a strong decrease in temperature, can lead to deep freezing of the soil. It should be noted that sharp temperature jumps in the spring and autumn periods, which are often accompanied by frosts, are very unfavorable for vegetation cover [1, 3].

Winter frosts have a depressing effect on the aboveground parts of white acacia (Robinia pseudoacia), gleditchia (Gleditschia treacantos) and mulberry (Morus alha), which are renewed in spring in the form of root growth, but apricot (Armeniaca vulgaris) tolerates winter frosts well. In addition, the development of plants in the arid zone is influenced by spring and, to a lesser extent, autumn frosts. The timing of the onset of both spring and autumn frosts in some years is highly susceptible to significant fluctuations.

As a rule, the last spring frosts occur at the end of April, and the first autumn frosts at the end of October, however, recent changes in climatic indicators have greatly shifted these dates.

The frosts of 1980 and 1982 during the flowering of tree species almost completely destroyed the forest strips of the arid zone, caused a delay in the leafing of trees for almost a month and were a prerequisite for the mass appearance of pests.

The number of meteorological risks affecting plants should also include the depth of soil freezing, the effect of which on vegetation is practically not traced by researchers. It is known that the depth of freezing of soils as a condition for the development of summer droughts due to the rapid rolling of spring meltwater, which does not have time to seep into the frozen soil. But it is impossible to limit the influence of frost only as an indirect causative agent of drought; one must think that its effect on plants is diverse. In recent years, the arid zone of the Chechen Republic has been characterized by few snowy or snowless winters.

So the winters of 2018/19, 2019/20, 2020/21, 2021/22 were practically snowless, and the snow cover appeared for a short time only at the end of January in early February. These snowless winters, although there were no severe frosts, affected the soil cover. As a result, the freezing of the soil reached almost 40 cm, which adversely affected the root system of perennial grasses, and they often fell out of plant communities, thereby impoverishing the richness of the plant world.

Not significant freezing in combination with strong dry and cold winds blowing during these months leads to winter drought and is often the cause of the death of young plantings in forest belts.

Probably, plants equally tolerate similar meteorological conditions. So, despite the fact that the tillering nodes of the grasshoppers and the tipchak are immersed in the soil, in cold, snowless winters, the soil is blown out of part of the sod and in the spring many, especially young, of these plants turn out to be dead. It is not surprising that under the influence of winter desiccation, cereals that have penetrated into the black-wormwood associations most often die, which weakly accumulate snow, which allows deep freezing of the soil.

Perhaps. that frost-breaking cracks also play a certain role in the death of plants. So in frosty years, at a depth of freezing of the soil of 40 cm, in the deeply frozen soil of the black wormwood covered with numerous cracks, you can find many dead segments of the rhizomes of the pinworm. It is possible that the effect of frost cannot be considered only negative. So, another [3] suggested that the same frost-breaking cracks can play a big role in enhancing water filtration into the soil.

The second manifestation of climate is an insignificant annual amount of atmospheric precipitation. A characteristic feature of precipitation in the summer months, when due to high evaporation they are almost useless for plants. Winter precipitation is low, winters, especially the last 30 years are snowless. The snow does not last more than a few days. The thickness of the snow cover does not exceed 5-10 cm. In some years, there may be severe blizzards and snowfalls. Snow melting, even in snowy winters, occurs very quickly, within 5-7 days. Meltwater quickly slides down and numerous small lakes remain in the depths for some time.

The changes caused in the vegetation cover by differences in the amount of atmospheric precipitation are manifested differently in the dry steppes and semi-deserts of the arid zone of the Chechen Republic. Grasshopper and typical ecosystems with soils relatively rich in organic substances and sufficiently washed, change their appearance and composition relatively weakly when meteorological elements change [4,5].

A different picture is observed in the zone of the Pritersky sand massif lying on sandy soils associated with a geologically younger territory. Here, both main groups of herbage – cereals and wormwood – are in an extremely unstable equilibrium, and any factor weakening one of these groups will immediately cause the victory of the second. As a result, changes in the moisture content of different years are particularly pronounced here (Fig. 1).

Stipa Joannis and Festúca valesiáca in arid ecosystems with an increase in the amount of precipitation is accompanied by an increase in the role of Stipa in the herbage. In tipchak communities, the value of thyrsa and kovylka increases sharply, increasing their abundance so much that the tipchak retreats to second place and the tipchak ecosystem turns into a tipchak – thyrsa or tipchak–kovylkovaya. Stipa, mainly Stipa Joannis, are beginning to occur more frequently in the others and kovylkov ecosystems. These changes occur relatively quickly, revealing in all Stipa species the ability to change their abundance and occupied area within 2-3 years. The content of Stipa Joannis increased from 30 to 60% during the hamid hamid period, more than doubled [6].

The second consequence of the increase in humidity is the increasing role of various grasses, in which the abundance of tall mesophilic plants – Filipendula hexapetala, Galium verum, Trifolium montanum, Salvia tesquicola, Lavatera thuringiaca, Vervascum lychnitis, Veronika langifola and a number of other species is rapidly increasing.

On the contrary, all conditions that weaken the accumulation of snow and interfere with the moistening of the soil will contribute to the development of droughts, and cause opposite changes in vegetation. The effect of drought on the vegetation cover of the grass and tipchak steppes is most clearly manifested in a sharp drop in productivity associated with a decrease in the density and height of plants. A rapid increase in air temperature, leading almost to the disappearance of spring, to a sharp transition from winter to summer, a rapid decrease in air humidity and the development of dry winds entail the same rapid burnout of arid ecosystems.

Figure 1: *A site with degraded vegetation cover in the arid zone of the Chechen Republic*

Plants dry quickly, without having time to get out, and their height barely reaches a third of normal size. This burnout is especially pronounced in grasshopper and tipchak ecosystems, which generally differ in the low growth of grass, and in dry years remain so underdeveloped that haymaking is impossible, since the mower does not capture grass (Fig. 2).

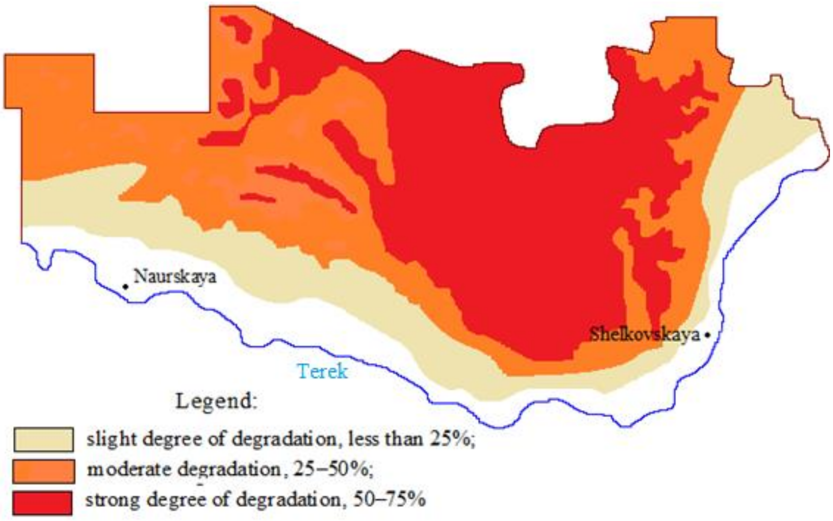

Figure 2: *Total indices of degradation of vegetation cover of the arid zone of the Chechen Republic*

Not only such moisture–loving species as Filipendula hexapetala, Lathyrus tuberosus, Viciacracca completely fall out of the herbage, but also ordinary steppe plants - Medicago falcata, Jurinea multiflora, Phlomis tuberose, Salvia tesquicola, Silene species, preserved only by single rare specimens. Even the ephemera and ephemeroids Androsace maxima, Erophila verna, Gagea bulbifera, G. Pusilla, Tulipa Schrenkii, T. Biebersteiniana and others are reduced in number two to three times compared to normal years.

The projective coverage in carpet associations is reduced to 60%, and the true coverage is reduced to 35-40%. The species saturation drops catastrophically; only 5-7 species remain on 1 m2 instead of 19-25, the landscape becomes less colorful, more monotonous, significantly impoverished. Productivity is reduced by 2-3 times and in grasshopper ecosystems is only 4.5 – 5.0 kg/ha instead of the usual 10-12, and in grasshopper and tipchak ecosystems, complete cutting at the root gives only 2.0-2.5 kg/ha of dry mass.

Climatogenic changes should be understood as radical changes in vegetation cover associated with its evolution over a long time. But speaking about them, it is necessary at the same time to dwell on those temporary, usually short-lived, changes that are born of a difference in the meteorological situation.

IV. Discussion

The scientific and practical interest of botanists and geographers in the problem of changing vegetation cover, in particular under the influence of changes in climatic conditions, was caused by the intensification of desertification processes.

Andreev, S. G. (2012) the processes of desertification, which have been developing recently against the background of global warming in the Northern Hemisphere, characterized by an increase in the average annual surface air temperature on land, especially in arid inland regions, are considered [7].

Askarova, U. B. writes that desertification is a process of irreversible changes in soil and vegetation and a decrease in biological productivity. In what it is impossible not to agree [8].

Bratkov V.V., Hajibekov M.I., Ataev Z.V. (2008) It is customary to understand "climate changes" as long-term (over 10 years) directed or rhythmic changes in climatic conditions on the Earth as a whole or in its large regions. There are geological, historical and modern climate changes. Climate fluctuations are cyclical or quasi–cyclical changes with a period of tens and hundreds of years. "Variability of a meteorological element" means non-periodic changes in the values of a particular meteorological element in a given place. The variability of a meteorological element to one degree or another can be characterized by its average daily variability, average variability of average monthly values, etc. [9]

Borlikov, G.M. Describes the dynamics of desertification of Chernozem pastures in changing natural and anthropogenic conditions. Currently, an ecological balance is maintained in this zone of the south of the European part of Russia [10].

However, in our opinion, changing climatic conditions can make this region of Russia an ecological disaster zone.

Modern climatic conditions of arid landscape complexes tend to aridize. In all parts of the arid zone, there are significant changes in meteorological conditions: the intensity of atmospheric humidification, there is a significant change from year to year. We observe 2-3-year periods of aridity or moisture. In recent years, despite the general global trend of climate warming, in the arid zone of the Chechen Republic there has been a general tendency to maintain conditions humidification. However, summer precipitation practically does not reach the earth's surface due to the high degree of evaporation.

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References

[1] Bayrakov I.A. (2013) Climatic conditions of the Chechen Republic.– Grozny: Publishing house of CHSPI,.– 186 p.

[2] The Chechen Republic: nature, economy and ecology. Textbook /I.A. Bayrakov, E.B. Bolotkhanov, A.I. Autorkhanov, H.E. Taymaskhanov, I.Ya. Shakhtamirov. – Grozny: Publishing House of the Chechen State University, 2006. – 375 p.

[3] Chirkov Yu.I. (1975) Fundamentals of agrometeorology. – L.: Hydrometeosidate. - 138 p

[4] Rozhanets-Kucherovskaya S.E. Geobotanical landscapes of the southern part of the Tersko-Kuma massif // Izv. RGO. 1925. Vol.68. Issue 4.

[5] Gozhev A.D. (1930) Types of sands of the western part of the Tersko-Dagestan massif and their economic use/ Gozhev A.D. Izv. GGO..Vol.52. Issue 4. pp.463-529.

[6] Bayrakov I.A. (2014) Problems of desertification of arid landscapes of the North Chechen lowland/ Bayrakov I.A. – Grozny: Publishing House of CHPI,.-170 p.

[7] Andreev, S. G. (2012) Climate as a factor of desertification in Central Asia / S. G. Andreev [et al.] //Engineering Ecology. No. 1. - pp. 31-37.

[8] Askarova, U.B. (2011) Problems of desertification and land degradation in the Republic of Kazakhstan / U. B. Askarova // Bulletin of the Development of Science and Education. N 3. - p. 3-6.

[9] Bratkov V.V., Hajibekov M.I., Ataev Z.V. (2008) Climate variability and dynamics of semi-desert landscapes of the North-Western Caspian region // Izvestiya Dagestan State Pedagogical University. Natural and exact sciences.. No. 4. – pp. 90-99.

[10] Borlikov, G.M. (2006) Dynamics of desertification of Chernozem pastures in the South of the European part of Russia / G. M. Borlikov [et al.] // Scientific thought of the Caucasus. N 2. - pp. 63-69.

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SEISMIC OSCILLATIONS OF CRUSTAL LAYER OF THE EARTH

Tukezban Hasanova, Tural Mammadli

•

Azerbaijan University of Architecture and Construction
atika2014@rambler.ru
t.mammadli@gmail.com

Abstract

Seismic push causes low-frequency oscillations of structures. Since the structures have a large mass, inertia forces occur during oscillations, resulting in high mechanical stresses (compression-tension and shear)at different places of the structures, which can exceed the strength of the material at one place or another and lead to damage or even collapse of the entire structure. Under seismic influences, as a result of inertial forces, low-frequency vibrations of structures occur in structures, mechanical stresses are generated in various places of structures that exceed the strength of the material, and can lead to damage or to the collapse of the entire structure. For this reason, buildings with anti-seismic reinforcement of structural elements are being erected in seismic areas. A structure, as a free body in space, has six degrees of freedom and the corresponding vibration modes: three translational displacements (vertical and two horizontal) and three rotational displacements: pendulum oscillations, oscillations around the longitudinal axis; vibrations around the transverse axis; vibrations around the vertical axis. The vibrations of an arbitrary structure with a foundation are the result of the superposition of different vibration modes with free vibration frequencies. In this work for the first time the crustal layer oscillation is described, frequency of oscillations from wavelength is determined.

Keywords: seismic effect, oscillation period, angular frequency, formation base, vibrations, rotational displacements

I. Introduction

Obviously, the vibrations of the structure are also influenced by the soils on which it stands. Seismic impact is determined in three parameters: the level of amplitudes, period and duration of oscillations. These parameters are critical for the stability of structures, and even a short-term load with very high acceleration may not be dangerous for many of them.

The longest period of the Earth's oscillations is about 1.5 hours. The periods of vibrations of the Earth's strata during earthquakes are of the order of a fraction of a second. Therefore, it can be assumed that earthquakes are independent of the Earth's vibrations.

In this research paper, earth layer is considered independently of the vibrations of the Earth.

Modernity, complexity and diversity of phenomena of non-stationary interaction of waves with obstacles in the form of solid and deformable bodies will assist in providing the processes of interaction of bodies of different physical nature. For major changes in design, construction and evaluation to be accepted, it is necessary that innovative structures be monitored for their interacting with the medium and studied for their deformation. The practice of modern construction industries requires the calculation of elements of structures and structures on the action of shock waves propagating in the medium or in the medium, filling it. To assist in achieving this goal in the given work is developing two-dimensional problem of propagation of seismic waves in an elastic medium. The two-dimensional problems of wave propagation in an elastic medium are interesting not only from a theoretical, but also from a practical point of view. In particular, seismic waves, given their rapid attenuation in depth, should be considered as two-dimensional. To receive the analytical and numerical solution of a task with the parameters, which are instantly increasing on border or in, the form of pushes with the subsequent attenuation attracts great theoretical and practical interest.

II. Methods

A layer of earth with a thickness of y_0 is considered, there are no stresses on the surface, $\sigma_{xy} = 0$ and и $\sigma_{yy} = 0$; at the base $v = 0$ and $\sigma_{xy} = 0$, i.e. there is no vertical displacement and the ground slides freely in the horizontal direction (Fig. 1)

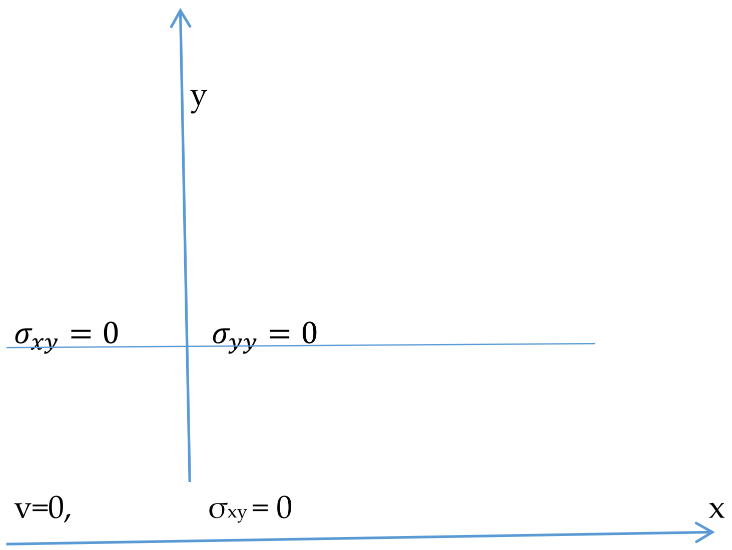

Fig. 1: *Horizontal ground slip*

Solutions of wave equations in polar coordinates r, θ are found

$$a^2\Delta\varphi - \frac{\partial^2\varphi}{\partial t^2} = 0$$
$$b^2\Delta\psi - \frac{\partial^2\psi}{\partial t^2} = 0 \tag{1}$$

under boundary conditions on the surface of cylindrical inclusion

$$U(t) = H(t)\,V_0 \tag{2}$$

in the form of

$$u_t = \frac{2r_0V_0\sqrt{ab}}{\pi}\left(\frac{1}{ab}\left(A_1(a,b) - \frac{a+b}{r_0\mu}\int\limits_{\frac{r-r_0}{a}}^{t} A_1(a,b)\,\mu\,d\tau\right) + \right.$$

$$+\frac{1}{br\mu}\int_{\frac{r-r_0}{a}}^{t} A_2(a,b)\ \mu\ d\tau)+\frac{2}{ar_0\mu}\cdot\int_{\frac{r-r_0}{a}}^{t} A_3(a,b)\ \mu\ d\tau+\frac{2}{r_0\ r}(A_4(a,b)-$$
$$-\frac{a+b}{r_0\mu}\int_{\frac{r-r_0}{a}}^{t} A_4(a,b)\ \mu\ d\tau)\ -\ \frac{1}{ar\mu}\int_{\frac{r-r_0}{b}}^{t} A_2(b,a)\ \mu\ d\tau\ -\ \frac{2}{r_0\ r}(A_4(b,a)-$$
$$-\ \frac{a+b}{r_0\mu}\int_{\frac{r-r_0}{b}}^{t} A_4(b,a)\ \mu\ d\tau)) \tag{3}$$

where: φ and ψ - potential functions, described waves the transferring volume expansion and rotation;

magnitudes $a=\sqrt{\frac{\lambda+2\mu}{\rho}}$ and $b=\sqrt{\frac{\mu}{\rho}}$ are determine the velocity of propagation of waves of expansion and waves of rotation;

λ и μ - constants of Lama; ρ - density of medium; Δ - Laplacian; V_0 – constant speed of cylindrical inclusion; $H(t)$- Hevisayd's unit function, determined by a formula

$$H(t)=\begin{cases}1,\ t>0\\0,\ t<0\end{cases} \tag{4}$$

III. Results

For simplicity, a two-dimensional problem for an elastic soil is considered. The equations of motion are

$$\rho\frac{\partial^2 u}{\partial t^2}=(\lambda+2\mu)\nabla^2 u \tag{5}$$
$$\rho\frac{\partial^2 v}{\partial t^2}=(\lambda+2\mu)\nabla^2 v \tag{6}$$

where ρ – soil density, λ,μ – Lame's constants, t - time, u,v – displacements in horizontal and vertical directions. $\nabla^2=\frac{\partial}{\partial x^2}+\frac{\partial}{\partial y^2}$, $\lambda\ and\ \mu$ are considered permanent.

Assuming that there is an oscillatory motion with an angular frequency and a standing wave length l, we have

$$u=Usin\omega tcos\frac{2\pi}{l}x \tag{7}$$

and

$$v=Vsin\omega tsin\frac{2\pi}{l}x \tag{8}$$

where u and v – fuction of y.

Substituting (7) and (8) in (5) and (6), we obtain

$$-\rho\omega^2 U = (\lambda + 2\mu)\left[-\left(\frac{2\pi}{l}\right)^2 U + U^{\shortparallel}\right] \tag{9}$$

$$-\rho\omega^2 V = (\lambda + 2\mu)\left[-\left(\frac{2\pi}{l}\right)^2 V + V^{\shortparallel}\right] \tag{10}$$

Solving equations (9) and (10) relatively to u and v, we obtain

$$u = c_1 sin\Omega y + c_2 cos\Omega y \tag{11}$$

$$V = D_1 sin\Omega y + D_2 cos\Omega y \tag{12}$$

where

$$\Omega\sqrt{\frac{\rho\omega^2}{\lambda+2\mu} - \left(\frac{2\pi}{l}\right)^2} \tag{13}$$

Shear stress

$$\sigma_{xy} = \mu\varepsilon_{xy} = \mu\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right) = \mu\left(\frac{2\pi}{l}V + u'\right) sin\omega t cos\frac{2\pi}{l}x \tag{14}$$

Satisfying the conditions at the lower bound: $y = 0, v = 0, \sigma_{xy} = 0,$

we get

$$D_2 = 0; \quad c_1 = 0 \tag{15}$$

On the upper border $y = y_0,\ \sigma_{xy} = 0, \sigma_{yy} = 0$, we get

$$\sigma_{xy}\big|_{y=y_0} = \mu(D_1 \sin\Omega y_0 - \Omega c_2 sin\Omega y_0) sin\omega t cos\frac{2\pi}{l}x = 0$$

or

$$\frac{2\pi}{l}D_1 - \Omega C_2 = 0 \tag{16}$$

From (11) and (15) expressions

$$\begin{gathered} U = c_2 cos\Omega y_0 \\ V = D_1 sin\Omega y_0 \end{gathered} \tag{17}$$

Further

$$\begin{aligned}\sigma_{yy} &= \lambda\Delta + 2\mu\varepsilon_{yy} = \lambda\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) + 2\mu\frac{\partial v}{\partial y} = \\ &= \left[\lambda\left(-\frac{2\pi}{l}U + V'\right) + 2\mu V'\right] sin\omega t cos\frac{2\pi}{e}x = \\ &= \left[-\frac{2\pi}{l}\lambda c_2 cos\Omega y_0 + (\lambda + 2\mu)\Omega D_1 cos\Omega y_0\right] sin\omega t cos\frac{2\pi}{e}x - \frac{2\pi}{l}\lambda c_2 \\ &+ (\lambda + 2\mu)\Omega D_1 \\ &= 0\end{aligned} \tag{18}$$

From (16) and (18) expressions

$$\omega^2 = \frac{2(\lambda + \mu)}{\rho} \tag{19}$$

where v – frequency

$$\nu = \frac{\omega}{2\pi}$$

One example of the carried-out calculation, considering bulkiness of the received results, corresponds to velocity of propagation of waves in rocky and semi-rocky breeds

a=2000m/sec; b=1400m/sec;

r_0 = 10 m; r = 100 m; 1000 m; 10000 m

r_0 - distances of inclusion

In considered medium the non-stationary elastic wave interacts with inclusion and generates the reflected waves moves. The time changes in the range of 0 sec., $0 \le r \le 10$ sec, Δt = 0,01 sec.

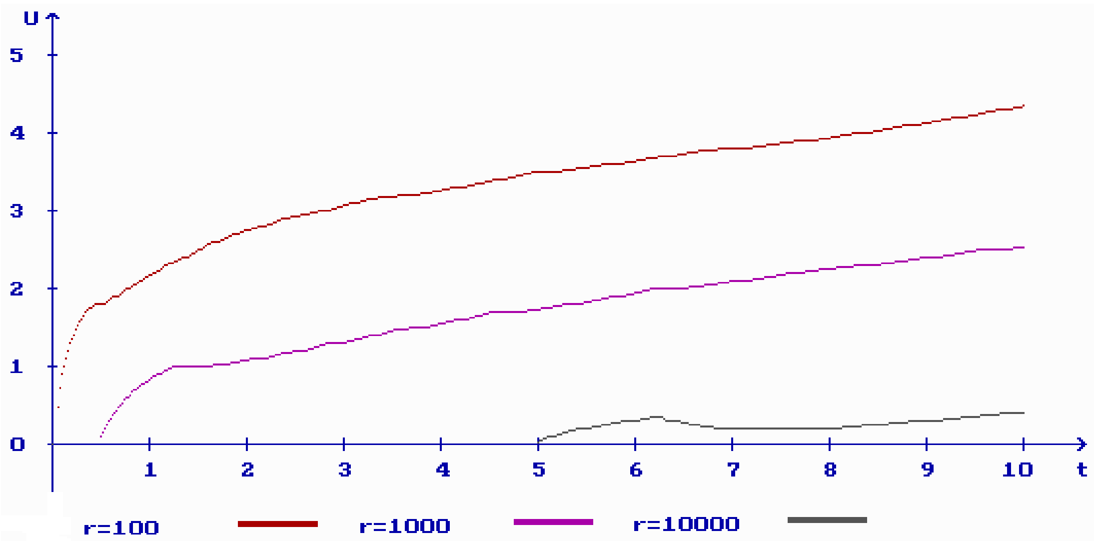

Fig. 2: *Attenuation of waves of displacements*

The top curve corresponds to dependence of $u_t(t)$ on t at r=100m; the average curve corresponds to dependence of $u_t(t)$ on t at r=1000m; the lower curve corresponds to dependence of $u_t(t)$ on t at r=10000m. As inclusion farther from the center, then more is observed attenuation of waves of displacements.

IV. Discussion

The frequency of the earthquake can be used to estimate the length of the standing wave of soil vibrations.

Here are materials on possible phenomena during earthquakes. In particular, assuming the Lame constants for the soil

$$\lambda = 1 \cdot 10^9 Pa, \qquad \mu = 0{,}8 \cdot 10^9 Pa,$$

We have according to (19)

$$\omega = 2\pi\nu; \;\; E = 2 \cdot 10^9; \;\; \rho = 2 \cdot 10^3 \text{ кг/м}^3; \;\; \nu - \text{frequency}$$

1) $l = 100\text{m}; \;\; \nu = 27{,}6 \;\; 1/sec$
2) $l = 300m; \;\; \nu = 9{,}2 \;\; 1/sec$

In further consideration, obviously, consider the Lamé constants $(\lambda = 1 \cdot 10^9 Pa)$ and μ $(\mu = 0{,}8 \cdot 10^9 Pa)$, depending on depth and, if possible, take into account friction at the bottom of the formation.

References

[1] Agalarov J.H., Mamedov Sh.A., Imamaliyeva J.N. (2003). Nonstationary waves excited by the rigid cylinder in elastic medium. Transactions Issue Mathematics and Mechanics Series of Physical – Technical and Mathematical Sciences. The Issue is Dedicated to 80th Anniversary of President of Azerbaijan Republic H. Aliyev, XXIII, № 1, Baku, p. 181 – 184.

[2] Kolsky, G. (1995). Stress waves in solids. - I.L. Moscow.

[3] Sadovsky, M.A., Golubeva, T.V., Pisarenko, V.F. (1984). Characteristic dimensions of rock and hierarchical properties of seismicity. Izv. USSR Academy of Sciences, Physics of the Earth, №2, p. 3-15.

[4] Yunga, S.L. (2000). Methods and results of studying of seismotectonic deformations. - M.: Science. p. 191.

[5] Yunga, S., Lutikov, A. (2005). Non double couple seismic sources, faults interaction and hypothesis of self-organized criticality // Natural hazards and Earth system sciences, №5. p. 11-15.

[6] Liu, H. S., Bo, J. S. and Liu, D. D. (2005). Review on study of seismic stability analysis of rock-soil slopes. Earthquake Engineering and Engineering Vibration, vol. 25, №1, pp. 164–171.

[7] Xu, G. X., Yao, L. K., Li, Z. H. and Gao, Z. N. (2008). Dynamic response of slopes under earthquakes and influence of ground motion parameters. Chinese Journal of Geotechnical Engineering, vol. 30, №6, pp. 918–923.

[8] Raghunandan, M. and Liel, A. B. (2013). Effect of ground motion duration on earthquake-induced structural collapse. Structural Safety, vol. 41, pp. 119–133.

ASSESSMENT OF INDIVIDUAL SEISMIC RISK FOR THE POPULATION, TAKING INTO ACCOUNT THE ACTUAL SEISMIC RESISTANCE OF BUILDINGS AND THE SEISMICITY OF SOILS

Gennadiy Nigmetov, Andrey Savinov, Temir Nigmetov
•
FGBU VNII GOCHS, Russia
tagirmaks@mail.ru savandr198@mail.ru t.nigmetov@yandex.ru

Abstract

In preparation for a catastrophic earthquake, it is important to plan and implement timely organizational and technical measures to protect the population in the zone of possible destructive seismic impact. In order to quantitatively assess the level of earthquake hazard, the vulnerability of buildings and possible losses among the population, the integral value of individual seismic risk is proposed. For a reliable assessment of individual seismic risk, it is necessary to know the parameters of the possible earthquake source, the macroseismic field, the seismic resistance of buildings caught in the 6-point zone of seismic impact, the seismicity of soils at the base of buildings and possible human losses. The methods currently used to assess individual seismic risk are based on many years of statistical data. We propose an end-to-end calculation-experimental approach to estimate possible losses and individual risk based on actual data on hazard, seismicity and earthquake resistance.

Keywords: earthquake, buildings, possible earthquake source

I. Introduction

The consequences of catastrophic earthquakes and individual seismic risk depend on many factors. But the most important factors on which individual seismic risk depends are seismic hazard, seismic vulnerability, or the earthquake resistance of buildings and the seismicity of soils. With timely and reliable short-term earthquake forecasting and notification of the population, up to 100% of the population can be protected, but at present there are no reliable methods for short-term earthquake forecasting. It is possible to protect the population by placing them in earthquake resistant buildings that have been properly designed with consideration of the seismicity of the soils at their base. The projected earthquake resistance of buildings is calculated according to the seismicity of the grounds at the base of the buildings. Since earthquake-resistant construction requires increased funding, it is important that the seismicity of the construction site, obtained in the surveys, corresponds to the actual data.[1] For existing buildings that have already been constructed, including those built using previously adopted norms, periodic verification of the earthquake resistance and seismicity of the sites is required. [2] An integral criterion of individual seismic risk is proposed for a comprehensive assessment of public safety, taking into account the earthquake resistance of buildings and seismicity of the site. When an earthquake threatens or after an earthquake, a mass rapid assessment of the earthquake resistance of buildings is required [3]. Existing rapid seismic testing methods are based on visual inspections that focus on the technical condition of the building and therefore provide an approximate rough estimate of earthquake resistance. Visual inspection, even with the use of traditional methods of instrumental control, fails to reveal hidden defects and take into account their impact on the integral stiffness of the building, which ensures the seismodynamic impact perception. The problem is that traditional methods of instrumental control, by means of which the pointwise examination of strength, reinforcement and structural cross-section do not allow to estimate the stiffness of each separate structure and the integral stiffness of the whole structural system.[4]

Thus, to assess individual seismic risk at different stages of seismic hazard development, taking into account the actual data on the seismicity of soils and the earthquake resistance of buildings, instrumental methods are required to determine the integral stiffness of the building, on the basis of which the actual seismicity of soils in the building base and its earthquake resistance can be estimated.

II. A method for calculating individual seismic risk using real data on seismic hazard, earthquake resistance and seismicity of soils.

Usually, a possible earthquake source (PES) in an earthquake zone forms over several years or decades, then triggers or discharges in the form of one or more strikes within a year, then fades out and a new PES occurs in a new location. [5]

Calculation of individual seismic risk must be performed at different, time-distributed stages of the PES:

1)at the PES threat stage, its projected parameters are determined: coordinates, depth and magnitude, time of possible triggering, then using a geographic information system (GIS) it is proposed to estimate consequences and individual risk for populations falling into the projected 6-point zone of seismic impact;

2) when the PES is triggered (the stage of the main strike) on the basis of real data of the earthquake origin obtained from geological services, an operative assessment of consequences and risks is made; the data obtained helps to promptly make decisions on organization of rescue works, verification of earthquake resistance of damaged buildings, population evacuation, and prevention of effects from secondary hazards;

3) assessment of possible risks from possible strong aftershocks is carried out by forecasted parameters of aftershocks, time of their possible triggering

4) after the main shock and aftershocks, data on the decay time of the epicentral zone and the time and parameters of the emerging PES are predicted for which the risks are calculated.

For short-term PES triggering locations estimation we suggest to use a complex approach based on the analysis of cloud cover data using satellite images, wind gust and thunderstorm activity maps, spectral analysis data of dynamic-geophysical observations.[6] Fig.1 shows an example of medium-term seismic activity forecast for the Black Sea-Caspian Sea region based on the complex method of seismic activity assessment. Regularities of the sequence of earthquake precursors manifestation, used in the complex approach, are given in Fig. 2 and 3. On the figures the entrance times of the earthquake precursors of the main strike and the strong aftershock are clearly seen by the example of the Nepal earthquake of 25.04.15.

Fig.3 shows how the cloud portrait shows characteristic " striped" anomalies, showing the possible location of PES triggering.

To calculate the macroseismic field from PES and to determine the boundaries of the 6-point zone, GIS uses data on tectonics, geology and terrain in the area of PES. In addition to data on seismic parameters in the form of a macroseismic field, real data on earthquake resistance are needed to assess possible consequences and risks. [7]

Real data on the seismic resistance of buildings and structures in the examined 6-point zone are proposed to be obtained by dynamic testing. With the help of dynamic tests we obtain the integral stiffness of buildings, which is directly proportional to the square of the frequency of natural vibrations of the building, the stiffness of the soil mass is also directly proportional to the square of the frequency of soil vibrations.

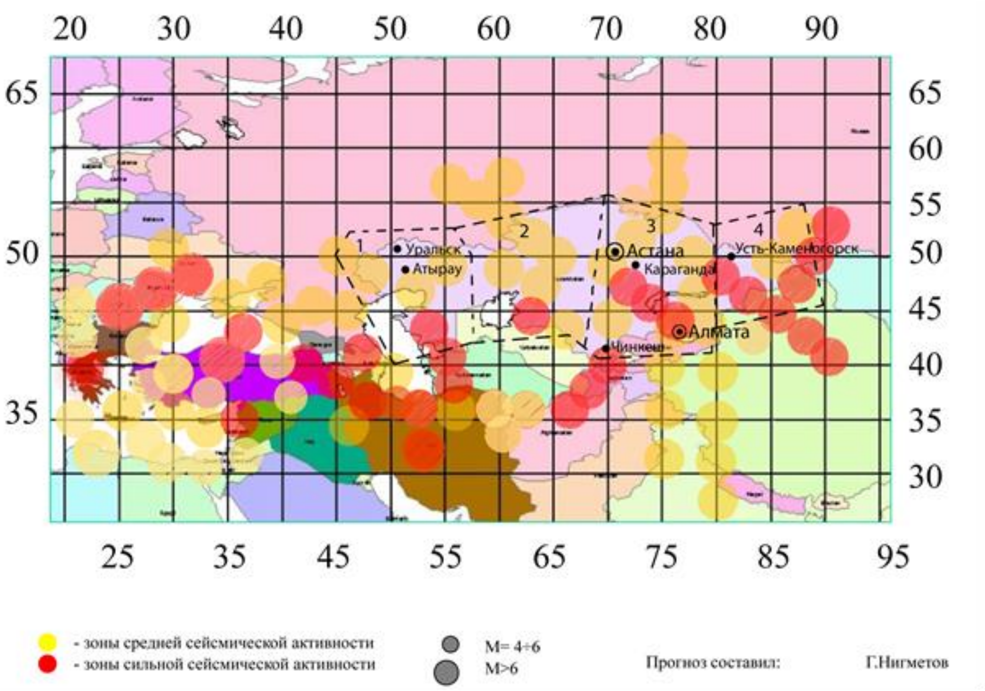

Figure 1: *Forecast of zones of increased seismic activity of the Black Sea-Caspian Sea region according to comprehensive analysis of precursors.*

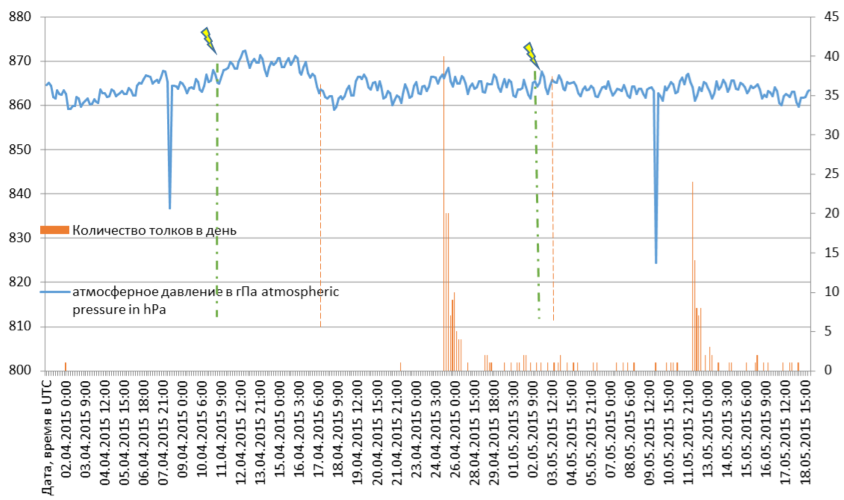

Figure 2: *Sequence of precursors of atmospheric pressure drop and lightning discharges on the example of the Nepal earthquake on 25.04.15.*

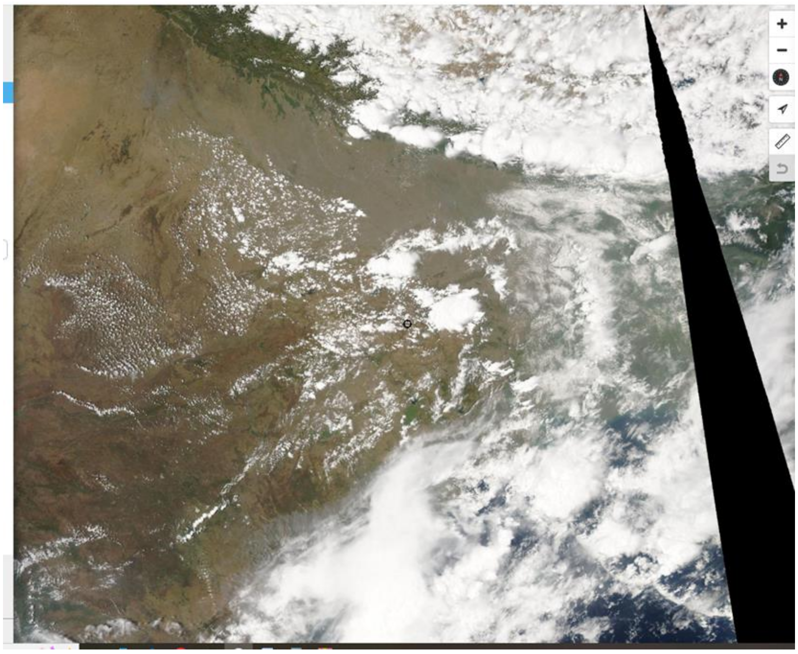

Figure 3: *The cloud cover before the strong earthquake in Nepal on 25.04.15.*

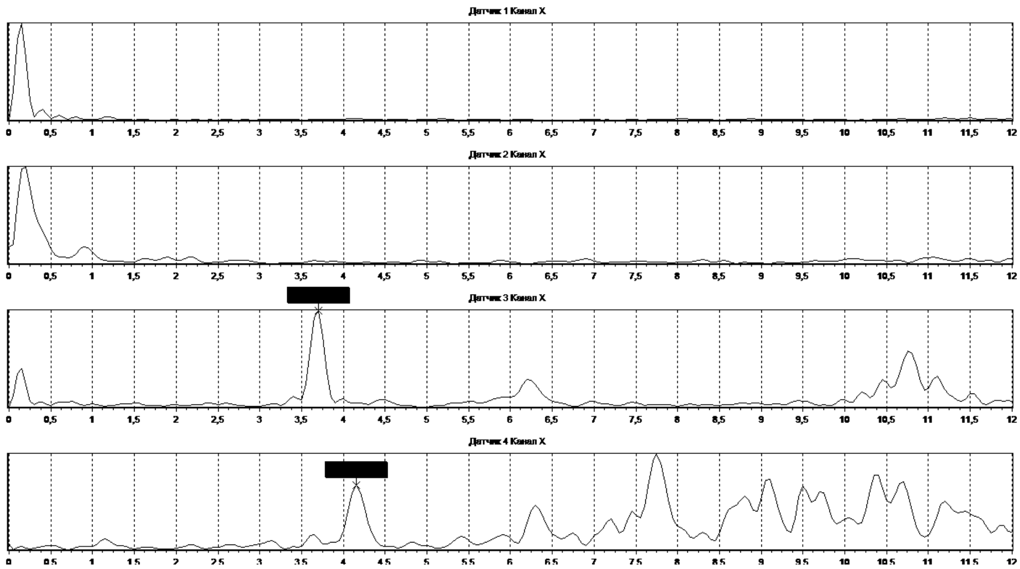

Figure 4: *Example of natural frequencies along the X-axis obtained in the dynamic tests of the historic building.*

To calculate the value of acceleration of earthquake resistance in dynamic tests through the square of the frequency, the following relation is proposed:

$$\boldsymbol{A} = \frac{4*\pi^2*\Delta d*f^2}{k_0*k_1*k_\varphi*\beta(T)} ,$$

where

Δd – the maximum allowable displacement of the building;

k_0 – coefficient, taking into account the peculiarity of the structural solution and the degree of its importance K_0 [7];

$\boldsymbol{k_1}$– a coefficient taking into account acceptable damage k_1;
$\boldsymbol{k_\varphi}$ – coefficient, taking into account the dissipative properties of the structure, $\boldsymbol{k_\varphi}$;
$\boldsymbol{\beta(T)}$ – dynamism factor of a structure ;
$\boldsymbol{f}$ – natural frequency of the building.[8]

Thus, to calculate the value of individual risk, we can get real data on the possible seismic hazard, the earthquake resistance of buildings, and data on the possible number of people falling into the 6-point zone of seismic hazard.

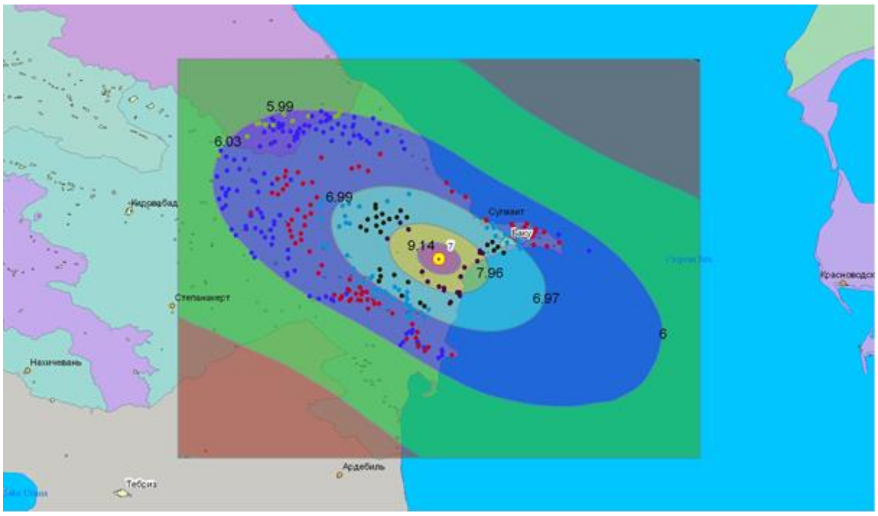

Figure 5: *Estimation of possible impacts for the predicted possible earthquake source.*

Based on real data on earthquake consequences the individual seismic risk is determined as quotient of mathematical expectation of losses in the considered 6 point zone of possible seismic event divided by time when earthquake is expected and by number of people in the considered 6 point zone.

$$Re_i = \frac{m_6}{T \times N_6} \leq [\, Re_i],$$

where:
Re_i – individual seismic risk, $\frac{1}{year}$;
[Re_i]- individual seismic risk norm;
m_6 – mathematical expectation of losses in the considered 6-point zone of possible earthquake, pers.;
T – time during which a possible seismic event is predicted, year
$\boldsymbol{N_6}$ – number of people in the considered 6-point zone of possible earthquake.

III. Results of calculation of individual seismic risk for the population of the Black Sea-Caspian Sea region.

Table 1 shows examples of calculations of individual seismic risks performed using the geoinformation system "Extremum". Calculations on the projected PES were performed for the Black Sea-Caspian Sea region. The GIS database on seismic resistance of buildings and seismicity of sites was specified for Krasnodar and Stavropol regions by the method of dynamic tests.

Table 1: *Assessment of possible individual seismic risk of territories for the population in the area of the Black Sea-Caspian Sea region.*

№	Location of possible earthquake origin (Country, nearest settlement, coordinates)	Predicted power of earthquake source M, depth of source H.	Time interval of possible triggering, year.	Possible projected individual risks, 1/year.	Excess of the projected risk over the risk rate equal to 10^{-5}1/year.
1.	Ukraine, 47 N Latitude, 32 E Longitude.	M=6, H=15 km	≥10	$3×10^{-4}$ 1/year.	30 times.
2.	Ukraine, Romania, 47 N Latitude, 30 E Longitude.	M=6, H=15 km	≥10	$1{,}8×10^{-4}$ 1/ year	18 times
3.	Romania 45,5 N Latitude, 29 E Longitude.	M=6, H=15 km	≥10	$2.2×10^{-4}$ 1/ year	22 times
4.	Bulgaria, 44 N Latitude, 25 E Longitude.	M=6, H=15 km	≥10	$3{,}1×10^{-4}$ 1/ year	31 times
5.	Serbia, 43,5 N Latitude, 22 E Longitude.	M=5, H=10 km	≥10	$4{,}9×10^{-5}$ 1/ year	4,9 times
6.	Turkey, 40 N Latitude, 30 E Longitude.	M=5, H=10 km	≥10	$2{,}4×10^{-4}$ 1/ year	24 times
7.	Turkey, 42 N Latitude 35 E Longitude	M=6, H=15 km	≥10	$4{,}2×10^{-4}$ 1/ year	42 times
8.	Turkey, 41,5 N Latitude 37 E Longitude,	M=6, H=15 km	≥10	$1×10^{-5}$ 1/ year	-
9.	Black Sea, 42,5 N Latitude, 38 E Longitude.	M=7,8, H=10 km	≥10	-	-
10.	Turkey-Georgia, 41 N Latitude, 41 E Longitude	M=6, H=10 km	≥10	$1{,}1×10^{-3}$ 1/ year	110 times
11.	Georgia, 42 N Latitude, 42 E Longitude.	M=6, H=10 km	≥10	$7{,}7×10^{-4}$ 1/ year	77 times
12.	Azerbaijan, Georgia, Russia, 42 N Latitude, 47,5 E Longitude	M=6, H=10 km	≥10	$4{,}3×10^{-3}$ 1/ year	430 times

13.	Russia, 44 N Latitude, 38 E Longitude	M=7, H=10 km	≥10	1,9×10^{-4} 1/ year	19 times
14.	Russia, Ukraine, 45 N Latitude, 36 E Longitude.	M=6,5, H=10 km	≥10	2,95×10^{-4} 1/ year	29,5 times
15.	Russia, Ukraine, 45 N Latitude, 35 E Longitude.	M=5,5, H=10 km	≥10	3×10^{-4} 1/ year	30 times

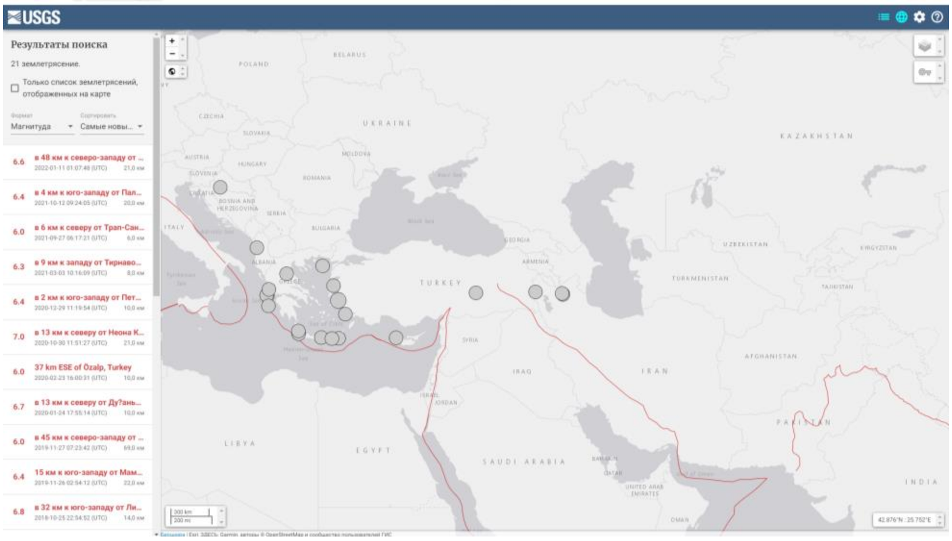

Figure 6: *Earthquakes with M≥6 occurred in the Black Sea-Caspian Sea region for the last 10 years (from data of the USGS).*

Fig. 6 shows that during the last 10 years in the Black Sea-Caspian Sea region under consideration the most earthquakes occurred in Turkey and the Balkans. In the Caucasian region the seismic energy did not strongly manifest itself during this period of time, that is why the threat of WHO triggering for Caucasian region still remains.

IV. Discussion

The proposed end-to-end individual seismic risk assessment technique for different stages of PES manifestation can be used both for one-time assessment of individual seismic risk and for its monitoring over time at all PES stages. Data in Table 1 and Figures 1 and 6 show that not all PES projections have materialized and that the risks to the population of the Black Sea-Mediterranean-Caspian Sea region exceed the normative value of 10-51/year, according to the authors. In order to clarify the values of individual risk for the territories of the Caucasus it is proposed:

- refine the maps of zones of increased seismic activity using complex precursors in the form of thunderstorm activity, atmospheric pressure drop, cloud portrait, seismic and geophysical data;
- to clarify the seismic resistance of typical buildings in the territories in question using the method of dynamic tests (proposed by the example of Derbent);
- to specify databases on buildings and population in the geoinformation system "Ekstremum" designed to calculate consequences of strong earthquakes;

- perform calculations of consequences and assessment of individual seismic risks (proposed on the example of Derbent).

The calculations performed on individual seismic risk assessment can be used for effective planning of measures for reduction of possible risks.

References

[1] Nigmetov, G., Savinov, A., Nigmetov, T., Savin, S., Simonyan, A. Dynamic-geophysical tests of the technical condition and earthquake-resistance of historical buildings. AlfaBuild. 2022. 21(1). DOI:10.57728/ALF.21.1.

[2] СП 442.1325800.2019 Здания и сооружения Оценка класса сейсмостойкости2019.

[3] Nigmetov, G., Akatev, V., Savinov, A., Nigmetov, T. Estimation of seismic resistance of buildings by the dynamic-geophysical method, taking into account the peculiarity of the interaction of the seismic wave with the «soil – construction» system. Structural Mechanics and Analysis of Construction. 2018. 1 (276). Pp. 24–30.

[4] Nigmetov, G. Some issues of short-term forecasting of seismic hazard and risk. CATALOQUE of seismoforecasting research carried out in Azerbaijan territory in 2009. 2009. Pp. 147–154.

[5] Larionov, V., Nigmetov, G., Sotin, V., Sushev, S., Shahramanian, M. Mobile diagnostic complexes for assessing the seismic resistance of buildings and structures. Seismostoikoe stroitl’stvo. Bezopasnoct’ sooruzhenii. 1999. 2. Pp. 41–43.

[6] Nigmetov, G. Fluctuations of the earth’s crust before destructive earthquakes. CATALOQUE of seismoforecasting research carried out in Azerbaijan territory in 2010. 2010. Pp. 99–104.

[7] Nigmetov, G., Chubakov, M. Monitoring problems of buildings and structures. Seismostoikoe stroitl’stvo. Bezopasnoct’ sooruzhenii. 2011. 4. Pp. 51–55.

[8] Напетваридзе, Ш.Г., Айзенберг, Я.М., совет по сейсмологии и сейсмостойкому строительству, М. Вероятностные оценки сейсмических нагрузок на сооружения. Наука, 1987.

IMPACT OF CLIMATE CHANGE ON THE GROUNDWATER OF THE GANIKH-AYRICHAY FOOTHILLS

Sevinj Rzaeva, Allahverdi Tagiyev, Sevil Zeynalova
•
Azerbaijan State Oil and Industry University
rzaeva.48@mail.ru allahverdi.taghiyev@gmail.com z7sevil@mail.ru

Abstract

Climate change has a negative impact on the water resources of the Republic of Azerbaijan. If we take into account that approximately 70 percent of the water resources of the Republic of Azerbaijan are formed at the expense of transboundary rivers, then the situation becomes even more complicated. According to the generally accepted hydrogeological zoning scheme of the territory of the Republic of Azerbaijan, the Ganikh-Ayrichay artesian basin is a class II artesian basin, included in the composition of the Kura basin. Ganikh-Ayrichay water valley is one of the underground water deposits of Azerbaijan, distinguished by its fresh water resources. Thus, since 2010, 5 m^3 of fresh water per second has been transported from this field to Baku through the water pipeline. In recent years, climate change has had a negative impact on the water resources formed in the Ganikh-Ayrichay foothill plain. Observations on the regime of underground water show that the level and consumption of water in pressurized water wells has decreased.

Keywords: water supply, aquifer, percent of mineralization, Ganikh-Ayrichay foothill plain, climate change

I. İntroduction

In the eastern part of the Ganikh-Ayrichay foothill plain, it is surrounded by Dashakhilchay from the west, Bumchay, Zaglichay from the east, the southern slopes of the Great Caucasus Mountains from the north, the Acinohur heights from the south and in the north-west of the South Caspian basin. The length of the working area is 40 km, the width is 15 km, and the area is 600 km^2 (Fig. 1.).

The following orographic units are distinguished within the boundaries of the research area and adjacent regions: the southern slopes of the Greater Caucasus, the Ganikh-Ayrichay valley and the Acinohur elevation. The absolute height in the drainage part of the southern slopes of the Greater Caucasus along the northern edges of the working area is 3000-3500 m, in the contact areas with the working area it is 700-800 m. The Ganikh-Ayrichay valley is a large orographic unit, a sloping-flat valley depression with a large area. The absolute height of the ground surface along the northern edges of the valley is 400-800 m, and on the southern edges (at the junction of Ganikh and Ayrichay) it is 188 m [1].

The age, lithological and petrographic composition of the rocks distributed in the research area, weathering, transport of the rocks distributed in those areas, etc. is related to Jurassic sediments are widely distributed in the northern part of the research area, in the subducting arch part of the Great Caucasus anticlinorium. Upper Jurassic sediments are mainly developed in this area (Fig. 2). The Upper Leyas (J_1,l) sediments are widely distributed in the watershed of the Great

Caucasus Mountains in the sources of the Philphilichay, Tikanlíchay, and Damiraparanchay rivers. These sediments are widespread in the Duruca anticlinorium extending from Kishchay to Vandamchay, they consist of clayey shales [2].

The Aalen (J_2a) floor is characterized by the Upper Aalen (J_2a_2) sand-clay layer in the studied area. These sediments developed in the upper reaches of Damiraparanchay, Bumchay, Tikanlichay, Philphilichay (southern edge of Leyas sediments flows) and Damiraparanchay, in the arch parts of the anticlinal fold. The thickness of sandstone layers reaches 30-40 m. The thickness of clay shales is 2-3 m.

Upper Aalen sediments form the central axial part of the Duruca anticlinorium. This anticlinorium extends from Shinchay to Vandamchay. Complete cutting of Aalen sediments is observed in the upper reaches of Hamzalichay, Badaldara River (the left tributary of Dashagilchay), Kungutchay and Kishchay. These sediments consist of dark gray, black sheeted clayey shales, sandstone layers.

The middle division (J_2) (Dogger) sediments are distributed in the arch parts of the Duruca anticlinorium in the upper reaches of the Hamzalichay, Badaldara (left branch of Dashagilchay), Chukhadurmaz (left branch of Kishchay) and Shinchay. Sediments consist of Khinalig sandstones, clayey shales, smoothed river pebbles and conglomerates. The total thickness of the layers reaches 200 m [3].

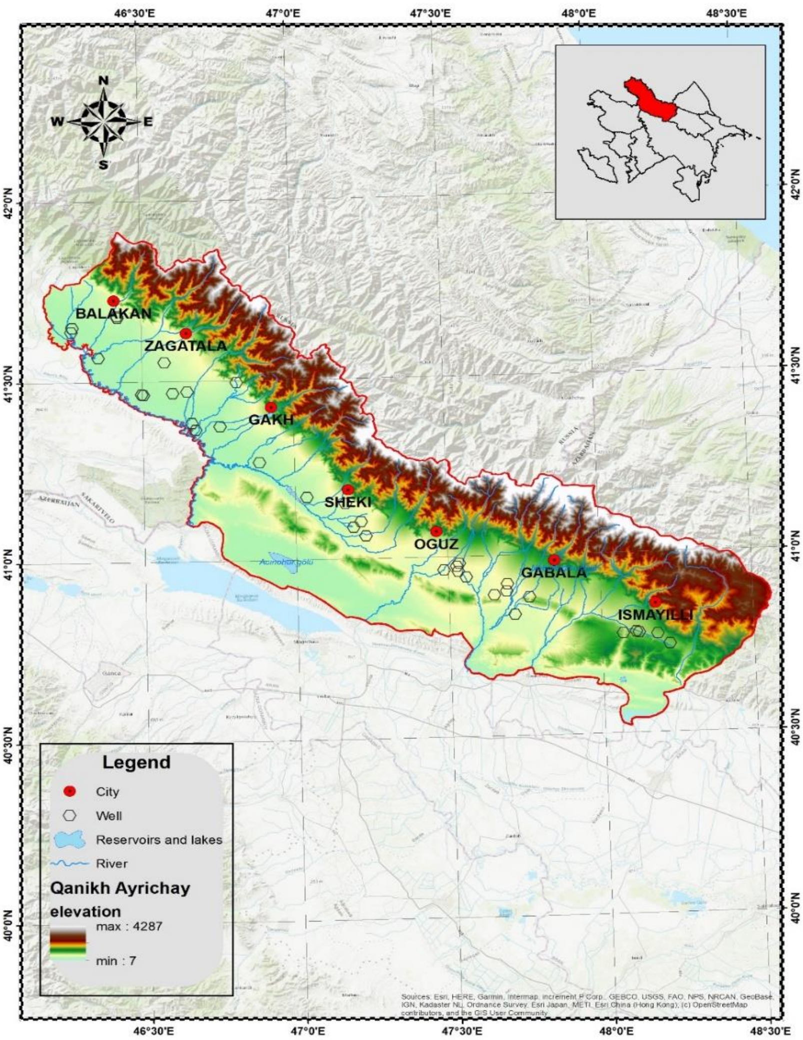

Fig. 1: *Physical map of the Ganikh-Ayrichay foothill plain*

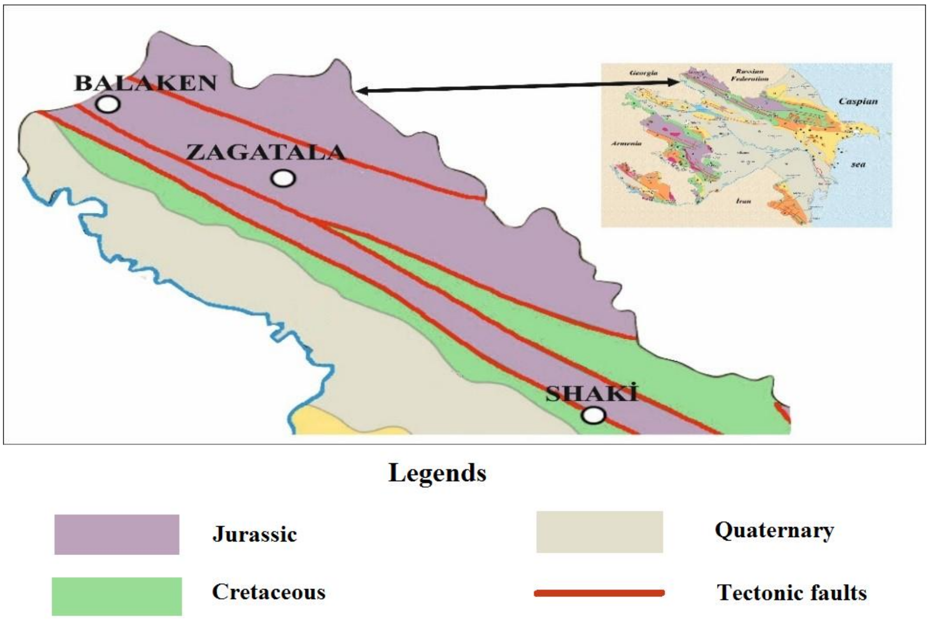

Fig. 2. *Geological map of the study area*

The bedrocks of the rivers flowing from the southern slopes of the Greater Caucasus are mainly composed of well-washed rock fragments of different sizes, smoothed layers of various degrees, and river pebbles. The initial parts of the flow cones are formed in the areas where the rivers leave the foothill zone and consist mainly of different sizes of gravel, large river stones, and a small amount of pebbles. Towards the center of the bearing cones, large-sized cobblestones and pebbles are gradually replaced by relatively small pebbles, sands of various sizes, sands, clays, and a small amount of clays. Since the process of changing the section in this form occurs gradually, sand, clay, and thin-layered clay alternate with sand, gravel, and pebbles of various sizes in the section in the center and skirts of the river cones [7,8,9].

In the Quaternary cross section of the valley, a ribbed structure is present at each of the flow cones of the rivers. In these structures, in the south direction, a single cross-section layer composed of large clastic rocks is divided into several horizons by different clay and clay layers in the south direction. However, although the thickness of siltstones and siltstones ranges from a few cm to 4-5 m, they do not have a regional distribution.

Due to its structural and tectonic structure, the Ganikh-Ayrichay valley is practically a closed basin of underground water [4,5]. It is 15-35 km wide and stretches in the form of a thin strip from north-west to south-east, forming a valley between the Great Caucasus mountain range and Acinohur. This valley is filled with alluvial and alluvial-proluvial sediments of the Quaternary period with great thickness and high permeability. Regionally distributed alluvial-proluvial horizons of the Quaternary period in the valley have a high level of water due to the presence of a large number of rivers passing through the valley, abundant atmospheric precipitation and groundwater from the rivers flowing from the southern slopes of the Greater Caucasus. Groundwater is formed due to percolation of atmospheric sediments, surface water (rivers, irrigation water), condensation of water vapors in the aeration zone, groundwater of rivers and underground flow from parent rocks.

The lithological and granulometric composition of the rocks that make up the valley shows a certain zonation from the foothills to the foothills of the cones of the rivers.

II. Methods

In order to study the impact of climate change on underground water in the Ganikh-Ayrichay valley, the changes of multi-year atmospheric precipitations and the multi-year changes of regime parameters of groundwater were studied (Fig.3).

The climate of the Ganikh-Ayrichay valley is characterized by mild hot summers and dry winters. The Great Caucasus mountain range blocks the Ganikh-Ayrichay valley from the flow of cold air from the north, creating a mild subtropical climate type in its territory. As you go up the slope, the temperate-warm climate type is replaced by a cold climate. The graph of changes in the amount of atmospheric precipitation in recent years is given below.

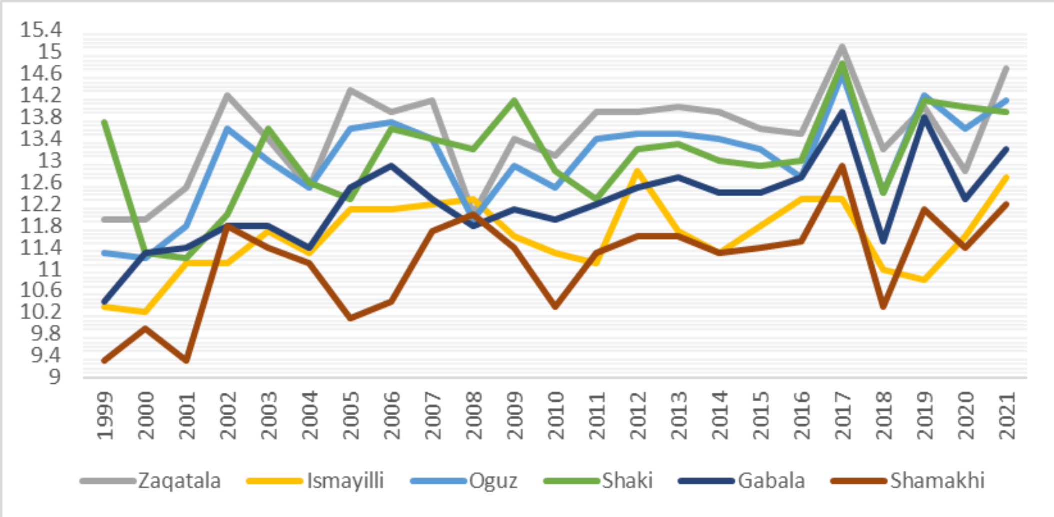

Fig. 3: *Scheme of perennial atmospheric precipitation in the Ganikh-Ayrichay valley*

Ground water horizon is formed as a single underground water horizon in the initial parts of the bearing cones. In the central parts of the bringing cones in the southern direction, the groundwater horizon is divided into several pressurized water horizons with clay and loam layers, as mentioned above. Since clay and clay layers do not have regional development, soil and pressurized water horizons form a single system with a single hydraulic connection.

Groundwater is widespread everywhere in the Ganikh-Ayrichay valley. An accurate description of the underground waters of the Ganikh-Ayrichay valley up to a depth of 300 m has been reflected in a number of research works. Groundwater in the areas where exploratory work is being conducted has been studied based on numerous well data. The depth of the groundwater is fully compatible with the morphological conditions of the area where it is spread. Thus, along the northern edges of the valley, in the upper parts of the flow cones of the rivers, the depth of groundwater is 70-100 m, and in the southern areas, at the foot of the flow cones and in the inter-cone sediments, it varies from a few cm to several meters.

The absolute height of the groundwater level decreases in the south and southwest direction from the foothills of the Greater Caucasus [4,5,6]. The level of non-pressurized water in the Ganikh-Ayrichay valley varies in the range of 0.8-5.9 meters (Fig. 4). According to the relief of the surface of the bearing cones and intercone depressions, the hydroisohypses of groundwater have a wavy shape. The underground water flow is in the south and south-west direction according to the slope of the relief. The slope of the ground water surface corresponds to the relief of the earth's surface and varies from 0.05 to 0.003. The thickness of the groundwater horizon varies from 4.6 m to 328.6 m (up to 400 m depth in the studied areas). The greatest thickness of the groundwater horizon is spread in the head parts of the bringing cones of the rivers.

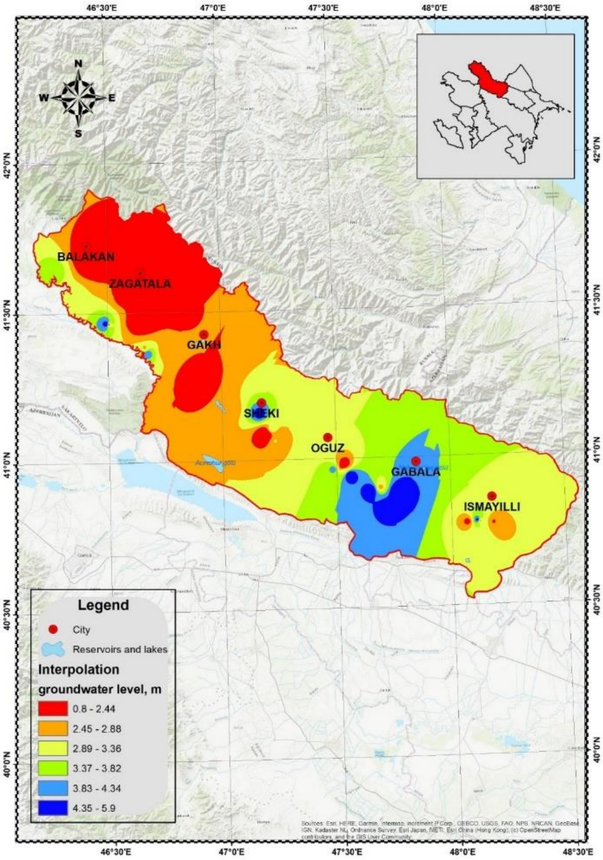

Fig. 4: *Groundwater level in the Ganikh-Ayrichay valley*

In the studied areas and in the parts connected with the foothills of the Greater Caucasus, the waters of the groundwater horizon come to the surface in the form of springs. The consumption of springs varies from 0.4 l/s to 300 l/s. The largest springs are located 2.5-3.0 km north of Mollali village of Oguz region. Here, the consumption of springs varies between 285-305 l/s. The most common consumption of springs varies between 10-40 l/s. The groundwater of the Ganikh-Ayrichay valley spreads along horizons with an absolute height of 380-400 m, coming out in the form of a spring at the foot of the cones of the rivers and in the depressions between the cones. The consumption of springs in these areas varies from 0.1-0.2 l/s to 20-30 l/s.

The spring of ground water to the surface of the earth is spread along horizons with an absolute height of 380-390 m in the areas where the southern edges of the Ganikh-Ayrichay valley meet with Acinohur. The consumption of the largest springs in these areas reaches 150 l/s. Among such springs, the "Girkhbulag" spring can be mentioned. This spring is located 3 km south of the village of Nich in the area where the northern foot of Acinohur elevation and the valley meet. The area of the spring is 1, 1.5 ha and it consists of many springs. The total consumption of those springs is up to 150 l/s. The consumption of other springs spread here varies from 10-20 l/s to 1-5 l/s. These springs combine to form the Karasu and Sarisu rivers.

Rocks in which groundwater is distributed have great water content. Consumption of wells detecting groundwater varies between 10÷15 - 45÷50 l/s. The specific consumption in wells varies between 0.6-6.6 l/s.m. The seepage coefficient of water retaining rocks varies between 1.4-31.51

m/day. The permeability of the groundwater horizon varies between 137-7620 m^2/day. The coefficient of level transfer in groundwater varies between 3.32x103 - 8.5x104 m^2/day.

The degree of mineralization of groundwater in the territory of the Ganikh-Ayrichay valley varies between 0.2-0.4 g/l and reaches 0.6 g/l in the southern parts of the valley. The type of chemical composition of groundwater is mainly hydrocarbonate-calcium.

The exact description of the chemical composition of groundwater and the degree of mineralization is given in the title "Characteristics of the quality of groundwater". Pressurized underground water is distributed in the area of the Ganikh-Ayrichay valley, starting from the zone where the groundwater comes to the surface in the form of a spring, and some areas to the north of it. In this zone, as mentioned above, groundwater and pressurized water create an aquifer that forms a single hydraulic system.

In the areas explored up to a depth of 350 m in the Ganikh-Ayrichay valley, water retaining layers consisting of several floors were discovered.

Pressurized water horizons are spread everywhere in the area, starting from the zone where groundwater appears in the form of a spring, to Acinohur in the south. The sedimentary rocks consist of cobbles, gravels, and occasional cobblestones and cobblestones. Fill rocks consist of sands, siltstones, and silts of various sizes. Pomegranate-grained sands dominate the granulometric composition of the filler rocks [10].

The depth of the ceilings of pressurized water horizons was revealed by means of wells at a depth of 4.0 m to 177 m (Tab 1., Fig.5.). In large parts of the studied areas, ceilings of pressurized water are spread at a depth of 30-40 m. Piezometric levels of pressurized water are located both below the ground surface (up to 71.0 m) and above the ground surface (+35 m). The slope of the surface of the piezometric level corresponds to the slope of the earth's surface. The slope varies from 0.05 to 0.0025.

The detected thicknesses of pressurized waters vary from 9.5 to 319 m. The layers that separate groundwater and pressurized water consist of clays or pebbles and pebbles with clay complement. According to the data of the wells dug during the earlier geological-exploratory works in the territory of the valley, the thickness of the separating layers ranges from 5-10 m to 45 m. However, as mentioned, these separating layers do not have regional development anywhere in the Ganikh-Ayrichay valley.

Most wells drilled for pressurized water are characterized by a large flow fountain. Depending on the lithological composition of the cut in the wells subjected to the mechanical suffosis process, as a result of the strong flow of sand, these wells fail due to subsidence in the area around the well.

The seepage coefficient of rocks in dry rocks ranges from 0.1-45.1 m/day to 70-80 m/day. Water permeability is 17-65 m^2/day in the foothill zone, 12500 m^2/day in the center of Agchay's intake cone, and 1663 m^2/day around the village of Sinjan. The transmission coefficient of the piezometric level varies between 3.9x104- 1.35x107 m^2/day. Pressurized groundwater is sweet everywhere, its mineralization rate is 0.1-0.6 g/l, and its chemical composition is calcium carbonate. The quality indicators of pressurized water are suitable for drinking and household purposes. This is also confirmed by the data of the exploratory well number 2Q dug in 1990-1992 in the north of Nic village. Quaternary sediments in the 0-940 m interval, Quaternary sediments in the 940-1028 m interval - Maykop sediments were discovered through the well.

III. Results

The influence of climate changes in the Ganikh-Ayrichay valley leads to the creation of very complex unique hydrometeorological conditions, including the occurrence of anomalous atmospheric events during the year. Studies conducted on the effects of climate change on the

Ganikh-Ayrichay valley show that the increase in air temperature and evaporation eventually leads to a decrease in water resources. As a result of the decrease in precipitation, water consumption in rivers may decrease or increase. For this, determining the balance of water resources, taking into account climate change, plays a major role.

Table 1: *Parameters of wells drilled into pressurized water horizons in the Ganikh-Ayrichay foothill plain*

No	Administrative region	The number of the well issued by the drilling organization or subsequently	The depth of the well, m	Water horizon			
				Type	Geological age	Lithological composition	heel depth, m
1	Ismailli	19/42	150	pressurized	Q_{I-II}	gravel, sand	150,0
2	Ismailli	19/45	150	pressurized	Q_{I-II}	gravel, sand	150,0
3	Ismailli	19/50	150	pressurized	Q_{I-II}	gravel, sand	150,0
4	Gakh	23/10	125	pressurized	Q_{III-IV}	gravel, sand	125,0
5	Gakh	23/E-11	100	pressurized	Q_{III-IV}	gravel, sand	100,0
6	Gakh	23/67	80	pressurized	Q_{IV}	gravel, sand	80,0
7	Gakh	23/74	70	pressurized	Q_{IV}	gravel, sand	70,0
8	Gakh	23/141	125	pressurized	Q_{III-IV}	gravel, sand	125,0
9	Gakh	KX-4	185	pressurized	Q_{III-IV}	gravel, sand	185,0
10	Gabala	20/B-8	120	pressurized	Q_{III-IV}	gravel, sand	120,0
11	Gabala	20/U-10	120	pressurized	Q_{III-IV}	gravel, sand	120,0
12	Gabala	20/49	120	pressurized	Q_{III-IV}	gravel, sand	120,0
13	Gabala	20/E-4	130	pressurized	Q_{III-IV}	gravel, sand	130,0
14	Oguz	21/43	150	pressurized	Q_{III-IV}	gravel, sand	150,0
15	Oguz	21/64	150	pressurized	Q_{II}	gravel, sand	150,0
16	Oguz	21/80	150	pressurized	Q_{II}	gravel, sand	150,0
17	Shaki	22/65	150	pressurized	Q_{III-IV}	gravel, sand	150,0
18	Shaki	22/71	150	pressurized	Q_{III-IV}	gravel, sand	150,0
19	Shaki	22/75	185	pressurized	Q_{III-IV}	gravel, sand	185,0
20	Shaki	22/153	150	pressurized	Q_{III-IV}	gravel, sand	150,0
21	Zagatala	24/193	60	pressurized	Q_{IV}	gravel, sand	60,0
22	Zagatala	24/213	60	pressurized	Q_{IV}	gravel, sand	60,0
23	Zagatala	24/158	110	pressurized	Q_{III-IV}	gravel, sand	110,0
24	Zagatala	24/201	140	pressurized	Q_{III-IV}	gravel, sand	140,0

As a way out of the problem, it is necessary to use water resources efficiently. After river waters, underground waters take the second place in terms of usage. For this reason, a unified groundwater management system should be created.

Global climate change will lead to disruption of the hydrological regime of water sources, mainly to changes in the quantity and quality of water resources. As a result of climate change, a sharp increase in the degree of water mineralization in the lower parts of the rivers will become inevitable.

Analysis of available meteorological data shows that various natural phenomena, including severe and persistent drought, may occur unexpectedly. In order to be ready for it, the gradual increase of existing water resources, the creation of water-saving, techniques and technologies, the development of new agrotechnical measures and the integrated management of water resources are one of the important conditions.

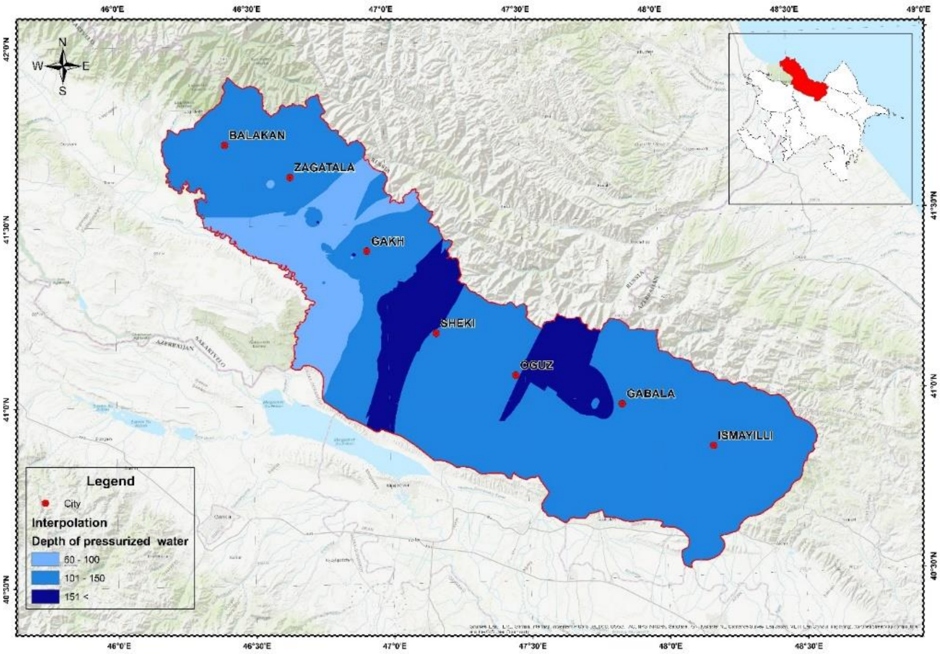

Fig. 5: *Depth map of pressure waters of Ganikh-Ayrichay valley*

References

[1] Bondarenko, L.V., Maslova, O.V., Belkina, A.V., Sukhareva, K.V. 2018. Global climate change and its aftermath. Herald of the Russian Economic University named after B. Plekhanova. 2, 84-93. https://doi.org/10.21686/2413-2829-2018-2-84-93

[2] Geology of Azerbaijan. 2008. Vol. VIII. Hydrogeology. Baku, Nafta-Press. 380 p.

[3] Israfilov, Yu.H, Israfilov, R.H., Guliyev, H.H., Efendiyev, G.M. 2016. Risk assessment of the water resources losses of the Azerbaijan republic due to climate changes. news of ANAS, Earth Sciences, № 3-4. 37-47.

[4] Taghiyev A.Sh. Climate change and water resources management. İnternational Scientific Cenference on Sustainable Development. Baku, 24-25 november, 2017. 55-61.

[5] Tagiev, I.I., Babaev, N.I. 2017. Some geochemical and hydrogeological, regularites of formation and distribution of mineralwaters of Azerbaijan. XXXIX International scientific-practical conference, Actual problems in modern science and ways of their solutions, Moscow, 15-19.

[6] Tagiev I.I. 2001. Status and problems of protection of the environment and nature use in the Republic of Azerbaijan, Ministry of Science and Technology of the USSR, Moscow.

[7] Tagiev, I.I., Kerimov, V.M. 2021. Prospects for the development of alternative energy and the use of thermal waters in Azerbaijan. Ural Geolog. Journal. 3 (141). 51-57.

[8] Tagiev I.I., Kerimov V.M., Sharifov J.J. Characteristics of the hydrogeological massifs of the Greater, Lesser Caucasus and Talysh (Azerbaijan) taking into account global climate change (in Russian), 2021, N 3 (94), 95-103. DOI:http://doi.org/10.17721/1728-2713.94.12

[9] Tagiyev I.I., Ismailova M.M., Karimov V.M., Sharifov J.J. Groundwater of Ganikh-Ayrichay foothills on the prospects of use Reliability: Theory and Applications, Special Issue № 3 (66) Volume 17, 2022, 113-118. DOI: https://doi.org/10.24412/1932-2321-2022-366-76-81

[10] Kerimov V.M., Sharifov, J.J., Mammadli, M.Z. 2021. Hydrogeological conditions of the Ganykh-Ayrichay valley. In the book: the development of science and practice in a globally changing world in terms of risks. Collection of materials of the IV International scientific-practical conference. Makhachkala. c. 71-76. DOİ: 10.34755/irok.2021.46.94.048

APPLICATION OF KANIADAKIS κ -STATISTICS TO EXTREME WIND SPEED LOAD DISTRIBUTIONS

Anna Bushinskaya[1,2] , Sviatoslav Timashev[1,2]

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[1] Science and Engineering Center "Reliability and Safety of Large Systems and Machines", Ural Branch, Russian Academy of Sciences, Russia
[2] Ural Federal University, Russia
bushinskaya@gmail.com
timashevs@gmail.com

Abstract

The article considers application of the Kaniadakis' κ-statistics [1-3] (non-extensive statistical mechanics) which introduced in 2001 in the framework of Einstein's special theory of relativity, to the analysis and adequate description of extreme wind loads. The κ-deformed Kaniadakis exponential function is used to introduce new classes of κ-deformed statistical versions of known distributions. These distributions coincide with the original ones with the exception that their κ-deformed tail follows the Pareto power law. This allows converting the original distributions into heavy-tailed distributions that more closely match the experimental data of mixed systems and systems operating under conditions of increased uncertainty. This allows, within the framework of known distributions of loads and impacts, to model above-standard stressors and analyze the near impossible to predict "Black Swan" and "Dragon-King" ultra-rare type of events with humongous consequences.

Keywords: Kaniadakis, κ-statistics, heavy-tailed distributions, black swan, dragon-king, wind speed**,** uncertainty.

I. Introduction

During the operation of a complex technical system, due to its complexity, no matter how carefully the calculations are carried out during its design, there always will be unforeseen impacts due to beyond- design (extreme) loads, which will eventually lead, at best, to its local damage. In this case, it is very important to know whether these damages will cause catastrophic destruction of the system as a whole or to its unsuitability for further operation. Such out-of-design or extreme loads and impacts fall on the tails of the so-called fat-tailed distributions. An example of such a distribution is shown in Fig.1.

The distribution shown in Fig. 1 is divided into two parts: central (solid thick line) and caudal (dashed thick line). Separation boundary K represents a threshold value determined by the specifics of the task. The central part represents the values at design loading (normal operation), the tail represents the beyond design values. The central part is usually described by standard distributions (exponential, Weibull, Rayleigh, lognormal, etc.), the caudal (tail) part is described by power-law or heavy-tailed distributions.

Below, we consider the application of Kaniadakis κ-statistics [1-3] to known distributions of loads and impacts, which makes it possible to simulate above-norm stressors in the tails of these distributions and analyze the consequences of beyond-design situations (including " Black Swan" and "Dragon-King" type disasters) . The use of κ -statistics makes it possible to obtain simple analytical closed-form expressions for all major statistical functions such as the probability density function, distribution function, survival function, quantile function, risk function, and cumulative risk function.

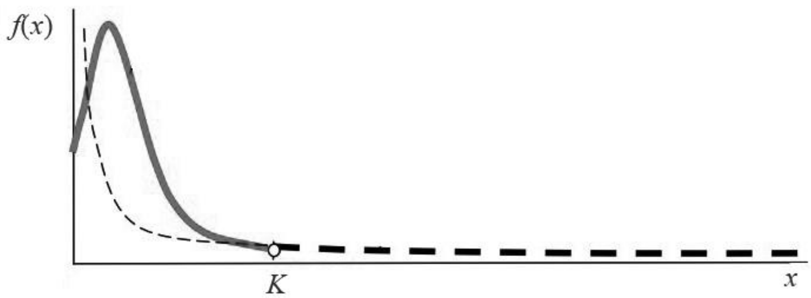

Figure 1: *Example of distribution of an impact, load or damage*

The analysis was made on the example of extreme wind speeds in the Arctic zone of the Russian Federation, obtained at various weather stations. Information about extremely high wind speeds is very important, since knowledge of the true distribution of wind loads is necessary when designing new and operating existing antennas and masts, bridges, wind turbines, high-rise buildings and other objects. This is especially true nowadays, when the extreme events frequency is observed to be constantly increasing [5].

The statistical theory of extremes is based on the idea that extreme identically distributed independent random variables obey one of the three probability distributions (Gumbel, Fréchet and Weibull) [6–8], and the Weibull law is successfully used to approximate the distribution of extreme wind speed. Another approach to studying extreme values is by approximating only the tail of the distribution. For this, the so-called Pareto distribution is used, to which the probabilities of events whose intensity (amplitude) exceeds a certain threshold value [6-8] are subjected. The question of how to assign / determine the point *K* is not disclosed in this article. This is a separate task, determined by the specifics of the problem under consideration.

The initial data for the analysis are taken from the works [6-8], devoted to the study of anomalous features of the wind regime. The study region includes the coastal zone of the Arctic (from the Kola Peninsula to the Chukchi Peninsula), as well as some inland areas (in total, data from more than 30 meteorological stations was used in the analysis). Standard station wind speed measurements at a height of 10 m, averaged over 10 minutes were used. The analyzed data is for the period of 1966–2013.

According to [6-8] one of the basic principles underlying the theory of extreme random processes is violated - the requirement that all sample data belong to the same set. It is shown that the analyzed sample data includes representatives of two different distributions, each of which is approximated by its own Weibull function. This is a situation where representatives of fundamentally different distributions occur among identical (by nomenclature) quantities. The main array of “intermediate” extremes is called “White Swans”, and the appearance of the largest and rarest phenomena in this sample is called “Black Swans” [9]. It should be noted that objects belonging to the same distribution have a similar genesis, i.e. large anomalies differ from their "smaller relatives" only in amplitude or degree of impact. Events that belong to a different distribution have a different genesis and characterize fundamentally different objects, called "Dragons" or "Dragons-Kings" [10].

II. Mathematical description of κ -statistics

Consider a random value (RV) X with probability density function (PDF) $f(x)$. In statistical mechanics, the general equation for the rate of change of f (t) is a first-order linear ordinary differential equation (ODE):

$$\frac{df(x)}{dx} = -r(x)f(x), \tag{1}$$

where the function $r(x)$ is the decay rate. The solution to this ODE is exponential

$$f(t) = c\exp\left(-\int_{x_0}^{x} r(t)dt\right), \tag{2}$$

with the standard normalization condition defining the constant c:

$$\int_{x_0}^{x} f(t)dt = 1 \tag{3}$$

As an exponential decision, consider three simple cases.

1. *Exponential model* for constant decay rate, ie

$$r(x) = \lambda, \tag{4}$$

which from Equ. (1) leads to the exponential PDF

$$f(x) = \lambda e^{-\lambda t}. \tag{5}$$

2. *Pareto distribution* type I. The PDF of the Pareto distribution is obtained from Eq. (1) with a decay rate function equal to

$$r(x) = \frac{p}{x}, \ \ p > 1, \tag{6}$$

with PDF in this case :

$$f(x) = \frac{p-1}{x_0}\left(\frac{x_0}{x}\right)^p, \ p > 1, \ x \in (x_0, +\infty), \ x_0 > 0. \tag{7}$$

3. *The κ-exponential model* [10-13]. has proven useful in many applications. According to [1-4], experimental data indicate that the PDFs should resemble an exponential function for $x \to 0$. However, as $x \to 0$, the Pareto PDF diverges. On the other hand, for high values of x, many experimental results show a Pareto – like PDF with power-law tails instead of tails with exponential decay. Therefore, as $x \to 0$ it follows that $r(x) \sim \lambda$, and as $x \to +\infty$ it follows that $r(x) \sim p/x$. Thus, the actual decay rate function $r(x)$ should smoothly interpolate between these two modes. A good suggestion for $r(x)$ was introduced in the context of special relativity where the function $r(x)$ is given via the Lorentz factor

$$\gamma_\kappa(q) = \sqrt{1+\kappa^2 q^2}. \tag{8}$$

This expression includes the dimensionless momentum q, where the parameter κ is the reciprocal of the dimensionless speed of light c, i.e. $\kappa \propto 1/c$. Then, taking

$$r(x) = \frac{\lambda}{\sqrt{1+\kappa^2\lambda^2x^2}}, \tag{9}$$

we get for $x \to 0$, the decay rate $r(x)$ corresponds to an exponential distribution, i.e $r(x) \sim \lambda$, and as $x \to +\infty$ corresponds to the Pareto distribution, i.e $r(x) \sim 1/\kappa x$.

The solution of ODE (1) leads to the following PDF:

$$f(x) = \lambda\left(1-\kappa^2\right)\exp_\kappa(-\lambda x), \tag{10}$$

where κ is the deformed exponential function given by

$$\exp_\kappa(x) = \left(\sqrt{1+\kappa^2 x^2} + \kappa x\right)^{1/\kappa}. \tag{11}$$

for $0 < \kappa < 1$.

It is important to note that as $k \to 0$ and as $x \to 0$, the function $\exp_\kappa(x)$ tends to the usual exponent, i.e.

$$\begin{aligned} &\exp_\kappa(x) \underset{\kappa\to 0}{\sim} \exp(x), \\ &\exp_\kappa(x) \underset{x\to 0}{\sim} \exp(x). \end{aligned} \tag{12}$$

On the other hand, the function $\exp_\kappa(-x)$ as $x \to +\infty$ is a power tail, i.e.,

$$\exp_\kappa(-x) \underset{t\to +\infty}{\sim} (2\kappa x)^{-1/\kappa}. \tag{13}$$

In addition, the κ-exponential satisfies the following identity

$$\exp_\kappa(x)\exp_\kappa(-x) = 1. \tag{14}$$

by analogy with the standard, undeformed exponential.

The κ-exponent is a very powerful tool that can be used to formulate a generalized statistical theory capable of considering systems described by distribution functions that have power tails.

Consider the application of the Kaniadakis κ-statistic to the Weibull distribution. According to [4], the κ-deformed Weibull cumulative distribution function:

$$F_\kappa(x) = 1 - \exp_\kappa\left(-(x/\tau)^\alpha\right), x \ge 0, \ \alpha, \tau, \kappa > 0, \tag{15}$$

where α is the shape parameter, τ is the scale parameter .

Another parameterization of the Weibull distribution is often used. The shape parameter α remains the same, but the scale parameter is replaced with $\beta = \tau^{-\alpha}$. Then

$$F_\kappa(x) = 1 - \exp_\kappa\left(-\beta x^\alpha\right), x \ge 0, \ \alpha, \beta > 0, \ 0 \le \kappa < 1. \tag{16}$$

It is easy to obtain the κ-deformed Weibull PDF :

$$f_\kappa(x) = \frac{dF_\kappa(x)}{dx} = \frac{e_\kappa\left(-\beta t^\alpha\right)\alpha\beta\kappa x^{\alpha-1}\left(1 - \dfrac{\beta\kappa x^\alpha}{\sqrt{1+\kappa^2\beta^2 x^{2\alpha}}}\right)}{\kappa\beta\kappa x^\alpha\left(\dfrac{\sqrt{1+\kappa^2\beta^2 x^{2\alpha}}}{\beta\kappa x^\alpha} - 1\right)}. \tag{17}$$

Introducing a substitution $y = \dfrac{\alpha\beta^2\kappa^2 x^{2\alpha-1}}{\sqrt{1+\kappa^2\beta^2 x^{2\alpha}}}$, yields

$$\begin{aligned} f_\kappa(x) &= \frac{e_\kappa\left(-\beta x^\alpha\right)\alpha\beta\kappa x^{\alpha-1}(1-y)}{\kappa\beta\kappa x^\alpha\left(\dfrac{1-y}{y}\right)} = \frac{e_\kappa\left(-\beta x^\alpha\right)\alpha\beta\kappa x^{\alpha-1} y}{\kappa\beta\kappa x^\alpha} = \\ &= \frac{e_\kappa\left(-\beta x^\alpha\right)\alpha\beta x^{\alpha-1}}{\sqrt{1+\kappa^2\beta^2 x^{2\alpha}}} = \frac{\alpha}{\tau}\frac{(x/\tau)^{\alpha-1} e_\kappa\left(-(x/\tau)^\alpha\right)}{\sqrt{1+\kappa^2 (x/\tau)^{2\alpha}}}. \end{aligned} \tag{18}$$

The shape parameter (index of power) α quantitatively characterizes the shape of the distribution, which is less (more) pronounced at smaller (larger) values of the parameter. The parameter τ is a scale parameter: if τ is small, then the distribution will be *more concentrated* around the mode; if τ is large, the distribution will be less concentrated and more scattered. Finally, the parameter κ characterizes and measures the heaviness of the right tail: the larger (smaller) its value, the thicker (thinner) the tail. As κ → 0, the distribution tends to the standard

Weibull distribution. It can be easily verified [4]

$$\lim_{\kappa\to 0} f_\kappa(x,\alpha,\tau,\kappa)=\frac{\alpha}{\tau}\left(\frac{x}{\tau}\right)^{\alpha-1}\exp\left(-(x/\tau)^\alpha\right),$$
$$\lim_{\kappa\to 0} F_\kappa(x,\alpha,\tau,\kappa)=1-\exp\left(-(x/\tau)^\alpha\right). \tag{19}$$

Since the exponential distribution is a special case of Weibull PDF with a shape parameter equal to 1, then as κ → 0 and α = 1, the κ-deformed functions tend to the exponential law. For $x \to 0+$, the distribution behaves similarly to the standard Weibull model, while for large values of x it approaches a Pareto distribution with a scale parameter $\tau(2\kappa)^{-\frac{1}{\alpha}}$ and a shape parameter $\frac{\alpha}{\kappa}$, i.e.,

$$\lim_{x\to +\infty} f_\kappa(x,\alpha,\tau,\kappa)=\frac{\frac{\alpha}{\kappa}\left(\tau(2\kappa)^{-\frac{1}{\alpha}}\right)^{\frac{\alpha}{\kappa}}}{x^{\frac{\alpha}{\kappa}+1}},$$
$$\lim_{x\to +\infty} F_\kappa(x,\alpha,\tau,\kappa)=1-\left(\frac{\tau(2\kappa)^{-\frac{1}{\alpha}}}{x}\right)^{\frac{\alpha}{\kappa}}. \tag{20}$$

From Eq. (15) one can find the quantile function (inverse distribution function) and the survival (reliability) function [4]:

$$F_\kappa^{-1}(p,\alpha,\tau,\kappa)=\tau\left(\ln_\kappa\frac{1}{1-p}\right)^{1/\alpha}=\beta^{-\frac{1}{\alpha}}\left(\ln_\kappa\frac{1}{1-p}\right)^{1/\alpha},\ 0<p<1,$$
$$S_\kappa(x,\alpha,\tau,\kappa)=\exp_\kappa\left(-(x/\tau)^\alpha\right)=\exp_\kappa\left(-\beta x^\alpha\right), \tag{21}$$

where the κ-logarithm of $\ln_\kappa(u)$ is the inverse of $\exp_\kappa(u)$, i.e. $\ln_\kappa(\exp_\kappa(x)) = \exp_\kappa(\ln_\kappa(x)) = x$, and is determined by the formula

$$\ln_\kappa(x)=\frac{x^\kappa-x^{-\kappa}}{2\kappa}.$$

The median of κ-deformed Weibull distribution

$$x_{med,\kappa}=\tau\left[\ln_\kappa(2)\right]^{\frac{1}{\alpha}}=\beta^{-\frac{1}{\alpha}}\left[\ln_\kappa(2)\right]^{\frac{1}{\alpha}}. \tag{22}$$

The mode $x_{\mathrm{mode},\kappa}$ of PDF can be obtained analytically as a function of the parameters α, β and κ. If $x_{\mathrm{mode},\kappa}$ is the point of PDF maximum, then by equating the derivative of the PDF to zero, we can find $x_{\mathrm{mode},\kappa}$ [4]:

$$x_{\mathrm{mode},\kappa}=\tau\left[\frac{\alpha^2+2\kappa^2(\alpha-1)}{2\kappa^2(\alpha^2-\kappa^2)}\left(\sqrt{1+\frac{4\kappa^2(\alpha^2-\kappa^2)(\alpha-1)^2}{\left[\alpha^2+2\kappa^2(\alpha-1)\right]^2}}+1\right)\right]^{\frac{1}{2\alpha}}. \tag{23}$$

According to [4], the moments of κ-deformed Weibull distribution can be calculated using the formula:

$$a_{r,\kappa}=\frac{\tau^r}{(2\kappa)^{\frac{r}{\alpha}}}\frac{\Gamma\left(1+\frac{r}{\alpha}\right)}{1+r\frac{\kappa}{\alpha}}\frac{\Gamma\left(\frac{1}{2\kappa}-\frac{r}{2\alpha}\right)}{\Gamma\left(\frac{1}{2\kappa}+\frac{r}{2\alpha}\right)}. \tag{24}$$

Where, in particular, the mean, variance and coefficient of variation:

$$M_\kappa[X] = \frac{\tau}{(2\kappa)^{\frac{1}{\alpha}}} \frac{\Gamma\left(1+\frac{1}{\alpha}\right)}{1+\frac{\kappa}{\alpha}} \frac{\Gamma\left(\frac{1}{2\kappa}-\frac{1}{2\alpha}\right)}{\Gamma\left(\frac{1}{2\kappa}+\frac{1}{2\alpha}\right)},$$

$$D_\kappa[X] = \frac{\tau^2}{(2\kappa)^{\frac{2}{\alpha}}} \frac{\Gamma\left(1+\frac{2}{\alpha}\right)}{1+2\frac{\kappa}{\alpha}} \frac{\Gamma\left(\frac{1}{2\kappa}-\frac{1}{\alpha}\right)}{\Gamma\left(\frac{1}{2\kappa}+\frac{1}{\alpha}\right)} - M_\kappa^2[X],$$

$$V_\kappa[X] = \sqrt{\frac{a_{2,\kappa}}{a_{1,\kappa}^2}-1} = \sqrt{\frac{\frac{\Gamma\left(1+\frac{2}{\alpha}\right)}{1+2\frac{\kappa}{\alpha}} \frac{\Gamma\left(\frac{1}{2\kappa}-\frac{1}{\alpha}\right)}{\Gamma\left(\frac{1}{2\kappa}+\frac{1}{\alpha}\right)}}{\left(\frac{\Gamma\left(1+\frac{1}{\alpha}\right)}{1+\frac{\kappa}{\alpha}} \frac{\Gamma\left(\frac{1}{2\kappa}-\frac{1}{2\alpha}\right)}{\Gamma\left(\frac{1}{2\kappa}+\frac{1}{2\alpha}\right)}\right)^2}-1}. \tag{25}$$

Denote

$$C_r = \frac{(2\kappa)^{-\frac{r}{\alpha}}}{1+r\frac{\kappa}{\alpha}} \frac{\Gamma\left(\frac{1}{2\kappa}-\frac{r}{2\alpha}\right)}{\Gamma\left(\frac{1}{2\kappa}+\frac{r}{2\alpha}\right)}. \tag{26}$$

Then the connection between the moments of the κ-deformed $a_{r,\kappa}$ and standard $a_r = \tau^r \Gamma\left(1+\frac{r}{\alpha}\right)$ Weibull distribution is given by:

$$a_{r,\kappa} = a_r C_r\,. \tag{27}$$

Now it is not difficult to obtain expressions relating the main numerical characteristics of the standard and κ-deformed Weibull distributions

$$\begin{aligned} &M_\kappa[X] = M[X]C_1, \\ &D_\kappa[X] = a_2C_2 - M^2[X]C_1^2 = D[X]C_2 + M^2[X]\left(C_2 + C_1^2\right), \\ &V_\kappa^2[X]+1 = \frac{a_{2,\kappa}}{a_{1,\kappa}^2} = \frac{a_2C_2}{a_1^2C_1^2} = \left(V^2[X]+1\right)\frac{C_2}{C_1^2}. \end{aligned} \tag{28}$$

III. Applications of κ -statistics to the analysis of extreme wind speeds

The analysis of extreme values of wind speeds was carried out separately for the cold and warm seasons, which in the Arctic are characterized not only by sharply contrasting temperatures, but also by features of the atmospheric circulation. The summer months here are, in fact, July and August, while the winter season covers not only December, January and February, but usually includes November, March and April as well.

To approximate the distribution function of the frequency of wind speeds, we used the Weibull law, which has the distribution function [6, 7]

$$\frac{n}{N} \approx F_\kappa(u) = 1-\exp\left(-\beta u^\alpha\right), u \ge 0,\ \alpha,\beta > 0,$$

where u is the wind speed module, n / N characterizes the accumulated frequency.

This expression can be transformed

$$ln\left[-ln(N-n)/N\right] = \ln u\,.$$

It follows that in special coordinates $\{ln\left[-ln\left(N-n\right)/N\right],\ \ln u\}$ the Weibull probability distribution is represented by a straight line. The degree of deviation of empirical points from it characterizes, together with known statistical criteria, the applicability of the theoretical distribution law.

Consider examples of the empirical distribution of the frequency of wind speeds (Fig. 2) [6]. It can be seen from Fig. 2 that the set of empirical points has a rectilinear section, however, when moving to especially large values, the regression line bends down. *This feature turned out to be typical for the data of all considered meteorological stations* [6]. In this case, the selection of a general linear dependence by the least squares' method is possible since most of the points fill the "linear" section. However, such an approximation will not satisfactorily describe the largest values of wind speed (located in the tail of the distribution) and as a result, *their probability will be significantly underestimated*. It was assumed that the sample included representatives of two different distributions, and each of them (since this is the case of extreme values) can be approximated by the Weibull law.

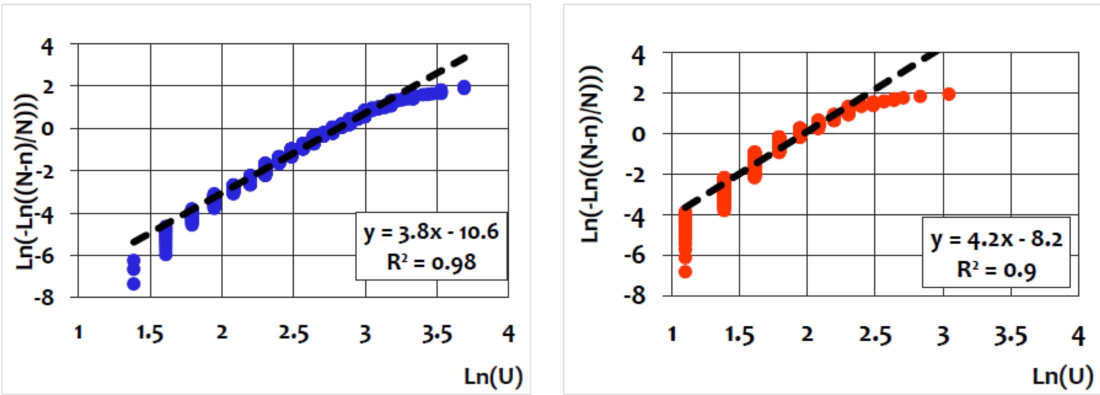

Figure 2: *Empirical distributions of extreme wind speeds (1966 - 2013) according to measurements at Teriberka station (left) in cold periods and at Okunev Nose station (right) in warm periods of the year, plotted in the coordinates of the Weibull probability distribution*

Thus, the selection of two independent straight lines (Weibull distributions) has been carried out. This situation is shown as an example in Fig. 3 [6] for two stations and different seasons.

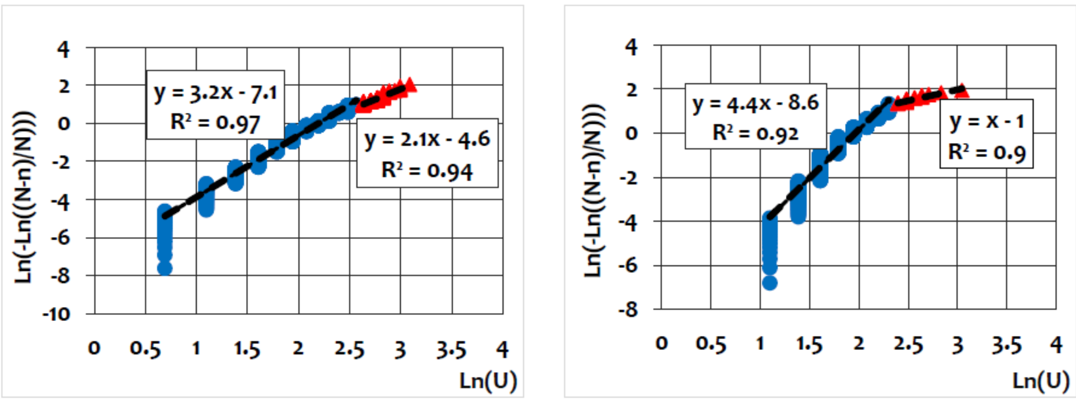

Figure 3: *Empirical distributions of extreme wind speeds of the year (1966 - 2013) according to measurements at Lovozero (left) stations during cold periods and Okunev Nose (right) during warm periods, constructed in the coordinates of the Weibull probability distribution, where the line segments correspond to two different laws of distribution.*

Each group of points with values greater than ($u > U_{th}$) and less than ($u < U_{th}$) is well approximated by its straight line in a special coordinate system, showing that the set of extremes is formed from values belonging to *different* general populations.

The obtained parameters of the Weibull distribution for the data of the three stations considered above are presented in Table 1 [7]. For the data of each station for the summer and winter periods, the parameters of two Weibull distributions were determined, describing: the main wind speeds distribution ("white and black swans" - "WS and BS") and the distribution of large (tail) values ("dragons" - "DR").

Table 1: *Weibull distribution parameters calculated for the period 1966–2013, separately for two groups of extremes corresponding to two families of distributions "WS and BS" and "DR" (for different periods and speeds, in m/s)*

Station	Family membership	winter period		Summer period	
		Parameter α	Parameter β	Parameter α	Parameter β
Teriberka	WS and BS	3.97	$1.6 \cdot 10^{-5}$	4.39	$3.1 \cdot 10^{-5}$
	DR	1.77	0.012	2.12	0.0081
Okunev Nose	WS and BS	3.40	0.0017	4.40	0.0002
	DR	0.52	1.1722	0.98	0.3816
Lovozero	WS and BS	3.19	0.0013	4.45	0.0003
	DR	1.69	0.0429	2.30	0.0202

The PDFs of the obtained distributions are shown in Figs. 4-6. Thus, in order to adequately describe the extremes of wind speed with one distribution, it is necessary to combine the PDFs as follows: before the intersection point of the PDF, the main distribution family is used ("WS and BS" - solid line), after the intersection point, the distribution of large (tail) values ("DR " - dotted line).

We modify the main distribution ("WS and BS") so that its tail part adequately describes large values of extreme wind speed. To do this, we construct a κ-deformed Weibull PDF, for which we choose the parameter κ so that the right tail corresponds to the tail of the "dragons" distribution. The results obtained are presented in Figs. 7-9.

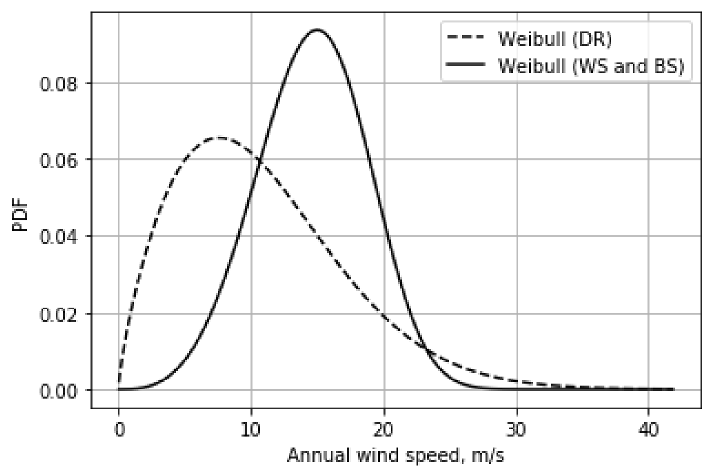

Figure 4: *PDF of extreme wind speeds (1966 - 2013) according to measurements at Teriberka station in winter, corresponding to two families of distributions "WS and BS" and "DR"*

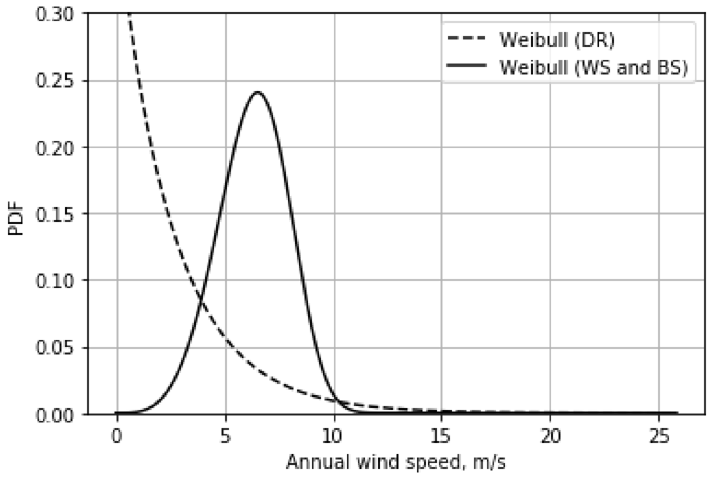

Figure 5: *PDF of extreme wind speeds (1966 - 2013) according to measurements at Okunev Nose station in summer, corresponding to two families of distributions "WS and BS" and "DR"*

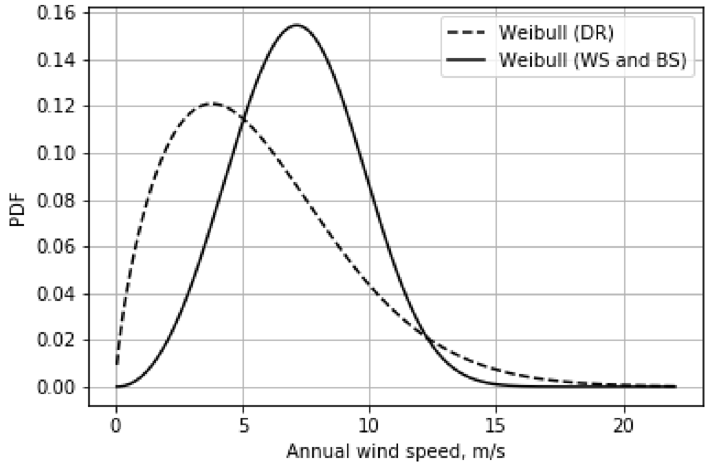

Figure 6: *PDF of extreme wind speeds (1966 - 2013) according to measurements at Lovozero station in winter, corresponding to two families of distributions "WS and BS" and "DR"*

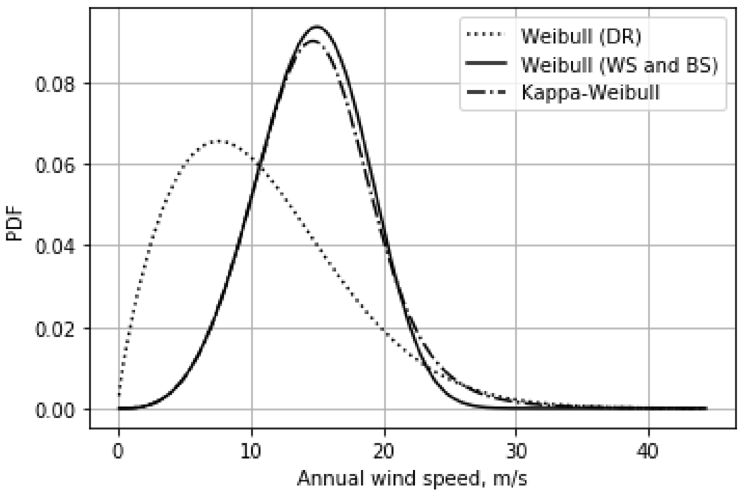

Figure 7: *PDF of extreme wind speeds according to measurements at Teriberka station (winter period) corresponding to three families of Weibull distributions: "WS and BS", "DR" and κ –deformed.*

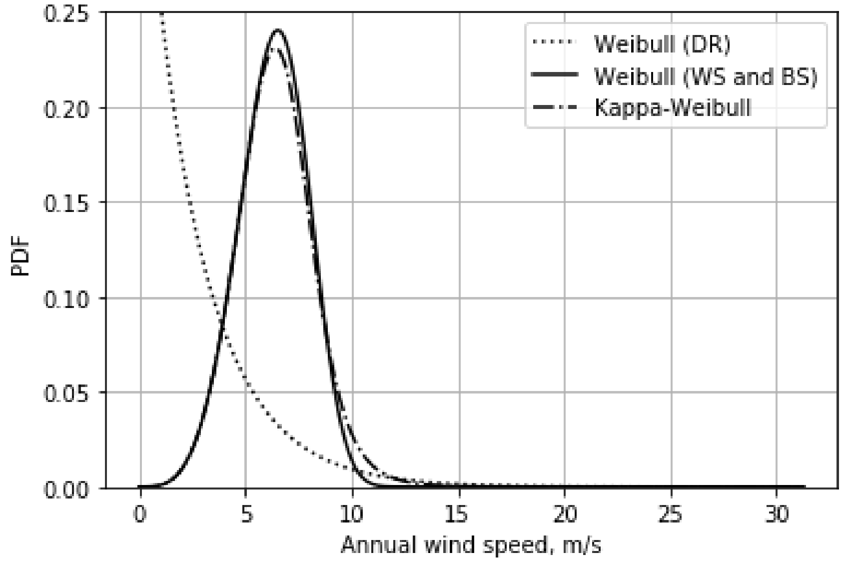

Figure 8: *PDF of extreme wind speeds according to measurements at Okunev Nose station (summer period) corresponding to three families of Weibull distributions: "WS and BS", "DR" and κ-deformed*

From Fig. 7-9 it can be seen that the κ-deformed distribution ("dot-dash" line) adequately describes not only the main distribution ("WS and BS" - solid line), but also almost completely coincides with the distribution of "dragons" - large (tail) extreme values (dotted line). Thus, κ-statistics allows describing data in which representatives of two different distributions are mixed with a *single κ-deformed distribution.*

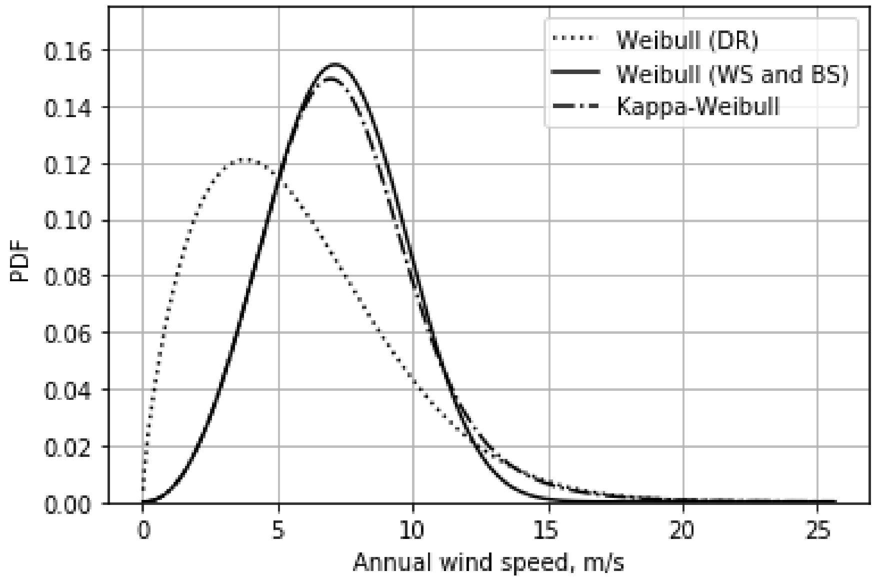

Figure 9: *PDF of extreme wind speeds according to measurements at Lovozero station (winter period) corresponding to three families of Weibull distributions: "WS and BS", "DR" and κ-deformed*

The processing of data from all weather stations showed similar results, which convincingly demonstrate the success of applying *κ-statistics* to the analysis of wind speed extremes, which consist of a mixture of values belonging to different general populations.

In [7], to characterize the geography of extremes and compare summer and winter conditions, quantile speed values were constructed using the formula:

$$U(p) = ln\left[\frac{1}{\beta} ln \frac{1}{1-p}\right]^{\frac{1}{\alpha}},$$

where p is the probability value and $U(p)$ is the corresponding quantile value of the wind speed.

The *p value* is expressed in terms of the "return time", which characterizes the time interval after which the same (or larger) speed anomalies reappear: $T = 1/(1- p)$. For the analysis of extremes, the value $p = 0.99$ was used. For the summer period (62 days - July and August), the total sample size for 48 years (1966–2013), subject to sieving every 3 days, is ~974 days. The share of events (1 – 0.99 = 0.01) is approximately 10 days. For 48 years, this corresponds to the situation of the appearance of an extreme $U(0.99)$ once in 5 warm seasons. For the cold season, $p = 0.99$ corresponds to the average time of extreme value $U(0.99)$ appearance once in two cold periods of the year. The values calculated from the station data (separately for "WS and BS" and "DR" and for the winter period) are presented in Table 2. The values calculated from the κ-deformed distribution are also presented (see formula (21)).

Table 2: *Quantile values of extreme wind speeds (winter period), m/s, U (0.99), calculated separately for three distribution families: "WS and BS", "DR" and κ-deformed*

Station	Distribution family		
	WS and BS	DR	κ-deformed
Teriberka	24	29	28.98
Lovozero	13	16	1 5.81

As can be seen from Table 2, the same quantile values are significantly larger (by 10–30%) in the distribution of "Dragons" than those of "Swans". Moreover, the values of the κ-deformed distribution *almost coincide* with the values of the "Dragons".

IV. Conclusion

The study of wind speed extremes based on standard observations in the coastal regions of the Russian Arctic shows that they represent two sets of data with different statistical properties, each of them obeying its own Weibull law. The κ-statistical approach presented in this paper made it possible to construct a κ-deformed Weibull distribution that adequately describes both sets of extreme wind speed data with different statistical characteristics.

It stands to reason to claim that the developed above approach is applicable to any other type of meteorological loads and impacts.

References

[1] Kaniadakis, G. Statistical mechanics in the context of special relativity. Phys. Rev. E 66, 17 (2002).

[2] Kaniadakis, G. Maximum entropy principle and power-law tailed distributions. Eur. Phys. J. B 70, 3–13 (2009).

[3] Kaniadakis, G., Scarfone, AM, Sparavigna, A. & Wada, T. Composition law of kappa-entropy for statistically independent systems. Phys. Rev. E 95, 052112 (2017).

[4] Clementi, F.; Gallegati, M.; Kaniadakis, G. A model of personal income distribution with application to Italian data. Empirical economics. 2011, 39, 559–591.

[5] The second assessment report of RosHydromet on climate change and its consequences on the territory of the Russian Federation. General summary. M., 2014. 58 p.

[6] Kislov A.V., Matveeva T.A. Wind speed extremes in the European sector of the Arctic // Meteorology and Hydrology. 2016. No 7. P. 5–14.

[7] Kislov A.V., Matveeva T.V., Platonov V.S. 2016. General description of the variability of hazardous weather phenomena in the Arctic. - In the book: "Changing climate and the socio-economic potential of the Russian Arctic", vol. 2. - Moscow, Liga-Vent, pp. 10–45.

[8] Kislov A.V., Matveeva T.A., Platonov V.S. 2015. Wind speed extremes in the Arctic. - Fundamental and Applied Climatology, No. 2, p. 63-80.

[9] Taleb NN The black swan: The impact of the highly improbable fragility. – Random House, 2010, vol. 2.

[10] Sornette D. Dragon-Kings, Black Swans and the prediction of crises // International Journal of Terraspace Science and Engineering, 2009, no. 2 (1), pp. 1-18. 7.

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EVALUATION OF THERMAL ENERGY PRODUCTION BY SOLAR PANELS FOR KARABAKH "GREEN" ENERGY ZONE

Nurmammad Mammadov[1], Samira Akbarova[1], Vagif Rustamov[2]

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[1]Azerbaijan University of Architecture and Construction
nurmammadov@mail.ru
samira.akbarova@azmiu.edu.az
[2]Ganja State University, Azerbaijan
info@gdu.edu.az

Abstract

The global "green" energy trend is also rapidly developing in Azerbaijan, although the country's economy is still mainly dependent on oil and gas production. Analysis of the prospects for the efficient use of renewable energy sources is a topical issue in terms of the implementation of the decree on the transformation of the Karabakh zone of Azerbaijan into a "green" energy zone. The article examines the prospects of applying solar vacuum tube panels for the climatic parameters of the Gubadli region of Karabakh. The thermal energy production capacity of the solar panels was evaluated by the "Helios-house" program. The results show that the number of Hevelius SCM-12 180-58 panels placed in the area of 50m² in Gubadli region should be 12 with the efficiency 70%, the heat loss coefficient of vacuum tubes is 0.5W/m², the average amount of thermal energy received by solar radiation is 1625 kW/m² and the total thermal energy production is 14938 kWhr/year. The proposed evaluation methodology can be applied to any region of Azerbaijan.

Keywords: Karabakh, "green" energy zone, solar panels, renewable energy sources, thermal energy

I. Introduction

The depletion of hydrocarbon resources and their negative impact on the environment has raised the need for renewable energy consumption in Azerbaijan, as well as around the world [11]. The country already has a positive experience in this area and uses solar, wind, and other environmentally friendly energy sources. The global "green" energy trend is also rapidly developing in Azerbaijan, although the country's economy is still mainly dependent on oil and gas production [10]. Azerbaijan has great potential in the field of renewable energy use. Azerbaijan sees its future energy supply policy as focusing on the consumption of "'green" energy. Azerbaijan, one of the world's leading countries in the development of oil and natural gas production, has set a goal to increase energy consumption from renewable energy sources to 50% by 2050. "Green" energy potential in megawatts for Azerbaijan is:

-solar energy - 5000, which has the most part of the total potential of renewable energy sources;

-wind energy - 4500, which is in the second place by the amount and using perspectives;

-biomass - 1500;

-geothermal energy- 800;

-energy potential of small rivers- 350.

Currently, special attention is paid to energy supply development projects in the liberated territories. Karabakh region has a huge potential for renewable energy sources. From 2021, the development of "green" energy zone projects in the liberated territories of Karabakh has begun. As the President of Azerbaijan Ilham Aliyev has repeatedly stated: "Karabakh region, as a "green" energy zone, must be exemplary for the whole world. The "green" energy comes from solar, wind, water, etc. with efficient and economically rational technologies". According to preliminary estimations, Karabakh areas have a potential of more than 4,500 megawatts of solar energy and up to 550 megawatts of wind energy [1].Wind energy production will also be developed in Kalbajar and Lachin regions. In the mountainous parts of these regions, the average annual wind speed reaches 7-8 m/sec. Wind plants producing wind energy will be used here. The Karabakh region is also rich by water resources, which is a favorable factor for the development of hydropower. 25% of Azerbaijan's local water resources are formed in Karabakh. It is expedient to build power plants on rivers such as Khakari, Bazarchay, Tartar and their tributaries [8]. Hot water projects are being developed in the near future: 3,000 m^3/day in Kalbajar and 400 m^3/day in Shusha.

Eight regions with high potential for solar energy have been selected in this Karabakh zone, as Kalbajar, Lachin, Gubadli, Zangilan, Jabrayil and Fizuli, which are considered the most favorable in terms of construction of solar power plants. The article examines the prospects of applying solar vacuum tube panels (SVTP) for the climatic parameters of the Gubadli region of Karabakh. The thermal energy production capacity of the solar panels was evaluated by the "Helios-house" program.

II. Using solar energy

Solar energy is used to generate both electricity and hot water. The types of using solar energy may be active and passive [9]. Passive solar use is applying some architectural solutions for optimization to gain solar energy: building shape, orientation, geographical location, shading, etc. Active solar use is applying some technologies: panels, turbines, pump stations, pressure regulators, and so forth. Figure 1 shows examples of active solar energy use- SVTP and photovoltaic panels [5].

a-  b- 

Figure 1: *Solar installations: a- solar vacuum tube panels, b- photovoltaic panels*

Hot water production by using solar technology is the most widely used method. Different types of solar panels are applied for this purpose. The simplest and cheapest way to use solar energy is to heat household water with SVTPs [6], [7], [2]. Unlike solar photovoltaic panels with an efficiency of 15-25%, SVTPs have an efficiency of up to 90%. They can successfully cope with receiving hot water in buildings at any temperature in spring, summer and autumn. In wintertime, additional heating sources are usually required to heat the building [12]. Therefore, solar water heaters are usually designed to operate in the spring-summer-autumn period and are used in addition to the main system in the winter. The solar hot water system consists of a solar panel, pump group, control devices, water storage tank, connecting elements and fittings, and expansion tank (Figure 2). It should be noted that solar heating is combined with traditional heating systems. [13] The evaluation of solar vacuum tube panels used for the production of hot water can be carried out through the program Helios-house.

a- b-

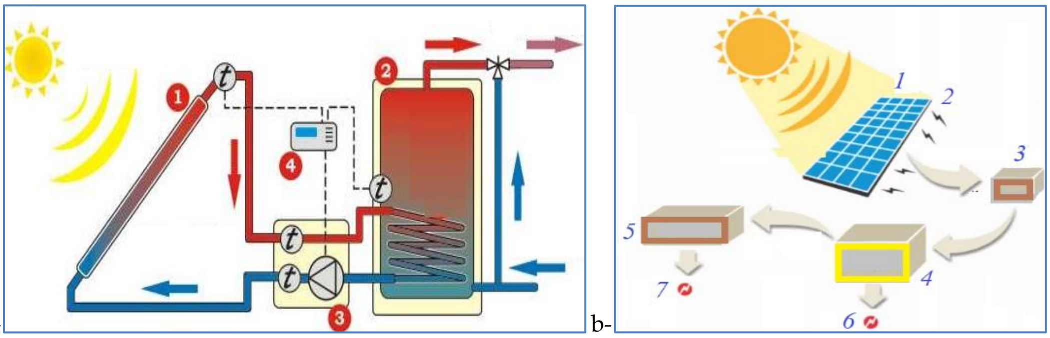

Figure 2: *Types of solar installations and their major component parts [14]:*
a- vacuum tube panels - for hot water production, 1-panel, 2- heat exchanger, 3- pump group, 4- controller;
b- photovoltaic panel for production electricity, 1-panel, 2-power supply, 3-controller, 4- rechargeable battery,
5- inverter, 6- direct current, 7- alternating current

SVTP is equipment for direct conversion of solar energy into thermal energy for hot water supply and space heating. It collects the thermal energy of the Sun carried by visible light and infrared radiation. Unlike photovoltaic panels (photocells) that produce electricity directly, SVTP heats the heat-carried medium directly. Modern domestic SVTPs are able to heat water up to the boiling temperature even at negative ambient air temperatures [15].

A SVTP cannot be 100% efficient, as it has inevitable losses in the conversion of thermal energy, as well as optical losses. The efficiency of the entire solar hot water system depends to a large extent on the efficiency of SVTP. All design features of any solar panels should ensure maximum absorption of solar energy and minimum heat loss [16]. The more solar energy the panel absorbs, the faster it converts this radiation into thermal energy and the less it losses on the way to the heat storage tank, the more efficient the DHW system will work. The efficiency of SVTP in practice can differ significantly from the calculated values (technical characteristics). It is necessary to take into account such parameters as the flow rate of the heat-carried medium and the connection of the collector groups, as well as some other recommendations. In most operation modes, a sufficient flow of heat-carried medium must be ensured through the solar panel, otherwise, if the heat-carried medium stagnates in the panel, it may overheat (in summer) or freeze (in winter). The circulation of the heat-carried medium is ensured by the use of individual pumps (Figure 3) or pump groups (solar pumping station). To ensure optimal operation modes of heat supply systems with solar panels, electronic solar controllers are used. The solar panel and the water heater are connected with a flexible pipe connection.

The temperature of the heat-carried medium in the solar collector can drop below zero (to the temperature outside) or exceed 100 ^{0}C, such harsh operation conditions impose restrictions on the use of water as a heat-carried medium. Thermal energy storage occurs due to the storage of heat in the volume of water. For this, the systems have reservoirs of considerable capacity. The capacity is determined by the recoverable thermal power of the panels and the required consumption of warm water (Figure 3).

III. Energy production capacity of the tubular solar panels

The evaluation of energy production of the solar hot water system was made for Gubadli city. The hot water demand of the consumer is taken as the initial estimation indicators and it is carried out through the evaluation program. The evaluation stages are as follows [3], [4]:

1. determination of the amount of solar water heating panels;
2. calculation of the amount of thermal heat due to total amount of solar radiation;
3. evaluation amount obtained hot water from SVTPs.

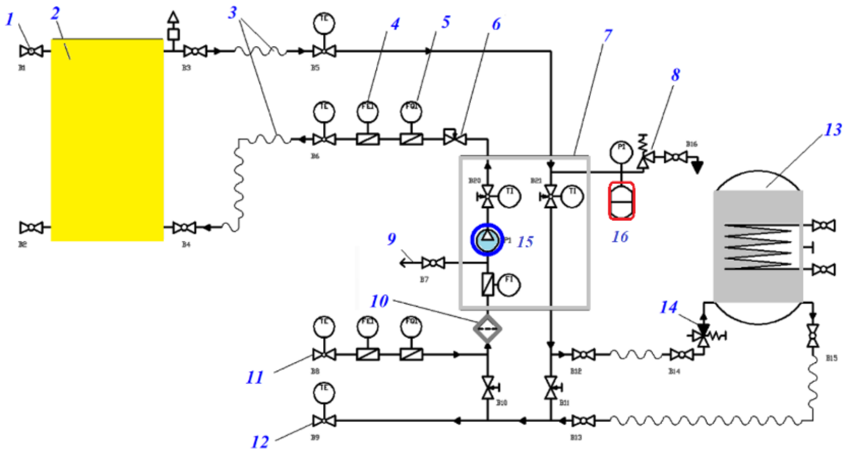

Figure 3: *Equipment of the systems with solar vacuum tube collectors:*
1- manifold connection, ball shut-off valve, 2- flat solar collector, 3- flexible piping, 4- flow meter with pulse output, 5- water meter, 6- pressure regulator, 7- pump group, 8- safety group with hydraulic accumulator, 9- filling connection with shut-off cock, 10- mesh filter, 11 heating radiator connection, return flow, 12- heating radiator connection, supply flow, 13- boiler-water heater, 14- combined safety valve, 15- circulating pump, 16-expansion tank

Preliminary information for evaluation- technical parameters of the applied Hevelius SCM-12 180-58 Polish panels (Table 1), which were studied:
- number of vacuum tubes in one panel- 12,
- diameter of vacuum tubes - 0.058 m,
- length of vacuum tubes - 1.8 m,
- effective area of one panel-1.9 m^2,
- number of vacuum tubes per 1 m^2 - 6,
- efficiency of the solar panel - 70%,
- heat loss coefficient of vacuum tubes - 0.5W/m^2,
- total area of the planned place for installation of equipment - 50m^2.

Table 1: *Technical specifications of Hevelius SCM-12 58/1800 solar panel*

Indicators	Unit of measurement	Quantity
Type	-	Vacuum tube
Geometric dimensions AxBxCxD	mm	1050x1990x1740x925
Weight	kg	40.7
The number of tubes in a collector	pieces	12
The length of a tube	mm	1800
Outer diameter of the tube	mm	58
Internal diameter of the tube	mm	47
The total area of one panel	m^2	1.9
The absorption coefficient of the panel	-	0.92
The production capacity of the panel	W	744
The diameter of the internal heat tube	mm	8
The stagnation temperature of the liquid	^0C	225.4
Volume of heat- carried medium per liter	litr	1.2
Maximum working pressure bar	bar	12

Project parameters obtained on the basis of preliminary indicators:
- number of actually installed panels - 12,
- inlet temperature of cold water - 10 °C,
- outlet temperature of hot water - 50 °C.

VI. Results

Results of the evaluation on hot water demand (Table 2,3,4):
- average annual amount of solar radiation - 1625 kW/m^2
- average amount of solar radiation by months, kWhr/m^2, was shown in Table 1,
- effective area of the planned place for installation of equipment - 22 m^2,
- average production of hot water per day - 2000 liter/day,
- average volume of hot water production throughout the year - 730 m^3/year,
- total thermal energy production - 14938 kWhr/year.

Table 2: *Average amount of solar radiation by months kWhr/m^2*

Month	The average amount of solar radiation	Month	The average amount of solar radiation
January	3.32	July	5.7
February	3.8	August	5.48
March	4.15	September	5.18
April	4.49	October	4.38
May	4.96	November	3.51
June	5.6	December	2.81
Average monthly indicator - 4.45			

Table 3: *Expected hot water production by solar panels for months, liters*

Month	Hot water amount	Month	Hot water amount
January	654	July	1127
February	751	August	1082
March	820	September	1023
April	886	October	865
May	980	November	693
June	1107	December	553
Average monthly indicator - 878 liters			

Table 4: *Energy production of solar panels by month kWhr/day*

Month	The average amount of solar radiation	Month	The average amount of solar radiation
January	32.64	July	50.55
February	37.12	August	47.46
March	39.86	September	43.23
April	43.47	October	37.88
May	46.99	November	30.89
June	51.50	December	29.30
Average monthly indicator - 40.93			

Thus, evaluation shows that it is possible to meet the hot water needs of buildings through SVTPs. Figure 4 shows the schedule of thermal energy production by months.

Currently, the authors have developed several projects for the efficient use of renewable energy sources in terms of implementing the transformation of Karabakh zone into a "green" energy zone. The paper is devoted to studying the application of solar vacuum tube panels for climatic parameters of the Gubadli region of the Karabakh "green" energy zone and the assessment of production capacity through an evaluation program Helios-house. The evaluation methodology for obtaining hot water by applying solar vacuum tube panels using "Helios-house" program consists of three main stages:

- the optimal number of solar panels that can be installed in the given area is determined;
- the average amount of solar radiation per month is evaluated;
- depending on the orientation and angle of the panels the amount of thermal energy is estimated.

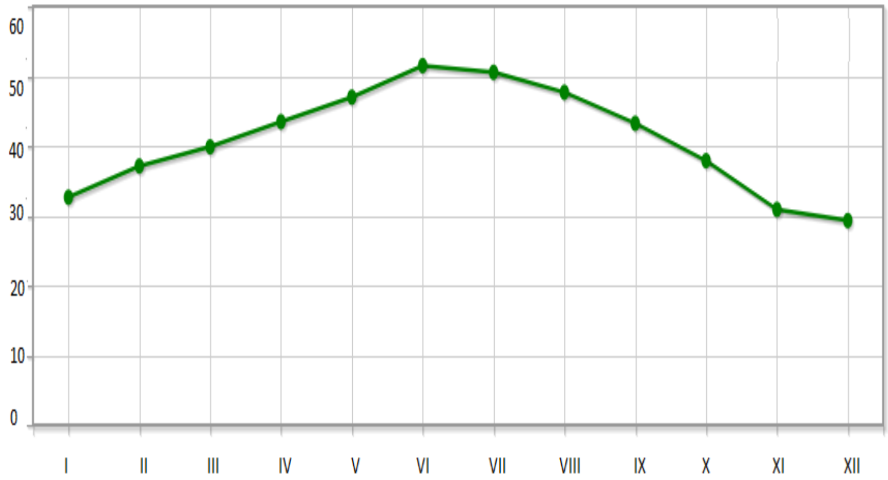

Figure 4: *Production of thermal energy by months, kWhr/day*

V. Conclusion

Solar energy use becomes more and more globally. Like other countries, Azerbaijan is trying to meet its thermal energy and electricity needs by applying renewable energy sources. It is predicted that by 2050, about 50% of the total amount of energy will be produced by "green" energy technologies. At present time Azerbaijan meets only 8% of energy consumption needs with renewable energy.

The obtained results of the study allow making the next conclusions on an initial assessment of meeting the hot water needs of buildings through solar vacuum tube panels. According to the sample evaluation, the amount of Hevelius SCM-12 180-58 (Poland) panels placed in an area of 50 m2 in the Gubadli region is 12, efficiency is 70%, the heat loss coefficient of vacuum pipes is 0.5W / m2, the average production of hot water per day - 2000 liter/day, the average volume of hot water production throughout the year - 730 m3/year, the average amount of thermal energy obtained by solar radiation is 1625 kW/m2 and the total heat production is 14938 kWhr/year.

The proposed evaluation methodology can be applied to any region of Azerbaijan.

References

[1] Azerbaijan 2030: National Priorities for Socio-Economic Development. https://president.az/en/articles/view/50474

[2] Böer, K.W. 2008. Advances in Solar Energy. Vol. 12. Boulder, Colo .: *American Solar Energy Society.*

[3] Eliasson, B. 2018. Renewable Energy: Status and Prospects. Växjö, Sweden: *ABB Environmental Affairs.*

[4] Fisch, M.N. 2012. A Review of Large-Scale Solar Heating Systems in Europe. *Solar Energy*, 63 (6): 355–66.

[5] Germanovich V., Turillin A. 2011. Alternative energy sources. Practical constructions on the use of wind energy, sun, water, earth, biomass energy - St. Petersburg: *Science and Technology*, 320 p.

[6] Gorjian Shiva. 2019. An introduction to the renewable energy resources.

[7] https://www.helios-house.ru/on-line-kalkulyator.html

[8]https://azvision.az/news/265046/-dunya-yasil-enerjiye-kecir--boyuk-potensiala-malik-azerbaycanda-hansi-isler-gorulur---.html

[9] Jalilov M.F. 2009. Alternative regenerative energy systems. *Textbook. Baku: NPM "Education"*, 409p.

[10] The State Program on Use of Alternative and Renewable Energy Sources in Azerbaijan. 2017.

[11] Yusifov J. 2018. Overview of the renewable energy Developments in Azerbaijan. *United Nations Framework Convention on Climate UNFCCC: Methodological issues while processing second national communications: Greenhouse Gas Inventories.*

[12] Yoo, J.J.; Seo, G.; Chua, M.R.; Park, T.G.; Lu, Y.; Rotermund, F.; Seo, J. 2021. Efficient solar cells via improved carrier management. *Nature*, 590, 587–593.

[13] Yang, D.; Yin, H. 2011. Energy Conversion Efficiency of a Novel Hybrid Solar System for Photovoltaic, Thermoelectric, and Heat Utilization. *IEEE Trans. Energy Convers*. 26, 662–670.

[14] Zhang, Y.; Ren, J.; Pu, Y.; Wang, P. 2019. Solar energy potential assessment: A framework to integrate geographic, technological, and economic indices for a potential analysis. *Renew. Energy*, 149, 577–586.

[15] Zubair, M.; Awan, A.B. 2021. Economic viability of solar energy export from the Middle East and North Africa to Europe and South Asia. *Environ. Dev. Sustain*. 23, 1–22.

[16] Zhang, H.L.; Baeyens, J.; Degrève, J.; Cacères, G. 2013. Concentrated solar power plants: Review and design methodology. *Renew. Sustain. Energy Rev*. 22, 466–481.

ASSESSMENT OF TERRITORIAL MAN-CAUSED RISKS IN THE ARCTIC TERRITORIES USING PROBABILISTIC-GRAPHIC MODELS

Ulyana Postnikova[1,3], Olga Taseiko[2,3], Inna Efremova[3]

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[1]Siberian Federal University, Russia
[2]Reshetnev Siberian State University of Science and Technology, Russia
[3]Krasnoyarsk Branch of the Federal Research Center for Information and Computational Technologies, Russia
ulyana-ivanova@inbox.ru
taseiko@gmail.com

Abstract

As a result of the work carried out, the main factors influencing on the formation of the technogenic load in the Arctic territories of the Krasnoyarsk Region were considered, taking into account natural and climatic features. On the basis of Bayesian networks, a methodology has been developed for assessing the probability of the occurrence of man-made hazards, followed by an assessment of the complex risk using the official statistics of the Russian Emergencies Ministry for the period 1996-2020. The obtained quantitative estimates made it possible to identify the main factors influencing on the formation of the man-made load in the Arctic territories.

Keywords: technogenic safety, territorial risk, Arctic territories, Bayesian networks

I. Introduction

The problem of the risks of catastrophic processes is particularly acute for Siberia and the Arcti territories, where there is a wide range of threats of various nature, and, at the same time, the main points of growth Russian economic potential are outlined. Under these conditions, the issues of social, natural and technogenic safety are of paramount importance, since they determine the prospects for the territories development. This gives unconditional relevance to research in the field of risks, methods for their assessment and mitigation of negative consequences.

The specificity of territorial development management is characterized, on the one hand, by a large amount of infrastructural, environmental, economic and social information, and on the other hand, by the lack of effective methods for its processing and a unified structured information space in the monitoring field. In addition, the amount and content of information required for sound scientific support of decisions is changing rapidly.

The technological development of Siberian territories and the growth of industry have a negative impact on environmental and social security and form a number of problems that may affect the region and the development of the country as a whole. The Krasnoyarsk Region is the largest industrial entity in the Siberian Federal District, the Arctic zone of which includes all the territories of the Taimyr Dolgano-Nenetsky municipal district, the northern parts of the Turukhansky district (where the city of Igarka is located), the Evenki municipal district, and the urban district of Norilsk [1]. Despite the uniqueness of the Arctic zone of the Krasnoyarsk Territory and the harsh natural and climatic conditions, objects that are sources of high technogenic load are operated: fire and explosion hazardous objects, radiation hazardous objects, hydrodynamic hazardous objects, transport routes, public utility systems, chemically hazardous objects, etc.

For the effective management of the Arctic territories and the analysis of integrated security, it is proposed to use methods and risk criteria. Quantitative values of risks characterizing the formation and implementation of hazardous processes and events are proposed as safety criteria.

II. Methods

To establish cause-and-effect relationships of technogenic risk factors, it is advisable to use the apparatus of Bayesian trust networks.

Bayesian networks are graphical models of events and processes based on the combination of the mathematical apparatus of probability theory and graph theory [2-4]. Bayesian networks are a convenient tool for describing fairly complex processes and events with uncertainties. The main idea of building a graphical model is associated with the concept of modularity, that is, the decomposition of a complex system into simple elements. Such a graph-theoretical approach to building a model makes it possible to take into account processes with many interacting variables, as well as to create data structures for the subsequent development of effective algorithms for their evaluation and decision making.

The Bayesian belief network is a directed acyclic graph. The graph is written as a set of independence conditions: each variable is independent of its main event, under such conditions the probability of a vertex event will be calculated using the total probability formula (1). If event A can occur only when one of the events B_1, B_2 ... B_n, which form a complete group of incompatible events, occurs, then the probability of event A is calculated by formula (1):

$$P(A) = P(B_1) \cdot P(A \mid B_1) + P(B_2) \cdot P(A \mid B_2) + \cdots + P(B_n) \cdot P(A \mid B_n) \tag{1}$$

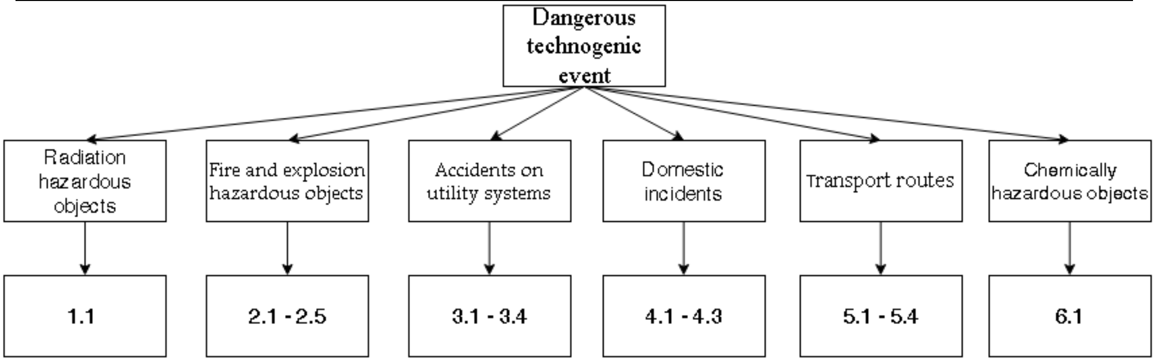
In the case if the distribution goes from the child vertex to the main vertex, the Bayes formula (2) will be used. Let H_1, H_2… be a complete group of events, and A be some event whose probability is positive. Then the conditional probability that the event H_k took place, if the event A was observed as a result of the experiment, can be calculated using the Bayes formula (2):

$$P(H_k \mid A) = \frac{P(H_k) \cdot P(A \mid H_k)}{\sum_{i=1}^{k} P(H_i) \cdot P(A \mid H_i)} \tag{2}$$

III. Results

As mentioned above, Bayesian network risk assessment begins with the construction of a graph. Figure 1 shows an acyclic directed graph of the occurrence of a technogenic risk.

The column considers 6 groups of factors of technogenic hazardous events due to the peculiarities of economic activity in the Arctic zone of the Krasnoyarsk Region. The main peak is represented directly by a dangerous man-made event. Child vertices represent groups of factors that are the cause of this event. Each group, in turn, contains a specific version of the development of an event. The results of calculating the probabilities of hazardous events are presented in Table 1.



1.1	Accident with the release of radioactive substances
1.2	Radioisotope thermoelectric generator accidents
2.1	Fire at objects with mass stay of people
2.2	Explosion industrial
2.3	Accident at an industrial facility
2.4	Industrial fire
2.5	Collapse of technical structures
3.1	Water supply disruption
3.2	Disruption of gas supply
3.3	Heat supply disruption
3.4	Power failure
4.1	Household collapse
4.2	Household explosion
4.3	Household fire
5.1	Railway accident
5.2	Air transport accident
5.3	Car accident
5.4	Water transport accident
6.1	Accident with the release of hazardous chemicals

Figure 1: *Bayesian network model*

Table 1: *The results of calculating the probability of the dangerous implementation man-made events for the Arctic territories of the Krasnoyarsk Territory*

Name of the main factors	Name of child factors	Probability of realization of a dangerous event	Probability of realization of a group of events
Transport routes	Railway accident	0,0062112	0,23913
	Air transport accident	0,136646	
	Car accident	0,04347826	
	Water transport accident	0,052795	
Radiation hazardous objects	Accident with the release of radioactive substances	0,0031	0,0031
Chemically hazardous objects	Accident with the release of hazardous chemicals	0,0217391	0,0217391
Fire and explosion hazardous objects	Fire at objects with mass stay of people	0,267080745	0,363354035
	Explosion industrial	0,01863354	
	Accident at an industrial facility	0,01863354	
	Industrial fire	0,04347826	
	Collapse of technical structures	0,01552795	
Accidents on utility systems	Water supply disruption	0,0217391	0,07452295
	Disruption of gas supply	0,0031	
	Heat supply disruption	0,0031	
	Power failure	0,04658385	
Domestic incidents	Household collapse	0,0031	0,288808696
	Household explosion	0,0031	
	Household fire	0,282608696	

Table 2 shows that the greatest contribution to the occurrence of a technogenic hazardous event is made by fire and explosion hazardous objects, especially household fires and at facilities with a mass stay of people.

In order to detail the indicators of the occurrence of man-made emergencies in the territory of the Arctic zone in the Krasnoyarsk Region, the probability of a hazardous event occurring is calculated for each territorial entity (Table 2).

Table 2: *The results of calculating the probability of the implementation of dangerous man-made events for each territorial entity of the Arctic zone in the Krasnoyarsk Region*

Name of the main factors	Name of child factors	Probability of realization of a dangerous event			
		Taimyr Dolgano-Nenetsky municipal district	Evenki municipal district	Turukhansky municipal district	Norilsk
Transport routes	Railway accident	-	0,00307	-	0,00307
	Air transport accident	0,015337	0,015337	0,030675	0,0552147
	Car accident	0,015337	0,006135	-	0,0214724
	Water transport accident	0,018405	0,027907	0,006135	0,00307
Radiation hazardous objects	Accident with the release of radioactive substances	-	-	-	0,00307
Chemically hazardous objects	Accident with the release of hazardous chemicals	-	0,0092	0,00307	0,0092
Fire and explosion hazardous objects	Fire objects with mass stay of people	0,0122699	0,06135	0,027907	0,171779
	Explosion industrial	-	0,0092	-	0,0092
	Accident at an industrial facility	0,00307	0,006135	-	0,0092
	Industrial fire	0,00307	0,0092	0,0092	0,0214724
	Collapse of technical structures	-	0,00307		0,01227
Accidents on utility systems	Water supply disruption	-	-	-	0,0214724
	Disruption of gas supply	-	-	-	0,00307
	Heat supply disruption	-	0,00307	-	-
	Power failure	0,0122699	0,0122699	-	0,0214724
Domestic incidents	Household collapse	-	-	-	0,00307
	Household explosion	-	-	-	0,00307
	Household fire	0,027607	0,082822	0,03681	0,128834

On the basis of the obtained results of assessing the probabilities of hazardous man-made events in the Arctic territory, we will calculate the complex man-made risk (3):

$$R_t^c = \sum_{i=1}^{n} P_i \cdot U_i \tag{3}$$

where P_i is the probability of occurrence of a certain risk factor; U_i is damage from a certain risk factor, million rubles (data obtained from the official database of the EMERCOM of Russia).

For the Arctic territories, a complex risk is determined for each technogenic factor (table 3). The main risk is associated with domestic fires and accidents in transport (air and river).

Table 3: *The results of the calculation of the technogenic risk of the Arctic zone in the Krasnoyarsk Region*

Name of the risk factor	Risk
Railway accident	0,00025
Air transport accident	7,99
Car accident	0,4
Water transport accident	1,9
Accident with the release of radioactive substances	0
Accident with the release of hazardous chemicals	0,144
Fire objects with mass stay of people	3,31
Explosion industrial	0,38
Accident at an industrial facility	0,26
Industrial fire	0,1
Collapse of technical structures	0,02
Water supply disruption	0,2
Disruption of gas supply	0,00005
Heat supply disruption	0,000003
Power failure	0,1
Household collapse	0,0001
Household explosion	0,0017
Household fire	9,33

IV. Discussion

The management of a territorial entity should be based on an assessment of the complex technogenic risk and the identification of the most dangerous factors that require special attention and control.

The development of urbanized territories requires new approaches to management tasks. The problems of increasing risks both for the life and health of the population and for the state of the environment are associated with an increase in anthropogenic impact. In both cases, qualitative and quantitative assessments of the risk of adverse situations and impacts become a key task, the solution of which determines the quality and effectiveness of the development and implementation of management decisions to protect the population and the environment.

Acknowledgements

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References

[1] On the state of protection of the population and territories of the Krasnoyarsk Territory from natural and man-made emergencies": State report. - Moscow: EMERCOM of Russia, 1996-2020.

[2] Tupalev, A.L. Cycles in Bayesian networks, probabilistic semantics and relations with neighboring nodes / A. L. Tupalev, S. I. Nikolenko, A. V. Sirotkin. // Proceedings of SPIIRAS. - 2006. - No. 3. - p. 240-263.

[3] Heckerman, D. Dependency Networks for Inference Collaborative Filtering and Data Visualization // Journal of Machine Learning Research. – 2000 – №1. – p. 49–75.

[4] Probabilistic Networks and Expert Systems: tutorial / R. G. Cowell, P. Dawid, S. L. Lauritzen, D. J. Spiegelhalter.– New York: Springer-Verlag, 1999. – 205 p.

ASSESSMENT OF ENVIRONMENTAL OIL SPILLS AND ECONOMİC-ENVİRONMENTAL RISKS

Gafar Ismayilov[1], Hajar Ismayilova[1], Hikmet Babirov[2], Rashid Jabrayilov[1]

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[1]Azerbaijan State Oil and Industry University
asi_zum@mail.ru
ismayilova.hecer@bk.ru
reshidcebrayilov@gmail.com
[2]Oil-Gas Scientific Research Project Institute, Azerbaijan
hbabirov@miswaco.slb.com

Abstract

The article classifies oil spills in the environment related to accidents in oil production and transportation processes and proposes a new methodological approach for the assessment of environmental and economic risks for various oil spill cases. It was determined that although this risk is low in some cases, it is important to take into account the cases where the consequences are severe because of large-scale oil spills.

Keywords: environment, oil spills, ecological factor, eco-economic risks, probability, accidents.

I. Introduction

The factor that most affects the economic performance of oil and gas production and transportation processes is the release of hydrocarbons into the environment during accidents. Accidents disrupt normal work routines, cause operational difficulties that lead to material losses, cause considerable damage to the environment and create a fire-explosion hazard. In such cases, the damage to the environment, the losses, and the recovery of work regimes are highly dependent on the prompt determination and elimination of accidents [1-3].

Table 1: *Deviation of the frequency of accidents by separate categories*

Categories	Accidents	Approximate frequency of accidents	Characteristics of accident probabilities
1	Practically impossible	$< 10^{-6}$ 1/year or once in morethan 1 million years	Although such cases are not excluded, they almost neverhappened.
2	Rare	$(10^{-6} - 10^{-4})$ 1/year or once in $10^4 - 10^6$ years	These cases have happened only a few times worldwide.
3	Unlikely	$(10^{-4} - 10^{-2})$ 1/year oronce in 100-10000 years	This kind of accident happens, but it is unlikely during the implementation of the project.
4	Likely	$(10^{-2} - 1)$ 1/ year oronce in 100 years	Such an accident is possible when the project is realized .
5	Practically unavoidable	>1/ year or not less than once in a year	On average, it can happen no less than once a year.

Accidents occurring in oil and gas extraction and transportation systems are divided into 5 categories according to the severity of their consequences [4-7]. The deviation of the frequency of accidents by separate categories is shown in table 1, and the characteristics of the results by degrees of severity in different categories are shown in table 2.

Table 2: *Categories of accidents by degrees of severity and characteristics of their consequences*

Categories of accidents by degrees of severity	Characteristics of the consequences of accidents
Imperceptible	No effect on the health and safety of the population. No damage or breakage in the object, no impact on natural resources.
Less valuable	No loss of life or serious damage to people, the object is slightly damaged, no idle state, light and short-term impact on the environment.
Severe	Serious damage to facilities and human life casualties is possible, but there is no fear for the health and life of people among the population, although there are negative, ultimately reversible effects on a number of natural resources.
Critical	Casualties and injury to a large number of people working at the facility, significant damage to the facility, and significant and long-term damage to two or more natural resources.
Catastrophic	The occurrence of an emergency resulting in a large number of human casualties and irreparable damage to a large number of natural resources.

According to the currently available operating experience, oil leaks from pipelines are divided into the following categories according to the size of the leak site and the amount of spilled oil [1,3,4]:

- small leaks: leaks that do not exceed 3-5% of the nominal consumption of the oil pipeline. Such leaks can occur from holes with a diameter of 5-10 mm (average 7.5 mm), which corresponds to the size of holes caused by corrosion in belts. Small leaks are mainly determined by the amount of hydrocarbon vapors in the air. According to operational experience, these leaks can be determined within 7 days;
- medium leaks: leaks that make up to 5-10% of the nominal consumption of the belt, holes varying in size from 10-50 mm are accepted as the places of leakage. Such leaks are usually identified and detected within 1hour by indirect means;
- major leaks: covers leaks of more than 10% of the rated consumption in the belt up to complete collapse. The dimensions of the leakage places are taken as a limit equal to the diameter of the belt from 50 mm. Major oilleaks can be detected within 5 minutes based on the indicators of the devices.
- "hidden" or hard-to-detect leaks: leaks in pipelines of up to 3% of nominal flow or very small leaks. Forthe purpose of evaluating such leaks, the size of the leaks can be taken as 3-5 mm (4 mm on average). Practically, these leaks are considered to be cases of leaks that are not detected by traditional methods or are very difficult to determine, and the time for their detection is conventionally accepted as 30 days [5].

II. Solution

It is also necessary to assess the direct damage caused by oil losses during oil spills. This assessment is also important for proper oil accounting and maintenance in case of accidents. Depending on the amount of oil spilled into the environment the value of oil loss due to an accident $G_{n.i}$ can be determined as follows:

$$G_{n.i} = G_{n.s.q} \cdot gt_s \qquad (1)$$

where:

$Q_{n.s.q}$ - sale price or cost of crude oil, AZN./t;

g - the amount of oil spilled into the environment per unit time, t/h;
t_S - the time period for oil leakage into the environment, hours (in calculations, it is considered as the time ofdetection of the leak).

Using the classification of oil spills by categories, it is possible to estimate the economic damage caused by oil losses. In the calculations, the selling price of 1 ton of oil included in expression (1) is accepted as $G_{n.s.q}$ (200 AZN on average). Based on the deviation of oil losses by leakage categories, the damages caused by oil losses that occurred in different pipelines, i.e. at different prices of the nominal consumption of oil, until the leaks were detected, were calculated. It has been established that if leakage cases are detected late, rather than withinthe nominal time, then the material damage will increase as much. If "hidden" leaks during operation remain undetected for 1 month, then the damage caused by oil losses for pipelines with nominal consumption values of10, 50, 100, 200, 500, 1000, 5000 t/h can be valued at 5.4; 27; 108; 270; 540; 2700 thousand AZN, respectively. Since the oil pipeline system is considered a potential source of danger during operation, the assessment of the risks of oil spills from possible accidents is of great ecological and economic importance. The level of risk largely depends on the magnitude of expected losses and the probability of occurrence. As environmental damage and oillosses increase by the amount of oil spills increases, the possibility of losses and damage that may occur also increases. In this case, the level of risk depends more on the magnitude of expected losses and their probability of occurrence. Therefore, the risk assessment procedure requires the knowledge of two quantities, first. These quantities are the cost of damage in the event of an accident and the probability of this event occurring. The integral risk for a number of events is defined as the sum of the risks of these events. In this case, the probability of the last event is defined as the multiplication of the probabilities of all events. Eco-economic risks can be calculated according to the classification of oil spills from pipelines based on the existing operating experience of oil pipelines. Assume that the oil spill accident is (g, m^3/hour). Then the rate of oil spill will be g/G (G – consumption of oil in the pipeline in the event of an accident, m^3/hour). Taking into account the information given above and the elements of probability theory, it is possible to write [8] for the determination of the eco-economic risk (R)related to oil spills:

$$R = R1i \cdot R2i \cdot Z \tag{2}$$

where:
R_{1i} - the risk of accidental oil spills with environmental consequences;
R_{2i} – the risk that causes the facility to be out of order or out of normal operation;
Z - the maximum economic damage caused by an oil spill.

According to the statistical analysis and logical conclusion, it can be accepted that there are various monotonically decreasing dependencies between the probability (risk) of $R1i$ and the degree of oil spillage. In this case, the probability of R2i, which is determined by a special group of experts, will be expressed by monotonically increasing dependencies according to the degree of oil spill (Fig. 1).

Taking into account the variation of R1i and R2i probabilities, depending on the degree of oil spill (g/G), the environmental-economic risks (R) for different scenarios were calculated as follows:

$$R_1 = R_{11}\, R_{21};\ R_2 = R_{11}\, R_{22};\ R_3 = R_{11}\, R_{23};\ R_4 = R_{12}\, R_{21};$$
$$R_5 = R_{12}\, R_{22}; R_6 = R_{12}\, R_{23}; R_7 = R_{13}\, R_{21}; R_8 = R_{13}\, R_{22}; R_9 = R_{13}\, R_{23}.$$

The variations of the calculated values of these risks for different deviation scenarios is shown in figure 2.

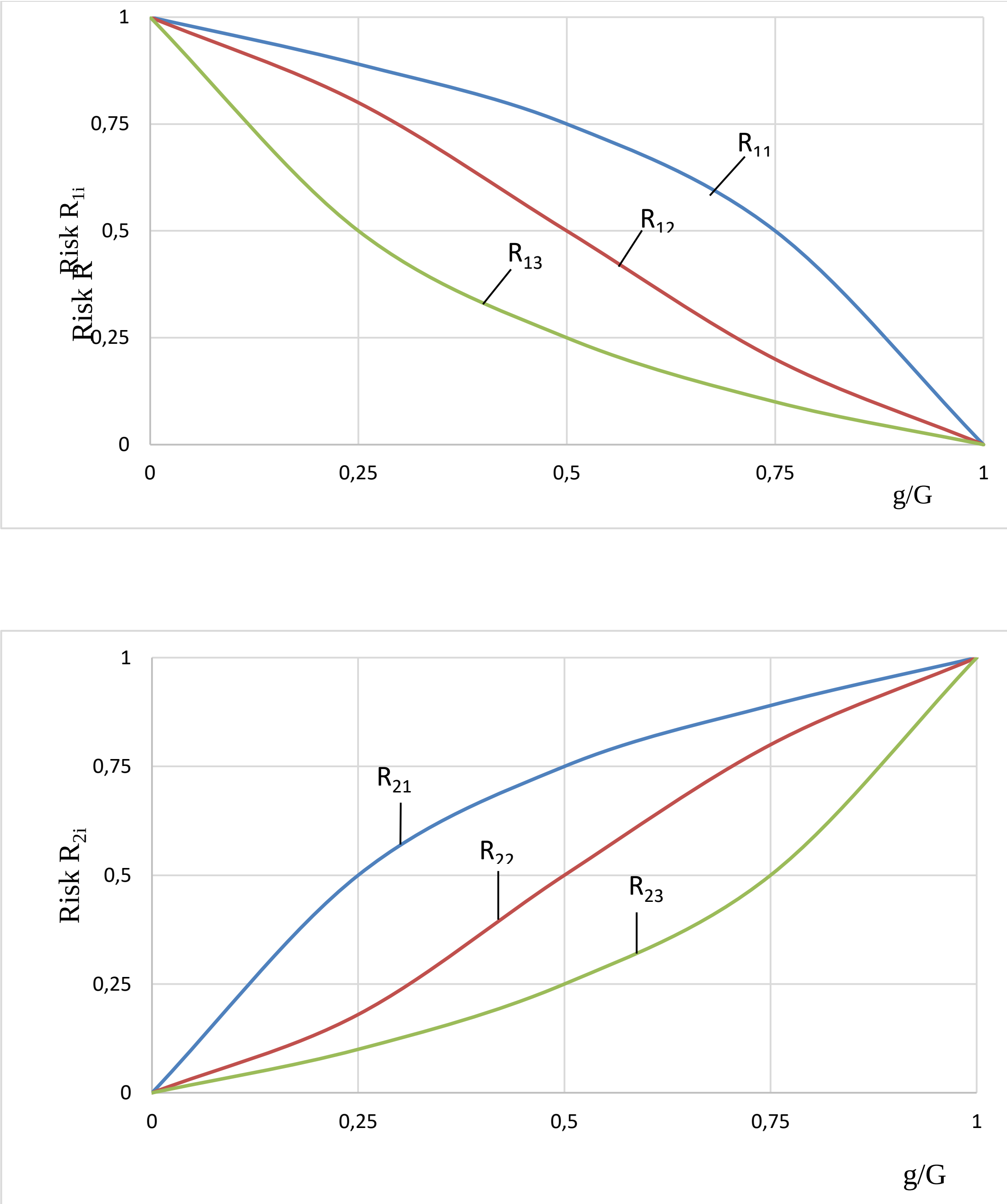

Fig.1: *Dependence of risks R_{1i} and R_{2i} on oil spills*

As given in Figure 2, the maximum risk for the considered options is 0.56, corresponding to option R1. This corresponds to the case of g/G = 50 % of oil spill risk. It means that Rmax= 0.56·Z. In addition to the mentioned, other considered options should also be explored and should not be overlooked. For example, although the maximum risk for the R3 option is low (about 0.25), the result can be alarming because it concerns large-scaleoil spills (about 75%).

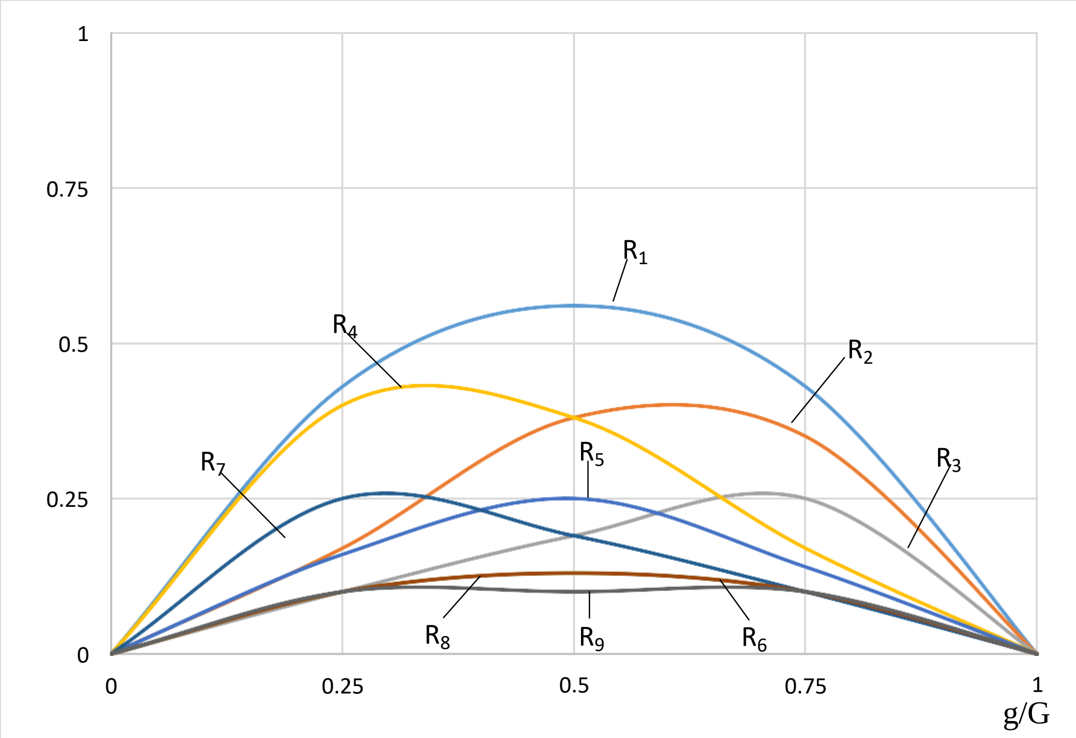

Fig. 2: *Dependence of ecological-economic risk on oil spills*

III. Conclusion

The classification of accidental oil spills that occurred during the extraction and transportation of oil was given, and the material and economic damage was assessed separately, including "hidden" leakage cases.

Taking into account that accidental oil spills result in sufficient environmental and socio-economic effects, a methodical approach was proposed for the evaluation of the environmental and economic risk factor. It was determined that even though the risks are low, large oil spills should be considered very dangerous.

References

[1] Instructions for accounting oil during its transportation. – Ufa: VNIISTPneft', 1995, 68 s. (in Russian)

[2] Ahmadov B.A., Ismailova H.G. The main sources of environmental pollution in Azerbaijan and evaluation of the ecological situation // News of Azerbaijan Higher Technical Schools, 2005, No 6 (40), s. 79-86. (in Azerbaijani)

[3] Kravchenko V.F. Environmental protection during transportation and storage of oil and oil products // Reviews of foreign literature. – M.: VNIIOENG, 1976, 60 s. (in Russian)

[4] Control of leaks of oil and oil products on main pipelines during operation. – M.: VNIIOENG,

1981, s. 2-16. (in Russian)

[5] Ismailova Kh.G. On the assessment of damage from accidental losses' for various categories of oil leaks / Proceedings of the 69th International Scientific Conference "Oil and Gas" - 2015". – M.: 2015, s. 98. (in Russian)

[6] Kremmer V.H. Oil and oil products leakage control system from pipelines // Transport and storage of oil and oil products. Foreign experience: Exp. – M.: VNIIOENG, 1980, s. 21-30. (in Russian)

[7] RD Methodological Guidelines for Assessing the Risk of Accidents at Trunk Oil Pipelines. – M.: NTTS on Safety in Industry of Gosgortekhnadzor of Russia. 2012, 120 s. (in Russian)

[8] Shakhov V.V. Introduction to insurance: economic aspect. – M.: Finance and statistics, 1992, 192 s. (in Russian).

ON ONE APPROACH TO NON-DESTRUCTIVE CONTROL OVER THE STATE OF PIPELINE SYSTEMS

Reshad Ismibayli[1], Yegana Ashrafova[2]

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[1]Azerbaijan University of Architecture and Construction
[2]Baku State University, Azerbaijan
reshadismibayli@gmail.com ashrafova.yegana@gmail.com

Abstract

In the process of long-term operation of pipeline systems for the transport of hydrocarbons (oil, gas) and other liquids, leaks occur in some of its sections over time. An important role of timely detection of leaks is occupied by methods of indestructible control over the state of pipeline systems that do not require the production of any technical actions. Non-destructive testing methods are based, as a rule, on mathematical methods and modern computer technologies. In this paper, using the example of the problem of determining the locations of fluid leaks, an approach is proposed based on solving an inverse problem with respect to a system of differential equations with partial derivatives that describes the process of fluid flow.

Keywords: oil-gas pipelines, non-destructive control methods, leaks, environmental risks, inverse problem.

I. Introduction

In the process of long-term operation of pipeline systems for the transport of hydrocarbons (oil, gas) and other liquids, leaks occur in some of its sections over time. Leaks occur due to pipeline breaks, which can have different causes and sizes.

The emerging leaks lead to great risks, which have both environmental consequences, but also causing great economic damage to mining and transport organizations.

Known and used are various methods of timely detection of leaks of raw materials. An important role is occupied by methods of indestructible control over the state of pipeline systems that do not require the production of any technical actions. In particular, in the case of underground pipeline networks, such methods do not require, for example, any earthworks.

Non-destructive testing methods are based, as a rule, on mathematical methods and modern computer technologies. In this paper, using the example of the problem of determining the locations of fluid leaks, an approach is proposed based on solving an inverse problem with respect to a system of differential equations with partial derivatives that describes the process of fluid flow.

An inverse problem for a pipeline network of complex loopback structure is solved numerically. The problem is to determine the locations and amounts of leaks from unsteady f low characteristics measured at some pipeline points. The features of the problem include impulse functions involved in a system of hyperbolic differential equations, the absence of classical initial conditions, and boundary conditions specified as nonseparated relations between the states at the endpoints of adjacent pipeline segments. The problem is reduced to a parametric optimal control problem without initial conditions, but with nonseparated boundary conditions. The latter problem is solved by applying first-order optimization methods [1]. Results of numerical experiments are presented.

This paper differs from many other studies [2] in which leak locations and amounts were determined either in a steady flow regime in a pipeline of complex structure or in a transient flow regime in a pipeline consisting of a single linear segment. In this study, we numerically solve an inverse problem [3] of determining leak locations and amounts in an unsteady flow in a pipeline network of complex (loopback) structure. The problem is described by a system made up of numerous subsystems of two hyperbolic partial differential equations with impulse actions specified at possible leakage points on pipeline network segments.

Another feature of the problem is the assumption that, due to the long duration of the process under study, exact information on its initial state is not available at the time of monitoring and that the states of the process (which is distributed in space) cannot be quickly measured at all points. Instead, there is information on a variety of possible initial states of the process and some state (regime) characteristics are measured at certain pipeline points starting at this time. One more feature of the problem is that its boundary conditions are specified as nonseparated relations (determined by physical laws) between the states at the endpoints of adjacent pipeline segments.

II. Problem statement

To simplify presentation of numerical schemes and to be specific, let us consider the pipe network, containing 8 segments as shown in figure 1. Numbers in brackets identify the nodes (or junctions). The set of nodes we denote by I : $I=\{k_1,...,k_N\}$; where $k_i, i=\overline{1,N}$ are the nodes; $N=|I|$ is the numbers of nodes in the network. Two numbers in parentheses identify two-index numbers of segments. The flow in these segments goes from the first index to the second (for example, the flow in the segment (1,2) is obviously from the node 1 to node 2.

Let J : $J=\{(k_i,k_j):k_i,k_j\in I\}$ is the set of segments and $M=|J|$ is it's quantity; $l_{k_ik_j}$, $d_{k_ik_j}, k_i,k_j\in I$ is a length and diameter of the segment (k_i,k_j) respectively; I_k^+ is the set of nodes connected with node k by segments where flow goes into the node, I_k^- is the set of nodes connected with node k by segments where flow goes out of the node; $I_k=I_k^+\bigcup I_k^-$ is the set of total nodes connected with node k and $N_k=|I_k|, N_{k^+}=|I_k^+|, N_{k^-}=|I_k^-|$, $N_k=N_{k^-}+N_{k^+}$.

Beside of inflows and outflows in the segments of the network there can be external inflows (sources) and outflows (sinks) with the rate $\tilde{q}_i(t)$ at some nodes $i\in I$ of the network. Positive and negative values of $\tilde{q}_i(t)$ indicate the existence of external inflow or outflow at the node i. However, in general case, assuming that the case $\tilde{q}_i(t)\equiv 0$ for the sources is admissible one can consider all nodes of the network as the nodes with external inflows or outflows. Let $I^f\subset I$ denote the set of nodes $i\in I$, where i is such that the set $I_i^+\bigcup I_i^-$ consists of only one segment. It means that the node i is a node of external inflow or outflow for the whole pipe network (for example $I^f=\{1,4,5,8\}$ in fig.1). Let $N_f=|I^f|$ is the number of such nodes, it is obviously that $N_f\le N$; I^{int} is the set of nodes not belonging to I^f, so $N_{\text{int}}=|I^{\text{int}}|$, i.e., $I^{\text{int}}=I/I^f$, $N_{\text{int}}=N-N_f$. In actual conditions, the pumping stations are placed, the measuring equipment is installed and the quantitative accounting is conducted at the nodes from the set I^f.

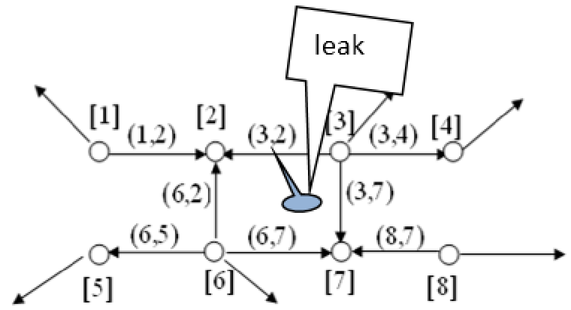

Fig.1: *The scheme of pipe network with 8 nodes*

We assume that at some instants of time $t \geq t_0$ at some points $\xi_{ks} \in (0, l)$, of any (ks)-th section of the pipeline network, fluid leakage with the flow rates $q_{ks}^{loss}(t)$ began. Using the generalized Dirac function δ(x), we can describe the motion of the liquid by the following linearized system of differential equations for unsteady flow of dripping liquid with constant density ρ in a linear pipe (k, s) of length l_{ks} and diameter d_{ks} of oil pipeline network can be written in the following form [4-8]:

$$\begin{cases} -\dfrac{\partial P^{ks}(x,t)}{\partial x} = \dfrac{\rho}{S^{ks}} \dfrac{\partial Q^{ks}(x,t)}{\partial t} + 2a^{ks} \dfrac{\rho}{S^{ks}} Q^{ks}(x,t), x \in (0, l^{ks}), \\ -\dfrac{\partial P^{ks}(x,t)}{\partial t} = c^2 \dfrac{\rho}{S^{ks}} \dfrac{\partial Q^{ks}(x,t)}{\partial x} + c^2 \dfrac{\rho}{S^{ks}} q_{ks}^{loss}(t) \delta(x - \xi_{ks}),\ t \in (0, T], \end{cases} \quad s \in I_k^+, k \in I. \tag{1}$$

here c is the sound velocity in the fluid; S^{ks} is the area of an internal cross-section of the segment (k, s); a^{ks} is the coefficient of dissipation (we may consider that the kinematic coefficient of viscosity γ is independent of pressure and the condition $2a^{ks} = \dfrac{32\gamma}{(d^{ks})^2} = const$ is quite accurate for a laminar flow). $Q^{k_i k_j}(x,t)$, $P^{k_i,k_j}(x,t)$ are the flow rate and pressure of flow, respectively, at the time instance t in the point $x \in (0, l^{k_i,k_j})$ of the segment (k_i, k_j) of the pipe network. $P^k(t), Q^k(t)$ are the pressure and flow rate at the node $k \in I$, respectively.

The conditions of Kirchhoff's first law (total flow into the node must be equal to total flow out of the node) are satisfied at the nodes of the network at $t \in [0, T]$:

$$\sum_{s \in I_k^+} Q^{ks}(l^{ks}, t) - \sum_{s \in I_k^-} Q^{ks}(0, t) = \tilde{q}^k(t),\ k \in I\ . \tag{2}$$

Also, the following conditions of flow continuity for the nodes of the net (the equality of the values of pressures on all adjacent ends of the segments of the network) hold:

$$P^k(t) = P^{k_i k}(l^{k_i k}, t) = P^{k k_j}(0, t),\ k_i \in I_k^+, k_j \in I_k^-, k \in I\ , \tag{3}$$

where $\tilde{q}^k(t)$ is the external inflow $(\tilde{q}^k(t) > 0)$ or outflow $(\tilde{q}^k(t) < 0)$ for the node k, $P^k(t)$ is the value of the pressure in the node k. We must note that they have significant specific features, consisting in the fact that the conditions (2) and (3) are non-separated (nonlocal) boundary conditions unlike classical cases of boundary conditions for partial differential equations.

The total number of conditions for all nodes from I^f is N_f. So, the total number of conditions in (2) and (3) is $[N_f + N_{\text{int}}] + [(2M - N_f) - N_{\text{int}}] = 2M$. As it was noted above the number of conditions in (2) is N, but in view of the condition of material balance ($\sum_{k\in I}\tilde{q}^k(t)=0$) for the whole pipeline network, we conclude that the number of linearly independent conditions is $N-1$. So, it is necessary to add any one independent condition. As a rule the value of pressure at one of the nodes $s\in I^f$ is given for this purpose, in place of the flow rate $q^s(t)$:

$$P^s(t)=\tilde{P}^s(t). \tag{4}$$

In the case of unknown points of leakages and their rates $\xi_{ks}, q_{ks}{}^{loss}(t)$ we will assume that at the ends of the pipeline sections a constant and rather long observation on pressure is made, i.e., the values of $P^n_{mes}(t),\ n\in I^f_p$ or $Q^m_{mes}(t), m\in I^f_q$ are known. It is quite natural to suppose that the sought leak spots do not coincide with the points of observation of regimes. In more general case, for every node from $I^f=I^f_q\bigcup I^f_p$, it is necessary to give the values of pressure ($I^f_p\subset I^f$ denotes the set of such nodes) or the values of flow rate (the set $I^f_q\subset I^f$) and I^f_p must not be an empty: $I^f_p\neq\varnothing$. So, we will add the following conditions to the condition (3):

$$\begin{cases} P^n(t)=P^{ns}(0,t)=P^n_{mes}(t), & s\in I^+_n,\ if\ I^-_n=\varnothing, \\ P^n(t)=P^{sn}(l^{sn},t)=P^n_{mes}(t), & s\in I^-_n,\ if\ I^+_n=\varnothing, \end{cases}\quad n\in I^f_p, \tag{5}$$

$$\begin{cases} Q^m(t)=Q^{ms}(0,t)=Q^m_{mes}(t), & s\in I^+_m,\ если\ I^-_m=\varnothing, \\ Q^m(t)=Q^{sm}(l^{sm},t)=Q^m_{mes}(t), & s\in I^-_m,\ если\ I^+_m=\varnothing, \end{cases}\quad m\in I^f_q, \tag{6}$$

When the spots of oil leakages from a pipeline and the rates of these leakages are known $\xi_{ks}, q_{ks}{}^{loss}(t)$, $(k,s)\in J$, it is sufficient to use one of the boundary-value conditions (5) or (6) to calculate the regime of liquid motion in the pipeline from (1) on the time interval $[t_0,T]$. One of them we will use in the functional, the form which will be given below.

The problem consists in the detection of the points of leakage $\xi=\{\xi_{ks},(k,s)\in J\}$ and corresponding losses of raw material $q^{loss}(t)=\{q^{loss}_{ks}(t),(ks)\in J\}$ at $t\in[t_0,T]$ with the use of the given mathematical model and obtained information.

It is important to note that if process (1) is rather long, then, due to the presence of friction typical of any real physical system, the influence of the initial state of the pipeline on the regimes of oil motion in it becomes weaker with time. Therefore, when the process is observed for a long time, i.e., within a large time interval $[t_0,T]$, the influence of the initial regime of oil flow in a pipeline (at $t=t_0$) on the current state of the process decreases, and there exists such τ $(\tau<T)$ that at $t>\tau$ the regime of oil motion experiences only the influence of the boundary-value conditions on the time interval $[t_0,T]$, where the quantity τ is determined by the parameters of the process and the characteristics of the pipeline [9]. Thus, we arrive at the problem without initial conditions.

III. Approach to the solution of the problem

In order to solve the problem posed, we will consider the functional that determines the derivation of regimes of oil flow at the given points of the oil pipeline section from those predicted:

$$\Im(\xi,q^{loss})=\int_{\mathrm{D}}\Big[\Phi(\xi,q^{loss};\gamma)+\Re(\xi,q)\Big]\mu_{\mathrm{D}}(\gamma)d\gamma\to\min, \tag{7}$$

$$\Phi(\xi, q^{loss};\gamma) = \sum_{m\in\tilde{I}_q^f}\int_{\tau}^{T}[Q^m(t;\xi,q(t),\gamma) - Q_{mes}^m(t)]^2\,dt,$$

$$\Re(\xi,q) = \varepsilon_1\left\|q(t) - \hat{q}\right\|^2_{L_2^Z[t_0,T]} + \varepsilon_2\left\|\xi - \hat{\xi}\right\|^2_{R^Z},$$

where $Q^m(t;\xi,q(t),\gamma), m\in\tilde{I}_q^f$ – is the solution of the problem (1)–(5) at the given values of $(\xi, q^{loss}(t))$, $[\tau, T]$ is the time interval of monitoring the process whose regimes already do not depend on the initial conditions; $\tilde{\xi},\tilde{q}\in R^m, \varepsilon_1,\varepsilon_2$ – are the regularization parameters. Since the initial conditions at time t_0 do not influence the process in the interval $[\tau, T]$, exact knowledge of the initial value of t_0 is not of primary importance.

Proceeding from the meaning of the problem considered, technological conditions, and technical requirements, we will assume that are restrictions on the identified functions and parameters:

$$0<\xi_{ks}\le l^{ks},\quad \underline{q}\le q^{loss}(t)\le\bar{q},\quad t\in[t_0,T],$$

where $\underline{q},\bar{q}$ are the given quantities.

As is seen, as to the determination of the points and rates of leakages the posed problem is the problem of parametric optimal control of an object described by a hyperbolic system. For its solution we use numerical methods (projections of the conjugated gradient) based on iteration procedures of first order optimization. To carry out this procedure, we obtain formulas for the gradient of functional (7). If as a result of the solution of posed problem we obtain that $\left|q^{loss}(t)\right|\le\varepsilon,\ t\in[\tau,T]$, this will mean that in this section of the pipeline network there is no leakage of raw material.

IV. Results of numerical experiments

We consider the following specially constructed test problem for oil pipeline network consisting of 5 nodes, as shown in figure 2. Here $N=6, M=5, I^f=\{1,3,4,6\}, N_f=4, N_{\text{int}}=2$. There are no external inflows and outflows inside the network. We assume that in the course of 30 min we observe the process (mode of operation of pumping plants at the ends of the sections) of oil transportation with the kinematic viscosity $\nu=1.5\cdot10^{-4}\,(m^2/s)$ and density $\rho=920\,(kg/m^3)$ ($2a=0.017$ for case being considered; the sound velocity in oil is $1200\,(m/s)$) in the sections of pipeline of diameter 530 (mm), of the lengths of the segments:

$$l^{(1,2)}=100\text{ (km)}, l^{(5,2)}=30\text{ (km)}, l^{(3,2)}=70\text{ (km)}, l^{(5,4)}=100\text{ (km)}, l^{(5,6)}=60\text{ (km)}.$$

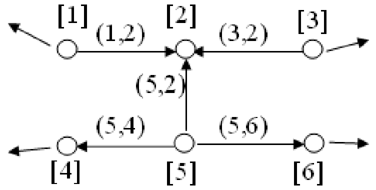

Fig.2: *The scheme of oil pipeline network with 5 nodes*

Let there was regime in the pipes at initial time instance $t=0$ with the following values of pressure and flow rate in the pipes:

$$\hat{P}^{1,2}(x)=2300000\text{-}5.8955x \text{ (Pa)},\ \hat{P}^{5,2}(x)=1745669\text{-}1.17393x \text{ (Pa)},$$
$$\hat{P}^{3,2}(x)=1827844\text{-}1.677043x \text{ (Pa)},\ \hat{P}^{5,4}(x)=1827844\text{-}2.35786x \text{ (Pa)},\ \hat{P}^{5,6}(x)=1827844\text{-}0.94415x \text{ (Pa)}.$$

$$\hat{Q}^{1,2}(x)=300\ (m^3/hour),\ \hat{Q}^{5,2}(x)=200\ (m^3/hour),\ \hat{Q}^{3,2}(x)=100\ (m^3/hour),$$
$$\hat{Q}^{5,4}(x)=120\ (m^3/hour),\ \hat{Q}^{5,6}(x)=80\ (m^3/hour),$$

Let the oil flow rate at the ends of this pipeline section be defined by the functions:

$$\tilde{P}_0^1(t)=2000000\text{+}300000\,e^{-0.0003t} \text{ (Pa)},\ \tilde{P}_0^3(t)=1900000\text{-}72156\,e^{-0.0004t}=\text{(Pa)},$$
$$\tilde{P}_l^4(t)=1800000\text{-}66571\,e^{-0.0007t} \text{ (Pa)},\ \tilde{P}_l^6(t)=1600000\text{+}86372\,e^{-0.0002t} \text{ (Pa)}.$$

On the assumption that the point of leakage is located at the point $\xi=30\ (km)$ of the first section of pipeline network and the rate of leakage is determined by the function $q^{loss}(t)=50-10e^{-0.0003t}\ (m^3/h)$, we solved the boundary-value problem (1)-(5) numerically and determined the numerical values of pressure at the ends of the section $P^n(t), n\in I_p^f$. Thereafter, with the aid of the probe of uniformly distributed random numbers these values were changed within 2% (to simulate the error of measurements) and used as the observed regimes of the process. The point and rate of leakage $\xi,\ q^{loss}(t)$ "forgotten" in this case.

To determine $\xi,\ q^{loss}(t)$, we used the method of the projection of conjugate gradients. The numerical solution of the boundary-value problem (1)–(5) was made using the scheme of the sweep method introduced in [10], on the grids with the steps $h_x=10m$ and $h_t=100(\sec)$.

Table 1 presents the obtained results of the minimization of functional (7) for different initial values of the identified parameters $(\xi,\ q^{loss}(t))^0$, as well as the required number of iterations (one-dimensional minimizations) of the method of projection of conjugate gradients. Here are the results of solving the problem under the conditions that the observed values of the flow rate at the ends of the network have measurement errors.

For this experiment, to generate observations for the inverse problem, by using a random number generator we add noises $\eta\chi_i Q^m(t_i)$ to the values $Q^m(t_i)=Q^m(t_i;\xi,q),\ t_i=ih_t,\ m\in\tilde{I}_q^f,\ i=1,...,N_t$ obtained by solving the direct problem, where χ_i - random variable, uniformly distributed on a segment [–1,1], $i=1,...,N_t$, η takes values equal to 0.0, 0.005 and 0.01, which corresponds to the noise level when measuring flow rates in vertices $\tilde{I}_q^f$ respectively in 0% (without noise), 0.5% and 1% from the measured value.

We use the following designations in table 1: $\tilde{\xi}^{(1,2)}$ – obtained leak location value, $\Im_0$ – initial value of the functional, $\tilde{\Im}$ – the resulting optimal value of the functional, N_{iter} – the number of iterations (one-dimensional minimizations) required by the conjugate gradient projection method, $\delta\xi^{(1,2)} = |\,\xi^{(1,2)^*} - \tilde{\xi}^{(1,2)}\,| / \xi^{(1,2)}$, $\delta q^{(1,2)} = \max\limits_{t\in[t_0,T]} |\,q^{(1,2)^*}(t) - \tilde{q}^{(1,2)}(t)\,| / |\,q^{(1,2)}(t)\,|$ – relative error values, respectively, at the location of leakage and its volume.

As can be seen from Table 1, an increase in the accuracy of measurements most significantly affects the accuracy of determining the volume of leaks, but in general, the order of error of the obtained values of the identified parameters is the same as the order of measurement error.

Table 1: *The results of numerical experiments*

η						
	$\xi_0^{(1,2)}$	60	20	90	10	45,685
	$q_0^{(1,2)}(t)$	$90-10e^{-0.0003t}$	$20-10e^{-0.0003t}$	$30-10e^{-0.0003t}$	$66+20e^{-0.0003t}$	$66+20e^{-0.0003t}$
0%	$\Im_0$	76.104	16.704	11.664	42.48	57.636
	$\tilde{\Im}$	$5.73\cdot10^{-7}$	$1.26\cdot10^{-7}$	$3.19\cdot10^{-6}$	$1.85\cdot10^{-6}$	$7.43\cdot10^{-7}$
	$\tilde{\xi}^{(1,2)}$	30.003	29.998	30.008	29.994	29.998
	N_{iter}	6	5	16	14	8
	$\delta\xi^{(1,2)}$	0.00009	0.00006	0.0003	0.0002	0.00006
	$\delta q^{(1,2)}$	0.0003	0. 0006	0.0003	0.0002	0.0003
0.5%	$\Im_0$	76.352	16.837	11.683	42.148	57.732
	$\tilde{\Im}$	0.023	0.014	0.024	0.017	0.020
	$\tilde{\xi}^{(1,2)}$	29.841	30.332	30.068	29.654	29.796
	N_{iter}	6	5	14	12	7
	$\delta\xi^{(1,2)}$	–0.005	0.011	0.002	–0.011	–0.006
	$\delta q^{(1,2)}$	0.043	0.030	0.049	0.041	0.042
1%	$\Im_0$	77.119	16.924	11.832	43.744	57.413
	$\tilde{\Im}$	0.067	0.071	0.073	0.062	0.065
	$\tilde{\xi}^{(1,2)}$	28.527	29.392	29.923	30.597	29.839
	N_{iter}	6	5	14	12	7
	$\delta\xi^{(1,2)}$	–0.049	–0.020	–0.002	0.020	–0.005
	$\delta q^{(1,2)}$	0.109	0.092	0.107	0.094	0.093

Figure 3 shows the graphs of the exact leak function and the resulting loss functions when solving problem assuming the presence of a leakage.

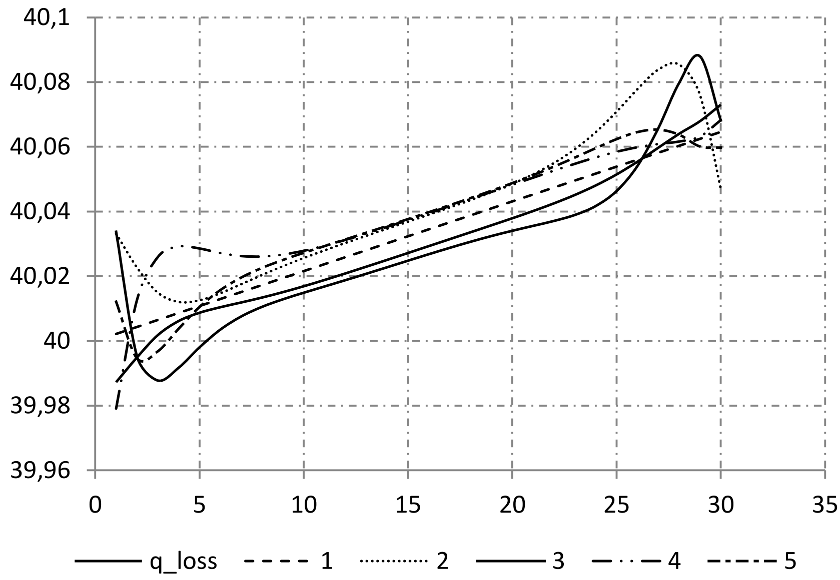

Fig.3: *The exact and experimental time dependences of raw material leakage.*

V. Conclusion

We propose a numerical solution to an inverse problem in the hydraulic network of complex loopback structure in the paper. The problem consists in determining the places and volume of leakage in the presence at some points of the pipeline the results of additional observations on non-stationary regimes of fluid flow. We reduce the stated problem to the parametric optimal control problem with unknown initial and non-separated boundary conditions, and use numerical methods of first-order optimization to solve the problem. The results of numerical experiments are given.

References

[1] Evtushenko Yu. G., Methods for Solving Optimization Problems and Their Applications in Optimization Systems ("Nauka", Moscow, 1982) [in Russian].

[2] Oyedeko K.F.K. Balogun H.A Modeling and Simulation of a Leak Detection for Oil and Gas Pipelines via Transient Model: A Case Study of the Niger Delta. (2015). *Journal of Energy Technologies and Policy*. 5:1. https://iiste.org/Journals/index.php/JETP/article/view/19389/19532

[3] Samarskii A.A. and Vabishchevich P.N., Numerical Methods for Solving Inverse Problems in Mathematical Physics (LKI, Moscow, 2009) [in Russian].

[4] Charnyi I.A., Unsteady Flows of Real Fluids in Pipelines (Nedra, Moscow, 1975) [in Russian].

[5] Chaudhry H.M. Applied Hydraulic Transients. Van Nostrand Reinhold, New York ,1988.

[6] Aida-zade K.R. and Ashrafova E. R. Localization of the points of leakage in an oil main pipeline under non-stationary conditions. (2012). *J. of Eng. Phys. and Therm.* 85:5:1148–1156. https://doi.org/10.1007/s10891-012-0757-z

[7] Aida-zade, K.R., Ashrafova, E.R. Numerical Leak Detection in a Pipeline Network of Complex Structure with Unsteady Flow. (2017). *Comput. Math. and Math. Phys.* 57:1919–1934. https://doi.org/10.1134/S0965542517120041

[8] Wichowski R. Hydraulic Transients Analysis in Pipe Networks by the Method of Characteristics (MOC). (2006). *Archives of Hydro-Engineering and Environmental Mechanics.* 53:3:267–291.
https://www.infona.pl/resource/bwmeta1.element.baztech-article-BAT3-0039-0044/tab/summary

[9] Ashrafova E.R. Numerical investigation of the duration of the effect exerted by initial regimes on the process of liquid motion in a pipeline. (2015). *J. of Eng. Physics and Therm.* 88:5:1–9. https://doi.org/10.1007/s10891-015-1305-4

[10] Aida-zade K.R. Ashrafova Y.R. Solving systems of differential equations of block structure with nonseparated boundary conditions. (2015). *J.of Applied and Industrial Mathem.* 9:1:1–10. DOI: 10.1134/S1990478915010019

METHODOLOGY FOR THE IMPLEMENTATION OF PROBLEMS CAUSED BY RESERVOIRS ON THE SEASHORE

Lia Matchavariani, Giorgi Metreveli

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Ivane Javakhishvili Tbilisi State University, Georgia
lia.matchavariani@tsu.ge
giorgi.metreveli@tsu.ge

Abstract

Geological, demographic, climatic (present-day eustasy) and anthropogenic (reservoirs, urban loadings) factors play an active role in the formation of the coastal zone. The anthropogenic factor acts against the background of natural factors and depending on the direction of their vectors increases or decreases. In such circumstances, it is expedient to create a long-term forecast of coastal dynamics using proven methods. In contrast to them, in order to study the anthropogenic factor, i.e., the impact of the reservoir on the state of coastal beaches, a new method for studying the limiting volume of the silting prism of a reservoir has been proposed. Therefore, for the long-term prediction of the dynamics of a specific section of the seashore under the influence of the reservoir, a methodology should be used, that, together with it, combines the research methods of the factors operating in the region. Such a technique has been first tested on the eastern coast of the Black Sea, in the Chorokhi delta, where the sea threatened the city of Batumi with complete destruction after river sediments were blocked in recent years by a cascade of six reservoirs. According to the forecast made by this technique, the coast of the city will no longer receive beach-forming sediments within a millennium. Taking into consideration that the sea annually carries away a large amount of beach-building material from the delta, the city of Batumi and the entire delta are threatened with a complete abrasive collapse. The long-term forecast created using the new method makes it possible to determine timely the duration of the impact of reservoirs on the coast, the risks of natural disasters, and start permanent artificial backfilling of the coast with sediments and its strengthening with appropriate anti-abrasive structures.

Keywords: abrasion, beach, sediment quarry, silting prism, silting tail

I. Introduction

Delta at the confluence of the river with the sea is an area of unstable dynamic equilibrium between land and sea. Here, solid material carried down by the river, sediment, and runoff, interacts with the sea. Most of them sink into the sea passing through underwater valleys and canyons, and some are carried by waves along the coast. Such sediments form protective beaches, and runoff creates coastal and bottom currents that enhance sediment transport. Accordingly, the beach is a layer whose parameters, coastal protection, and other functions are determined by the amount and characteristics of sediments.

Urbanic and climatic processes are taking place in deltas, against the background of long-term (centuries long) movements of land and sea level. In the current century, due to their impact, the parameters of hydrometeorological events, storm waves, and currents more and more often reach catastrophic levels. In turn, both climatic and urban factors significantly increase the requirements for the complex use of rivers with reservoirs. Clearly, anthropogenic activity has a negative effect on the safety and social conditions of the settlements located in their deltas, since the reservoir blocks the flow of river sediment for many years, which leads to the destruction of coastal beaches [3, 10, 14, 17, 18, 19]. Finally, the abrasive effects of sea waves end up destroying the delta, settlements, infrastructure, and communications.

Reservoir silting processes have been satisfactorily studied [1, 2, 4-9, 11-13, 15, 16]. An exception is the study of the consequences and risks of the impact of the reservoir on the seashore. Therefore, the dynamics of the delta in the area of influence of the reservoir, the social conditions of the population, and the types of vulnerability should be studied with such a method that includes the processes of the dynamics of the prism of the reservoir (Fig. 1). Using this method, it becomes possible to create a long-term forecast of the impact of the reservoir on a particular delta.

Figure 1: *Fragments of the Silting Prism of Mountain Reservoirs (Zhinvali)*

Thus, the goal of the study is to create a methodology that includes methods for studying the main factors acting on the seashore, laws of the reservoir silting prism dynamics, and creates the conditions for preparing a long-term forecast of the dynamics, protection-adaptation, and development of the region affected by the reservoir. Using this method, it is possible to calculate the risks of a disaster in a timely manner and start the permanent artificial filling of the coast with sediment, as well as build coast protection structures according to a scheme corresponding to the litho-dynamic and other characteristics of the coast.

In the current century, the process of using rivers as water reservoirs have significantly intensified on the eastern coast of the Black Sea. In recent decades, a cascade comprised of six reservoirs was built on the Chorokhi River. In the coming decades, seven more should be added to them(Fig. 2). In addition, it is also planned to build two by two reservoirs on the Rioni and Enguri rivers. These actions have led to a significant deficit in sediment on most parts of the sea coast, starting the degradation of the beaches, which threatens the population living in the deltas, infrastructure, communications, and port complexes with catastrophic erosion.

Figure 2: *Borchka, Deriner,and Yusufeli Reservoirs, Turkey*

Most of these factors are characterized by a long period of action, low inertia, and the irreversibility of results. Therefore, to adapt-neutralize their results, appropriate projects are needed, which must be created ahead of time.

The research area includes the eastern coast of the Black Sea - the coastal strip of Georgia, the basins of the rivers Rioni, Enguri, and Chorokhi where separate reservoirs and their cascades operate; also, Kodori and Bzibi gorges, because they are promising in terms of creating integrated reservoirs. Batumi (1882-2021) and Poti (1873-2021) marine and hydro-meteorological monitoring (1870-2021) stations operating in the region. The assessment of geological and geodesic processes was performed with the data of repeated geodetic plans (1902-1952), the results of the active geodetic network, and special geodetic measurements [17].

II. Methods

This study uses traditional statistical (least squares, mathematical expectation) and analog methods in the research process. During the implementation of research work on the impact of reservoirs on the environment and population, the methods of "estimating the regional parameters of the background of current climate variability" and "determining the limiting volume of the reservoir's silting prism" were created[16]. In their implementation, the results of natural experiments for the study of water reservoirs were used [12].

III. Results and Discussion

At the beginning of the current century, when the Muratli Reservoir was built (2005) on the Chorokhi, the reality of catastrophic coastal erosion of the region became obvious. The commissioning of the next reservoirs of the cascade – Borchka (2007), Deriner (2012), Artvini (2020), and Yusuflu (2021) confirmed that if in the current decade the source-ore to fill the degradable beaches was not selected, and the sediment conveyor "ore– shore" was not put into operation, storm waves shortly (2030-2050) will damage the runway of Batumi airport and the nearest residential buildings.

The aforementioned technique was used (tried) for the first time on the eastern coast of the Black Sea, in the delta of the Chorokhi River, where the multifunctional city of Batumi with a population of 150 thousand people is situated. A significant share of the oil transported by the Baku-Ceyhan pipeline passes through the Batumi port to many countries. The city is located on the southern part of the Colchis plain, the so-called Kakhaberi plain, which is built of the Chorokhi sediments. Due to the constant lack of sediment, the Kakhaberi plain, as well as Batumi with its surrounding settlements, infrastructure, and communications, will inevitably become a victim of marine erosion as the cascade of the Chorokhi reservoir blocked the sediment flow that filled the beaches for a long time (Table 1).

Table 1: *The years of reservoirs operation on the Chorokhi, morphometric parameters, and terms of maximum silting (the construction of 7 additional reservoirs is scheduled which will increase the mentioned period to 2260)*

River	Reservoir	Year of operation	Volume of reservoir, km^3	Marginal volume of silting prism tail, km^3	Marginal volume of silting prism$(W + W_{tail})$,km^3	Term of marginal silting of water reservoirs, year
Chorokhi	Muratli	2005	0.04	0.01	0.05	6.0
	Borchka	2010	0.45	0.16	0.61	73.0
	Deriner	2012	2.10	0.75	2.85	339
	Artvin	2016	2.13	0.76	2.89	344
	Yusufeli	2024	2.13	0.76	2.89	344
Adjaristskali	Shuakhevi	2015	0.15	0.05	0.20	24
	Total:		7.0	2.49	9.49	1130

Obviously, it is necessary to determine the period during which the coast will remain in the mode of sediment deficit. Calculating its duration is also necessary because the sea takes 80-100 thousand m^3 of beach-building material from the delta every year, and if it was compensated by river sediment before the cascade was activated, during the cascade's operation, it will be necessary to artificially fill the sediment deficit following the relevant principles.

Determination of the indicated period (T yr.) is possible using the method of the threshold value of the silting prism of each reservoir. Its essence is that the sediment accumulates in the reservoir until the sediment completely fills it, i.e., it creates an accumulation body – the silting prism. At the same time, the tail/train of this prism will be formed synchronously above it (Fig.3). Such tail starts from the dam, completely covers the reservoir, and extends into the tributaries to the intersection, where the river can transport the full spectrum of sediments to the lower basin. The length and width of such a tail significantly exceed the parameters of the reservoir mirror, and the volume reaches 20-30% of the reservoir size (W).

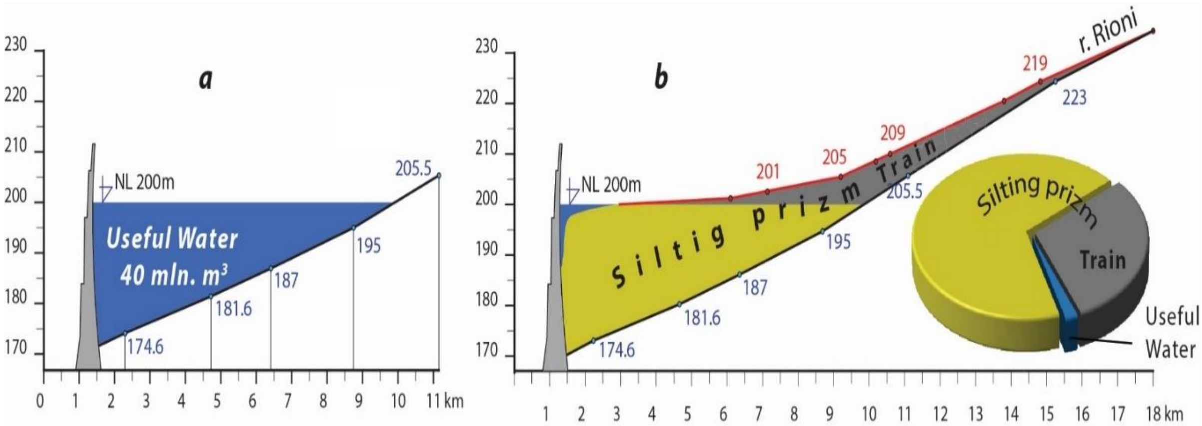

Figure 3: *Gumati Reservoir longitudinal sections in initial (a) and finishing phases (b) of operation*

Finally, the silting of the reservoir ends when a body with a volume of ~1.3Wj forms in it. And its surface is an accumulative plain inclined towards the dam, which starts from the dam and extends to an imaginary intersection of tributaries, from where they can transport sediment to the lower basin. Taking into account this regulation, the complete silting volume (R) of the Chorokhi cascade can be determined with acceptable accuracy using the following expression:

$$R = 1{,}3 \sum_{j}^{n} Wj, \quad n=1,2,....,6$$

In the expression, 1.3Wj denotes silting limit value of each water reservoir (Fig. 2).

According to long-term monitoring data of the hydrological station Erge, the annual sediment volume of the Chorokhi reached 8.4 mln m^3 until 2005, or 0.0084 km^3. Of this volume of sediments, 2.5 mln m^3 were large beach-forming sediments. Of these, ~0.2 mln m^3 was used to fill and restore coastal beaches, the rest was lost in the underwater canyon of the river.

The long-range forecast produced by this method makes it possible to calculate disaster risks in time and proceed to the constant artificial filling of the coast with sediment, as well as to strengthen the coast with structures that correspond to the characteristics of a particular land area.

The catastrophe can be avoided if the following procedures are performed by the proposed method: determine the dominant factors that define the regime of the beaches along the studied coast; select methods for analyzing these factors; establish the duration of the impact of reservoirs on the delta; identify detect an alternative source of Chorokhi deposits (ore).

On the coast of the region under study, during historical time, the activity of geological (tectonics, sedimentation-consolidation) and oceanographic (abrasion, eustasy) factors was a priority. Since the 1900s, the climatic factor has intensified in the Black Sea basin and the eustasy provoked by it – the rise in sea level, which is the result of thermal expansion of water. This process began in the 1960s and accelerated dramatically in the 2010s. Accordingly, the urban factor has intensified – subsidence caused by the weight of the underlying buildings, the vector of which is opposite to the geological factor in this region. Under the influence of the geological factor, the coast was rising at a rate of ~10 cm/yr. until the 1960s. In subsequent decades, the urban load created by constructions on the coast increased so much that this component almost neutralized the influence of the geological relief, and the coast, composed of alluvial layers, began to subside. This is confirmed by the results of the standard geodetic network and sea level monitoring. This is a negative fact since the subsidence of the coast brings the collapse of coastal erosion closer.

To determine the parameters of modern eustasy, the long series of sea levels constructed based on the monitoring results of the Batumi Oceanographic Station is used. It is possible to determine the parameters of the secular coastal movements using repeated data of geodetic planning. The parameters of modern climate change can be determined from monitoring data of the main meteorological elements of the regional climate background [air temperature (t), precipitation (p), wind (w), and air humidity (h)]. The variational parameters of these elements are also determined: trend (τ), average values for characteristic time intervals (M[t,p,w,h]), and the main statistical characteristics – a polynomial equation and a correlation coefficient.

In the 2010s, the activation of the lower reservoir of the Chorokhi cascade (Muratli) intensified erosion processes in the delta so much that it became necessary to carry out special research works to make a forecast of the expected erosion of the delta and the Batumi seashore. According to research results, shortly (2030-2040), sea waves will directly attack airport runways and nearby residential buildings (Fig. 4). After making new forecasts for the impact of the silting prism of reservoirs [13, 16] on the sea coast in 2020-2022, it will become obvious that the Cascade threatens the area surrounding Batumi with complete abrasion collapse (Fig. 5). According to the same studies, a disaster can be avoided by selecting a full-fledged deposit substituting the Churokhi R. sediments. Most likely, such an object is the Rioni River sediments forming a silting prism of the Gumati reservoir.

Figure 4: *Expected erosion of the Chorokhi River delta and the Batumi coastline under conditions of permanent sediment deficit*

IV. Conclusions

The impact of the reservoir on the sea coast is extremely negative. It blocks the flow of sediments that fill the beaches for a long time, and the permanent deficit of sediments caused by their cascade reaches many centuries in some places and ends with the collapse of the coastal erosion. Such negativity can be avoided by the methodology which combines all the rules and methods that form the multifactorial regime of the coast and determines the terms for the maximum silting of the reservoir silting prism. Its advantage is that it determines the duration of a particular water reservoir or cascade with reasonable accuracy and allows early identification of means to prevent abrasive collapse in due time.

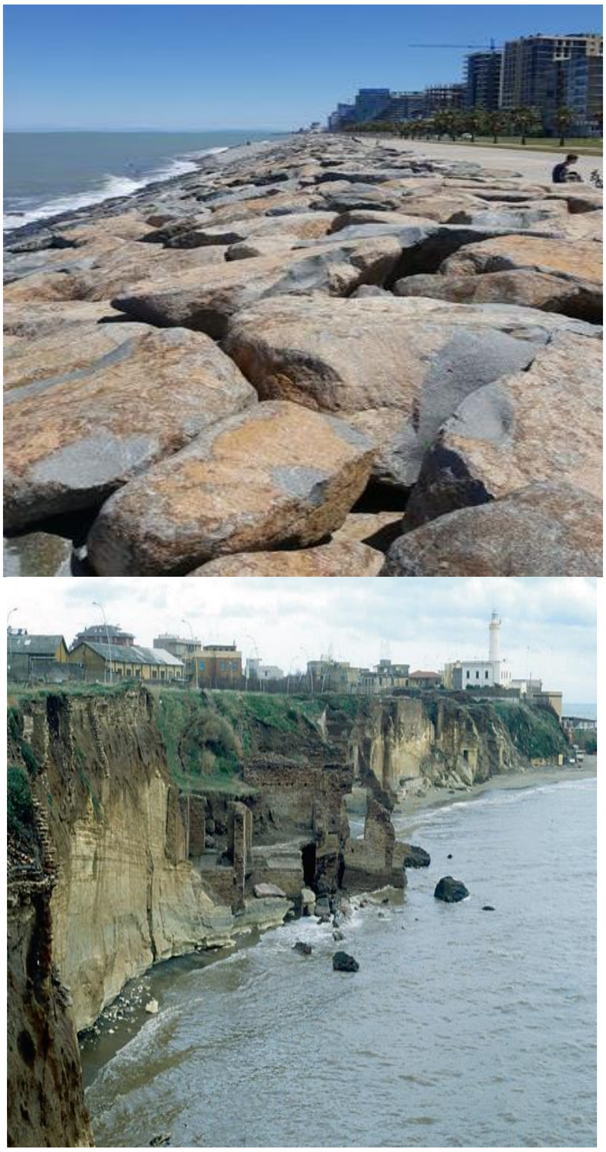

Figure 5: *Covering massive boulders, protecting against the abrasive effects of waves (A); Result of the abrasive collapse of sea waves (B)*

References

[1] Andredaki, M., Georgoulas, A., Hrissanthou, V., Kotsovinos N. (2014). Assessment of reservoir sedimentation effect on coastal erosion in the case of Nestos River, Greece. *Intern. Journal of Sediment Research*, 29(1), 34-48.

[2] Bennett, S.J., Dunbar, J.A., Rhoton, F.E., Allen, P.M., Bigham, J.M., Davidson, G.R., Wren, D.G. (2013). Assessing sedimentation issues within aging flood-control reservoirs. *Reviews in Engineering Geology*, 21, 25-44.

[3] Burova V.N. (2020). Abrasion Risk Assessment on the Coasts of Seas and Water

Reservoirs. *Geodetski list*, 74(2), 185-98.

[4] Caputo, M. and Carcione, J.M. (2013). A memory model of sedimentation in water reservoirs. *Journal of Hydrology*, Elsevier, 476, 426-432

[5] Detering, M. and Schuettrumpf, H. (2014). Reservoir Siltation and Ecological Life Span of Dams. *Wasser Wirtschaft,* Springer,104 (1-2), 30-33.

[6] Garg, V., Jothiprakash, V. (2013). Evaluation of reservoir sedimentation using data driven techniques. *Applied Soft Computing*, Elsevier, 13(8), 3567-3581.

[7] Gopinath, G., Ashitha, M.K., Jayakumar, K.V. (2014). Sedimentation assessment in a multipurpose reservoir in Central Kerala, India. *Environmental Earth Sciences*, 72(11), 4441-4449.

[8] Hajji, O., Abidi, S., Habaieb, H., Mahjoub, M.R. (2014). Regionalization and contribution to the study of reservoir sedimentary: Lakes of Cape Bon and the Tunisia Central. Proceeding of the 11th Intern. Conference on Hydroscience & Engineering "Hydro-Engineering for Environmental Challenges", Germany, 575-582.

[9] Hosseinjanzadeh, H., Hosseini K., Kaveh, K., Mousavi, S.F. (2015). New proposed method for prediction of reservoir sedimentation distribution. *International Journal of Sediment Research*, 30(3), 235-240

[10] LoucksDaniel, P., Eelco van Beek (2017). Water Resource Systems Planning and Management: An Introduction to Methods Models and Applications. Springer, 624 p.

[11] Mansikkamäki, H. (2013). Monthly sedimentation in some reservoirs of hydroelectric stations in Finland. *Fennia-International Journal of Geography*, 2013, 143(1).

[12] Matchavariani, L., Metreveli, G., Alaverdashvili M., Lagidze L., Svanadze D., Gulashvili Z., Bregvadze G. (2016). Results of Field Experiments of Reservoirs' Siltation for Harmonious Realization of Hydropower and Coastline Problems. 2nd Intern. Conference on Science, Engineering & Environment, SEE-Osaka, Japan, 639-644.

[13] Matchavariani, L., Metreveli, G., Lagidze, L., Svanadze, D., Gulashvili Z. (2017). Solution of Reservoirs' Siltation Problem for Hydropower Development and Coastal Protection. *Intern. Journal of GEOMATE*, Japan, 206-212.

[14] Matchavariani, L., Metreveli, G., Gulashvili, Z. (2021). Role of Water Reservoirs in the Seashore Dynamics. Proceedings of the 21th Intern. Multidisciplinary Scientific GeoConference SGEM2021, 3(3.1), Albena, Bulgaria, 285-292.

[15] Metreveli, G., Matchavariani, L. (2016). Research Method of Silting the Mountain Reservoirs under the Current Climate Change. *Journal of Water Resources and Ocean Science. Science Publishing* Group, 5(2), 22-27.

[16] Metreveli, G., Matchavariani, L., Gulashvili, Z. (2019). Method for Hydrological Parameters Definition of Silting Prism and Equilibrium Bed in Water Reservoirs. Proceedings of the 19th Intern. Multidisciplinary Scientific GeoConference SGEM2019, 19(3.1), Albena, Bulgaria, 363-368.

[17] Metreveli, G., Matchavariani, L., Gulashvili, Z. (2022). Positives and Negatives of Water Reservoirs. Samshoblo, ISBN: 978-9941-9784-6-3, 200 p. (in Georgian).

[18] Patriadi, A., Soemitro R., Warnana D.D., Wardoyo, W., Mukunoki, T., Tsujimoto, G. (2021). The Influence of Sembayat Weir on Sediment Transport Rate in the Estuary of Bengavan Solo River, Indonesia. *Intern. Journal of GEOMATE*, vol. 20, Issue 81, 35-43.

[19] Starodubtsev, V.M., Bogdanets, V.A. (2016). Dynamics of the Tsimlyansk Reservoir Coastline. *SWorldJournal*, 1102, 7-15.

GOALS TO REDUCE GREENHOUSE GAS EMISSIONS. ACHIEVEMENT OF CARBON NEUTRALITY IN RUSSIA AND IN THE WORLD

Muslim Eskiev, Aishat Baysangurova, Elita Yaumieva
•
Chechen State University named after A.A. Kadyrov, Russia
yaumiyeva87@bk.ru
salamova_chgu@mail.ru

Abstract

The fight against climate change is one of the key tasks both at the international level and in a single country. All regions of the world today are assessing the negative consequences of global warming, developing regulatory mechanisms in order to reduce the negative impact on the climate and adapt to it as much as possible, as well as transform economies to move towards a low-carbon development model. Goals are set and commitments are made to reduce greenhouse gas (GHG) emissions. More than 140 countries, accounting for 90% of global GHG emissions, have already reported targets for achieving carbon neutrality. Accordingly, business and entire sectors of the economy determine their opportunities in this direction, setting their own goals and identifying tools for reducing emissions and developing new technological solutions. Obviously, it is impossible to immediately switch to a new economic model and technologies with zero greenhouse gas emissions. For some industries, in principle, such solutions are complex, and alternatives to them appear extremely slowly. To achieve carbon neutrality goals, carbon dioxide capture, capture and storage projects play an important role. A climate project is a set of measures that reduce (prevent) greenhouse gas emissions or increase GHG1 absorption. The result of the implementation of climate projects are carbon units, expressed as the number of avoided or absorbed emissions in tons of CO2 equivalent. Special requirements are imposed on these projects and their justification, and their results are confirmed by external experts.

Keywords: greenhouse gas emissions, climate initiatives**,** climate change, environmental protection, technological solutions

I. Introduction

An increase in the concentration of greenhouse gases (hereinafter referred to as GHGs) in the atmosphere is one of the main challenges of the 21st century. The problem of climate change entails a number of negative, and often almost irreversible, consequences. The concern of country leaders with this issue led to the fact that in 1992 an international agreement was signed - the UN Framework Convention on Climate Change (hereinafter - the UNFCCC) [1]. To achieve the goals of the UNFCCC, the Third Conference of the Parties to the UNFCCC adopted the Kyoto Protocol, which is the first global agreement to reduce GHG emissions at the global level, which is based on the principle of common but differentiated responsibilities. The Kyoto Protocol was built on a top-down principle and included 3 market mechanisms: an emissions trading system, a joint implementation project and a clean development mechanism. As part of the top-down approach, a binding target for reducing total emissions has been defined, and based on this, emission targets have been set for developed countries and countries with economies in transition [2]. Despite strong initial support from the international community, the Kyoto Protocol did not lead to significant global emission reductions because developing countries (such as the largest emitters China and India) made no quantifiable emission reduction commitments. This approach proved to be untenable, therefore, under the Paris Agreement, which actually replaced the Kyoto Protocol in 2015, the opposite “bottom-up” approach was used. Within the framework of this principle, it is assumed that each country independently sets national emission reduction targets based on its energy strategy, for the implementation of which it will be able to use the most convenient and effective methods of regulation, both market (different from the mechanisms of the Kyoto Protocol) and non-market ones.

The European Union is the world leader in green initiatives, despite the fact that the combined share of all countries is only 9.7% of global emissions. On December 1, 2019, the European Commission was headed by Ursula von der Leyen, for whom the further strengthening of climate policy is one of the priorities [4]. On December 11, 2019, the European Commission approved the proposed European Green Deal and submitted a corresponding communiqué with a roadmap (for consideration by the European Parliament, the Council of the EU, the European Council and a number of committees). Although the communiqué has no legal force, it characterizes the main directions of the EU green policy. The Green Deal is positioned as a new European strategy for sustainable growth and climate leadership: by 2050, Europe should become the first climate-neutral continent (with zero net greenhouse gas emissions). The deal affects a wide range of sectors of the EU economy, but above all energy, transport, agriculture and energy-intensive industries, which account for the bulk of European greenhouse gas emissions [1-2]. The European Commission estimates that current policies will only reduce EU GHG emissions by 60% by 2050, so countries plan to consider increasing the EU climate target for reducing GHG emissions by 2030 from 40% to at least 50% through measures such as extending the European GHG Emissions Trading Scheme to new sectors of the economy; increasing climate targets for sectors not covered by the system; adjusting the regulation of land use and forestry, as well as through the introduction of a carbon levy on imported goods. The introduction of such a levy would solve the problem of “carbon leakage” associated with international trade: companies from countries that have quantitative obligations to reduce emissions are motivated to move carbon-intensive production to developing countries where there are no such obligations (the so-called “pollution harbors”), and then import the products back. Approximately 25-30% of global emissions are imported and exported from country to country. The European Union is a net importer of carbon, the main exporters of CO2 to the EU are the countries of North America, Russia, China. Despite the fact that the implementation of the "pivot to the East" continues, Russia still remains one of the main partners of the European Union in energy trade. Further decarbonization of the EU economy increases the risks of shrinking the traditional Russian export market, and the introduction of a carbon tax on imports of goods, according to BCG estimates, could potentially cost the Russian oil and gas sector $1.4–2.5 billion annually, the ferrous metals and coal sector — 0.6–0.8 billion US dollars, non-ferrous metals — 0.3–0.4 billion US dollars, other sectors of the economy — 0.8–1.1 billion US dollars [4]. In addition, BCG analysts point out that, due to its higher carbon intensity, Russia may lose part of the EU oil market to Saudi Arabia due to lower profitability, and for producers of nitrogen fertilizers, the carbon fee may become extremely high, reaching 40-65% of the current export value of fertilizers2. However, it is not yet clear how the responsibility for collecting such taxes on exporters will be distributed and how the collected funds will be used.

II. Methods

The challenges posed by current global climate policy trends dictate the need for further level. A pollutant is any substance whose concentration or quantity in the environment exceeds natural background values. Pollutants introduce adverse changes in the physical, chemical or biological properties of the environment and have a negative impact on public health. Emissions of pollutants are accounted for by their state of aggregation (solid, gaseous and liquid), by individual substances (ingredients) and by type of emission sources (stationary and mobile) [5]. Regional data are aggregated by source of emissions: statistical accounting of pollutants from stationary sources has been carried out since 2000, and from mobile sources, taking into account railway transport, since 2012. According to Rosstat, most of the pollutants are in the gaseous and liquid state: in 2019, their share in Russia amounted to 94.5% of all air pollutants. More than a third was carbon monoxide (37.9%), sulfur dioxide - 18.1%, hydrocarbons (without volatile organic compounds) - 17.5%, and nitrogen oxides - 12.7% [6].

A significant driver of demand for carbon credits is corporate commitment to carbon neutrality, linked both to voluntary carbon neutrality targets and market expectations, including the investment community, and a premium for carbon neutral products. Climate projects must meet several basic principles: 1. The principle of Additionality implies the reduction or absorption of more emissions over a certain period of time than in the implementation of a scenario in which there is no project. Moreover, it must be proven that the project would not have been implemented without additional financial resources raised in the carbon market [7]. 2. The principle of persistence (Permanence) shows that the project must not only ensure the absorption of emissions, but also prevent the subsequent return of carbon to the atmosphere (for example, in forest projects it is necessary to prevent forest fires). 3. The principle of avoiding double counting (Double-counting) is that the amount of carbon units received as a result of the project should be sold only once and must 5 One year later: The path to carbon negative — a progress report on our climate 'moonshot' — The Official Microsoft Blog 6 carbon-market-survey-2021.pdf (refinitiv.com) 7 Taskforce on Scaling Voluntary Carbon Markets, January 25th, 2021. Summary pack (TSVCM_Summary.pdf (iif.com)) to be submitted only one register. In case projects are implemented in regulated industries, the volume of received and sold carbon credits is added to the volume of recorded emissions of organizations for which they are implemented [8]. 4. The principle of leakage prevention (Leakage) assumes that the implementation of the project should not lead to the fact that the emission source was transferred to another region. 5. These principles have been recognized as the basis for the standards and schemes of the carbon market for over 20 years. But, nevertheless, these standards and requirements for projects as a whole are not unified enough. With the similarity of the standards used, there is no consensus on the market about full confidence in them. Many leading companies, such as Microsoft5, are ready to additionally analyze climate projects on their own in order to minimize risks and sustainable removal of GHGs from the atmosphere. According to a study by Refinitiv6, certification of a project to a certain standard is only the second most important factor in selecting a climate project after determining the category of the project (e.g. removal of emissions is preferred over simple reduction, reforestation is preferred over reforestation projects REDD+) [9]. In addition, it is also important to increase the confidence of buyers of carbon credits through transparent pricing and to keep a balance between new and long-term projects. To consolidate the voluntary market for carbon units and increase its efficiency, the Taskforce on Scaling Voluntary Carbon Markets (TSVCM) initiative was created, within which it is planned to develop a single standard (Core Carbon Principles), increase market liquidity (including the creation of a secondary market), increase confidence in the use carbon credits to offset emissions, further drawing the attention of buyers to this mechanism. The concept of carbon market development is based on the notion that, regardless of their origin, greenhouse gases that accumulate in the atmosphere have a negative impact on the climate system on a global scale. Accordingly, reducing their emissions, wherever it occurs, serves to mitigate climate change. In recent years, the market has been turning into a powerful economic mechanism for mobilizing global resources for the development and dissemination of the most promising low-carbon technologies and, in general, for transferring the world economy to an innovative, low-carbon development path [6].

III. Results

Voluntary (verified) schemes for offsetting emission reductions based on the implementation of investment projects in this area have already existed for about 30 years. The catalyst for their development was the entry into force of the Kyoto Protocol in 2005. In this market, companies can act as issuers of credits (carbon credits) or as buyers of credits to offset their carbon footprint. Voluntary carbon credit purchasers are generally commercial and non-profit organizations that are not subject to mandatory emission control schemes but who nonetheless make a voluntary commitment to reduce or eliminate their carbon footprint [7]. This can be done by offsetting your emissions, in whole or in part, by purchasing carbon credits verified against voluntary standards. In most cases, the acquirers do so in order to fulfill their corporate social responsibility strategy or to improve the company's image. However, in a number of cases, purchasers purchase voluntary emission reduction units in the hope of subsequently offsetting them against future mandatory GHG emission control and reduction requirements [8]. During its existence, the voluntary market has created its own carbon schemes, standards and registries, which are gradually gaining official recognition. The voluntary market, in contrast to the regulated market, is more flexible and allows the choice of the most suitable standard for a particular project from a variety of standards. In addition, its concept and mechanisms make it possible to reduce emissions in the most economically feasible way (that is, in a way independently chosen by the company and where it is currently cheaper and more profitable). In order to be compensated for voluntary emission reductions, the beneficiary must meet strict requirements, including quantification. The processes may differ depending on the standard, but it is most common to go through a similar series of steps [9].

At the global level, standards such as the Gold Standard, the Verified Carbon Standard (VCS), which account for about 85% of the total market, and the Clean Development Mechanism (Clean Development Mechanism (CDM), American Carbon Registry (ACR), Climate Action Reserve (CAR), Plan Vivo. While international mechanisms are very similar, they are often distinguished by the areas of projects that they take into account. For example, all standards accept carbon credits from forestry projects and waste management, but only the American Carbon Registry and Clean Development Mechanism are loyal to the potential of carbon capture, storage and utilization (CCS) projects. Speaking about the project implementation timeframe, all standards consider the project start date to be the day when the project began to generate GHG reductions or removals (with the exception of the Gold Standard, where the project start is considered to be the day when the project founder began to bear the costs of it) [10]. For AFOLU (agriculture, forestry and other land uses), the start date of projects is the day on which preparatory work (eg soil preparation) began. However, the period during which a project generates carbon credits varies depending on the standard: the duration of AFOLU projects can range from 20 to 100 years; for other types of projects, different standards set different time frames, which range from five years to 21 years. However, none of the standards addresses projects that are longer than 100 years, although such approaches are already being developed. All analyzed standards require that the implementation of projects does not lead to negative consequences for the social and environmental environment, to violation of the current legislation [8].

In addition to requirements for reducing emissions, purchasers of voluntary carbon credits also make demands on the social and environmental significance of carbon projects, preferring, all other things being equal, those in which this focus is better expressed. In particular, such requirements can be traced in one of the most popular standards, the Gold Standard [9]. This probably explains to some extent the fact that in 2021 special attention is paid to projects aimed at preserving and preventing deforestation, which are not only natural carbon sinks and storages, but also the habitat of various fauna and flora, including rare and disappearing. In addition, such projects are characterized by long cycles, since it takes a long time from the planting of trees to the effect of the first serious emission reductions. However, this direction is gaining more and more supporters. If in 2020 the segment ranked second in terms of the number of issued and redeemed carbon units, then in eight months of 2021 it took the leading positions (45% and 47% of the total market volume, respectively). Thus, the number of units based on forest and land projects in circulation has already increased by almost 90% compared to the whole of 2020, and those purchased by 16% [4-5].

IV. Discussion

Solving the problem of climate change has become one of the key challenges of the 21st century for politicians around the world [5]. In recent decades, global climate change and its regional impact continues to negatively affect the stable economic development of any country. Thus, anomalous hydrometeorological processes contribute to an increase in the number of natural disasters, mudflows, floods, squalls, droughts, strong winds, heavy rains, forest fires, fluctuations in the level of water bodies and other phenomena. At present, the economy not only of individual states, but of the whole world as a whole is subject to significant damage under the influence of climate change. A real danger to humanity is being created, which requires active decisions and actions from the world community, scientists and politicians. The report of the Intergovernmental Panel on Climate Change on the consequences of global warming of 1.5°C, published in 2018, indicated that even a 1.5°C increase in temperature will lead to irreversible changes for the environment [9]. To limit global warming, human-caused carbon dioxide (CO2) emissions need to be reduced by 45-60% by 2030 compared to 2010, scientists say. And by 2050, we need to reach zero balance, when all anthropogenic CO2 emissions will be absorbed by ecosystems. In the Eastern Europe, Caucasus and Central Asia (EECCA) region, countries are already feeling negative impacts from climate change. On the territory of all EECCA countries, an increase in the average annual temperature is recorded. The Central Asian region is considered one of the most vulnerable regions in the world. Also, in the EECCA countries, changes in the duration of the seasons, the amount and distribution of precipitation, drought, flooding, and a decrease in the provision of water resources are already being recorded. As global temperatures rise, the negative impact will only increase. All countries in the EECCA region have ratified the Paris Agreement, which set the goal of not allowing global temperatures to rise by more than 2°C and to make significant efforts not to exceed global temperature rises of more than +1.5°C. Achieving these goals will depend on a wide range of different policy instruments that can be used at the national level to mitigate climate change.

The World Business Council for Sustainable Development (WBCSD) is a global coalition of 170 companies from 35 countries and 20 industries [10]. It cooperates with a network of 50 national and regional business councils and partner organizations, including about 1000 companies. The Council's largest members include BP, Shell International, Volkswagen, Gaz de France, Philips, Stat Oil, ABB, Alcan, Alcoa, Chevron Texaco and many other world business leaders. Russia's business council includes Gazprom, Basic Element and AFK Sistema (www.wbcsd.org). In connection with the problem of global climate change, WBCSD, together with the World Resources Institute (WRI), has launched an initiative to develop and promote internationally GHG accounting and reporting standards for companies, corporations and industry associations. Most of the largest companies, non-government and many official organizations have joined this initiative. A wide range of specialists (about 700 experts from the largest companies around the world) from most industries, industry associations and leading industry and environmental institutions, as well as government agencies were involved in the work on the standard. In addition to the protocol, guidelines and software tools have been created for calculating GHG emissions and their absorption by terrestrial ecosystems. In the near future, a standard for accounting and reporting on GHG emissions and removals for emissions management projects should appear. These developments should help companies and other industry organizations and associations: to conduct an inventory of emissions that meets the requirements of the IPCC for the quality of accounting and reporting; ensure comparability of assessments and reporting of different companies; comparability of GHG reporting formats with other types of corporate reporting, including financial reporting; create an information base for effective emission management and development of a reduction strategy [8]. In general, the protocol will help to minimize companies' costs for inventory, facilitate the fulfillment of climate obligations to states, and increase commercial attractiveness in the eyes of external partners and investors. The peculiarities of the inventory of companies/concerns and industry associations are determined by the fact that, unlike a country or region that has certain territorial boundaries and a diversified structure of sources of GHG emissions and sinks, companies' enterprises are often scattered geographically. However, they have a more homogeneous structure of sources, typical for the respective industry [9]. The modern business is distinguished by a complex system of production location. The energy supply, the production of components, packaging, etc. closely link companies all over the world. The protocol recommends following the concept of boundaries, similar to those used in financial reporting. The latter are based on the concepts of control/management and influence. Control/governance is defined as the ability of a company to direct the operational policies of an enterprise/division, usually when the company owns a controlling stake (> 50%) of the shares of the enterprise/division.

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References

[1] Zubrzycki, S.; Kutzbach, L.; Pfeiffer, E.-M. Permafrost-affected soils and their carbon pools with a focus on the Russian Arctic. Solid Earth 2019, 5, 595–609.

[2] Schuur, E.A.G.; McGuire, A.D.; Schadel, C.; Grosse, G.; Harden, J.W.; Hayes, D.J.; Hugelius, G.; Koven, C.D.; Kuhry, P.; Lawrence, D.M.; et al. Climate change and the permafrost carbon feedback. Nature 2018, 520, 171–179.

[3] Leap, F. Measuring and Modelling Soil Carbon Stocks and Stock Changes in Livestock Production Systems: Guidelines for Assessment (Version 1). Livestock Environmental Assessment and Performance (LEAP) Partnership; FAO: Rome, Italy, 2019; p. 170.

[4] Davidson, E.A.; Janssens, I.A. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature, 2018, 440, 165–173.

[5] Abakumov, E.; Maksimova, E.; Tsibart, A. Assessment of postfire soils degradation dynamics: Stability and molecular composition of humic acids with use of spectroscopy methods, 2020, 29, 2092–2101.

[6] Gao, Y.; Couwenberg, J. Carbon accumulation in a permafrost polygon peatland: Steady long-term rates in spite of shifts between dry and wet conditions, 2020, 21, 803–815.

[7] Leggett, J. A.; J. Logan and A. Mockey, China's Greenhouse Gas Emissions and Mitigation Policies, vanov, A.; Stolbovoy, V. The initiative «4 per mille»—A new global challenge for the soils of Russia, 2019, 98, 185–202.

[8] Kudeyarov, V.N. Soil-biogeochemical aspects of arable farming in the russian federation, 2019, 52, 94–104.

[9] Ryzhova, I.M.; Telesnina, V.M.; Sitnikova, A.A. Dynamics of soil properties and carbon stocks structure in postagrogenic ecosystems of southern taiga during natural reforestation. Eurasian Soil Sci. 2020, 53, 240–252.

[10] Morkovina, S.; Panyavina, E.; Shanin, I.; Avdeeva, I. Economic aspects of the organization of carbon farms on forest site. Actual Dir. Sci. Res. Xxi Century: Theory Pract. 2021, 9, 17–26.

A SHORT REVIEW OF ENVIRONMENTAL AND HEALTH IMPACTS OF GOLD MINING

Palma Orlović-Leko, Branimir Farkaš, Ivo Galić

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University of Zagreb, Croatia
palmaorlovic@gmail.com
branimir.farkas@rgn.hr
ivo.galic@rgn.hr

Abstract

Gold mining is attracting increasing attention in many countries of the world. On the other hand, this sector causes numerous environmental and human health issues. The main problems are associated with: (i) Acid Mine Drainage (AMD) with low pH values and high concentrations of heavy metals, (ii) using large quantities of hazardous chemicals such as mercury and cyanide and (iii) mining dust. Degree of the impact depends of the scale mining (small or large scale), type of mine (surface and underground) as well as of the chemical reagents that use in the production process. Modern technology has made it possible to reduce environmental impacts of mining activities.
This brief review looks at the gold mining sector (industrial and artisanal) and its key impact on environmental as well as on health of workers and communities (residents who live in proximity to the mine)..

Keywords: pollution, air, soil, water

I. Introduction

Mining is a profitable industry, but it is also one of the most pollutant source for terrestrial and aquatic ecosystems [1–3]. All environment components suffer the consequences of metal mining activities (including all phases of the mining cycle): preparation of the mining site, excavating, dewatering, crushing, grinding, separation, smelting, refining, management of tailings and waste-rock [1]. Furthermore, environmental pollution affects the health of both miners and communities living around mining complexes [2, 4–6]. Degree of the impact depends of the scale mining (small or large scale), type of mine (deep or open cast mine) and the use of hazardous materials in the extraction and processing stages [1–3, 7]. The old abandoned mines that were not closed "lege artis" also can cause environmental and human health dangers. [8–10]. Note, the abandoned mine sites are those mines that are no longer operational, not actively managed, not rehabilitated, causing significant environmental problems, and for which no one is currently accountable for the site's remediation or rehabilitation [10]. Within the environmental impact category, air and water/soil pollution are interconnected [11]. The term pollution of the environment refers to an increase of a concentration of pollutant relative to its natural level. An important fact is that pollutants transported more rapidly over long distances from mine by atmospheric aerosol than by other media such as water and soil [12].

Metal mining generate large volumes of waste (referred to as tailings) containing hazardous minerals from the original ore and metals that are concentrated in solid wastes or drainage [13–15]. Some effluents generated by the gold mining industry contain large quantities of toxic substances such as cyanides, mercury or sulfuric acid [16]. In arid areas, mine tailings are subject to aeolian dispersion and water erosion, while in temperate environment they are a source of metal leachate or metal-rich acidic wastewater [17]. In the case of water erosion, metals and other potentially undesirable elements introduced into water bodies; dissolved metals become are more bioavailable to organisms [11 and references therein].

Mineral dust emitted from mining operations and mine tailings, may mobilize high levels of metals and metalloids [12]. The climate change can substantially increase the potential for dust emissions and its transport [18]. Therefore, the role of mining activities in the fate and transport of environmental pollutants could become increasingly important [12]. Removal of trace metals from the atmosphere by precipitation affects chemistry and biogeochemistry in the surface waters [11 and references therein]. Atmospheric transport of the particle–associated metals/metalloids contribute to health effects; exposed human population may develop respiratory, neurological and other serious health problems [12].

Mining industry introduces heavy metals to the environment in quantities many times exceeding natural soil background concentrations [4,19,20]. The most toxic ones, arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb), are associated with gold [4,19]. An important ecological property of metals is their persistence and ability to accumulate in ecosystems [21]. They can accumulate in human organisms through food chain causing serious maladies [20]. Miners may experience adverse health effects due to long periods of exposure to heavy metals in the soil [19].

Water is the biggest victim of mining [2]. Surface and groundwater pollution is one of the significant impacts of mining activity due directly influence in quality of life/health. The impact of mining on surface and groundwater is due to acid mine drainage (AMD), heavy metal and processing chemicals, erosion and sedimentation [2,22,23]. Sulfide–containing minerals, in the reaction with air and water form sulphuric acid i.e. acidic water mine waters ($pH < 7$) referred to as AMD or acid rock drainage (ARD) [22]. This process forming in any part at both active and abandoned mine sites where metal sulfides are exposed to air and water, including rock waste and tailings is one of the single greatest environmental challenge in the mining sector [8,9,22]. Due to the higher mobility of metals at low pH, acid mine waters usually contain high concentrations of toxic metals and metalloids and can cause serious ecological problems and can affect water quality and thus aquatic biota [8,9].

Leachates from mine tailings may be more aggressive than discharges from mine pits and underground workings [22]; this makes the management of waste dumps of utmost importance [13]. Through surface runoff and groundwater circulation, AMD from mines reaches surface and groundwater. The problem of AMD pollution does not finished with the closure of the mine, on the contrary, it can last for centuries. Flooding of abandoned mines leads to discharge of AMD into river valleys [8,9]. However, when ores contain a high proportion of minerals that can neutralize acidic waters, oxidation of mineral sulfides does not lead to the formation of AMD [14].

Spill, leak, or leach of toxic chemicals using to separate the target mineral from processing facilities into nearby water bodies may lead to large–scale water pollution [22]. Additionally, due the heavy use of water in processing ore and of discharging untreated water into rivers, mining have adverse impacts on the rivers surrounding the mines [2].

As mentioned above, also erosion of waste materials at mining sites can affect surface water quality. Besides, erosion of the exposed earth from the open-pit may carry substantial amounts of sediment into streams, rivers and lakes. Consequently, sedimentation and siltation of the receiving waters can result into significantly higher turbidity and conductivity, thus, affecting the physiology and behaviors of various aquatic species, including the fish [22]. Therefore, protecting water quality is a high priority environmental challenge in mining and mineral processing.

This article summarizes the basic literature information of the environmental and health risks associated with gold mining operations.

II. Different scales of gold mining operation (small and large)

According to scale of mining operations, studies of gold mining and health are divided into small–scale (artisanal, surface type) and large–scale (industrial, underground or open pit type) mining [1]. Artisanal and Small–Scale Gold Mining (ASGM) refers to the informal (illegal) occupational sector employing unskilled workers (and sometimes children). [4,7]. Work is typically done with minimal or no mechanization and without appropriate professional and environmental protection measures [7]. However, artisanal mining is very important for the economy of developing countries [24]. This method of gold production occurs in at least eighty countries in the Global South. Approximately 90% of all employment in gold mining and 20% of global gold production are based on small–scale extraction [25,26]. Large–scale gold mining (LSGM) requires huge capital investment [1]. This type of mining employs highly trained and educated personnel and uses sophisticated machinery [1]. Large-scale mining involves both deep pit and surface methods [1]. In the wake of increasingly environmental challenges posed by the mining sector, the ASGM sector receives much attention over LSGM [1]. However, in any system of mining there is potential environmental risks introduced.

2.1. ASGM and associated hazards

Small–scale gold miners use large quantities of hazardous chemicals (such as mercury or cyanide) in the extraction and processing stages to recover gold from ore [4,27]. Elemental mercury is used in extraction of gold from raw ore through amalgamation [27]. The amalgam is heated to evaporate the mercury and separate the gold. In a report "The World's Worst Pollution Problems 2016", the artisanal gold mining was identified as one of the world's top ten pollution problems due it releases more mercury into the environment than any other sector worldwide [28]. For example, in study in the Bolivian Andes found that mercury vapor levels at the two mining sites were approximately 30 times larger than reference concentration of the United States Environmental Protection Agency (USEPA) [4]. Likewise, one report estimated that 5 tons of mercury is released from ASGM operations in Ghana each year [2]. Further, in Myanmar it was found that the maximum mercury concentration in the atmosphere in the gold mining area reached 74,000 ng/m^3 that exceeded the WHO guideline of 1,000 ng/m^3 [27]. The vaporized mercury that is emitted into the atmosphere without any treatment, not only polluting the environment, but harming human health, especially the health of workers [27]. Therefore, workers involved in the gold mining operations, their families as well as surrounding communities can be exposed to dangerous levels of elemental Hg vapor [30]. Note, approximately 15 million people, including approximately 3 million women and children, participate in artisanal small-scale gold mining (ASGM) in developing countries [30]. It is important to note that inhalation of Hg vapor can produce harmful effects on the nervous, digestive, and immune systems and the lungs and kidneys (WHO 2007).

The ASGM had major effects on water bodies [2]. Releases of mercury to the environment can result in the contamination of freshwater fish with methylmercury. Consequently, ASGM community can be exposed to this very toxic substance from food sources [29].

In order to comply with modern environmental standards, reducing mercury use is a key step in realizing ASGM development opportunities. Esdaile and Chalker [31], in their work, emphasize that mercury–free gold mining is possible and they encourage researchers, funding agencies and journal editors in chemistry and allied fields to consider how they might marshal their resources and expertise to address this global mercury problem.

Cyanide is considered as one of the most cost–effective methods to extract bits of gold. It is faster and more effective at extracting gold than mercury amalgamation [7]. The process involves dissolution of gold from the ore in a dilute cyanide solution and extraction of the gold in a complex in the presence of lime and oxygen [6]. On the other hand, it is known that cyanide is a very fast–acting poison [32]. If cyanide is properly manufactured, handled and used, it does not pose a risk to human health or the environment. However, ASG miners use cyanide with minimal personal protection [6,7]. In one study on cyanide exposure in a gold mining community, in the Philippines, 35% subject respondents had elevated blood cyanide level and the adverse health symptoms [7]. The study of environmental impacts of gold mining in Essakane site (Burkina Faso) showed that the artisanal miners in the area are predominantly illiterate and do not have enough knowledge about the effects of chemicals such as mercury and cyanide [3]. Thus, to reduce the adverse effects of ASSM on the health of mining communities and the environment, among others, it is recommended better education of the risks as well as simple controls to reduce exposure [4].

In addition to Hg, ASGM sites are commonly associated with high levels of the toxic heavy metals such as arsenic (As), cadmium (Cd) and lead (Pb) [4, 19]. Mentioned metallic elements can cause adverse health effect in humans even at exposure to low concentrations. They are classified as human carcinogens according to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer [33]. In the study conducted in Bolivian Andes, in an area of ASGM operations, arsenic concentrations in soil were 3–4 orders of magnitude above background levels [4]. There is also evidence the arsenic contamination of the biotic and abiotic samples in proximity to mining sites [34]. Gold deposits frequently contain various forms of arsenic: arsenides, sulfides, and sulfosalts. Arsenic sources associated with gold mining include waste rocks, residual water from ore concentrations, roasting of some types of gold-containing ores to remove sulfur and sulfur oxides, and bacterially enhanced leaching [34]. Arsenic may be mobilized in aqueous environments where cyanide has been used to leach gold ores [35]. It has been noted that gold miners may have a number of health problems associated with arsenic, such as increased mortality from lung, stomach and respiratory tract cancer [34].

Mining activities such as rock drilling and related milling operations generate copious amounts of dust, which is mainly contain of crystalline silica. In particular, ASG miners are exposed to the crystalline silica dust. In the process of the separating the gold from the other minerals, when ASG miners crush and grind the ore manually, crystalline silica dust is released into the air. Exposure to dust is an important risk factor for many respiratory diseases. Constant exposure to silica dust can cause silicosis and significantly contribute to tuberculosis incidence rates in mining communities [3,6].

2.2. LSGM and associated hazards

The LSGM possess detrimental effects on the environment, due to their continued use of modern, sophisticated machinery and harmful chemicals, as well as extended blasting levels [1]. The research conducted on a single large–scale mining company in Ghana have been shown that large-scale gold mining operations threaten the environment. The study discovered the air pollution, noise pollution (due noise several species of animals migrated to favorable environments), deforestation. The LSGM have also caused excessive damage to the lands/soil of mining communities within mining area. It has been shown that agricultural land as well as forest reserves were reduced. The rivers and streams in the closeness to mining pits were greatly polluted by mine wastewater drainage and heavy run-off from the waste rocks at mining pit. [1].

Porgoa and Gokyay have been analized the environmental impacts of industrial gold mine (open-pits mining) activities in the Essakane area [3]. The results showed that exploiting of gold mine directly or indirectly contributes to air pollution. The use of cyanide to obtain the gold from ore constitutes a potential risk for the ecosystems, the local population’s health, and livestock production. The results also showed that there is a significant degradation of natural landscape and topography of the soil.

III. Modern gold mining in Europe

The European gold mining industry is among the most modern and safest worldwide, and it based on "Best Available Techniques" (BAT) [37]. A modern gold mine uses high-tech processes, and automation to extract and process gold ore and the most up to date technology to protect human health and safety [37]. An overwhelming majority of modern gold mines operating around the world uses dilute solutions of sodium cyanide for gold recovery. Cheaper method that could replace cyanide, do not exist at this time. Only in some cases, the nature of the ore enables the use of cyanide-free processes such as gravimetric separation and flotation concentration [37]. It is important to highlight that the use of cyanide in ore processing is regulated by specific requirements enacted by the EU to aim the safe use and to prevent risks for human health and the environment. Cyanide is either recycled and re-used in the process or destroyed prior to any disposal of tailings. The fact that cyanide further naturally degrades in the tailings facility means that final concentrations in the tailings can even become very difficult to detect [37].

Note, a focus on environmentally responsible mining not only includes measures to protect human health and prevent accidents, it also includes modern mine site rehabilitation following the closure of the facility as to mitigate environmental effects and preserve biodiversity.

IV. Conclusion

This brief review looks at the gold mining sector and its key environmental as well as health impacts, both for miners and for the communities living around mine. Numerous quantitative studies shown the interlinkages between mining operations and effects on the landscapes, water and terrestrial ecosystems, and health miners as well as affected communities. These negative effects are caused by the physical degrading nature of mining, as well as the use of chemicals and other harmful substances in the mineral processing.

The principles of sustainable development have had a growing influence on the development of environmental policy. Mining can become more environmentally sustainable by developing and integrating practices that reduce the environmental impact of mining activities [23]. Implementation of the best available technologies, adequate trainings, and standard working practices should render mining safer occupation than ever before [38].

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References

[1] Usman Kaku, D., Cao, Y., Al-Masnay, Y.A. and Nizeyimana, J.C. (2021). An Integrated Approach to Assess the Environmental Impacts of Large–Scale Gold Mining: The Nzema-Gold Mines in the Ellembelle District of Ghana as a Case Study. *Int. J. Environ. Res. Public Health*, 18: 7044–7064.

[2] Emmanuel, A.Y., Jerry, C.S. and Dzigbodi, D.A. (2018). Review of Environmental and Health Impacts of Mining in Ghana. *J Health Pollut*., 12,8(17):43–52.

[3] Porgo, M. and Gokyay, O. (2017). Environmental impacts of gold mining in Essakane site of Burkina Faso. *Human and Ecological Risk Assessment: An International Journal,* 23(3): 641–654.

[4] Pavilonis, B., Grassman, J., Johnson, G., Diaz, Y. and Caravanos, J. (2017). Characterization and risk of exposure to elements from artisanal gold mining operations in the Bolivian Andes. *Environmental Research*, 154: 1–9.

[5] Kyaw, W.T. Kuang, X. and Sakakibara, M. (2020). Health Impact Assessment of Artisanal and Small–Scale Gold Mining Area in Myanmar, Mandalay Region: Preliminary Research. *Int J Environ Res Public Health,* 16;17(18):6757–6769.

[6] Utembe, W., Faustman, E.M., Matatiele, P. and. Gulumian, M. (2015). Hazards identified and the need for health risk assessment in the South African mining industry. *Human and Experimental Toxicology,* 34(12): 1212–1221.

[7] Leung, A.M. and Lu, J.L.D.P. (2016). Environmental Health and Safety Hazards among Indigenous Small-Scale Gold Miners Using Cyanidation in the Philippines. *Environmental Health Insights,* 10: 125–131.

[8] Wolkersdorfer, C. and Bowell, R. (2004). Contemporary Reviews of Mine Water Studies in Europe, Part 1 – *Mine Water and the Environ*., 23: 162–182.

[9] Wolkersdorfer, C. and Bowell, R. (2005). Contemporary Reviews of Mine Water Studies in Europe, Part 2 – *Mine Water and the Environ*., 24: 2–37.

[10] Mhlongo, S.E. and Amponsah-Dacosta, F. (2016). A review of problems and solutions of abandoned mines in South Africa. *International J of Mining, Reclamation and Environ*., 30(4): 279–294.

[11] Orlović-Leko, P., Vidović, K., Ciglenečki, I., Omanović, D., Dutour Sikirić, M. and Šimunić, I., (2020). Physico-chemical characterization of an urban rainwater (Zagreb, Croatia). Atmosphere 11, 144. https://doi.org/10.3390/atmos11020144

[12] Csavina, J., Field, J., Taylor, M.P., Gao, S., Landázuri, A., Betterton, E.A. and Sáez, A.E. (2012). A review on the importance of metals and metalloids in atmospheric dust and aerosol from mining operations. *Science of the Total Environment,* 433: 58–73.

[13] Ata Akcil, A. and Koldas, S. (2006). Review article: Acid Mine Drainage (AMD): causes, treatment and case studies. *Journal of Cleaner Production*, 14: 1139–1145.

[14] Basir, N.A.M., Yaacob, W.Z.W., Mohammed, N.H., Atta, M. and Zarime, N.A. (2019). Prediction and Remediation of Water Quality in Monitoring Potential of Acid Mine Drainage. *American Journal of Engineering and Applied Sciences*, 12 (2): 173–184.

[15] Naickera, K., Cukrowskaa, E. and McCarthy, T.S. (2003). Acid mine drainage arising from gold mining activity in Johannesburg, South Africa and environs. *Environmental Pollution* 122: 29–40.

[16] Bach, L., Nørregaard, R.D., Hansen, V. and Gustavson, K. (2016). Review on environmental risk assessment of mining chemicals used for mineral separation in the mineral resources industry and recommendations for Greenland. Aarhus University, DCE – Danish Centre for Environment and Energy, 34 pp. Scientific Report from DCE –Danish Centre for Environment and Energy No. 203. http://dce2.au.dk/pub/SR203.pdf

[17] Mendez, M. O. and Maier, R. M. (2008). Phytoremediation of mine tailings in temperate and arid environments. Rev. *Environ. Sci. Biotechnol*. 7: 47–59.

[18] Mifka, B., Telišman Prtenjak, M., Kuzmić, J., Čanković, M., Mateša, S. and Ciglenečki, I. (2022). Climatology of dust deposition in the Adriatic Sea; a possible impact on marine production. *Journal of Geophysical Research: Atmospheres*, 127, e2021JD035783. https://doi.org/10.1029/2021JD035783www.euromines.org

[19] Tun, A.Z., Wongsasuluk, P. and Siriwong, W. (2020). Heavy Metals in the Soils of Placer Small-Scale Gold Mining Sites in Myanmar. J Health Pollut.;10(27):200911. doi: 10.5696/2156-9614-10.27.200911. PMID: 32874767; PMCID: PMC7453810.

[19] Ghazaryan, K.A., Hasmik, S., Movsesyan, H.S., Naira, P. and Ghazaryan, N.P. (2017). Heavy metals in the soils of the mining regions of Kajaran, Armenia: a preliminary definition of contaminated areas. *Academic J. of Science,* 07(03):421–430.

[20] Wong, C.S.C. and Li, X., Thornton, I. (2006). Urban environmental geochemistry of trace metals. *Environ. Pollut*., 142: 1–16.

[21] Jhariya, D. C., Khan, R. and Thakur, G. S. (2016). Impact of mining activity on water resource: an overview study. *Proceedings of the Recent Practices and Innovations in Mining Industry*, Raipur, India, 19–20.

[22] Ugya, A. Y., Ajibade, F. O. and Ajibade, T. F. Water pollution resulting from mining activity: An overview. *Proceedings of the 2018 Annual Conference of the School of Engineering &*

Engineering Technology (SEET), The Federal University of Technology, Akure, Nigeria, 17–19 July, 2018.

[23] Mkpuma, R.O., Okeke, O.C. and Abraham, E.M. (2015). Environmental Problems of Surface and Underground Mining: a review. *The International Journal Of Engineering And Science (IJES)* 4 (12):12–20.

[24] Ofosu–Mensah, E.A. (2011). Historical overview of traditional and modern gold mining in Ghana. *International Research Journal of Library, Information and Archival Studies* 1(1): 006–022.

[25] World Bank: *2020 State of the Artisanal and Small-Scale Mining Sector. 2020.*

[26] Inter–Governmental *Forum on Mining, Minerals, Metals and Sustainable Development: Global Trends in Artisanal and Small–scale Mining: A Review of Key Numbers and Issues. 2017.*

[27] Tomonori Kawakami, Misa Konishi, Yuki Imai, and Pyae Sone Soe (2018). Diffusion of mercury from artisanal Small–Scale Gold Mining (ASGM) sites in Myanmar. *GEOMATE Journal* 17 (61):228–35.

[28] Bernhardt, A. and Gysi, N., (2016). The World's Worst Pollution Problems: The Toxics Beneath Our Feet. *Pure Earth and Green Cross Switzerland*. Available online: http://www.worstpolluted.org/docs/WorldsWorst2016.pdf (accessed on 3 July 2022).

[29] Kyaw, W. T., Kuang, X. and Sakakibara, M. (2020). Health Impact Assessment of Artisanal and Small–Scale Gold Mining Area in Myanmar, Mandalay Region: Preliminary Research. International journal of environmental research and public health, 17(18), 6757–6769.

[30] Gibb, H. and O'Leary, K. G. (2014). Mercury exposure and health impacts among individuals in the artisanal and small-scale gold mining community: a comprehensive review. *Environmental health perspectives*, 122(7), 667–672.

[31] Esdaile, L.J. and Chalker, J.M. (2018). The mercury problem in artisanal and small-scale gold mining. *Chem. Eur. J.*, 24: 6905 – 6916.

[32] Hamel J. (2011). A review of acute cyanide poisoning with a treatment update. *Crit Care Nurse*, 31:72–82.

[33] Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K. and Sutton DJ. Heavy metal toxicity and the environment. Exp Suppl. 2012;101:133-64. doi: 10.1007/978-3-7643-8340-4_6. PMID: 22945569; PMCID: PMC4144270.

[34] Eisler, R. (2004). Arsenic Hazards to Humans, Plants, and Animals from Gold Mining. In: Reviews of Environmental Contamination and Toxicology. Reviews of Environmental Contamination and Toxicology, vol 180. Springer, New York, NY. https://doi.org/10.1007/0-387-21729-0_3

[35] Straskraba, V. and Moran, R.E. (1990). Environmental occurrence and impacts of arsenic at gold mining sites in the western United States. *International Journal of Mine Water* 9: 181–191.

[36] Gottesfeld, P., Damian Andrew, D. and Dalhoff, J. (2015) Silica Exposures in Artisanal Small-Scale Gold Mining in Tanzania and Implications for Tuberculosis Prevention, *Journal of Occupational and Environmental Hygiene*, 12:9, 647–6535.

[37] Sustainable gold mining in Europe – Euromines. Available online: https://www.euromines.org/files/publications/sustainable-gold-mining-europe-english-language-version.pdf (accessed on 3 July 2022).

[38] Pokhrel, L.R. and Dubey, B. (2013). Global Scenarios of Metal Mining, Environmental Repercussions, Public Policies, and Sustainability: A Review. Crit. Rev. *Environ. Sci. Technol.*, 43: 2352–2388, DOI: 10.1080/10643389.2012.672086

NATURAL HAZARDS AND ENVIRONMENTAL DECISION-MAKING

Zelimkhan Musostov[1], Albina Berkaeva[2], Isa Basnukaev[3]

•

[1]Chechen State University, Grozny named after A.A. Kadyrov, Russia
zmr@hotmail.co.uk
[2]North Ossetian State University named after K.L. Khetagurov, Russia
[3]Grozny State Oil Technical University named after acad. M.D. Millionshchikov, Russia
i.basnukaev@mail.ru
salamova_chgu@mail.ru

Abstract

Natural hazards have been in wait for mankind in all periods of its existence, leading to the destruction of material values and the death of people. Despite significant scientific achievements in the field of forecasting and preventing natural disasters, it is not possible to completely prevent their occurrence. Against the background of active human intervention in the environment and the associated climate change, the number of natural disasters is significantly increasing. This necessitates the transformation of the economic system, the development of new models of "green" growth, which implies harmonious relations between man and the biosphere. The article presents a modern assessment of natural hazards and the risks of their occurrence, as well as developed directions for making environmental decisions to minimize them.

Keywords: natural hazards, natural disasters, environmental solutions, disaster prevention, ecology, green economy.

I. Introduction

Environmental protection is one of the most significant and urgent tasks of our time. As a result of humanity's irresponsible attitude to environmental issues, negative climate changes are observed, pollution of natural environments is steadily increasing, natural resources are being depleted, biological diversity is declining, and people's physical and moral health is deteriorating. But the most serious consequence of human intervention in the biosphere is the rapid increase in natural hazards: according to the UN World Meteorological Organization, over the past 50 years, the number of natural disasters has increased 5 times. Every year, more than 100 million people are forced to turn to the international humanitarian system for help due to storms, floods, droughts and forest fires [1].

In general, natural hazards are hazards associated with natural disasters that pose a direct threat to property, life and health of people [2]. These phenomena (natural disasters) do not depend on a person and go beyond the average natural states in terms of scale, duration and intensity of manifestation. They cause significant and irreversible damage to natural and social systems due to their inability to adapt to rapidly changing environmental conditions.

II. Methods

The key source of natural hazards is the interaction of individual systems of the Earth associated with the flow of physical, physico-chemical and biochemical processes, as well as the exchange of various types of energy. These processes naturally determine the continuous transformation of the face of the planet. Natural disasters follow certain patterns:

- they have a certain spatial attachment (for example, a flood can occur only in the place of a natural reservoir or watercourse, and earthquakes practically do not occur on platform areas that are far from the junctions of lithospheric plates);
- the frequency and power of a natural phenomenon are inversely proportional to each other (the most serious natural disasters happen quite rarely);
- any natural disaster is more or less predictable, because it has specific signs and precursors;

Throughout the entire period of human existence, protective measures against natural disasters have been developed to minimize their damage to society and the economy.

Thus, the forecasting of natural disasters is based on a comprehensive assessment of their frequency and severity in different areas, as well as tracking typical signs of their occurrence.

The classification of natural hazards according to their areas of occurrence is shown in Fig.1.

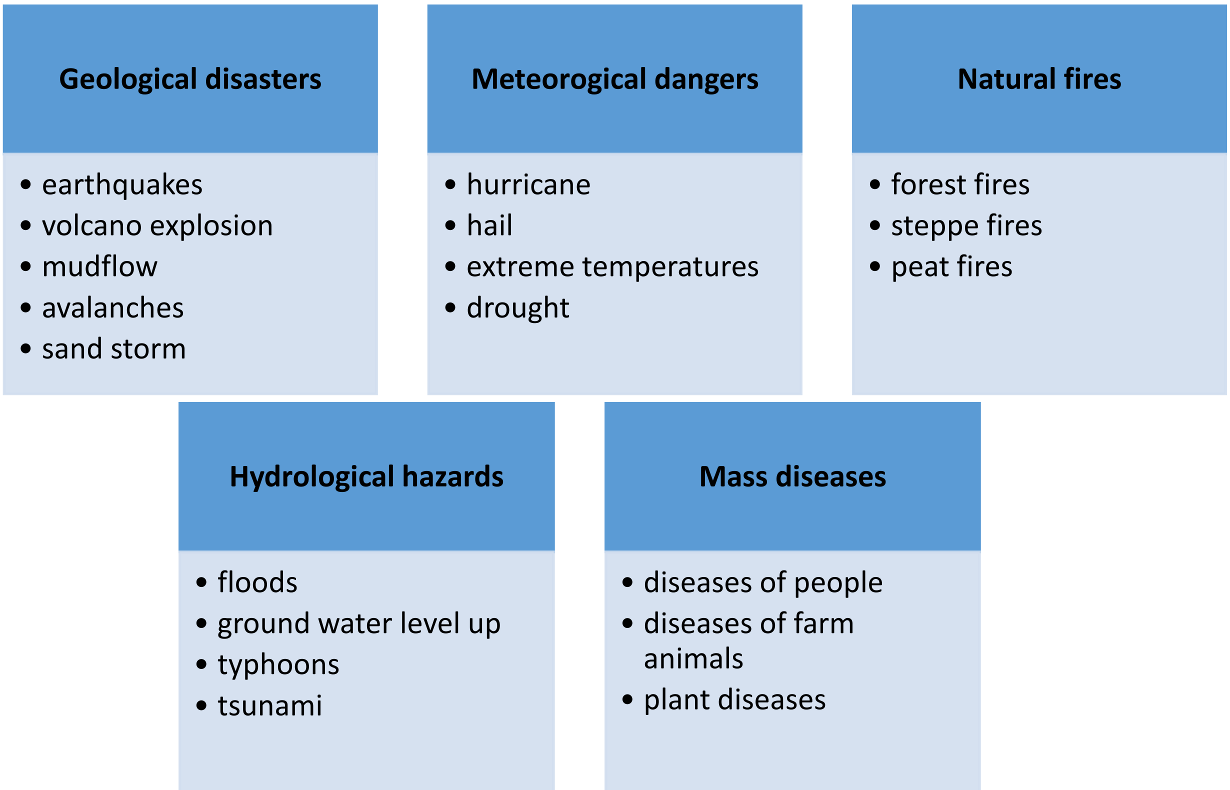

Figure 1: *Classification of natural hazards by areas of occurrence [3]*

III. Results

On the territory of the Russian Federation, due to a significant variety of physical and geographical conditions, there is virtually the entire spectrum of known varieties of natural hazards.

Geological hazards are associated with the structure of the Earth, this category includes earthquakes, volcanic eruptions, mudflows, landslides and collapses. In Russia, the strength of tremors is changed using a 12-point scale, the most common throughout the world. The seismic situation is monitored by the Geophysical Survey of the Russian Academy of Sciences, which has a large number of branches and subordinate organizations in the regions. Most of the country's territory is located in seismically quiet zones, and for this reason there is no need for an extensive system of seismic stations. The largest earthquake in the modern history of Russia is the earthquake on Sakhalin Island, which occurred on May 27, 1995. Its capacity was from 8 to 10 points, as a result, the village of Neftegorsk was completely destroyed, more than 2,000 people died.

Weather hazards include hurricanes, storms, tornadoes, storms, heavy winds, heavy snowfalls, blizzards, droughts, extreme heat or cold. Hurricanes are the movement of winds with a speed of 32 m/s or more, they can cause significant damage to infrastructure and pose a serious threat to the population. In Russia, hurricanes form mainly in August and September, while they are observed in various regions. There is a certain cyclicality in the occurrence of hurricanes, which allows them to be relatively accurate in forecasting. A tornado that occurs in a thundercloud and forms a huge funnel is a rare occurrence for the Russian Federation, but over the past decades, the damage from this natural phenomenon has amounted to about 80 million rubles. Also noted are the problems associated with severe drought, which was observed in 2002 and 2010. In particular,

Natural fires occur when uncontrolled burning of vegetation, they can spread over large areas and cause significant damage to agriculture, as well as residential buildings. Natural fires are divided into forest and peat. In the USSR in 1972, a dry summer led to peat and forest fires on an area of 1.8 million hectares. In 2010, in Russia, abnormal heat led to massive fires in the Central Federal District, and then in other Russian regions.

Massive forest fires were noted in 2022; fires have covered 2.2 million hectares of land since the beginning of the year. A special fire regime has been introduced in 14 regions, including Voronezh, Omsk, Amur and Sverdlovsk Regions, Krasnoyarsk and Khabarovsk Territories, Buryatia and Khakassia. The most tense situation is observed in Siberia, where 776 hectares of forest have been destroyed by fire. Most fires are recorded in the Krasnoyarsk and Altai Territories, Irkutsk, Kemerovo, Omsk, Kurgan regions, where not only the forest, but also agricultural land suffers. Over a few months, more than 1,200 buildings in 80 settlements burned down, of which 730 were residential buildings. About 20 people died, more than 2,000 lost their homes. On May 7, 2022, the Governor of the Krasnoyarsk Territory Alexander Uss declared a state of emergency in the region.

Hydrological hazards are storms, tsunamis, floods and floods. In the Russian Federation, about 50-70 major floods are observed every year, 300 cities and tens of thousands of villages and villages are located in areas with a risk of hydrological emergencies. First of all, these are the basins of the Volga, Amur, Terek, Don, Lena and Ob rivers. The average annual damage from floods is approximately 40 billion rubles. In recent decades, the largest floods were the floods in the Krasnodar Territory on July 6-7, 2012, caused by heavy rains and the flood in the Far East in July-October 2013, which affected up to 200 thousand people. The total damage from the flood exceeded 527 billion rubles.

Epidemics and pandemics are distinguished among mass diseases. An epidemic implies an abnormally wide spread of an infectious disease; a pandemic is declared when the disease spreads to a number of countries and entire continents, up to covering the entire globe. Infectious diseases are divided into four groups: respiratory tract infections, intestinal infections, blood and infections of the external integument. In the modern history of Russia, the largest epidemic was the spread of the coronavirus infection COVID-19. Outbreaks of this disease were noted in all Russian regions, as of July 2022, more than 380 thousand people died from coronavirus. The total damage from this pandemic exceeded 35 trillion USD.

Epidemiologically dangerous diseases can affect not only people, but also farm animals and plants. For example, in 2021, the following dangerous animal diseases were registered in Russia: African swine fever, highly pathogenic avian influenza, contagious nodular bovine dermatitis, sheep and goat pox. The development of diseases was stopped at the time of their detection, which made it possible to avoid widespread infection - epizootypes.

Systematization of hazardous natural phenomena and processes can be carried out not only by origin, but also by the nature of the impact on ecosystems and humanity. In this case, there are:

- catastrophic events (earthquakes, floods, tsunamis, landslides, etc.);
- dangerous phenomena (droughts, desertification, ravine erosion, etc.);
- adverse events (glacier movement, swamping, suffusion, etc.).

According to the mechanism of occurrence, it is possible to separate natural hazards that arise in the form of a trend (adverse climate change), extreme (frost, drought, flood) and disruption (storm, tornado, collapse). By temporal regularity, one can single out natural hazards that occur periodically (an eruption of an active volcano, a flood) and at a random moment (an earthquake, a tsunami).

On the basis of research and the construction of physical and mathematical models, it can be argued that a gradual climate change is taking place on Earth. In particular, the findings of the studies indicate that the main territory of the Russian Federation will experience an increase in surface air temperature during the 21st century. This may affect Siberia, the Arctic and the northern regions of the country to the greatest extent. In areas with sufficient water resources, these resources will increase, and in contrast, dry regions may face further reduction in moisture and the risk of drought. In the Central Federal District, a decrease in snow cover is expected, while in the north and in the Asian part, snow cover will increase, which will lead to floods and floods in the spring.

Also, throughout the century, the process of reducing the ice cover of the Arctic Ocean will continue, at the same time, the boundary of permafrost will move and the layer of seasonal thawing will increase. These changes may lead to the risk of emergencies of natural origin:

- increased snowmelt and heavy rains will lead to more major floods;
- sudden changes in temperature will lead to the emergence of hurricanes, tornadoes and typhoons;
- an increase in average air temperature will cause drought and, as a result, large-scale forest fires;
- accelerated melting of snow and glaciers will lead to a rise in the level of the world ocean and flooding of large coastal areas;
- the process of melting permafrost will contribute to landslides and weakening of the foundations of buildings and various structures;
- in flooded areas, the number of ticks will increase, which will lead to the emergence of new foci of infections and an increase in the period of infectious danger;
- abnormally high summer air temperature will lead to an increase in mortality;
- climate change will cause a decrease in the volume of sources of drinking water.

Cardinal climate change will cause multiple natural emergencies that can cause accidents and disasters and cause significant damage, as well as become a threat to the lives of people living in the northern and southern regions.

The ongoing natural and climatic changes require a change in the existing methods of managing and making changes in the economic model and lifestyle of a person. At the level of macroeconomics, these changes should occur when drawing up long-term development programs, which should take into account natural changes in a particular region and in general, at the level of the whole country. At the microeconomic level, changes should affect technological processes, the organization of production and everyday life.

To prevent emergencies and effectively respond, the following activities are required:

- creation of a centralized system that monitors potentially dangerous natural phenomena;
- establishing areas of greatest risk and determining the frequency of occurrence of hazardous situations;
- limitation of economic activity in permafrost thawing zones;
- creation of a new technical regulation providing for the operation of equipment in new conditions;
- increasing measures to protect the population living in potentially dangerous regions.

So, the current ecological crisis threatens the possibility of sustainable development of human civilization. The degradation and destruction of ecosystems leads to the destabilization of the biosphere, the loss of its integrity and the ability to maintain the qualities of the environment necessary for life. Overcoming the crisis is possible only on the basis of the formation of a new, harmonious type of relationship between man and nature.

IV. Discussion

Under these conditions, Russia, as a country with the largest territory in the world, as well as a huge natural resource, economic and intellectual potential, must take responsibility for the comprehensive protection of the environment and the maintenance of the global functions of the biosphere. Meanwhile, very little attention is paid to the issues of ensuring national and global environmental security in the country, which, together with the irrational use of natural resources by the largest commercial corporations, leads to active degradation of the natural environment.

According to the current Environmental Doctrine of the Russian Federation, the main factors of such degradation in the Russian Federation include:

- the predominance of resource-producing and resource-intensive sectors in the structure of the economy, which leads to the rapid depletion of natural resources and degradation of the natural environment;
- low efficiency of nature management and environmental protection mechanisms, including the absence of rent payments for the use of natural resources;
- a sharp weakening of the managerial and control functions of the state in the field of nature management and environmental protection;
- a high share of the shadow economy in the use of natural resources;
- low technological and organizational level of the economy, high degree of depreciation of fixed assets;
- the consequences of the economic crisis and the low standard of living of the population;
- low level of ecological consciousness and ecological culture of the population of the country.

These factors have a significant impact on the state of the environment in the Russian Federation.

In developed countries, the scientific community, governments and corporations are gradually beginning to unite in order to jointly confront global environmental challenges. This trend finds expression in the tightening of responsibility for environmental pollution, the development and implementation of new environmental standards, the formation of an ecological culture of the population and business. The largest companies make commitments in the field of social and environmental responsibility, integrating them into the structure of their corporate strategy.

In Russia, the problems of environmental protection are largely ignored, which confirms the lack of appropriate legal regulation, the widespread use of irrational forms of nature, the low authority of environmental organizations and the steady dominance of economic interests over environmental ones.

Meanwhile, ensuring environmental protection, rational use and reproduction of natural resources is one of the key constitutionally significant benefits that form the basis of long-term socio-economic development, determine the material basis for the development of future generations.

The most serious damage to the environment is currently caused by the activities of large corporations operating in the mining, petrochemical, metallurgical, pulp and paper, and leather industries.

These enterprises have huge profits, which, in conditions of high corruption, allows them to successfully circumvent environmental prohibitions and carry out activities that pose a serious danger to the environment and public health.

Despite the tendency taken from Western countries to develop codes of corporate social responsibility and the formation of annual reports that include paragraphs on environmental protection, the actual environmental activity of corporations in Russia remains extremely low. Meanwhile, the effectiveness of ensuring environmental safety as one of the most important factors in the development of Russia as a legal and social state depends on the environmental responsibility of business.

So, the adoption of environmental decisions at the level of individual corporations is of fundamental importance for ensuring the sustainability of ecosystems and reducing natural hazards. The environmental responsibility of business is one of the areas of social responsibility, which involves:

- awareness by the subjects of entrepreneurial activity of their direct functions in the system "society - nature";
- understanding of the need to recognize and comply with societal norms regarding environmental protection;
- assessment of one's own activities in the context of its environmental consequences for the company and its employees, as well as for the local community, the state and the world as a whole;
- willingness to modify their activities in order to avoid adverse environmental consequences of their implementation.

The creation of a system for making environmental decisions and protecting the environment within the framework of the social responsibility of business should begin with a comprehensive analysis of the current situation, which can be carried out at various levels.

The result of such an analysis should be methods that ensure a reduction in the discharge of harmful substances into the natural environment, as well as a higher level of solid waste processing. These measures will stop the growing environmental crisis and reduce the level of natural hazards around the world.

References

[1] The UN announced a five-fold increase in natural disasters in the world in 50 years // RBC. – URL: https://www.rbc.ru/society/01/09/2021/612f595f9a7947bf996c4375 (date of access: 07/15/2022).

[2] Krepsha N.V. Dangerous natural processes / N.V. Strong. - Tomsk, TPU Publishing House, 2014. - 290 p.

[3] Dangerous natural processes: textbook / M. V. Bedilo, A. G. Zavorotny, A. N. Nerovnykh [and others] / 2nd ed. revised and additional – M.: Academy of GPS EMERCOM of Russia, 2020. – 308 p.

THE METHOD TO DECREASE ERROR OF CHIMNEYS DEFORMATION MEASURING UPON CONTINUAL REFLECTOR LESS INCLINED MEASURING USING TOTAL STATIONS

Sefail Verdiyev
•
Azerbaijan University of Architecture and Construction
sefailverdiyev@gmail.com

Abstract

In the article the suggested method to decrease error of chimneys deformation continual inclined measuring using total stations is described. It is determined that upon continual inclined reflector less measurements of chimneys deformation in power industry the most significant factors causing error of inclined measurements are angle of beam incidence, duration of measurements series, beams propagation. The method for forming and further accounting of equally distributed on time systematic error of measurements of chimneys inclination by way of synthesis of special order for organization of measurements using total station is suggested. The mathematical basics of the method is described.

Keywords: chimney, deformation, measurements, total stations, error.

I. Introduction

It is well known that the non-reflector mode of total station measurements, having a fairly high speed of execution, is characterized by a much larger error compared to the measurement mode using prismatic reflectors [1-4].

As noted in the work [1], the principle of operation of an electronic total station in the non-reflector mode does not differ from the mode of operation of a conventional total station, where the measurement of the oblique distance to the object, as well as two angles (horizontal and vertical) allows you to determine the coordinates of the point under study. The angle of incidence, the type and color of the reflecting surface significantly affect the energy of the reflected beam, and hence the accuracy of the measurements. Another, no less important factor affecting the accuracy of remote measurements is the coincidence of the direction of the total station beam with the direction to the Sun. So, for example, according to [1], a distance of 30 m is measured with an error of 0.228 mm if these directions coincide and 0.2098 mm if they do not coincide, i.e. directions are opposite.

According to the work of [2], the measurement range of electronic total stations in non-reflector mode in some new devices reaches 1500 meters for white reflective surfaces or several hundred meters for dark ones. At the same time, according to [3], the cost of non-reflective measurements is only 5% of the cost of reflective measurements. As for the possibilities of compensating for errors arising in this mode, when studying the absolute displacements of distant objects, systematic errors are mutually compensated. In addition, repeated measurements can significantly reduce the random component of this error.

II. Methods

As noted in the work [4], the above factors can significantly affect the results of assessing the verticality of heat pipes of power facilities, measured using electronic total stations in the non-reflector mode (Fig.1).

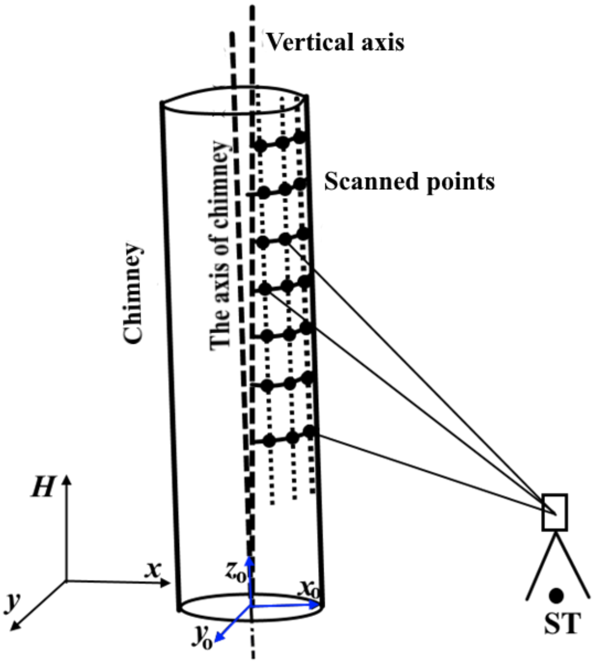

Fig.1: *Scheme for measuring the verticality of heat pipes of power facilities using an electronic total station in a non-reflector mode.*

As noted in the work [4], according to the European EUROCODE standard, the maximum allowable deviation of heat pipes with a height of H_d is determined by the formula.

$$\Delta[m] = \frac{H_d[m]}{1000} \cdot \sqrt{1 + \frac{50}{H_d[m]}} \tag{1}$$

According to [4], the joint use of the Leica TS30 total station and the Riegl Vr-400 laser scanner makes it possible to determine a cloud of points on the surface of an object and model them geometrically on a certain coordinate system. Further model calculations carried out using the appropriate Matlab program allows you to determine the inclination of the heat pipe. Without going into the algorithmic and software of such calculations, we note that according to the data given in [4], the accuracy of determining the slope of the heat pipe in this method depends significantly on the number of studied points on the surface of the object.

The foregoing actualizes the issue of developing special methods to compensate for the effect of battery discharge on the measurement error. Further in this section, we consider the question of finding such an optimal procedure for conducting a long-term series of total station measurements in which it would be possible to synthesize a systematic error uniform in time in the form of the sum of errors due to the angle of incidence of the beam and also due to battery discharge, due to the choice of a special time sequence of oblique measurements. The corresponding scheme of measurements is show in Fig.2.

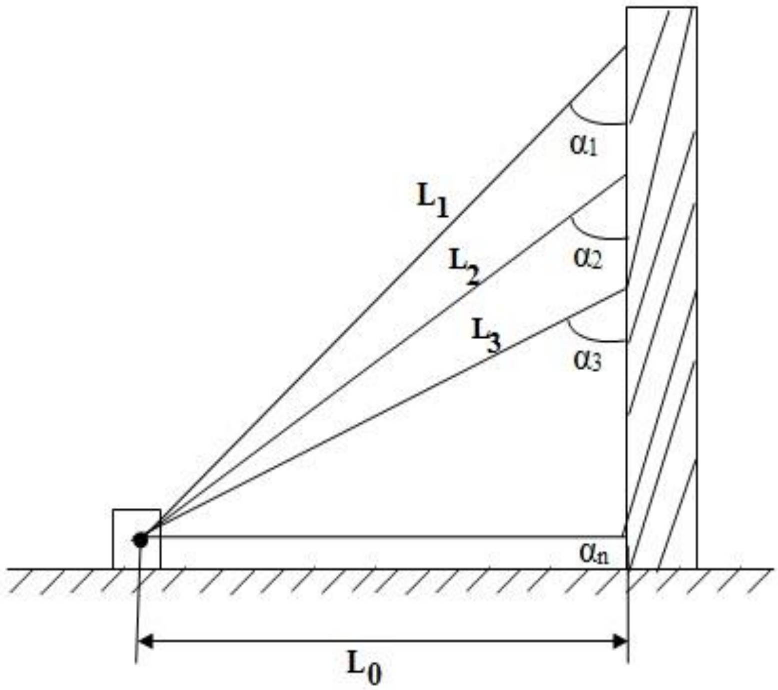

Fig. 2: *Scheme of performing compensated multipoint measurements of chimney deformation.*

III. Results

It is determined that when carrying out long-term non-reflector total station measurements of the inclination of heat pipes of power facilities, the most significant factors leading to the appearance of inclination measurement errors are the angle of incidence of the beam, the duration of a series of measurements and the path of the beam.

A method is propose for the formation of a systematic error of measurements of the inclination of a heat pipe, uniform in time, by synthesizing a special procedure for organizing total station measurements, followed by taking into account the systematic error. The mathematical substantiation of the proposed method is given.

IV. Discussion

This fact is well illustrate in Figure 1, where it is seen that the mean square error of the calculation result decreases almost exponentially with an increase in the number of measurement points in the range of $10^4 – 10^5$ estrus.

The work notes [4] that this error arises due to such reasons as different angles of incidence of the laser beam on the surface of the object, non-uniformity of the reflective properties of the surface, and also due to the meteorological factor, which consists in a rather significant increase in temperature over the time period of multipoint measurements. The corresponding change curve for a period of four hourly measurements is shown in Fig.4.

At the same time, it is well known that when carrying out such long-term series of measurements, measures must be taken to eliminate the effect of the influence of the discharge of the battery of meters on the measurement result. As shown in the work [2], the effect of discharging the total station battery can lead to measurement errors reaching several millimeters at a distance of 8.5m.

The corresponding curve of dependence of the measurement error due to the effect of battery discharge on the duration of the measurement series is shown in Fig.5. [2].

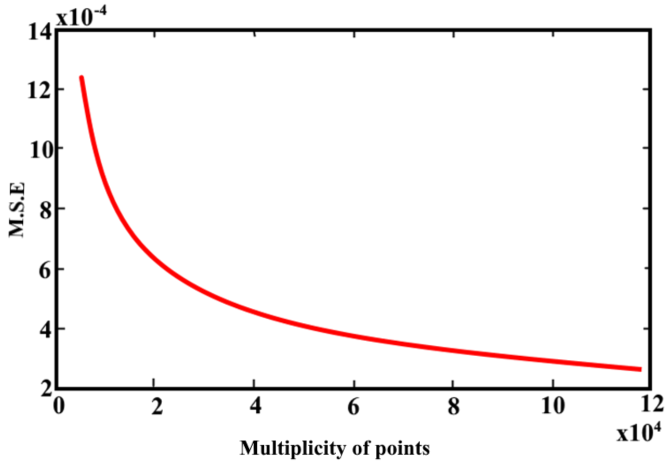

Fig.3: *Curve of dependence of the error in determining the slope of the heat pipe on the number of measured points on the surface of the object [4].*

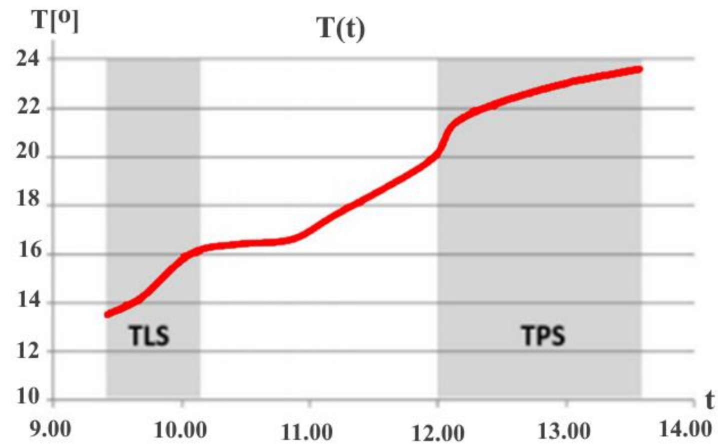

Fig. 4: *Graph of temperature changes up to a period of four hourly measurements of the positions of points on the surface of the heat pipe in the number of 105 units [4].*

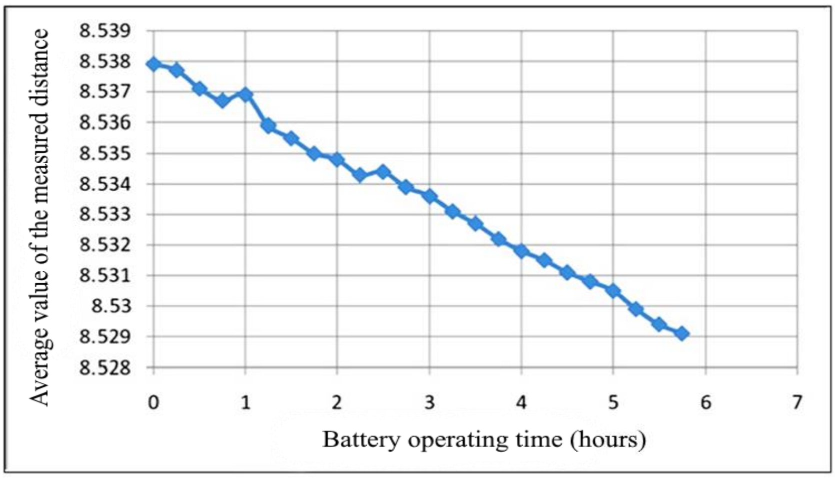

Fig. 5: *Graph of the change in the measurement error of the distance to the object with an electronic total station at a distance of 8.5 m, depending on the duration of the series of measurements.*

We assume that there are the following causes of measurement error:

1. Current time – *t*
2. The angle of incidence of the beam on the surface of the pipe – α
3. Different beam distances – *L*

Because L_i and α_i are interdependent, we denote the angles of incidence as

$$\alpha_i = 90^\circ - arccos\frac{L_0}{L_i} \tag{2}$$

In general, we write

$$L_i = \varphi(\alpha_i) \tag{3}$$

Therefore, the total error Δ_0 can be written as a function depending on two arguments, *t* and α.

$$\Delta_0 = f(t, \alpha) \tag{4}$$

We write the total differential (4) as

$$d\Delta_0 = \frac{\partial f}{\partial t}dt + \frac{\partial f}{\partial \alpha}\partial\alpha \tag{5}$$

If we take into account that the change in the argument α occurs on the scale of the current time, then we write

$$\alpha = \varphi(t) \tag{6}$$

From (6) we get

$$d\alpha = \varphi'(t)dt \tag{7}$$

Taking into account (7) in (5) we write

$$d\Delta_0 = \frac{\partial f}{\partial t}dt + \frac{\partial f}{\partial \alpha}\cdot\varphi'(t)dt = [k_1 + k_2\varphi'(t)]dt \tag{8}$$

where $k_1 = \frac{\partial f}{\partial t}$; $k_2 = \frac{\partial f}{\partial \alpha}$

Integration (8) within $t_{min} \div t_{max}$ gives

$$d\Delta_{0\ int} = k_1\cdot dt + k_2[\varphi(t_{max}) - f(t_{min})] \tag{9}$$

From expression (9) under the condition

$\Delta_{0\ int} = 0$

We get:

$$\varphi(t_{max}) = \frac{k_2\varphi(t_{min}) - k_1\Delta t}{k_2} = \varphi(t_{min}) - \frac{k_1}{k_2}\cdot\Delta t \tag{10}$$

Since, by definition, k_1 and Δt are positive values, and k_2 is a negative value, then with the growth of Δt, the value of $\varphi(t_{max})$φ should increase. From heuristic considerations, it is clear that dependence (10) in the real case can be implemented if the following inequality is satisfied

$$\varphi(t_{min}) < \varphi(t_{max}) \tag{11}$$

or, taking into account (6),

$$\alpha(t_{min}) < \alpha(t_{max}) \tag{12}$$

Thus, if we take $\varphi(t_{min}) = \alpha_0$ we write expression (10) as

$$\varphi(t_{max}) = \alpha_0 + \left|\frac{k_1}{k_2}\right|\Delta t \tag{13}$$

Thus, as is clear from expression (13), in order to mutually compensate for the influence of the above two factors, at the beginning of a series of total station measurements, one should examine the points located on the upper zone of the heat pipe, gradually decreasing in the direction of increasing the angle α. Thus, a large error due to a small beam incidence angle at the beginning of the measurement interval will be summed up by a small error arising from battery discharge, and vice versa, a small error due to a large beam incidence angle at the end of the measurement series time will be summed up by a large error due to-for battery drain.

Thus, the resulting sums can be considered as systematic components of the error and can be taken into account in further processing of the calculation results.

Thus, the fundamental possibility of organizing serial long-term measurements of the deformation (slope) of the heat pipe of power facilities with compensation for a specially formed systematic measurement error is shown.

References

[1] Ashraf A.A, Beshr, Islam M., Abo Elnaga. Investigating the accuracy of digital levels and reflectorless total stations for purposes of geodetic engineering. Volume 50, Issue 4, December 2011, pp. 399-405.

[2] Hossam El-Din Fawzy. Evaluate the accuracy of reflector-less total station. April 2015.

[3] V.Kontogianni, Stathis Stiros. Monitoring with electronic total stations: Performance and accuracy of prismatic and non-prismatic reflectors. Geotechnical News.2007. 25(1): pp. 30-33.

[4] Marjetič, A. TPS and TLS laser scanning for measuring the inclination of tall chimneys. Geodetski glasnik 2018. 49, pp. 29-43.

GREENHOUSE GAS MANAGEMENT AND RELATED ECONOMIC ACTIVITIES

Rashiya Bekmurzaeva
•
Chechen State University named after Akhmad Kadyrov, Russia
raya.bek@yandex.ru

Abstract

In this article, the author talks about a global change in society - warming. It is based on the adverse effects of climate change – health risks, flooding, fires, land degradation. The reason for all these climate changes is the increase in the concentration of greenhouse gases. Combating climate change, greenhouse gas emissions - achieving carbon neutrality or decarbonization.

Keywords: global warming, greenhouse gases, carbon neutrality, emission reduction, Paris Agreement

I. Introduction

The pandemic did not bring relief to the environment: in 2020, despite the slowdown in economic processes, the temperature of the planet continued to rise, glaciers continued to melt, and the level of carbon dioxide in the atmosphere reached a maximum in 3 million years. This was reported to the World Meteorological Organization at the UN.

It is clear that global warming and the consequences of these changes have adverse effects and increasingly affect the country's socio-economic institutions, infrastructure and human health.

Under these conditions, there is a need to develop a system for adapting to global climate change, reducing losses and gaining benefits associated with monitoring the environment and subsequent climate change.

In recent years, the population and the economy of the country have been exposed to the greatest danger as a result of earthquakes, floods, severe storms, fires, chemical disasters, radioactive materials, environmental and man-made disasters. Strategic changes are needed.

Among the predicted negative consequences of climate change for Russia are: increased risk to human health; the frequency of growth, the intensity and duration of droughts, heavy rainfall, flooding and watering of soils dangerous for agriculture, the increase in forest fires, the disorganization of the natural balance, as well as the consumption of large amounts of energy resources and changes in ecological diversity.

If we take into account the positive results expected for Russia in connection with climate change, we can single out: the deconstruction of energy resources during the heating season; improving the ice situation, which means improving the conditions for transporting goods to the Arctic, the presence of the Russian continental shelf in the Arctic Ocean; increasing the fertility of forest resources in the northeast; increase in productivity in cattle breeding.

The warmest year in Russia was 2020. On average, the temperature in our country is rising faster than in other parts of the world. In addition, we are increasingly seeing dramatic climate changes in our cities: unusual heat in the Urals, heavy rains, thunderstorms and floods in the Krasnodar Territory, fires in Yakutia. People are forced to migrate to other areas due to the deterioration of the urban environment.

Dramatic climate change is caused by rising concentrations of greenhouse gases in the global atmosphere, such as atmospheric carbon dioxide (CO_2), methane ($CH_4$4) and nitrous oxide (N_2O). It is mainly caused by human activities. Atmospheric isotopes confirm that the burning of fossil fuels plays an important role in increasing the concentration of CO_2 in the atmosphere.

The oil and gas sector, often caused by pollution of the planet, produces only 12% of all anthropogenic sources of gas emissions (direct emissions from production and emissions from energy companies) - less than in the agricultural sector (13%), energy, transport and industry [1].

Fossil fuels needed for energy production are the main source of greenhouse gases. According to the World Resources Institute, 76% of carbon dioxide concentration goes to the energy sector. This term covers both products important for industry and domestic needs (30.4%), as well as fuel assessment in transport (15.9%), in industrial production (12.4%), in construction and construction services (5, 5%) and other industries (Fig. 1) [2].

The Russian Institute of Climate and Global Ecology has calculated that in the Russian Federation this share is even slightly higher - 78.7%. The National Anthropogenic Emissions Inventory states that half (55.9%) of emissions come directly from electricity generation for cities, homes, offices and industries.

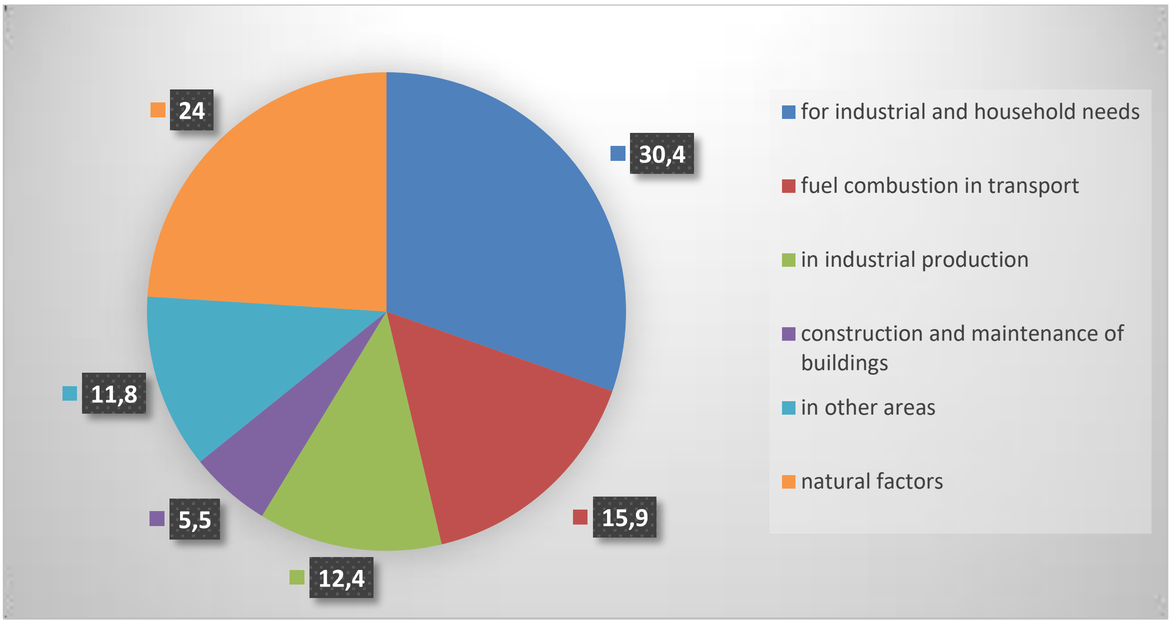

Figure 1: *Emission of carbon dioxide from human activities*

II. Methods

The fight against climate change has gone so far that Europe, which has decided to become decarbonized by 2050, has prepared a surcharge on foreign manufacturers that used products with high greenhouse gas emissions in their production.

The main way to decoupling an enterprise (reducing emissions) is to increase the share of renewable energy sources in consumption.

According to the Agora Energiewende Institute's Ember analytical center, in 2020, for the first time in history, the share of renewable energy sources in electricity generation in Europe exceeded the share of energy resources - 38% compared to 37%, respectively [3].

Companies from different countries are literally "competing" to present the largest project that will reduce greenhouse gas emissions.

Thus, the metallurgical giant ArcelorMittal has begun developing a technology for the production of low-carbon steel. Its competitors from ThyssenKrupp and RWE presented a solution for the production of iron on hydrogen.

Airlines like Lufthansa are developing new jet fuels, diamond miners are working on carbon capture technology using recycled kimberlite, cement manufacturers are coming up with new formulations of “carbon neutral” cement and mineral additives.

The lion's share of domestic external supplies falls on fuel and energy products. According to the Federal Customs Service, in 2020 their share in total exports amounted to 49.6%. At the same time, the EU accounted for 38.5% of Russian commercial turnover (41.6% in 2019). It is Russia's largest trading partner.

Most importers have long been preparing to work under the new rules. For example, back in China, in November 2016, a Program was developed and approved that provides for the reduction of greenhouse gas emissions per unit of GDP. China has launched pilot projects on CO_2 trade [4].

In developed countries, all sectors of the economy can be decarbonized by 2050, in developing countries - by 2060, according to the report of the International Commission on Energy Transition. CO_2 emissions must be reduced by 55%, for this it is necessary to reduce the consumption of fossil fuels by an average of 42% [5].

The Paris Agreement signed by 192 countries under the UN Framework Convention on Climate Change in 2015 became the basis for creating the current measures to regulate carbon emissions. This is a continuation of the Kyoto Protocol of 1992 [6]. The purpose of this agreement is to limit the growth of average temperatures on the planet to 1.50°C (Fig. 2). To do this, all signatory countries must take steps to reduce emissions of water vapor, methane, ozone, in particular CO_2. The authors and signatories of these documents proceed from the fact that it is this process that causes global warming, which is dangerous for the existence of all mankind.

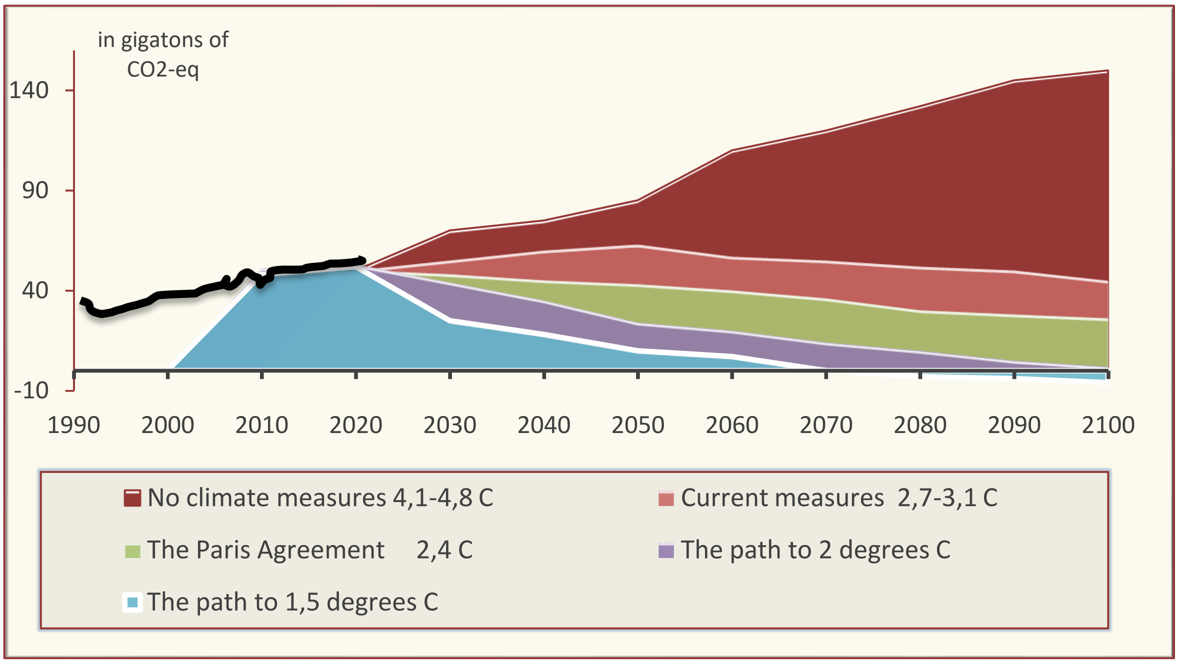

Figure 2: *Global greenhouse gas emissions and warming scenarios*

In Russia, in order to fulfill the obligations related to the regulation of greenhouse gas emissions and preparations for the ratification of the Paris Agreement, the Decree of the Government of the Russian Federation of November 3, 2016 N 2344-r developed an Implementation Plan. A number of measures were approved to improve the state regulation of greenhouse gas emissions. [7].

III. Results

In order to resolve long-term controversies and provide scientifically motivated information on the balance of man-made and natural flows of carbon dioxide, ozone gases in the Russian Federation, the President of Russia in the register of instructions for the implementation of the Address to the Federal Assembly in 2021 regulated "the creation of a national system for high-precision monitoring and utilization of climate-active gases."

Such an ultra-precise greenhouse gas analysis scheme must be based on the relationship of three factors: satellite monitoring systems, ground-based monitoring, and mathematical modeling using these data. Note that to implement a representative soil structure analysis of greenhouse gas fluxes, a network of several thousand small test plots in different types of ecosystems is needed to evaluate regular changes in CO_2 stocks (Fig. 3). In terms of satellite analysis of greenhouse gas flows, of course, it should be based on the development of strategic directions of the domestic space segment and maintaining the digital sovereignty of our country.

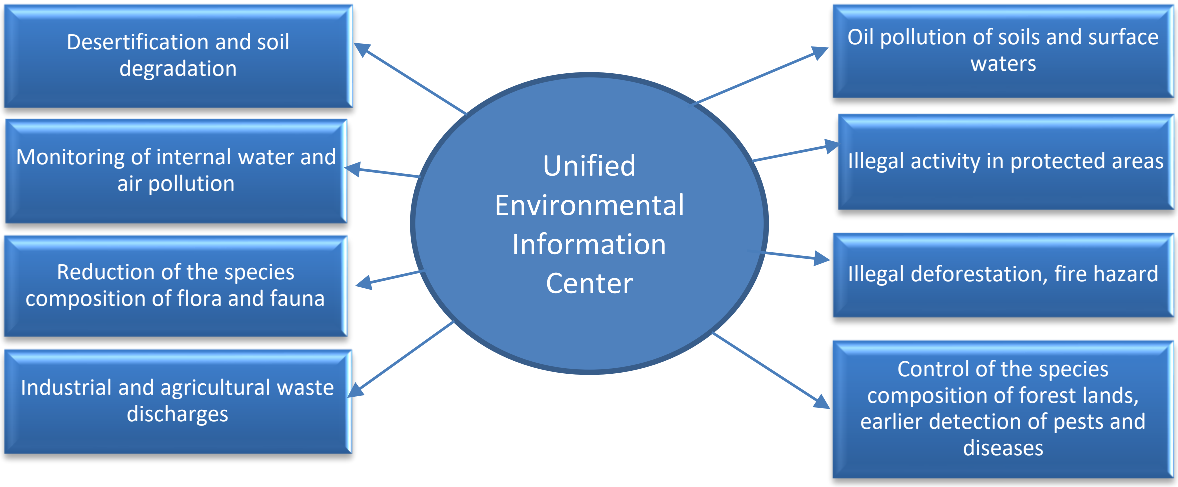

Figure 3: *Methods for controlling CO_2 emissions*

In Russia, a system of carbon landfills will be introduced to develop a method for measuring sequestration and emissions of carbon and other greenhouse gases (methane, nitrous oxide). In order for the system to take into account the geographical features of the climate and soil, seven pilot regions were selected: the Kaliningrad, Sakhalin, Novosibirsk, Tyumen regions, the Chechen Republic and the Krasnodar Territory. In addition, these sites will be engaged in the reproduction of plant varieties with a high ability to absorb greenhouse gases.

Russia cannot deny climate ratification: this may create risks for the sustainable development of the national economy after 2040.

The Ministry of Economic Development has prepared a strategy for the long-term development of Russia with low greenhouse gas emissions until 2050.

The Ministry of Development offers the following scenarios for the development of climate regulation: basic, intensive, inertial, and a scenario without state support measures (Fig. 4). So far, the agency recommends adopting a baseline scenario with an emphasis on sustainable use of forests and energy conservation. Such a scenario may be logical until around 2030, but then many countries are likely to move towards forced reductions in greenhouse gas emissions, putting pressure on Russia as well.

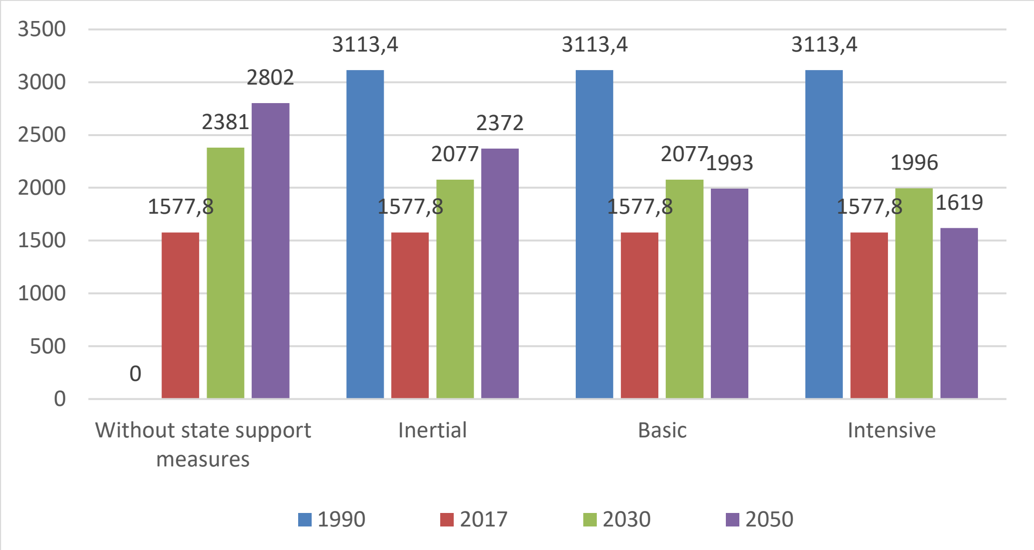

Figure 4: *Increase in greenhouse gas emissions under various scenarios for the development of climate regulation in the Russian Federation*

In the baseline scenario, by 2050 the Russian Federation will reduce greenhouse gas emissions by 36% to 2 billion tons of CO_2 equivalent. At the same time, the cumulative reduction in emissions will be 80-81 billion tons, i.e., approximately 8% of the global carbon budget (an acceptable amount of carbon dioxide that enters the atmosphere without causing a temperature increase of more than 2 degrees).

In this scenario, the Ministry of Economic Development proposes the following measures:

– Massive introduction of energy-saving technologies in the power industry, industry, buildings and transport in order to reduce the loss of energy resources.
– Increasing waste recycling, regeneration of large landfills and the use of methane.
– Promotes the production and use of products with high energy efficiency.
– Strengthen the protection of forest areas from fires, pests, reduce deforestation, include cultivated forests on abandoned agricultural lands in the state register, etc. [3].

In the intensive scenario, Russia will reduce emissions by 36% by 2030 and by 48% by 2050, to 1.6 billion tons of CO_2. By 2100, hydrocarbon neutrality will reach zero net greenhouse gas emissions. At the same time, RA will make the most significant contribution to limiting the increase in global temperature to 1.5°C, and the cumulative reduction in emissions will be 90 billion tons of CO_2 equivalent by 2050.

Additional measures are implemented in the intensive scenario [3]:

- Tax and collection taxes.
- Establish a national labeling system for high-carbon products and disclose information to consumers about the origin of electrical energy.
- Create incentives for buildings to be equipped with solar panels, photo panels, etc.
- Expansion of producers' responsibility, introduction of payment for disposal, reclassification of part of the waste into secondary raw materials.
- Prohibition of clear-cutting.

When preparing the climate strategy, the Ministry of Economy of the Russian Federation takes into account macro-indicators of long-term forecasts for the development of Russia's socio-economic activity for 2036. It includes the price of Russian oil Ural at the level of $57.6 per barrel in 2019-2024, by 2036 it should be at the level of $55.5 per barrel [8].

IV. Discussion

Changes in the global climate have already created new dangers and problems for many countries and regions, and in the future, the negative consequences of such changes could be truly tragic. Despite the ongoing scientific and research disputes on the causes and factors of global warming, the world community has taken an unambiguous point of view - it is necessary to take decisive measures to reduce anthropogenic emissions and increase greenhouse gas emissions into the atmosphere.

It is obvious that the solution of the global problem can only be achieved through the joint efforts of all countries of the world. But each country has its own national interests, sometimes contradicting the interests of other countries. And yet, global threats should unite people to find compromise solutions acceptable to all. It was not easy to reach consensus by signing the UN Framework Convention on Climate Change, which for the first time provided for economic mechanisms for cooperation within the framework of the goals of the UNFCCC.

However, one political declaration is not enough to participate in the mechanisms of the Kyoto Protocol. It also requires political desire, a strategy for controlling greenhouse gas emissions, information support for emissions and emissions of sinks, legislative and institutional support for activities to reduce greenhouse gas emissions, mechanisms for integrating into the global carbon market, etc. All this is possible and does not require significant costs, which is confirmed by the calculations of the Ministry of Economy of the Russian Federation.

If the company is involved in operations on the international market, it is necessary to prepare for international and Russian requirements. Why is it necessary to determine the amount of greenhouse emissions. If the mass exceeds 150 thousand tons per year, then it will need to be reported already in 2022. If the mass of emissions is 50,000 tons per year or more - after 2024. Company reports will be checked, a register and analytical data will be provided [9].

Russia is a country with a rich natural resource potential, we have a large share of mining enterprises and primary processing enterprises. And this is a serious challenge for Russian companies, and not only for large companies, but also for small and medium enterprises.

References

[1] International legal regulation of the fight against global warming and the approaches of Russia and the CIS countries to the ratification of the Paris Agreement on climate change of December 12, 2015.

[2] Zerkalov D.V. Problems of sustainable development. [Electronic resource] Reader. - K .: Osnova, 2012.

[3] Energy Fresh - Russia has a plan to reduce greenhouse gas emissions by 2050/

[4] Zhilina I.Yu. Decarbonization of the Chinese economy in the context of global climate change. Moscow, 2019.

[5] Invest $27 trillion and switch to green energy: how businesses and governments are trying to stop global warming - Future on vc.ru

[6] Andrianov V.V. Challenges of the climate agenda for the foreign and domestic policy of the Russian Federation. Moscow, 2022.

[7] Uroshleva A. Prospects for regulating waste management and greenhouse gas emissions in the framework of ensuring environmental safety. GARANT.RU, February 11, 2019.

[8] Climate management: how to solve the problem of a reliable balance of emissions and removals of greenhouse gases. https://blogs.forbes.ru

[9] Gagut L.D. Economic mechanism of noospheric development. Moscow, 2009.

ALGORITHMS FOR CONTROLLING THE ONSET OF ANTHROPOGENIC PROCESSES IN URBAN DEVELOPMENT AREAS IN SEISMICALLY ACTIVE REGIONS

Telman Aliev, Naila Musaeva

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Institute of Control Systems, Azerbaijan National Academy of Sciences
Azerbaijan University of Architecture and Construction
telmancyber@gmail.com , musanaila@gmail.com

Abstract

It is noted that during changes in the geodetic state of urban development area, as well as the technical condition of the objects located there, the noisy signals coming from the corresponding sensors contain noise correlated with the useful signal. It is shown that the characteristics of the relationship between the useful signal and the noise are informative attributes of the beginning of anomalous natural phenomena, as well as changes in the stress-strain state of objects of the urban development complex. We have developed algorithms for calculating the estimates of the relay cross-correlation functions, normalized cross-correlation functions, as well as the correlation coefficient between the useful signal and the noise. It is noted that the use of the algorithms for calculating these characteristics in control systems allows detecting nascent anomalous processes, as well as defects of building structures at the initial latent stage and to prevent the possibility of accident situations.

Keywords: control, seismically active regions, noise, noisy signal, cross-correlation function, correlation coefficient

I. Introduction

It is known that the main objective of urban development is the design and development of cities, districts, complexes, residential and industrial zones, etc. Therefore, architectural and urban development objects are the territories where cities, villages, administrative districts, etc. are located. And buildings, structures, residential and industrial complexes, etc. are considered to be architectural and urban development objects.

At the same time, urban development areas are subjected to various kinds of natural and man-made impacts. For instance, man-made impacts are a result of the activities of industrial and military facilities, the movement of rail, road, sea, river transport, communications network, etc. Depending on the duration, cyclicity and degree of anthropogenic impacts are determined by the impact on civil and military complexes, residential buildings, national economy facilities, etc. Other dangerous effects on urban development areas are such natural processes as earthquakes, landslides, hurricanes, floods, etc. And one of the most dangerous natural phenomena are landslides, which lead to displacement of rocks as a result of seismic shocks, overwetting, washout of the slope and other processes. Such phenomena can occur on rocky terrain as well as on sand, clay, etc. Powerful landslides can cause an earthquake and vice versa, landslides can occur as a result of an earthquake.

In order to avoid the negative impact of natural and anthropogenic impacts on the state of objects, urban development monitoring is carried out. For this purpose, geodetic monitoring is first carried out, i.e., soil processes are studied, subsidence, displacement and subsidence of massifs are evaluated, groundwater is analyzed, possible seismically hazardous and landslide zones and areas are identified. At the same time at the stage of construction as well as during operation such defects of building structures and constructions as misalignments, cracks, shifts, displacements are identified and their stress-strained state is assessed. Thus, the current state and dynamics of changes in the technical condition of buildings and structures are assessed, possible accidents are predicted and appropriate recommendations are given.

In order to carry out such monitoring, appropriate sensors, such as displacement sensors, pressure sensors, reinforcement and anchor loads, crack aperture sensors, inclinometers, accelerometers, etc., are installed in the information locations of the analyzed area and building structures. The data on the geodetic state of the urban development complex as well as of the building structures and constructions are transmitted in the form of signals to the central monitoring station. The obtained digital information is recorded, processed, analyzed and conclusions are made about the geodetic condition of the urban development area and the stress-strain state of the building structures, the presence of defects and the degree of damage. In addition, conclusions are made about the causes that led to this or that defect.

However, existing systems of urban monitoring do not provide control of the latent period of change of the geodetic state of the territory under study, as well as the technical condition of the objects located there [1–2]. This is especially important for territories affected by seismic vibrations, landslides, dangerous vibrations and other natural processes, because after each weak but frequent earthquake or a small but repeated landslide, invisible and undetectable microscopic cracks, deformations, bends, etc., appear which subsequently can lead to serious damage that requires large costs [1–2].

In [1, 3-4] it is shown that changes in the geodetic state, as well as formation of even the smallest damages of objects of the urban planning complex is accompanied by the appearance of additive noise, which are correlated with the useful signals of noisy signals coming from the above sensors. The conducted studies have shown that the use of the technology for processing and analyzing noise and characteristics of the interrelation of noisy signals in the systems of noise monitoring of the urban development complex allows identifying the early latent period of defect and damage initiation, determining the dynamics of its development, and reducing the risks of accidents of urban development objects in seismically active and landslide-prone regions.

II. Problem statement

It is known that in practice, real signals are the sum of useful signals $X(t)$ and noise $E(t)$, i.e., $G(t) = X(t) + E(t)$. Because of the contamination of the useful signals $X(t)$ with the noise $E(t)$ there are tangible errors in determining the estimates of their correlation functions $R_{XX}(\mu)$. In this case, the total noise $E(t)$ is the sum of noise $E_1(t)$ from the influence of external factors and the noise $E_2(t)$, correlated with the useful signal, which arises when the geodetic state of the investigated area changes and a defect is generated during the operation of objects, i.e., $E(t) = E_1(t) + E_2(t)$.

Suppose that $G(t)$ is a sampled stationary random signal with normal distribution, consisting of the useful signal $X(t)$ and the noise $E(t)$ with mathematical expectation m_E=0. In this case the formula for calculating the estimate of the correlation function $R_{GG}(\mu)$ can be represented as [1, 3-4]:

$$R_{GG}(\mu) = \frac{1}{N}\sum_{i=1}^{N} G(i\Delta t)G\big((i+\mu)\Delta t\big) = R_{XX}(\mu) + R_{XE}(\mu) + R_{EX}(\mu) + R_{EE}(\mu)\,, \tag{1}$$

where $R_{XX}(\mu) = \frac{1}{N}\sum_{i=1}^{N} X(i\Delta t)X\big((i+\mu)\Delta t\big)$ is the autocorrelation function of the useful signal

$X(t)$; $R_{XE}(\mu) = \frac{1}{N}\sum_{i=1}^{N} X(i\Delta t)E\big((i+\mu)\Delta t\big)$, $R_{EX}(\mu) = \frac{1}{N}\sum_{i=1}^{N} E(i\Delta t)X\big((i+\mu)\Delta t\big)$ are the cross-correlation functions between $X(t)$ and $E(t)$; $R_{EE}(\mu) = D_E = \frac{1}{N}\sum_{i=1}^{N} E(i\Delta t)E\big((i+\mu)\Delta t\big)$ is the variance of the noise $E(t)$.

Given that $R_{EE}(\mu)$ =0 at μ≠0, the total error will be

$$\lambda_{GG}(\mu) = \begin{cases} 2R_{XE}(0) + R_{EE}(0) & when \quad \mu = 0 \\ R_{XE}(\mu) + R_{EX}(\mu) & when \quad \mu \neq 0 \end{cases}. \tag{2}$$

Because of this, the inequality $R_{XX}(\mu) \neq R_{GG}(\mu)$ takes place. It is clear from this that the basic information needed for monitoring is contained in the estimates of the noise characteristics $R_{XE}(\mu)$, $R_{EX}(\mu)$, $R_{EE}(0)$. Since the noise $E(t)$ cannot be isolated from the noisy signal $G(t)$, it is impossible to draw adequate conclusions about the geodetic state of construction objects on the estimate $R_{GG}(\mu)$ in urban development areas it is not possible to make adequate conclusions about the geodetic state and the stress-strain state of construction objects. In this regard, there is an obvious need to create algorithms and technologies to find the estimates of the noise variance D_E the and cross-correlation functions $R_{XE}(\mu)$, $R_{EX}(\mu)$ between the useful signal and the noise.

III. Algorithms for calculating the characteristics of the relationship between the useful signal and the noise

As shown above, in the normal geodetic state of the urban development area and objects located there, noise $E(t) = E_1(t)$ arises from random external factors that have no correlation with the useful signal $X(t)$. However, at the beginning of the latent period of change in the geodetic state of the area and the technical condition of objects, the noise $E_2(t)$ emerges which is correlated with the useful signal. Therefore, from this point on, the correlation between the useful signal $X(t)$ and the total noise $E(t) = E_1(t) + E_2(t)$ is non-zero. In this case, the initiation and development of malfunctions is essentially reflected in the estimates of the cross-correlation functions and the correlation coefficient between $X(t)$ and $E(t)$ [1, 3-4]. Therefore, for controlling the latent period of the origin and the dynamics of the development of natural anomalies and technical malfunctions, it is quite often more appropriate to use in monitoring systems the estimates $R_{XE}(\mu)$, $R_{EX}(\mu)$, as well as the correlation coefficient r_{XE} between the useful signal and the noise as a carrier of diagnostic information. In the following paragraphs, we show the possibility of using estimates of the relay cross-correlation functions, normalized cross-correlation functions, as well as the correlation coefficient between the useful signal and the noise as informative attributes.

It is known that the estimates of the relay cross-correlation functions can be calculated from the expression [1]:

$$R^{r}_{XE}(\mu) = \frac{1}{N}\sum_{i=1}^{N} sgnX(i\Delta t)\, E\big((i+\mu)\Delta t\big), \tag{3}$$

where $sgnX(i\Delta t) = \begin{cases} +1 \;\; when\; X(i\Delta t) > 0 \\ 0 \;\;\; when \;\; X(i\Delta t) = 0 \\ -1 \;\; when \;\; X(i\Delta t) < 0 \end{cases}.$

Obviously, to use this formula it is necessary to determine the samples of the noise $E(i\Delta t)$ and the useful signal $X(i\Delta t)$ that cannot be measured directly or extracted from the noisy signal $G(t)$ [1]. Let us consider one of possible variants of the approximate estimation of the relay cross-correlation function $R^{r*}_{XE}(\mu)$ between the useful signal $X(t)$ and noise $E(t)$ as a result of calculation of the relay correlation function $R^{r}_{GG}(\mu)$ of the noisy signal $G(t)$ [1]:

$$R^{r}_{GG}(\mu) = \frac{1}{N}\sum_{i=1}^{N} sgnG(i\Delta t)\, G\big((i+\mu)\Delta t\big), \tag{4}$$

where $sgnG(i\Delta t) = \begin{cases} +1 \ \ when\ G(i\Delta t) > 0 \\ 0 \ \ \ when\ \ G(i\Delta t) = 0 \\ -1 \ \ when\ \ G(i\Delta t) < 0 \end{cases}.$

It is shown in [1, 3-4] that the estimate of the relay cross-correlation function $R_{XE}^{r*}(\mu\Delta t)$ at different time shifts μ between $X(i\Delta t)$ and $E(i\Delta t)$ can be determined from the formula:

$$R_{XE}^{r*}(\mu) = \frac{1}{N}\sum_{i=1}^{N} sgnG(i\Delta t)\Big(G\big((i+\mu)\Delta t\big) - 2G\big((i+\mu+1)\Delta t\big) + G\big((i+\mu+2)\Delta t\big)\Big). \quad (5)$$

It is clear that with the normal geodetic state of the area and the technical condition of the objects due to the lack of correlation between $X(t)$ and $E(t)$ the estimate of the relay cross-correlation function $R_{XE}(\mu)$ between the useful signal and the noise will be close to zero. When various anomalies and defects occur, the value of the estimate of the relay cross-correlation function will vary depending on the degree of correlation between $X(t)$ and $E(t)$. And the distinctive feature of this algorithm is that if there is a correlation between $X(t)$ and $E(t)$, differences in the values of the estimates $R_{XE}^{r*}(\mu = 0)$, $R_{XE}^{r*}(\mu = \Delta t)$, $R_{XE}^{r*}(\mu = 2\Delta t)$, ... at different time instants unambiguously reflect the dynamics of malfunction development, which makes it possible to obtain reliable information about the risk of accidents.

In addition, to assess the latent period of the initiation of anomalous seismic processes and landslides, as well as the technical condition of objects in the urban development area, it is advisable to use estimates of the normalized cross-correlation function, as well as the correlation coefficient between the useful signal $X(t)$ and the noise $E(t)$.

In this case, using formula (5), the calculation of the normalized cross-correlation function can be reduced to the form [1]:

$$\rho_{XE}^{r*}(\mu) = \frac{R_{XE}^{r*}(\mu)}{\sqrt{\frac{2}{\pi}}\cdot\sigma_E^*}, \quad (6)$$

where the mean square deviation σ_E^* of the noise can be calculated from the expressions [1, 3-4]:

$$\sigma_E^* = \begin{cases} \sqrt{R_{GG}(0) - 2R_{GG}(\Delta t) + R_{GG}(2\Delta t)} & \text{for the general case} \\ \sqrt{R_{GG}(0) - R_{GG}(\Delta t)} & \text{for the special case} \end{cases}. \quad (7)$$

It is known that the value of the normalized cross-correlation function at μ=0 is the correlation coefficient. Therefore, the value of the correlation coefficient between the useful signal $X(t)$ and the noise $E(t)$ can be calculated from the expression:

$$r_{XE}^* = \rho_{XE}^{r*}(0) = \frac{R_{XE}^{r*}(0)}{\sqrt{\frac{2}{\pi}}\cdot\sigma_E^*}. \quad (8)$$

IV. Technologies for determining the latent period of changes in the geodetic state and technical condition of objects of the urban development area

To assess the geodetic state and technical condition of objects in the urban development area, the estimates of the relay and normalized cross-correlation functions, as well as the correlation coefficients between the useful signal $X(t)$ and the noise $E(t)$ for each of the monitored parameters should be calculated at different time instants t_1, t_2, t_3, ... t_k. The obtained values of the estimates are entered into the database of informative attributes, which can be represented in the form of matrices:

$$S1 = \begin{bmatrix} R^{r*}_{X_1E_1}(\mu)t1 & R^{r*}_{X_1E_1}(\mu)t2 & \cdots & R^{r*}_{X_1E_1}(\mu)tk \\ R^{r*}_{X_2E_2}(\mu)t1 & R^{r*}_{X_2E_2}(\mu)t2 & \cdots & R^{r*}_{X_2E_2}(\mu)tk \\ \cdots & \cdots & \cdots & \cdots \\ R^{r*}_{X_nE_n}(\mu)t1 & R^{r*}_{X_nE_n}(\mu)t2 & \cdots & R^{r*}_{X_nE_n}(\mu)tk \end{bmatrix}, \tag{9}$$

$$S2 = \begin{bmatrix} \rho^{r*}_{X_1E_1}(\mu)t1 & \rho^{r*}_{X_1E_1}(\mu)t2 & \cdots & \rho^{r*}_{X_1E_1}(\mu)tk \\ \rho^{r*}_{X_2E_2}(\mu)t1 & \rho^{r*}_{X_2E_2}(\mu)t2 & \cdots & \rho^{r*}_{X_2E_2}(\mu)tk \\ \cdots & \cdots & \cdots & \cdots \\ \rho^{r*}_{X_nE_n}(\mu)t1 & \rho^{r*}_{X_nE_n}(\mu)t2 & \cdots & \rho^{r*}_{X_nE_n}(\mu)tk \end{bmatrix}, \tag{10}$$

$$S3 = \begin{bmatrix} r^{r*}_{X_1E_1t1} & r^{r*}_{X_1E_1t2} & \cdots & r^{r*}_{X_1E_1tk} \\ r^{r*}_{X_2E_2t1} & r^{r*}_{X_2E_2t2} & \cdots & r^{r*}_{X_2E_2tk} \\ \cdots & \cdots & \cdots & \cdots \\ r^{r*}_{X_nE_nt1} & r^{r*}_{X_nE_nt2} & \cdots & r^{r*}_{X_nE_ntk} \end{bmatrix}. \tag{11}$$

After appropriate training, the geodetic state and technical condition of the objects in the urban development area is identified. For instance, if the geodetic indicators of the noise characteristics have changed in some limited area, and the estimates of the noise characteristics of the technical condition have changed only for nearby objects, it can be regarded as the beginning of a hidden period of landslide occurrence. If the geodetic indices of noise characteristics have changed for quite an extensive territory, and the estimates of noise characteristics of technical conditions have changed for all objects simultaneously on this territory, this indicates the beginning of a latent period of preparation for an earthquake. It is possible to judge about the dynamics of geodetic processes by the intensity of changes in the noise characteristics. And the noise-characteristics will take different values depending on the type of terrain, e.g., rock, sand, clay, etc. At the same time it is necessary to carry out monitoring of technical condition of buildings, constructions, structures and other objects in the urban development already at the initial stage of occurrence of anomalous natural phenomena.

Depending on the values of the relay and normalized cross-correlation functions, as well as the correlation coefficients between the useful signal $X(t)$ and noise $E(t)$ at different time instants, conclusions are made about the geodetic state of the urban development area, for instance: 1 – ground waters are leaking; 2 – displacements and shifts in the soil are observed; 3 – subsidence of soil masses are observed; 4 – a source of vibrations is detected; 5 – a source of seismic vibrations is detected; 6 – a landslide zone is detected, etc. For each of these states the intensity of the process is defined: a – not developing; b – developing very slowly; c – developing slowly; d – developing with average intensity; e – developing intensively; f – developing very intensively; g – developing rapidly, etc. Then the matrices of the geodetic state of the urban development area take the form:

$$GS1 = \begin{bmatrix} R^{r*}_{X_1E_1}(\mu)t1 & R^{r*}_{X_1E_1}(\mu)t2 & \cdots & R^{r*}_{X_1E_1}(\mu)tk \\ R^{r*}_{X_2E_2}(\mu)t1 & R^{r*}_{X_2E_2}(\mu)t2 & \cdots & R^{r*}_{X_2E_2}(\mu)tk \\ \cdots & \cdots & \cdots & \cdots \\ R^{r*}_{X_nE_n}(\mu)t1 & R^{r*}_{X_nE_n}(\mu)t2 & \cdots & R^{r*}_{X_nE_n}(\mu)tk \end{bmatrix} \begin{bmatrix} 1-a \\ 2-b \\ \cdots \\ k-z \end{bmatrix}, \tag{12}$$

$$GS2 = \begin{bmatrix} \rho^{r*}_{X_1E_1}(\mu)t1 & \rho^{r*}_{X_1E_1}(\mu)t2 & \cdots & \rho^{r*}_{X_1E_1}(\mu)tk \\ \rho^{r*}_{X_2E_2}(\mu)t1 & \rho^{r*}_{X_2E_2}(\mu)t2 & \cdots & \rho^{r*}_{X_2E_2}(\mu)tk \\ \cdots & \cdots & \cdots & \cdots \\ \rho^{r*}_{X_nE_n}(\mu)t1 & \rho^{r*}_{X_nE_n}(\mu)t2 & \cdots & \rho^{r*}_{X_nE_n}(\mu)tk \end{bmatrix} \begin{bmatrix} 1-a \\ 2-b \\ \cdots \\ k-z \end{bmatrix}, \tag{13}$$

$$GS3 = \begin{bmatrix} r^{r*}_{X_1E_1t1} & r^{r*}_{X_1E_1t2} & \cdots & r^{r*}_{X_1E_1tk} \\ r^{r*}_{X_2E_2t1} & r^{r*}_{X_2E_2t2} & \cdots & r^{r*}_{X_2E_2tk} \\ \cdots & \cdots & \cdots & \cdots \\ r^{r*}_{X_nE_nt1} & r^{r*}_{X_nE_nt2} & \cdots & r^{r*}_{X_nE_ntk} \end{bmatrix} \begin{bmatrix} 1-a \\ 2-b \\ \cdots \\ k-z \end{bmatrix}. \tag{14}$$

Similar conclusions are made about the presence or absence of latent damage and the dynamics of their development for structures and objects of the urban development area, for instance: 0 - technical condition is serviceable; 1 - operational without damage; 2 - limited operational with minor damage; 3 - limited operational with minor damage developing intensively; 4 - non- operational; 5 - pre-emergency; 6 - emergency, etc., depending on the values of the noise characteristic estimates at a given time instant. Then the matrices of the technical condition of structures and objects take the form:

$$TS1 = \begin{bmatrix} R^{r*}_{X_1E_1}(\mu)t1 & R^{r*}_{X_1E_1}(\mu)t2 & \dots & R^{r*}_{X_1E_1}(\mu)tk \\ R^{r*}_{X_2E_2}(\mu)t1 & R^{r*}_{X_2E_2}(\mu)t2 & \dots & R^{r*}_{X_2E_2}(\mu)tk \\ \dots & \dots & \dots & \dots \\ R^{r*}_{X_nE_n}(\mu)t1 & R^{r*}_{X_nE_n}(\mu)t2 & \dots & R^{r*}_{X_nE_n}(\mu)tk \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ \dots \\ k \end{bmatrix}, \tag{15}$$

$$TS2 = \begin{bmatrix} \rho^{r*}_{X_1E_1}(\mu)t1 & \rho^{r*}_{X_1E_1}(\mu)t2 & \dots & \rho^{r*}_{X_1E_1}(\mu)tk \\ \rho^{r*}_{X_2E_2}(\mu)t1 & \rho^{r*}_{X_2E_2}(\mu)t2 & \dots & \rho^{r*}_{X_2E_2}(\mu)tk \\ \dots & \dots & \dots & \dots \\ \rho^{r*}_{X_nE_n}(\mu)t1 & \rho^{r*}_{X_nE_n}(\mu)t2 & \dots & \rho^{r*}_{X_nE_n}(\mu)tk \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ \dots \\ k \end{bmatrix}, \tag{16}$$

$$TS3 = \begin{bmatrix} r^{r*}_{X_1E_1t1} & r^{r*}_{X_1E_1t2} & \dots & r^{r*}_{X_1E_1tk} \\ r^{r*}_{X_2E_2t1} & r^{r*}_{X_2E_2t2} & \dots & r^{r*}_{X_2E_2tk} \\ \dots & \dots & \dots & \dots \\ r^{r*}_{X_nE_nt1} & r^{r*}_{X_nE_nt2} & \dots & r^{r*}_{X_nE_ntk} \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ \dots \\ k \end{bmatrix}. \tag{17}$$

IV. Discussion

The conducted analysis shows that using the matrices of noise characteristics (9)-(11), (12)-(14), (15)-(17), it is possible to identify an early stage of occurrence of changes in the geodetic state of an urban development area, as well as the technical condition of the objects located there. At the same time the objective of geodetic monitoring is to identify the latent period of the emergence of hazardous natural phenomena. The main objective of technical monitoring is to detect latent defects in the roof, facade, microcracks in the walls, the possibility of deformations, etc. This can be done by calculating the characteristics of the relationship between the useful signal and the noise. The combination of geodetic and technical control makes it possible to objectively assess the condition of the urban development complex; to prevent in a timely manner the risk of the risk of destruction of buildings, structures and constructions in seismically active regions; to identify the causes and sources of risks both for individual buildings and for the entire complex; to reduce the cost of maintenance and major repairs; to alert personnel to the possibility of destruction of objects with catastrophic consequences.

References

[1] Aliev, T. A. Noise Control of the Beginning and Development Dynamics of Accidents, Springer, 2019, 201 p. DOI: 10.1007/978-3-030-12512-7

[2] Jooste, A.F. & de Kock, I.H. & Musango, J.K. (2019). A systematic literature review of sustainable urban planning challenges associated with developing countries. *South African Journal of Industrial Engineering*. Vol. 30(3), Special Edition, pp. 253-261 253. DOI:10.7166/30-3-2247

[3] Aliev, T.A. & Musaeva, N.F. & Suleymanova, M.T. (2018). Algorithms for Indicating the Beginning of Accidents Based on the Estimate of the Density Distribution Function of the Noise of Technological Parameters. *Automatic Control and Computer Science*. Vol. 52. Issue 3. pp. 231–242. DOI: 10.3103/S0146411618030021

[4] Aliev, T.A. & Musaeva, N.F. (2019). Technologies for Early Monitoring of Technical Objects Using the Estimates of Noise Distribution Density. *Journal of Automation and Information Sciences*. Vol. 51, no. 9, pp. 12-23.

HYDROGEOLOGICAL CONDITIONS OF THE SHIRVAN STEPPE OF AZERBAIJAN

Chingiz Gulmammadov[1], Makhluga Mammadova[2], Allahverdi Tagiyev[3]

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[1]Azerbaijan S&P Association of "Hydraulic engineering and melioration"
gcin56@mail.ru
[2]Baku State University, Azerbaijan
m.mahluga@rambler.ru
[3]Azerbaijan State Oil and İndustry University
allahverdi.taghiyev@gmail.com

Abstract

According to the results of the author`s research on the long-term average level of groundwater, the degree of mineralization, salinization of soils and changes in groundwater regime during 1977-2020, as well as the collection of materials in this direction during 1930-2020, the hydrogeological conditions of the Shirvan plain were studied. Based on the analysis of the results the regime types of groundwater were separated and a correlative dependence was found between regime types and factors forming the regime. Five genetic types have been identified according to the factors forming the regime and the synchrony of changes in groundwater levels. Under the influence of natural and anthropogenic factors, the level of groundwater, the degree of mineralization, the chemical composition, the chemical composition and salinity of the soils have changed. During the period from 1958 to 2020, the level of groundwater in the area increased by more than 4.1 m due to irrigated agriculture, and their mineralization degree decreased by 16.2 g/l due to filtration of the surface water and removal of mineralized water through drainage. As a result of the analysis regime types of groundwater were separated and a correlative dependence was found between regime types and factors forming the regime. According to the factors forming the regime and the synchrony of changes in groundwater levels, the genetic types of the regime-climate, hydrological, irrigation, irrigation-drainage, irrigation were separated and their areas of distribution were determined. The climate type regime is characterized by a high correlation between the rise and fall of groundwater level and the seasonal and perennial periodicity of atmospheric precipitation, the hydrological type is characterized by a similar dependence on the surface flow, the irrigation-drainage type is characterized by a similar dependence between irrigation water and surface water basins.

Keywords: groundwater, pressure water, mineralization, chemical composition, groundwater level, salinity, regime, regime-forming factors.

I. Introduction

The water and land resources of Azerbaijan are in a limited state and are constantly exposed to man-made effects from year to year. On the other hand, 71% of the surface waters of the republic come across the border of neighboring states in a certain degree of pollution. The total underground water resources of Azerbaijan are 8.5÷9.5 billion. m^3, and surface waters 28÷32 billion m^3 depending on the water level of the year [1]. The total population of the republic is more than 10 million people. In low-income years, water shortage is 4÷5 billion m^3. The use of water and the demand for it in the republic increases from year to year at a great pace. In this regard, it is necessary to rationally and economically use existing water resources and look for new sources.

One of such sources is underground water. When extracting and protecting groundwater to protect against pollution and depletion, it is necessary to study in detail the hydrogeological conditions and the impact of natural and man-made processes on them and take preliminary preventive measures.

In the territories where groundwater is extracted and used, pollution and depletion of groundwater occurs, pressure underground horizons fail, due to the infiltration of irrigation and other waters, the level of groundwater rises, there is waterlogging of land, physical, chemical, bacteriological, sometimes even radioactive pollution, changes in the structure and tension of soil in the geological environment, activation of exogenous geodynamic processes, re-salination of soil, changes in the composition of groundwater, sometimes disturbance of relief and landscape.

In recent years, scientifically unsubstantiated displacement of internal and surface parts of the Earth: merciless exploitation of underground fossils, including underground water, construction of hydrotechnical structures, large-scale construction of irrigation and reclamation systems, random cutting of forests, destruction of landscapes, etc. lead to changes in the geological and hydrogeological conditions of the territory. On the other hand, global climate change - temperature increase, drought, uneven temperature distribution, increase in intensity of natural cataclysms and other natural processes seriously influence the formation of hydrogeological processes. In such conditions, study changes in hydrogeological conditions under the influence of anthropogenic factors and take proactive measures that are extremely important. [2].

II. Methods

The territory of the Shirvan Steppe covers the left bank of the Kura River from the Mingechaur reservoir in the north-west to the Hajigabul district in the south-east. Within the borders of the steppe landscape are the territories of Yevlakh, Agdash, Goychay, Ismailli, Ujar, Zardab, Kurdamir, Agsu, Shamakhi and Hajigabul administrative districts. The total area of the Shirvan steppe is 680 thousand. га, из них 450 thousand. The area is suitable for irrigation, but due to the lack of water, only 225 thousand. Irrigation is carried out on the square.

Soil salinity in the southern part of the steppe massif is higher than in the north. In addition, the southern part is the discharge of groundwater, and the northern part is the zone of formation and transportation of groundwater. In the north, the soils are relatively light, the filtration coefficient in the thickness of 0-2 and 2-5 m is 3÷10 m/day, in the southern part - 0.1÷0.2 m/day. Territories with a filtration coefficient of 0.1÷0.2 m/day make up more than 80% of the total area. In a thickness of 2-5 m, the filtration coefficient is 3-5 times greater than in a thickness of 0-2 m. This difference causes a change in the flow rate and salt reserves [3-7].

The total length of irrigation systems is 74,000 km, and the specific length is 10.9 m/ha, the water surface area is 5.31 thousand km2 [2, 4]. The supply of ground water through trunk collectors for one linear meter of length is 2.4 m^3/ha.

Drainage waters flowing into the Kuru River and flowing into the sea (m3/sec) are indicated in Table 1.

Table 2 shows the participation of average long-term pressure, ground and irrigated waters in the drainage runoff of the Shirvan steppe, in m^3/sec (Table 2).

In the 30s of the last century, irrigation and reclamation works in Azerbaijan were poorly developed and irrigation canals and collector-drainage networks were located very densely in the irrigated territories. During these years, the depth of groundwater in the Kura-Araks lowland of the Republic, including the Shirvan steppe, was 5.0-10.0 m or more. In irrigated areas, the groundwater level began to systematically rise. In 1951 in all irrigated areas, the occupied area with a groundwater depth of 5.0-10.0 and deeper than 10.0 m decreased from 33% to 20% (i.e. 1.5

times), at the same time, the occupied area with the depth groundwater occurrence deeper than 3.0 m decreased by 2.6 times (Table 3).

Table 1: *Mean annual drainage water discharge in Shirvan steppe (m^3/sec) [1, 7].*

Months	Drainage water flowing into the Kura River	Drainage water flowing into the sea	Total
I	0,54	36,58	37,12
II	0,42	33,02	33,44
III	0,73	35,76	36,49
IV	0,96	41,73	42,69
V	1,01	46,18	47,19
VI	0,87	40,17	41,04
VII	0,70	36,37	37,07
VIII	0,55	33,75	34,30
IX	0,47	28,69	29,16
X	0,31	24,42	24,73
XI	0,36	27,73	28,09
XII	0,43	30,95	31,38

Table 2: *Participation of pressurized, groundwater and irrigated water in drainage flow of the Shirvan steppe [7]*

Geographical location of the area	Participation of different waters in drainage runoff		
	Pressurized water	Groundwater	Irrigated waters
Bozdag-Alijancay	11-20	47-62	44-18
Alijanchai-Turyanchai	13-37	35-42	42-21
Turianchai-Geokchai	25-38	33-45	42-17
Geokchai-Akhsu-Girdimanchai	14-32	43-52	43-16
Limit of change	11-29	46-50	43-21

Table 3: *Location of the area by depth of groundwater occurrence (1951), in the steppes of the Kura-Araks lowland, in % of the total area [4, 7]*

Steppes	Area, km^2	Depth of groundwater occurrence, m					
		0 - 1	1 – 2	2 – 3	3 - 5	5 – 10	> 10
Shirvan	6917	0,1	10,6	16,6	31,5	36,4	4,8
Southeast Shirvan	1563	18,3	25,5	28,8	18,3	14,0	-
Karabakh	2054	6,5	20,47	14,8	29,53	16,9	11,8
Mil	2907	8,8	20,6	34,8	28,6	7,2	-
Mugan	4658	8,5	36,6	40,4	14,5	-	-
Salyan	727	20,0	30,0	32,9	17,1	-	-
Total for the Kura-Araks lowland	18826	6,36	22,04	26,15	24,92	17,43	3,10

Since 1950, a new stage in the development of land irrigation has begun in Azerbaijan. In 1952, the Varvara reservoir was built and put into operation, and in 1953 the Mingachevir reservoir, which has no analogues in the republic and in the world, in terms of multifunctionality (energy, irrigation, fish farming, tourism, sports, and other purposes). Along with the construction of these unique hydraulic structures, in order to provide the land of the KAN with irrigated water, the Upper Karabakh Canal was built in 1955, the Upper Shirvan Canal was built in 1958, and in 1960 the main canals - the Main Mugan and the Sabir Canal [4, 7].

In 1962, the occupied area of groundwater, lying at a depth of more than 10.0 m, can be said to have not been on the map at all. Groundwater, occurring at a depth of 0 - 5.0 m, occupied more than 84% of the territory of the Shirvan steppe (Table 4).

Table 4: *Location of the area by depth of groundwater occurrence (1962), in the steppes of the Kura-Araks lowland, as a percentage of the total area [7, 8]*

Steppes	Area, km^2	Depth of groundwater occurrence, m					
		0 - 1	1 – 2	2 - 3	3 - 5	5 - 10	> 10
Shirvan	6917	18,06	24,20	22,15	19,79	13,80	19,0
Southeast Shirvan	1563	25,3	32,10	20,10	15,30	7,20	-
Karabakh	2054	14,5	51,9	20,45	7,69	5,8	-
Mil	2907	12,8	50,19	24,03	8,42	5,18	-
Mugan	4658	16,6	62,4	20,40	0,6	-	-
Salyan	727	56,4	14,5	6,60	12,5	-	-
Total for the Kura-Araks lowland	18826	18,44	40,95	21,45	11,33	7,10	0,73

Observations show that the level regime of groundwater to a lesser extent depends on precipitation. In various periods of the year, mainly autumn-winter periods, the groundwater level is relatively deep. Starting from April, the groundwater level gradually rises and in July-August the maximum amplitude is observed. From October to January, there is a decrease in the level of groundwater. In the territory where the depth of the groundwater level is up to 3.0 m, their fall and rise to a large extent does not occur. In rare cases, these changes occur in the range of 0.3-0.6 m. However, in irrigated areas located closer to the canals, the amplitude of changes in the groundwater level is 0.3-0.6 m, sometimes more. In 1989, on the territory of the Shirvan steppe, the depth of the groundwater level was up to 1.0 m, 1.0 - 1.5 m, 1.5 - 2.0, 2.0 - 3.0, 3.0 - 5.0 , and more than 5.0 m, respectively, accounted for 4.3%, 18.0%, 28.5%, 36.8%, 10.2% and 2.2% of the total irrigated area, and in 2016, respectively, were 6.3%, 14.8%, 23.0%, 41.7%, 14.5% and 1.8%. As can be seen from V.R. Volobuev, in 1989, on irrigated areas, the area where the depth of occurrence is above the critical level is 22.2%, and in 2016 it was 21.1%. This is due to the fact that there is more drainage flow in the territory [7–8].

In 1989, if irrigated areas with groundwater salinity below 1.0 g/l, 1.0, 3.0 and above 3.0 g/l respectively accounted for 14.8%, 32.2% and 53% of the total area, 0%, then in 2016 they were 26.6%, 33.1% and 40.3%. In the Shirvan irrigated massif in 1989, saline, slightly, strongly and very strongly saline territories respectively amounted to 37.6%, 38.4%, 14.9% and 9.1%, and in 2016 - 44.7% , 29.0%, 18.1% and 8.2%.

Groundwater is common in river fans and the Kura belt throughout the Shirvan steppe and their depth varies from 1.0 to 7.0 m. More than 5.0 m and deeper groundwater is mainly observed in the upper part of the river fan . In the south, in the Kura zone, groundwater occurs at a depth of 3-5 m (Table 5). The filtration coefficient of the rocks of the aquifer varies in the range of 0.1 ÷ 22.0 m/day, the highest value is the upper part of the alluvial fans. When pumping water from wells, the flow rate was 0.06 ÷ 6.0 l/s. In the upper part of the alluvial fans and in the Kura strip, groundwater mineralization is up to 1 g/l, and water hardness is 3.43 ÷ 11.54 mg. equiv/l [1, 4]. The first confined aquifer was discovered in wells in three areas that are separated from each other, Alicanchay-Turyanchay, Goychay and Girdimanchay-Agsuchay alluvial fans of Khivalin age sediments at a depth of 31-182 m. They are separated from groundwater by clays 5-85 m thick. horizons in the upper part of the Agsucay alluvial fan are represented by gravel, and in the rest of the area - by sand and sandy loam. The thickness of the aquifer varies in the range of 15 - 77 m, the piezometric water level before the operation of the Upper Shirvan Canal throughout the territory was below the surface of the earth, and at present - in places 0.9 ÷ 16.5 m below the surface of the earth, in the north it is + 0.64 ÷ + 4.6 m, and in the south, on the left bank of the Kura River, 1.3 ÷ 4.3 m below the ground. In the Goychay section, the piezometric water level is both below the ground (-20.8 m) and higher (+7.2 m), and in the Girdimanchay-Agsuchay section - above the ground (+0.4 ÷ + 8.2 m) along the absolute elevation of the relief varies from 76.3 to 0 m, the slope of the terrain is 0.02 ÷ 0.007. The filtration coefficient of aquifers varies in the range of 0.3 ÷ 25.5 m/day. When pumping water from wells, the flow rate was: 13.3 l/s in the Alijanchay-Turyanchay area, 9.2 l/s in the Goyvhay area, and 1.4 l/s in the Girdimanchay-Agsuchay area. In the upper and central parts of alluvial fans, groundwater mineralization is up to 1.0 g/l, and in the lower part it is more than 3.0 g/l [1, 4].

The second pressure aquifer was opened by wells in the rocks of the Khazar age at a depth of 75 - 274 m, and in the Kura zone at a depth of 150 - 235 m (Table 6). This horizon is found everywhere, except for the Alijanchay alluvial fan. The second aquifer is separated from the first by clayey sands 10–160 m thick, and in some places 70–110 m thick. Their thickness varies within 10 - 40 m (77 m in places) [1, 4]. The filtration coefficient of aquifers is 0.3÷35.3 m/day. The piezometric level on the Girdimanchay-Agsuchay site is set above the ground - 2.1 ÷ 2.7 m, on the Goychay site and below the ground and above, and on the Alijanchay-Turyanchay site below the surface, in the Kura strip above the ground - 1.3÷4.3 m. Flow slope 0.02÷0.0004. When pumping water from wells, the flow rate varies within 0.18 ÷ 6.7 l/s. The total hardness of water is 1.6 ÷ 5.2 mg equiv/l.

The third confined aquifer was opened by wells in the Alijanchay-Turianchay and Girdymanchay areas with sediments of Baku age in the river fans at depths of 62-333.4 m. The third confined aquifer is not found in the Goyvhay area. The third confined aquifer is separated from the second aquifer by clay layers 7–165 m thick, and in many places 10–80 m thick. The thickness of these soils is 4.5 - 86.4 m, mostly 20-70 m. Their filtration coefficient is 0.1÷17.9 m/day, mostly 9 m/day. The piezometric water level is uniquely located above the earth's surface - +7.5 ÷ + 23.0 m. When pumping water, the flow rate of the well changes in the range of 3.01 ÷ 8.5 l/s.

Groundwater suitable for use (mineralization 1…3 g/l) is distributed in the upper and middle parts of the river fans. The total mineralization of groundwater increases towards their movement; in the middle part of the alluvial fans, the mineralization rises to more than 3 g/l and is unsuitable for use. With an increase in mineralization, a change in the chemical composition of groundwater occurs. Fresh and low-mineralized waters have a hydrocarbonate-sulfate, sulfate-hydrocarbonate anionic composition and a mixed composition of cations. Where salinity is of great importance, water types undergo metamorphism to the sodium chloride type. In general, there is a limited amount of groundwater in most of the Shirvan steppe. And in the direction of the axis of the alluvial fans of the rivers Goychay, Turyanchay and Agsuchay, the areas are considered favorable.

After 1975, with the removal of groundwater by collector-drainage systems, in the 0-2 m thickness, the salinity of soils decreased - 0.19%, and in the thickness of 2-5 m - 0.21%. In irrigated canals and irrigated areas, there are chloride-sulfate-magnesium-sulfate-sodium types of water (0.3 ÷ 1.0% salinity), and sometimes sodium-potassium type of salinity (1.0 ÷ 1.5%) [1,8] .

The groundwater regime of the Shirvan steppe was studied by many researchers - O.P.Savarensky, V.A.Priklonsky, N.V.Rogovskaya, D.M.Kats, G.Yu.Israfilov, F.Sh.Aliev, Ch.J. Gulmammadov and others [2,8]. To date, there are a large number of works that consider this issue in various aspects [7,8].

The climatic type includes regimes with a high correlation between fluctuations in the level of groundwater, seasonal and long-term periodicity of precipitation; the hydrological type is characterized by a similar dependence - on surface runoff, for the irrigation-irrigation-drainage type - on water supply and catchment. The climatic regime is widespread where there is no influence of artificial factors. The hydrological type of regime is distinguished in the zone of influence of the river. Kura, where there is no drainage effect, which is characterized by the synchronism of seasonal and integral curves of the groundwater level and the flow of the river. Hens. The correlation coefficient between the groundwater level and the river flow is 0.75 [7].

Table 5: *Level of occurrence, groundwater salinity and degree of soil salinization in Shirvan irrigation massif (thousand ha) [4,8]*

Districts	Years	Irrigated areas suitable for agriculture	Depth of groundwater occurrence, m					Salinity degree of groundwater, g/l			Degree of soil salinity			
			< 1,0	1,0 - 2,0	2,0 - 3,0	3,0 - 5,0	>5,0	< 1,0	1,0 - 3,0	> 3,0	Unsalted	Lightly salted	Medium saline	Highly saline
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Agdash	1984	37,7	1,7	16,4	16,8	2,8	0	4,5	17,8	15,4	8,2	15,6	8,9	5,0
	1986	39,3	3,6	19,6	13,6	2,4	0	4,4	18,8	16,1	18,4	15	4,6	1,3
	1988	38,1	1,7	14,7	15,8	5,2	0,7	5,9	14,2	18	19,1	12,6	4,6	1,8
	2012	34,5	4,2	15,0	8,4	4,3	2,5	4,02	23,9	6,5	12,1	10,9	8,1	3,4
	2015	34,5	0,27	20,1	11,2	3	-	18,2	12,2	4,1	13,7	10,9	5,8	4,1
	2018	34,5	0,9	20,9	13,0	5,3	-	14,2	16,2	4,1	13,7	11,0	5,7	4,1
Geokcha	1984	25,9	2,8	9,1	11,8	2,2	0	1,2	11,6	13,1	12,1	6	4,3	3,5
	1986	26,1	2,5	11,8	9,4	2,4	0	9,3	9,1	7,7	13,2	6,5	3,8	2,6
	1988	26,2	0,6	11,0	10,8	3,6	0,2	9,9	9,7	6,6	13,1	7,1	3,2	2,8
	2012	26,2	4,1	9,8	5,4	4,4	2,5	9,6	10,9	5,7	14,9	6,1	3,9	1,3
	2015	26,2	0,36	12,0	9,9	3,9	-	14,6	5,2	6,4	15,7	5	4,4	1,1
	2018	26,2	0,7	10,8	9,0	4,8	0,9	13,6	6,2	6,4	15,7	5,0	4,5	1,0
Zardob	1984	30	8,1	9,7	4,8	2,1	5,3	2,5	4,4	23,1	7,3	2,5	3,6	16,6
	1986	30,4	3,4	17,2	8,9	0,9	0	4,6	11,4	14,4	7,9	7,3	3,7	11,5
	1988	30,8	1,5	21,6	6,9	0,8	0	4,2	8,9	17,7	9,6	9,4	4,4	7,4
	2012	32,7	0,79	15,9	10,5	5,6	0,45	2,7	10,2	20,3	13,2	8,1	5,2	6,7
	2015	33,2	0,45	11,8	17,6	3,4	-	5,9	14,6	12,7	9,5	11,3	7,4	5
	2018	33,2	0,5	14,0	13,0	5.7	-	4,9	15,5	12,8	9,5	11,3	7,4	5,0
Ujar	1984	24	3,2	11,9	7,5	1,4	0	0	7,7	16,3	2,5	6	7,3	8,2
	1986	24,6	2,8	13,0	7,8	1	0	0,9	7,2	16,5	4,8	11,5	5,4	2,9
	1988	25,3	2	14,5	7,8	1	0	1,6	6,7	17	4,9	12,5	5	2,9
	2012	24,9	0,58	13,2	9	2,2	-	1,2	4,5	19,2	10,8	5,4	2,8	5,9
	2014	24,9	0,39	9,8	9,4	5,3	-	0,91	8,9	15,1	10,8	4,4	2,8	6,9
	2018	24,9	–	14,1	8,7	2,1	-	2,9	5,8	16,2	9,7	6,8	6,3	2,1
Kuurdamir	1984	52,2	4,5	12,4	15,2	7,7	12,4	0	0	52,2	5,1	6,8	16,8	23,5
	1986	53,8	3,9	28,3	16,8	3	1,8	0,3	11,2	42,3	16	22,9	11,1	3,8
	1988	54,8	3,4	30,9	16	3,4	1,1	1,2	12,3	41,3	16,1	24,7	10,3	3,7
	2012	52,8	2,4	23,6	16,3	5,8	4,7	2,1	11,6	39,1	12,5	23,8	11,1	5,4
	2015	52,8	6,6	16,7	16,7	11,3	1,5	8,6	13,1	31,1	23,4	18,9	7,3	3,2
	2018	52,8	2,0	21,7	16,2	11,6	1,3	5,6	16,1	31,1	23,3	18,9	7,3	3,2
Agsu	1984	34,7	4,2	14,0	12,2	2,1	2,2	0	12,4	22,5	14,3	8,6	7,9	3,9
	1986	34,4	3,4	13,5	13,1	2,2	2,2	0	14,2	20,2	13,9	11,4	6,3	2,8
	1988	34,6	1,8	15,8	12,5	2,5	2	2,3	8,3	24	14	13,7	4,5	2,4
	2012	37	2,2	18,0	11,7	3,8	1,4	3,4	11,9	21,7	12,2	12,2	8,7	3,9
	2015	37	0,2	6,1	24,9	5,8	-	2,9	16,7	17,4	20,5	10,3	4,7	1,5
	2018	37	0,2	9,0	22,0	5,8	-	2,9	16,7	17,4	20,5	10,3	4,7	1,5

The irrigation type of regime is formed under the influence of infiltration waters through canals and irrigated fields. The correlation coefficient between the groundwater level and the canal discharge is 0.91. Irrigation-irrigation-drainage type is identified on the basis of a close correlation dependence on drainage flow with a correlation coefficient of 0.74. Irrigation-irrigation type of groundwater regime has a close correlation with water supply. The influence of waterfalls on the level of groundwater, in addition to feeding them with seepage water, is also exerted by seepage water from irrigated fields.

III. Results

In the Shirvan steppe, hydrogeological conditions - basically the natural level and hydrochemical regime of groundwater under the influence of anthropogenic factors have undergone a serious change. Since 1930, due to the construction of large hydraulic structures and irrigation and reclamation systems, as well as the expansion of irrigated areas and the intensive use of surface irrigation, the level and hydrochemical regime of groundwater has changed dramatically. In 1930, the groundwater level averaged 7.0 m, and in 1970 - 2.4 m. From 1930 to 1950, the groundwater level rose by an average of 5 cm per year, and from 1950 to 1980. by 19 cm, in subsequent years, due to evaporation and the operation of collector-drainage networks, the level stabilized. After the construction of the Upper Shirvan Canal - five years later (built in 1958), the piezometric level of the first pressure aquifer came to the surface of the earth, and then stabilized.

In the study area, the hydrochemical regime of groundwater has seriously changed and more than halved, while the pressure regime has not changed. Mineralization of groundwater from 1950 to 1960 rose, and then gradually decreased. This is due to the flow of irrigated water into groundwater and the operation of collector-drainage networks. It was revealed that ground and pressure waters of the same mineralogical composition differ in chemical composition and type. Groundwater with a mineralization degree of up to 1.0 g/l is mainly of a sulfate-hydrocarbonate composition, and pressure waters are of a hydrocarbonate-sulphate type. And with a degree of mineralization up to 3.0 g/l, they are mainly chloride-sulfate-sodium type and sulfate-chloride-magnesium type.

For 80 years, the groundwater level in the territory of the Shirvan steppe has risen by more than 4.1 m, and their mineralization has decreased by 16.2 g/l. The groundwater regime is mainly formed by land irrigation and drainage.

According to the synchronism of changes in the regime-forming factors and the level of groundwater, genetic types of the regime were distinguished - climatic, hydrological, irrigation, irrigation-irrigation-drainage, irrigation-irrigation, and the areas of their predominant development were determined. The climatic type includes regimes with a high correlation between fluctuations in the level of groundwater, seasonal and long-term periodicity of precipitation; the hydrological type is characterized by a similar dependence - on surface runoff, for the irrigation-irrigation-drainage type - on water supply and catchment.

References

[1] Aliyev F.Sh. Podzemnie vodi Azerbaijanskoy respubliki, ispolzovanie zapasov i geologicheskie problemi. [Underground waters of the Republic of Azerbaijan, use of reserves and geological problems]. Baku: Chashyogly, 2000, 325 p.

[2] Ahmadzada A.D., Hashimov A.C. Kadastr podzemnix i vodoxozyaystvennix system. [Cadastre of land reclamation and water management systems]. Baku: Azernashr, 2006, 626 p.

[3] Khasayev Q.A, Ismailov C.M., M.Ya.Asadov, P.A.Abdullaev, Sh.D. Danyalov, A.G. Rahimova, G.M.,Magerramov. «Ocenka qidrogeoloqo-mileorativnoqo usloviya zemel, raspolojennix v zone vliyaniya Verxne – Chirvanskoqo kanala i razrabotka nauchno obosnovannix meropriyatiy dlya ix uluchsheniya». ["Assessment of hydrogeological and ameliorative conditions of lands located in the zone of the impact of Upper Shirvan Canal and development of scientifically justified measures for its improvement"]. Azerbaijan Hydrotechnique and Melioration Scientific Production Association annual report. Baku: 2019, 65 p.

[4] Gulmammadov Ch.D. Interrelationships of surface and ground waters in the Shirvan steppe of Azerbaijan. // Intern. scientific journal, Volgograd: №10 (62), 2018, Vol. II. pp. 14 - 20.

[5] Geology of Azerbaijan, vol. VIII, "Gidrogeologiya I injenernaya geologiya". ["Гидрогеология и инженерная геология"]. Baku: 2008, 368 p.

[6] Gulmammadov Ch.D. The impact of manmade activities on hydrogeological conditions. International scientific journal, Volgograd: № 2 (78), 2020, Vol. I., pp. 15 – 19.

[7] Listengarten V.A. Formirovaniye resursov podzemnix vod alluvialno – prolluvialnix ravnin. [Formation of groundwater resources of alluvial-proluvial plains]. Baku: Elm Publishing House. 1987. 164 p.

[8] Israfilov Yu.G. Formirovaniye, proqnoz I racionalnoe ispolzovanie resursov presnix podzemnix vod predqornix ravnin Azerbaijanskoy respubliki. Aftoreferat Doktor nauk [Formation, forecast and rational use of resources Fresh groundwater resources in foothill plains of Azerbaijan Republic. Author's abstract]. Doctor of Geological and Mineralogical Sciences, Baku: 2005, 48 p.

HEALTH RISK MANAGEMENT AS AN INNOVATIVE MECHANISM FOR ENSURING OIL REFINERIES ARE SAFE FOR THE LOCAL POPULATION

Marina Fomenko[1], Georgy Fomenko[2], Sahiba Kalaeva[3], Elena Skuratova[4]

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[1]Research and Production Enterprise „Cadaster“, LLC, Yaroslavl, Russia
fomenkoma@rcs-cad.com
[2]Group of Companies Institute for Sustainable Innovation, Yaroslavl, Russia
info@npo-kad.ru
[3]Yaroslavl State Technical University , Yaroslavl, Russia
kalaevasz@ystu.ru
[4]Research and Development Institute „Cadaster“, NGO, Yaroslavl, Russia
skuratova@rcs-cad.com

Abstract

The research is aimed at developing and approbation of decision-making algorithm to ensure environmental safety of oil refining areas for local population based on the mechanism of health risk assessment. Its implementation at all stages of the life cycle of environmentally hazardous production facilities ensures compliance with the regulatory level of environmental impacts on the border of the enterprise sanitary protection zone and the adjacent residential areas.

Methodologically, the research is based on conceptual provisions of the risk management theory and corresponding standards of ISO 31000 series, which prescribe regulated risk management procedures: risk identification (by risk hazards and their sources); risk assessment and their prioritization by degree of significance; planning and implementation of risk management tools; monitoring residual risks. Risk assessment was performed using the standard Russian health risk assessment methodology.

The algorithm is a set of sequential procedures for making decisions to ensure the residual health risk meets regulatory requirements. Emphasis is placed on the stages of design and operation of an environmentally hazardous facility when the level of health risks posed is particularly sensitive to the results of the decisions made. Timely identification of hazards and assessment of health risks allows to define the location of environmentally hazardous facilities at the design, considering their risk-posing capacity. During operation stage, the riskiest areas of the sanitary protection zone boundary and the industrial site, priority facilities and chemical toxicants (in terms of created risks) are identified. This provides a basis for adjusting the industrial and environmental control programs, prioritizing investment programs and plans of environmental protection (considering the expected reduction of the health risk), as well as operational documentation (to minimize the possibility of creating high risk emissions). Risk management tools are used - risk avoidance, reducing the severity of consequences, reducing the probability of risks.

The algorithm makes it possible to ensure meeting the regulatory requirements for residual health risk during the operation of environmentally hazardous oil refinery facility, while avoiding significant financial costs because of environmentally insufficient planning and technological decisions made. The algorithm can be used for the operating industrial facilities and new construction objects, regardless of the industry specifics. It is applicable to chemical pollution of atmospheric air, acoustic and electromagnetic influence, pollution of water.

Keywords: risk management; health risk assessment; chemical air pollution; regulatory level of residual health risk; priority risk-posing oil refineries, priority risk-posing chemical toxicants

I. Introduction

In today's world, wealth creation is accompanied by increasing risks [1], and billions of people are confused and anxious when they think about what is happening, as habits and traditions of economic management are rapidly losing effectiveness. The significant increase in the role of anthropogenic and natural risks in recent years [2-4] changes the traditional understanding of sustainable development[1] towards considering it as the ability of individuals, communities and geosystems[2] to survive in the face of disasters and long-term negative impacts. This vision of sustainability is particularly relevant when it comes to populations in regions with highly developed industries, especially mining, oil refining, petrochemical, metallurgical, fertilizer and heat production industries. The size of the negative consequences and damage to health from the impact of industrial emissions on vital organs, at first glance, cannot be compared with the situations of major human-made accidents and disasters. Nevertheless, the available ecological and economic calculations prove it is rather high, almost comparable [5].

The burden of disease associated with air pollution is now on a par with other major global health risk factors, such as tobacco smoking. According to the WHO, each year exposure to air pollution causes 7 million premature deaths and the loss of millions of healthy years of life. Up to 30% of deaths from leading non-communicable diseases (strokes, lung cancer and chronic obstructive pulmonary disease) and 25% of deaths from heart attacks are linked to air pollution, with adverse health effects most pronounced among women, children, the elderly and the poor [6]. Back in 2013, the IARC[3] classified outdoor air pollution as carcinogenic to humans (group 1). The increasing risk of lung cancer with increasing air pollution has been confirmed[4].

According to Russian legislation, compliance with regulatory environmental requirements is established as one of the mandatory conditions for the operation of an industrial enterprise, which implements the constitutional right of citizens to a favorable environment. Particularly strict requirements are imposed on environmentally hazardous facilities[5], which include oil refineries - when commissioning new and (or) reconstructing existing facilities, as well as during their operation, along with ensuring non-exceeding technological emission standards and (or) maximum allowable emissions (in accordance with current legislation), responsibility is established for ensuring an acceptable level of health risk on the border of the sanitary protection zone. This regulatory context creates new challenges for the board, the management, and the line personnel of the refinery. Responsibility for the environmental well-being of the population of adjacent areas makes it necessary to consider and assess its environmental impacts and the measures taken to reduce such impacts in the broad context of risk-based management. It puts the task of reducing health risks among the priorities of effective corporate management, in accordance with the ESG principles of environmental and social responsibility.

In the risk-oriented logic, ensuring the environmental safety of the population means that the actual value of the health risk created by industrial emissions at the sanitary protection zone

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[1] On October 20, 1987, the Plenary Session of the UN General Assembly adopted a resolution defining the basic principle of sustainable development as defined by the Brundtland Commission: "It is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

[2] A geosystem is a relatively integral area developed in close interconnection and interaction of nature, population and economy, the integrity of which is determined by direct, reverse and transformed links between geosystem subsystems.

[3] International Agency for Research on Cancer (IARC), part of the UN World Health Organization

[4] https://www.iarc.who.int/wp-content/uploads/2020/12/pr292_E.pdf

[5] I and II categories of hazard (Chapter VII SanPiN 2.2.1/2.1.1.1200-03 "Sanitary Protection Zones and Sanitary Classification of Enterprises, Structures and Other Objects").

boundary of the enterprise does not exceed the regulatory established risk level, which is considered to be an acceptable residual risk to health[6]. The legislative enshrinement of the BAT mechanism (Best Available Techniques)[7] to a large extent ensures an acceptable residual risk. The enterprises also pay serious attention to the implementation of special measures to clean air emissions, wastewater treatment, waste recycling, which also contributes to the improvement of the environment in the old-developed regions and reduces the negative impact on public health [7]. While technological and environmental measures are undoubtedly necessary, they should also be recognized as insufficient, especially when it comes to the operation of existing enterprises or their reconstruction, with the introduction of new industrial plants.

Practical experience shows that enterprises are often forced to solve the difficult task of achieving and confirming the acceptability of the residual risk to health, i.e., not exceeding the regulatory value. The situation is particularly acute in the old-developed regions, with historically established fractional building, where the residential areas are in the immediate vicinity of the industrial sites of operating enterprises. In fact, we are talking about the impossibility of reconstruction and modernization, and sometimes even the functioning of the existing production, having in mind the risks of exceeding the regulatory indicators of residual health risk, for example, planned repairs, preventive maintenance works, emergencies, etc. A serious adjustment of the management of industrial enterprises, corporations and industrial groups and their process of decision-making on the development of industrial activity is necessary - not only when selecting a site for new construction, but primarily to ensure the operation of existing production facilities, with the possibility of their reconstruction and modernization in compliance with established environmental requirements.

Determination of approaches, development of specific methods of providing the regulatory level of residual risk to health is a very complex research task. It requires to consider individual disparate techniques of situational response as parts of a single system, with the change of the target orientation of the analysis from purely practical to deep understanding of the issues of ecological safety of human, as the most important recipient of the negative environmental impacts of hazardous industrial facilities. Such comprehension is based on the fundamental context of ensuring the resilience of Human-Dominated Ecosystems [8] changing under the significant influence of hazardous industrial objects.

Without claiming to be an exhaustive implementation of such theoretical concepts, as well as to cover all the relevant aspects of sustainable corporate development, within the framework of the ESG approach[8], these studies were aimed at creating a decision-making algorithm to ensure the environmental safety of the population of oil refining regions based on the mechanism of health risk assessment (hereinafter referred to as the Algorithm). They were conducted over several years, based on the results of numerous design, consulting and research works performed

[6] Recognition that no economic activity can be completely environmentally neutral ("presumption of environmental guilt").

[7] BAT reference book, Decree of the Government of the Russian Federation of December 23, 2014 N 1458 "On the procedure for determining a technology as the best available technology, as well as the development, updating and publication of information and technical reference books on the best available technologies", Art. 3 Federal Law of 10.01.2002 N 7-FZ "On environmental protection", Decree of the Government of the Russian Federation of 24.12.2014 N 2674-p "On approval of the List of areas of the best available technologies ", Decree of the Government of the Russian Federation of 23.12.2014 N 1458 "On the order of technology determination as the best available technology.

[8] ESG is an acronym for Environmental, Social, and Governance. ESG helps stakeholders understand how an organization is managing risks and opportunities related to environmental, social, and governance criteria. Corporate Finance Institute. https://corporatefinanceinstitute.com/resources/knowledge/other/esg-environmental-social-governance/

for Russian oil refineries – both with the specific goal (development of risk-oriented environmental management mechanisms, substantiation of sufficiency of sanitary protection zone boundaries of industrial enterprises and industrial hubs, risk-oriented approach to assessment and reduction of vulnerability of ecosystems and population) and in a broader context of identification and assessment of actual levels of negative environmental impact.

The algorithm is developed as a sequence of actions, covering all stages of the life cycle of an industrial facility/installation. This article provides a description of this algorithm, the detailed content of the stages and procedures of this algorithm application; discusses specific health risk management mechanisms applied at each stage and their practical relevance; substantiates the need for its implementation with corporate management practices.

II. Methods

In methodological terms, the research is based on the provisions of the risk management theory, the conceptual provisions of which, implemented in the ISO 31000 Risk Management series, have been widely used in corporate and governmental management. In general, the risk management process is cyclical and includes the identification of hazards, their sources and created risks; risk assessment and prioritization according to their importance; planning risk management measures (including avoidance, mitigation, and reduction of risks). Regarding the environmental sphere, the risk is defined as the probability of an event having adverse consequences for the environment and caused by adverse impact of industrial and other activities, natural and human-made emergencies (Federal Law dated 10.01.2002 N 7-FZ "On Environmental Protection").

In the field of ensuring public safety from negative environmental impacts, the provisions of the theory of health risks, due to their high social significance and relevance, are now the most regulatory grounded, with normative consolidation in the legislative systems of several countries. At the same time, health risk assessment is considered as a mandatory part of the health risk management process from negative environmental impacts; moreover, it performs the function of monitoring the management process, according to relevant risk indicators (planned, current, regulatory, predictive). From a health and environmental point of view, enterprises are responsible for risk to society and are obliged to share it in proportion to their contribution [9], which is most consistent with the modern perspective of risk management[9], and is the "distribution of possible deviations from expected results and objectives due to uncertainty events, which may be internal or external to the enterprise". This vision of health risk is close to most Russian researchers [10-13].

In accordance with the objectives of this research associated with the limitation of the negative impact of oil refineries on the air, methodological tools were used to assess the risk to public health under the impact of chemical substances polluting the environment, according to the provisions of which are regulated by "Guidelines for risk assessment for public health under the impact of chemical substances polluting the environment" R 2.1.10.1920-04 (approved by the Chief State Sanitary Doctor of Russia 05.03.2004). This document prescribes a sequential (staged) study, including hazard identification, exposure assessment, dose-response relationship assessment, risk characterization. It defines the requirements for the composition and methodology of studies, the data used, and the obligation to perform an uncertainty analysis for each stage. Thus, it sets validation and verification requirements to the results obtained - intermediate and final.

Mathematical modeling of dispersion of average annual concentrations was performed by

[9] By modern perspective of risk management, we mean a comprehensive, integrated and coordinated process within an organization to manage all types of risks it faces.

means of PC "Ecolog", ver. 4.5, calculation block "Averages" ver. 4.5 (Integral, SPb). Calculations of carcinogenic and non-carcinogenic risks were performed using MS Excel 2007 and calculation block "Risks" ver. 4.5, implementing Guide P 2.1.10.1920-04. Cartographic works were performed using a computer geoinformation system (Arc Gis 10.1). The main input data for mathematical modeling were current volumes of "Maximum allowable emissions", sections of "Lists of environmental protection measures" and projects of sanitary protection zones, programs of medium-term development of enterprises. Information about climatic and weather characteristics of the studied territories of oil refineries location was provided by regional division of Russian Hydrometeocenter.

The research is based on the results of a number of projects carried out and currently being carried out for oil refineries located in different geographical zones of Russia. Areas of their location are characterized by specific natural conditions (climatic characteristics, primarily wind and temperature regimes; topography; background condition of atmospheric air, etc.) and socio-economic conditions (urban development situation, proximity and features of the location of residential areas. Specific quantitative indicators in this article (Results) are given according to the results of a project on the implementation of risk-oriented environmental safety management of an oil refinery [14].

III. Results

The Algorithm of making decisions on ensuring environmental safety of the population of oil refining areas based on the health risk assessment mechanism (hereinafter referred to as the Algorithm) is a set of sequential procedures for making reasonable decisions that ensure meeting regulatory requirements for residual health risk to the population exposed to potential negative environmental impacts. The Algorithm illustrates a single iteration (cycle), as part of a continuous process of management of the production enterprise, at all stages of its life cycle, with a special emphasis on those of them, where the level of created health risks is particularly sensitive to the results of decisions made. Each time estimated values of health risk are determined (except for special cases) by the cumulative impact of all objects of the industrial site - existing and new construction.

Stage 1 - Design. Actions are aimed at avoiding additional health risks by making informed design decisions on the master plan in a timely manner. The following actions are included:

1.1 Reasonable choice of location of environmentally hazardous facilities, based on analysis of alternatives. In practice, three alternative locations for the new environmentally hazardous production facility were assessed during the reconstruction project. The most preferable option, with significant financial savings and placement at a site with good logistics and communications, turned out to be blocked by the risk factor (based on the results of a rapid assessment of health risks). The option of placement with a minimum increase in health risk, due to the lack of communications on the site, had unacceptably high financial costs. As a result, the option with an acceptable increase in health risk and acceptable financial costs was taken as optimal.

1.2 Detailed verification of the adopted option of location of environmentally hazardous facilities for compliance with the condition of not exceeding the regulatory level of residual health risk. During the design work, health risks for the adopted option were assessed. The results showed that the regulatory level of residual risk was not exceeded. This result was included in the set of design documents for the reconstruction of the enterprise and served as one of the mandatory conditions for obtaining a positive conclusion of the state environmental expertise.

Stage 2 - Construction. The construction process, due to its technological specifics, does not pose significant risks to public health and is short-term in nature.

Stage 3 - Operation. The actions are aimed at reducing the likelihood of occurrence and minimizing damage from the risk by assessing health risks, determining the priority (in terms of the value of generated risks) of the areas of sanitary protection zone boundary and industrial sites, production facilities and chemical toxicants. A set of actions includes the following:

3.1 Identification of the most hazardous areas of the sanitary protection zone and the industrial site, priority facilities and chemical toxicants (in terms of the magnitude of the created risks). During the analysis of riskogenic situation at the enterprise it was revealed that the most dangerous parts of the sanitary protection zone boundary are in the southern and north-eastern directions. The most hygienically significant receptor points are concentrated in these parts of the sanitary protection zone boundary. The areas of the industrial site that create the most significant impacts are localized in these directions. As the detailed analysis showed, even if the orientation and configuration of non-carcinogenic risks distribution (in the shape of oval with orientation to the northwest) is preserved, the introduction of new facilities expands the area of risk distribution. The results of the geographical orientation of the risk fields located within the sanitary protection zone boundary and correlated with the general plan of the enterprise (as applied to the task of new construction facilities location) show that it is unacceptable to locate new production facilities in the north-western part of the industrial site.

The priority riskogenic production facilities are: among the new construction objects - hydrocracking unit and sulfur production unit; among the existing facilities - unit 35-11 / 300-2, unit L-24-T-6, unit L-24-200-86. A detailed analysis showed that the highest priority is given to the new construction sites - hydrocracking unit (14.5%) and sulfur production unit (contribution - 13.8%); the existing facilities are rated approximately at the same level - distillation unit ELOU-AVT-4 (contribution - 3.2%), automated light oil products cycle loading unit with a vapor recovery unit (contribution - 2.6%) and tar visbreaking unit (contribution - 2.1%).

The list of priority risk-generating chemical toxicants (the most dangerous, with non-carcinogenic and carcinogenic properties) included 11 items (out of 27 pollutants identified at the facility), including 11 non-carcinogenic substances (sulfur dioxide, sulfur dioxide, hydrogen sulfide, kerosene, nitrogen oxide, vanadium pentoxide, xylene, benzene, carbon black, benzo/a/pyrene, ethylbenzene) and 4 substances with carcinogenic effect (benzene, carbon, ethylbenzene, benzo/a/pyrene).

3.2 Adjustment of industrial control and industrial environmental control programs based on the results of riskogenic situation dynamics. Based on the results of the analysis of risk priority of the sanitary protection zone boundary areas, production facilities and chemical toxicants (clause 3.1), the programs were adjusted in terms of measurement locations, measurement schedules and lists of controlled substances. In particular, control points where the maximum risk load is formed were selected, including: at the sanitary protection zone boundary and at the boundary of residential development / the boundary of regulated areas, taking into account the location of sections of the industrial site where the greatest risks are created, as well as installations with the greatest contribution to the total risk indicator. Changes were made to the sampling schedules: for each new construction facility, within the first year after commissioning, the number of days of testing for the full list of characteristic toxicants was determined. The list of analyzed substances in the control points was corrected - priority risk-generating toxicants were included (non-carcinogens - sulfur dioxide, nitrogen dioxide, nitrogen oxide; carcinogens - benzene, carbon; as well as pollutants specific to the enterprise: kerosene, hydrogen sulfide, vanadium pentoxide, xylene).

3.3. Refinement of plans for the implementation of investment measures (including environmental protection facilities), considering the potential to reduce the level of health risk for each facility. As practice shows, measures to prevent losses of commercial products, such as the construction of a unit for sealed loading of oil products into rail tank cars, have a high potential to reduce health risks compared to even targeted environmental protection measures.

3.4 Specification of technical operational documentation, in order to minimize the probability of exceeding the regulatory level of residual risk to health of the population (carrying out commissioning, repair work, maintenance, etc.). In practice, this means reducing the probability of exceeding the regulatory level of residual risk to health, with strict compliance with technological standards and standards of industrial safety, for example, by minimizing short-term salvo emissions of priority chemical toxicants by diluting in time and by localization at the site of the corresponding sources of emissions (during repairs, maintenance, etc.).

3.5 Ensuring compliance with the established regime of using the territory of the sanitary protection zone. Practice shows the effectiveness of such measures as preventing the placement of industrial and civil facilities that pose a threat of exceeding the regulatory values of health risks at the sanitary protection zone boundary; eliminating existing and preventing potential unauthorized waste dumps; landscaping and planting of the area.

Stage 4 - Decommissioning. In the case of termination of operation, liquidation (including demolition) of the object there are no standard actions within the framework of the management of health risks.

IV. Discussion

The results of the research on the development and testing of the decision-making algorithm to ensure environmental safety of the population of oil refining areas on the basis of the health risk assessment showed its feasibility and high efficiency both in terms of compliance with applicable legal requirements, and in the aspect of sustainable business development in accordance with ESG-approaches. Testing at a number of oil refineries showed that actions within the Algorithm, due to the application of the health risk assessment, allow to ensure compliance with the regulatory indicator of residual health risks at the sanitary protection zone boundary. At the same time, the monitoring of the current indicators of health risks, with the analysis of the dynamics, in comparison with the regulatory values, is an indispensable and recurring element of many actions. Health risk management is implemented by the following tools:

At the design stage: risk avoidance, as a result of (1) a reasonable choice of location of new facilities at the industrial site of the existing enterprise, (2) reasonable planning decisions on the placement of environmentally hazardous production facilities at the industrial site of a new enterprise; reduction of health risk by reducing the potential damage and/or reducing the probability of risk realization, as a result of the use of technologies whose environmental impacts meet the BAT level, as well as effective.

During the operation stage: reduction of health risk by decreasing the likelihood of risk occurrence, as a result of improving the effectiveness of systems of industrial and environmental control (clarifying the location of measurement points, measurement schedules, controlled substances); decreasing of health risk by reducing the potential damage and/or the likelihood of risk execution, as a result of (1) changing the priority of investment activities, including environmental protection; (2) specification of operational requirements to minimize the level and probability of riskogenic emissions by minimizing the duration of simultaneous operation of environmentally hazardous installations, separation of maintenance and preventive work by time and location at the industrial site, etc.; (3) ensuring compliance with the established regime of using the sanitary protection zone, primarily by preventing the placement of industrial and civil facilities that pose a threat of exceeding the regulatory values at the sanitary protection zone boundary.

The relevance of the Algorithm is associated with the need to abandon the previously established practice of planning decisions (the initial stage of design - decisions on the general plan), guided primarily by economic and technological considerations, while actually ignoring the environmental aspects of the functioning of future facilities (including health risks). This leads to a violation of environmental legislation, with appropriate economic and reputational sanctions. One should also consider the low environmental performance of environmental protection measures at the stage of operation, which is limited already at the construction stage by the selected technologies and localization of sources of pollution of emissions and discharges of pollutants [15].

The algorithm is universal. It can be used for existing production facilities and new construction projects, as part of the reconstruction and modernization of enterprises. It is also effective in the implementation of investment projects for the construction of new industrial enterprises. The sphere of its application is not determined by industry specifics - it can be used in the management practice of any enterprise or industrial company, first of all, those which have environmentally hazardous production facilities. Finally, the logic of the Algorithm and the sequence of actions are relevant not only in relation to chemical pollution of atmospheric air, but also in situations of health risks from acoustic and electromagnetic effects, from contamination of water.

In general, it should be emphasized that, in accordance with the logic of risk management, health risks created by the enterprise should be integrated into the overall risk management system of the enterprise (along with the risks of industrial safety, financial, operational, climatic risks, etc.). It is obvious, that within the framework of the enterprise risk management system, created health risks can be identified as a risk of non-compliance with the established legal requirements in the field of environmental safety of the population. Nevertheless, there is no doubt that indicators characterizing the risk-posing capacity of the enterprise for the population should be included in the decision-making process in risk management, strategic planning, current operational management and financial planning.

References

[1] Beck W. Risk Society. On the way to another modernity. Moscow: Progress-Tradition, 2000. 384 p.

[2] The Global Risks Report 2018. 13th Edition. World Economic Forum; The Global Competitiveness and Risks Team. Geneva, 2018. 68 p.

[3] The Global Risks Report 2021. 16th Edition / World Economic Forum. Geneva, 2021. 97 p. URL: https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2021.pdf.

[4] The Global Risks Report 2022. 17th Edition / World Economic Forum. Geneva, 2022. 117 p. URL: https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2022.pdf.

[5] Golub A. The Effects of Increasing Population Granularity in PM2:5 Population-Weighted Exposure and Mortality Risk Assessment. Environmental Health Perspectives. 2021. №12. P. 127703-1-3.

[6] Rakitskii V.N., Avaliani S.L., Novikov S.M. et al. Health risk analysis of exposure to atmospheric pollution as part of the strategy to reduce the global epidemic of noncommunicable diseases. *Health Risk Analysis*. 2019, 4.

[7] Kalaeva S.Z., Makarov V.M., Markelova N.L. Conversion of hazardous waste in the demanded magnetite. S.Z. Kalaeva, V.M., Markelova. Proceedings of the International Conference Modern technology of life support. Yaroslavl: Yaroslavl State Pedagogical Univ. 2020. Pp. 116-120.

[8] Fomenko G.A. Spatial design and ecosystem services. *Problems of Regional Ecology*. 2020, 1. Pp. 60-73.

[9] Olson D., Desheng W. New Frontiers in Enterprise Risk Management. Springer, 2008.

[10] Avaliani S.L., Andrianova M.M., Pechennikova E.V. et al. Environment. Health Risk Assessment (World Experience). Moscow: Consulting Center for Risk Assessment, 1996. 246 p.

[11] Bolshakov A.M., Krutko V.N., Putsillo E.V. Assessment and risk management of the impact of the environment on the health of the population. Moscow: Editorial URSS, 1999.

[12] Onishchenko G.G., Novikov S.M., Rakhmanin Yu.A. et al. Fundamentals of risk assessment for public health under the impact of chemical substances polluting the environment M.: Research Institute of Ecology and Emergencies, 2002. 408 p.

[13] Fomenko G.A., Avaliani S.L., Knyazkov L.A. et al. Procedure for determining the shares of enterprises in financing measures to maintain and manage the sanitary protection zone, based on the methodology of risk assessment of public health: approved by the Head of the Office of the Federal Service for Supervision of Consumer Rights Protection and Human Welfare in the Yaroslavl region. Yaroslavl, 2008.

[14] Fomenko G.A., Fomenko M.A., Borodkin A.E. et al. Risk-oriented approach to environmental safety management of an oil refinery. Strategic Decisions and Risk Management. 2018, 1. Pp.102-109.

[15] Fomenko G.A. Sustainable ecosystem design: prerequisites and approaches. Yaroslavl: ANO NIPI "Cadaster", 2021. 216 p.

THE USE OF REMOTE DATA FOR MONITORING DEFORMATION PROCESSES IN HYDROCARBON DEPOSITS

Alexander Fremd
•
Institute of Seismology of the Ministry of Emergency Situations, Kazakhstan
afremd@list.ru

Abstract

The paper considers the issues of possible use of data on micro-amplitude displacements of points on the Earth's surface as indicators of manifestations of induced seismicity. The results of the performed processing of the X-ray interferometry data, presented by the corresponding graphs, in comparison with the data of the epicenter of borehole seismological observations on the field area for the same period of time testifies to the unconditional connection of manifestations seismicity with anomalous features of amplitude graphs.

The revealed regularities allow using the data of the interferometry radar not only for the purposes of areal mapping of deformation processes, but also as a tool for monitoring the manifestations of seismicity caused by the exploitation of the deposit and the accompanying disturbances of geodynamic equilibrium. This work is purely methodical in nature.

Keywords: technogenic seismicity, deformation processes, seismic risk, interferometry, development of hydrocarbon deposits.

I. Introduction

Manifestations of geodynamic activity in subsurface use areas in the form of techno- or endogenous seismic events are essentially the final phase of the cycle of accumulation and discharge of stresses in the geological environment. The consequences of such a discharge can be both tangible and tragic [1, 2]. Therefore, monitoring of the geodynamic activity of the territory with the integrated use of both ground-based geophysical methods and remote ones is an integral part of the field development process. The advantage of remote research methods is the possibility of obtaining data on geodynamic processes occurring not only in individual observation points, but also in the possibility of a holistic and one-time study of the entire area of the object.

Since all geodynamic processes proceed continuously, it is important to distinguish trend and anomalous components against their background. It is with the latter that manifestations of seismicity caused by man-made impact on the subsoil can be associated. And here, in order to understand what is happening, it is extremely important to establish and fix microseismic (micro-amplitude) events, which in the future can serve as a trigger in the onset and development of avalanche-like voltage discharges [3].

In this paper, the possibilities of radar survey as a tool for monitoring studies of technogenic seismicity at an active hydrocarbon field are considered.

II. Methodology

Radar survey is a type of active survey in which a probing satellite system generates a radio wave pulse and receives a return signal reflected by the earth's surface.

To solve the problems of monitoring deformation processes, data obtained over a five-year period by the COSMO SkyMed satellite system (e-GEOS, Italy) was used. This system consists of four satellites that allow high-resolution (4 m) shooting with a frequency of up to 8 times a month, which ultimately made it possible to obtain in a short time the necessary set of images that meet the processing requirements in the system of the SARScape software complex (Harris Geospatial Solutions, USA), which is a set of additional program modules ENVI (Harris Geospatial Solutions, USA).

In total, at the final stage of processing, 71 images were used, obtained over five seven-month cycles in the same shooting geometry and having the same polarization.

For comparison, data from borehole seismological observations conducted independently for the purpose of monitoring seismic activity associated with the development of the field were used. The results of these observations are presented by tabular data of the time and coordinates of the hypocenters of micro-earthquakes recorded on the research area.

The purpose of the performed analysis was to simultaneously identify characteristic signs of induced seismicity over the entire research area using graphs of vertical displacements of points on the Earth's surface.

III. Results

The peculiarity of the data used is that, gathered together, they made it possible to track the development of deformation processes of the earth's crust, caused, among other things, by their technogenic component, over a relatively long period of time.

It was assumed that a confident correlation of the features of the graphs of vertical displacements at points distant from each other by a relatively large distance can serve as a sign characterizing the state of geodynamic equilibrium of the geological environment in the mining diversion zone.

Figure 1 shows a conceptual model of geomechanical evolution

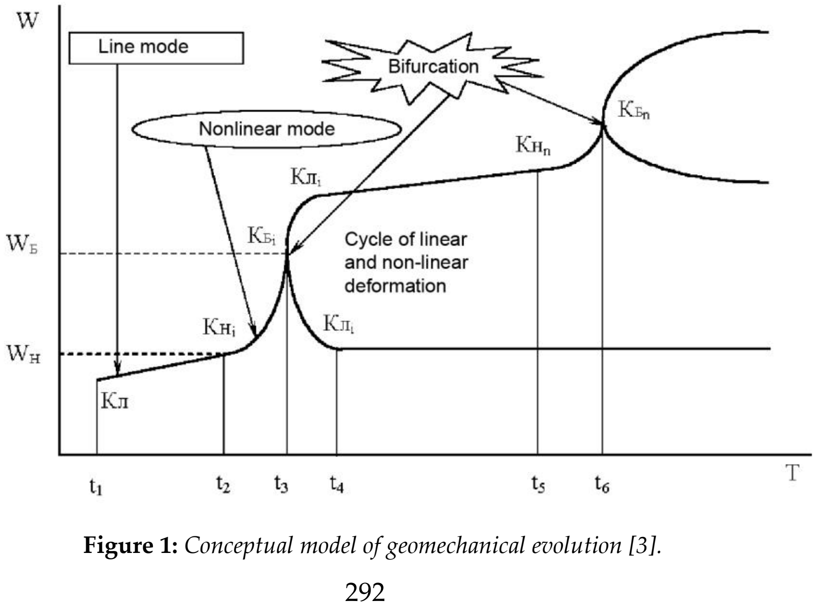

Figure 1: *Conceptual model of geomechanical evolution [3].*

The main control parameter of the model is the energy W. As it is noted in the works of Melnikov N.N. et al., (2001, 2009) at the initial stage of operation of the field, development proceeds in a linear-deterministic mode. At the same time, the geomechanical evolution of processes developing in the geological environment is carried out by alternating stages of linear and nonlinear deformation with the probability of abrupt transition or bifurcations (catastrophes).

When the control parameter W reaches the limit values, the natural-technical system enters the stage of nonlinear development, the consequences of which are expressed in the spatio-temporal localization of events, among which there may be dangerous geodynamic phenomena such as simultaneous catastrophic subsidence, large-scale landslides and man-made earthquakes [3].

Let us consider from these positions two series of graphs constructed for independent and remote points located on the area of the mining allotment (Figures 2, 3).

The graphs characterize the dynamics of deformation processes that occurred in the geological environment during 2015-2019. Each point marked on the graph with a red cross corresponds to the date of the survey of the corresponding period of monitoring observations. It is obvious that against the background of a relatively stable trend, there are characteristic areal manifestations of local geodynamic processes.

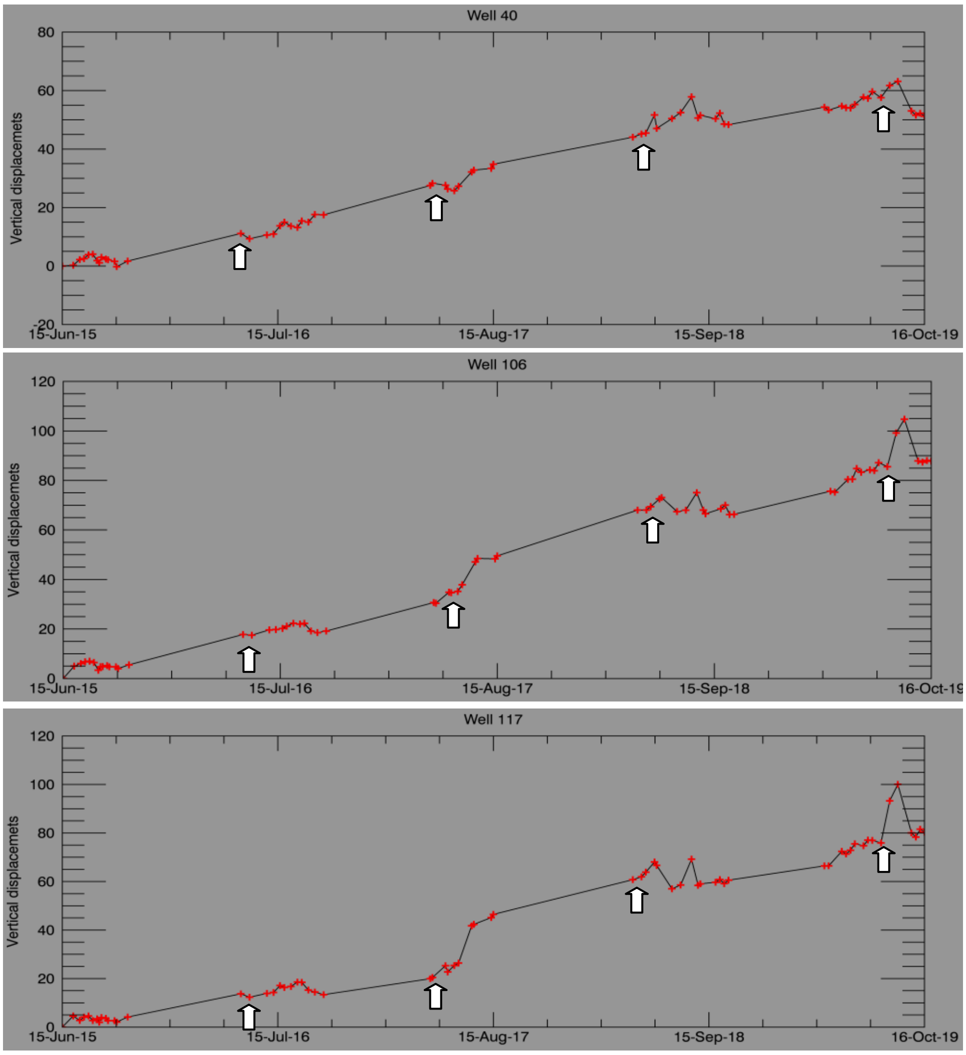

Figure 2: *Installation of graphs of vertical displacement amplitudes for "borehole" points*

On the presented graphs, the arrows indicate the time points of a possible transition of the geological environment to a state of new geodynamic equilibrium, accompanied by the discharge of accumulated stresses in the form of micro-earthquakes. It can be seen that, without exaggeration, in each cycle of monitoring observations, anomalous manifestations of vertical displacements are recorded almost everywhere and at the same time. Moreover, as will be shown below, the direction of the offsets is in full accordance with the direction of the trend.

In particular, it is possible to state the occurrence at the end of the 2017 cycle, which is steadily traced for the most part of the mountain branch, of an anomaly of displacements of a characteristic table-shaped shape, with an amplitude of about 20 mm, which existed until the beginning of the 2018 cycle (Figure 3).

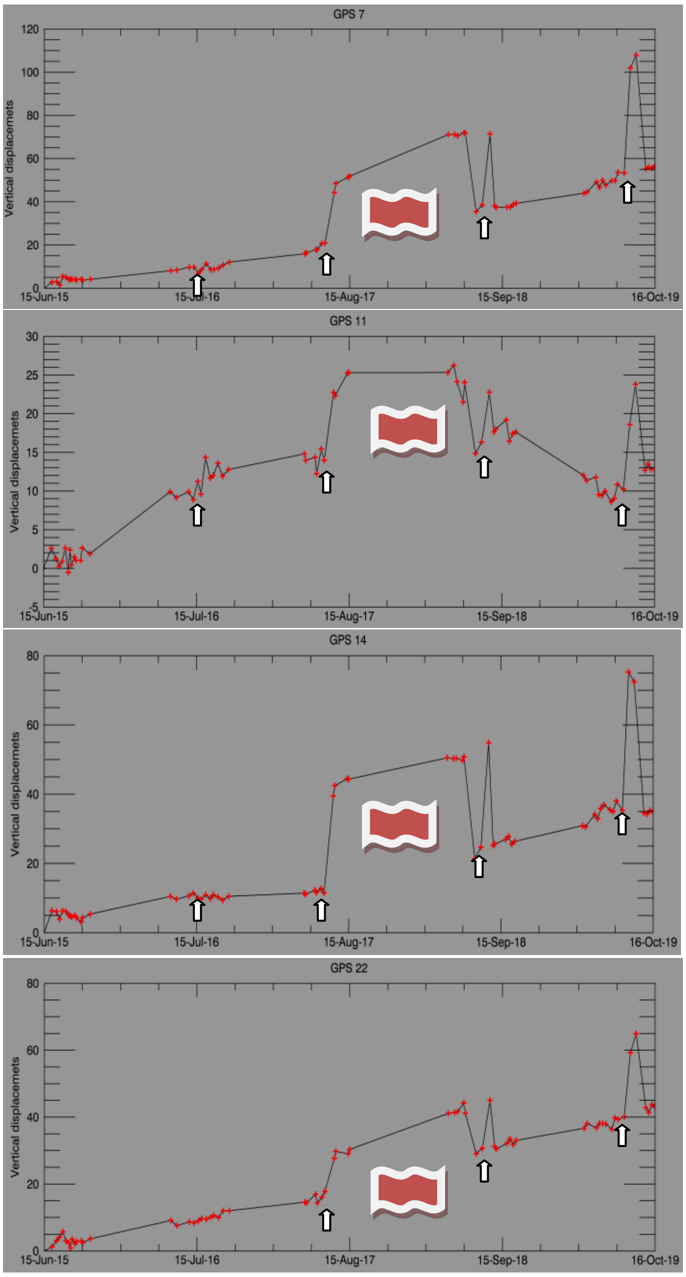

Figure 3: *Installation of graphs of vertical displacement amplitudes for GPS points*

Considering in detail the pulse anomaly that occurred at the end of July 2019, it can be stated that a one-time abrupt change in the amplitude of vertical displacements occurred in the territory of the mining allotment, recorded in a number of points remote from each other (Figure 4). Moreover, the displacement sign is in full accordance with the trend direction (Figure 5).

In accordance with the concept mentioned above, this event can be interpreted as the result of the discharge of accumulated stresses and the transition of the system to an updated state of geodynamic equilibrium, which is confirmed by the actual material.

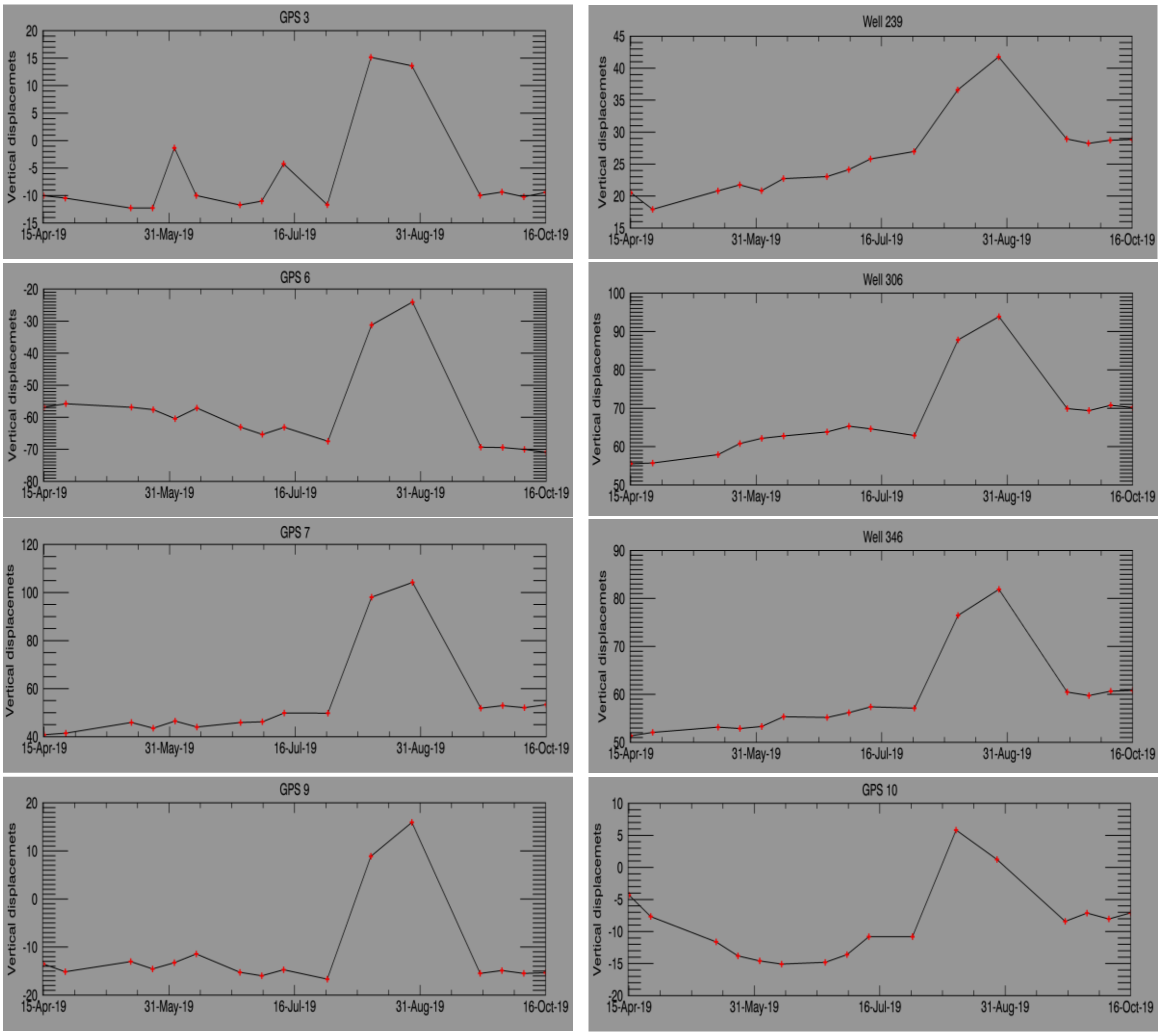

Figure 4: *Installation of graphs of vertical displacement amplitudes for the points "GPS" and "borehole" for 2019.*

The event that occurred was recorded at most points of the geodynamic polygon and, judging by the nature of the graphs, the next stage of linear permanent stress accumulation began in the geological environment at the end of the monitoring cycle in 2019.

The amplitude graphs shown in Figures 4 and 5 indicate that the recorded displacements cannot be attributed to random fluctuations. Moreover, the point where the sign change occurs (Figure 5) may indicate a section of the area experiencing various types of deformation processes for the current period of time.

To confirm the reliability of the above conclusions, the results of borehole seismometric observations were compared with the data of X-ray interferometry (Table).

Obviously, the 2019 event cannot be considered a coincidence, since all the earthquakes recorded before and after it do not correspond to the nature of the graphs shown in Figures 4 and 5.

The time scale of plotting for 2015-2018 (Figures 2 and 3) does not allow us to strictly identify the events shown in the table with the features of amplitude anomalies noted on the graphs. However, upon closer examination, their correlation is not in doubt.

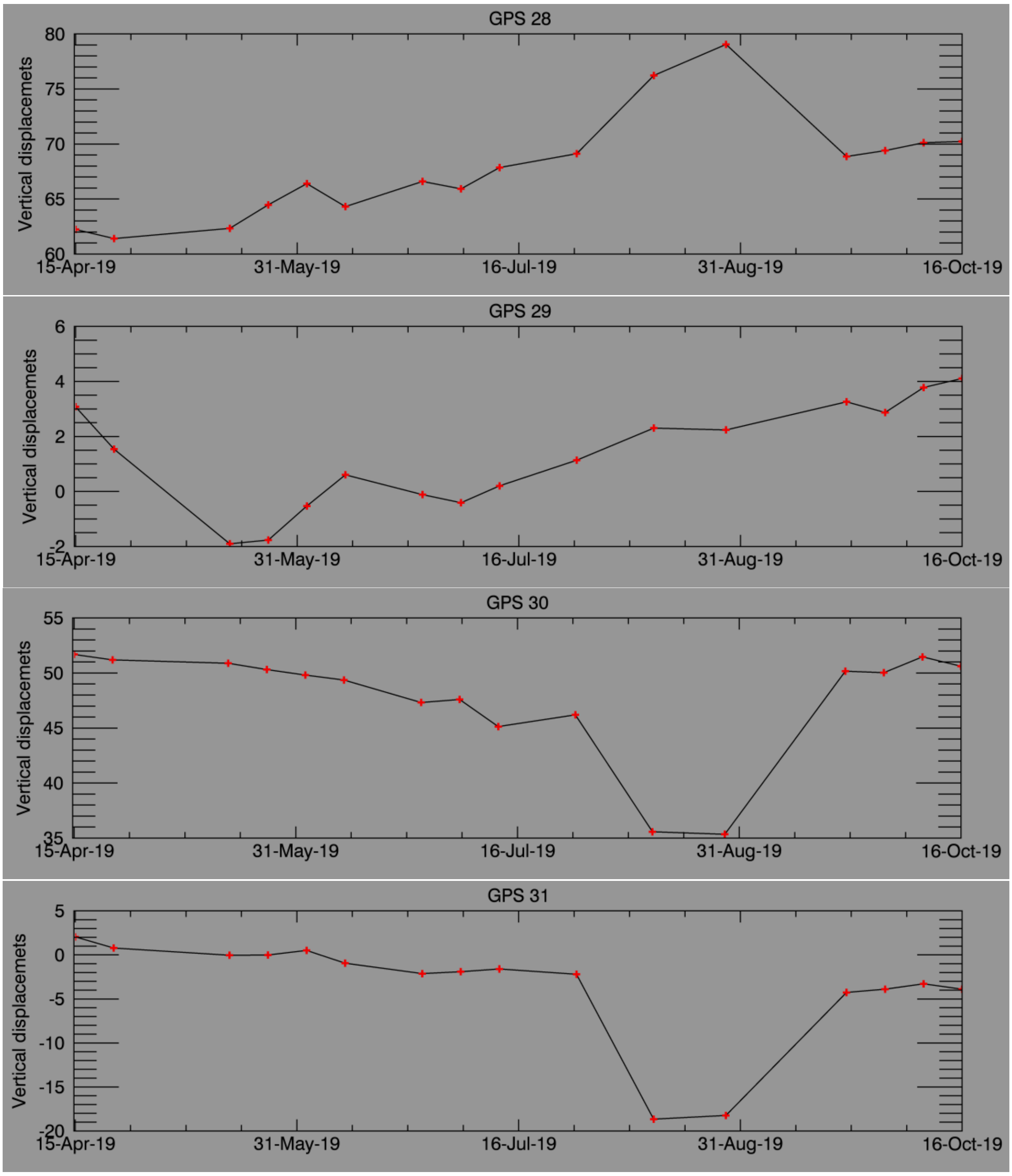

Figure 5: *Installation of graphs illustrating the change of the sign of vertical displacements for GPS points for 2019.*

Table: *Micro-earthquakes recorded in wells during periods conducting monitoring observations during 2016-2019*

No. no.pp.	Date			Time		Note
	year	month	number	hour	mines.	
1	2016	07	15	20	05	Registered events: before - 03.06. and after – 30.07
2				20	08	
3	2017	05	08	23	09	Registered events: before - 23.05. and after – 19.09
4	2018	09	08	15	25	
5		11	09	02	40	
6		29	09	18	14	
7				21	28	
8		30	09	12	42	
9	2019	20	07	00	11	Registered events: before - 07.07. and after – 27.07

Thus, the verification results allow us to conclude that, despite the discrete-time nature of satellite imagery, the data of detailed monitoring observations by X-ray interferometry can be used as an additional retrospective indicator of seismic events. Moreover, what is important, geodynamic zoning can be performed and areas of the area that have experienced certain types of deformation processes for certain periods of time can be shown. This kind of information may be of paramount importance for subsoil users as a technogenic factor indicating their hidden and possibly irreversible development.

IV. Conclusion

It is established that the trend nature of the displacements can be considered the background of abnormal manifestations, possibly of a technogenic nature.

The obtained graphs indicate the trend-impulse form of development of geodynamic processes dominating at the polygon, fitting into the conceptual model of geodynamic evolution

In accordance with the above-mentioned concept, geodynamic processes on the territory of the mining allotment proceed in a linearly deterministic mode, that is, in the mode of alternating periods of stress accumulation with subsequent discharge and the transition of the system to an updated state of geodynamic equilibrium.

It can be assumed that at the end of the monitoring cycle of 2019, the next stage of linear permanent accumulation of stresses due to man-made impact on the subsoil began.

Thanks

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References

[1] Sashurin A.D. Diagnostics of geodynamic activity at the subsurface use site. Seminar No. 8, GIAB, 2004, N6. pp. 185-187.

[2] Sashurin A.D. Modern geodynamics and the development of disasters at subsurface use objects., Geodynamics and the stressed state of the Earth's interior. Proceedings of the International Conference. Novosibirsk. IGD SB RAS, 2004. pp. 369-371.

[3] Melnikov N.N., Kalashnik A.I., Kalashnik N.A. Technogenic geodynamic processes in the development of oil and gas fields of the Barents Sea shelf. Bulletin of the Moscow State Technical University, volume 12, No. 4, 2009, pp. 601-608.

CARBON LANDFILL AS A RISK MANAGEMENT TOOL IN THE SYSTEM OF SUSTAINABLE DEVELOPMENT

Konstantin Ordov[1], Seda Aslakhanova[2]

•

[1]Russian University of Economics named after G. V. Plekhanov, Russia
[2]Chechen State University named after A.A. Kadyrov, Russia
ordov-reu@mail.ru
salamova_chgu@mail.ru

Abstract

Adaptation to climate change, implementation of the new climate agenda and a number of international climate agreements and standards require scientifically based information and analytical support of the country's economy and population with data on the current and expected states of the climate system. Particularly relevant are the development and testing of technologies for controlling greenhouse gas emissions and calculating the carbon balance of territories. Climate change affects, to one degree or another, the sphere of interests of any subject of the Federation and practically any sector of the economy and social sphere of the Russian Federation. The planning and implementation of many large investment and production projects are highly sensitive to climate and climate change issues and require efforts to ensure that the implemented measures are cost-effective and at the same time contribute to reducing the risks and mitigating the effects of a changing climate, ensuring social and environmental security. At the same time, it is important to keep in mind that, in addition to a direct impact on the economy and population of the Russian Federation, the weather and climate factor has a significant impact on the system of international trade, economic and political relations. This article shows that it is carbon polygons that are the tool of modern climate policy that provide observations, assessment and forecasting of climate change and its consequences, as well as allow developing and testing technologies for remote and ground monitoring of greenhouse gas emissions and other parameters significant for climate change.

Keywords: carbon polygons**,** greenhouse**,** gas emissions, climate, environmental protection.

I. Introduction

Earth's average surface temperature has increased by 1.3 degrees Fahrenheit over the past century and is projected to increase by another 3.2 to 7.2 degrees in the 21st century, according to the Intergovernmental Panel on Climate Change [1]. These seemingly minor changes in temperature can have serious consequences for farmers. According to the Environmental Protection Agency, an increase in average temperature can: lengthen the growing season in regions with relatively cool spring and autumn periods; adversely affect crops in regions where summer heat is already limiting production; increase the rate of soil evaporation; and increase the likelihood of severe droughts. Innovative farming practices such as conservation tillage, organic production, improved farming systems, land restoration, land use change, and irrigation and water management are ways farmers can address climate change. Good management practices have many benefits that can also improve profitability, improve farm energy efficiency, and improve air and soil quality [2,3].

Carbon farming describes a set of sustainable practices that are capable of increasing soil carbon uptake, i.e. carbon sequestration. Increasing soil carbon sequestration will help reduce CO2, CH4 and N2O emissions into the environment. Carbon farming, which results in the reduction of greenhouse gas (GHG) emissions, is referred to as abatement activities. It holds carbon in vegetation and soil and reduces greenhouse gas emissions [4]. A carbon offset credit is a payment made by a carbon emitter (power plant, mine, refinery, etc.) to the developer or owner of a carbon sequestration process (forest reserve owner, biochar project developer, etc.). Carbon farming involves one land management change such as zero tillage, agroforestry, methane-reducing feed additives, or stubble retention that maximizes carbon sequestration and emission reductions1. In carbon farming, CO2, CH4, and N2O will decrease with increasing soil carbon uptake due to increased soil aeration by adding organic carbon, which reduces denitrification and increases CH4 uptake capacity. Soil organic carbon adds electron acceptors and increases the redox potential of the soil, decreasing its ability to source N2O [4]. Carbon farming causes microbial immobilization of available N2 in the soil, which reduces the soil's capacity as a source of N2O2. There are several promising options for reducing greenhouse gas emissions in carbon agriculture; storing carbon in soils and degraded grasslands through forests, tree planting and regrowth, storing carbon through the incorporation of biochar which is carbon negative, and replacing fossil fuels with biofuels. Carbon farming gives landowners the opportunity to earn carbon credits by storing carbon or reducing greenhouse gas emissions from their own land. These carbon credits can then be sold to a government-appointed body that wishes to offset its emissions [5]. In fact, carbon agriculture is a voluntary carbon offset scheme that provides economic rewards to landowners who take steps to reduce greenhouse gas emissions. Carbon farming reduces emissions by capturing when carbon is stored on the ground and avoiding emissions, which prevents greenhouse gas emissions from escaping into the atmosphere. It involves the implementation of practices that improve the rate at which CO2 is removed from the atmosphere and converted into plant material and/or soil organic matter. Carbon farming is successful when carbon gains from improved land management and/or conservation practices exceed carbon losses [6]. Its benefits include reducing greenhouse gas emissions, sequestering carbon, increasing biodiversity, protecting against drought, and improving water use efficiency. The development of various programs will facilitate the buying and selling of carbon credits between landowners and government agencies. Landowners receive carbon credits for storing carbon in the soil, and then the credits are collected and sold to reduce emissions. These loans are often bought independently of the exchange, they can boost the client's financial position and help prove how useful these methods are in mitigating the effects of an industrial society. Nanomaterials are of great interest in various fields due to their unique and useful chemical, physical, mechanical and biological properties [6]. However, these properties also endow ENM with an innate ability to interact with biological systems, which can lead to detrimental environmental impacts (or even to the restoration of contaminated soil and groundwater). The properties of materials such as gold, silver, or nanoform iron can differ significantly from those of the original materials. This is leading to a number of new applications for such materials in items including foodstuffs and food packaging materials [7]. For example, quantum dots, fullerenes, carbon nanotubes, silicon dioxide and silver nanoparticles can be found in electronics, cosmetics, and food packaging. Some of them are safe, and some may pose a risk to the environment and human health. A recent study showed that by 2010, 63–91% of the more than 300 kilotons of ENM produced worldwide ended up in landfills; 8–28% got into the soil, 0.4–7% into surface water bodies, and 0.1–1.5%2 into the atmosphere. However, the study was a broad global assessment. In developing countries such as India, the scale of potential massive releases of ENM to the environment needs to be studied in detail [6,7]. Unlike developed countries (USA, Europe or Japan), the Indian industry has become interested in nanotechnology only recently, and many large companies have now initiated nanomaterials programs on their own or in collaboration with academic/research institutions. Many of these companies are working on value-added applications of nanomaterials, despite the increased use, there is limited or no information available on the disposal of waste nanomaterials in the Indian subcontinent. If nanomaterials are carried in landfills or in soil, they can end up in drinking water sources or large surface water bodies. Given that most nanomaterials end up in soil, understanding the impact of these nanomaterials on soil organisms or ecosystems is required for sound risk assessment and policy discussion. Interestingly, most of the potential dangers of these nanomaterials are not documented, and ordinary people are not aware of this.

Important research is available around the world on the presence of nanoparticles in some foods sold in supermarkets, but the health effects of nanomaterials used in foods are not well understood, even by manufacturers or large companies. However, recent research indicates that nanomaterials (such as carbon nanotubes, nanoclay, and metal oxide nanoparticles) are present in some food packaging materials and are involved in several stages of the food chain. They are expected to improve packaging performance and ultimately the longevity of food products in consumer markets. In addition, they are used for invisible nano-alignment or nano-barcodes. However, the impact of nanomaterials from food packaging on human health is lacking both in the Indian market and globally. It is also not well known what types and categories of nanomaterials can be dangerous and to what extent for the human body and the environment. Thus, consumers of such food products and commercial products based on nanotechnology produced by national and international companies may need sound guidance.

II. Methods

Natural shifts in global temperatures have occurred throughout human history. However, in the 20th century, global temperatures increased dramatically. Scientists attribute the rise in temperature to an increase in carbon dioxide and other greenhouse gases emitted from fossil fuel burning, deforestation, agriculture and other industrial processes. Scientists call this phenomenon the enhanced greenhouse effect [7]. The natural greenhouse effect traps the sun's heat before it can be released back into space. This allows the Earth's surface to remain warm and habitable. Elevated levels of greenhouse gases amplify the natural greenhouse effect by trapping even more heat from the sun, resulting in global warming. The main greenhouse gases associated with agriculture are carbon dioxide ($CO2$), methane ($CH4$) and nitrous oxide ($N20$) [8]. While carbon dioxide is the most common greenhouse gas in the atmosphere, nitrous oxide and methane stay in the atmosphere longer and absorb more longwave radiation. Therefore, small amounts of methane and nitrous oxide can have a significant impact on climate change. Several excellent resources and fact sheets explain the greenhouse effect and the science behind climate change. Climate change can have both beneficial and detrimental effects on agriculture. Some studies show that warmer temperatures lengthen the growing season, and increased carbon dioxide levels in the air result in higher yields for some crops. A warming climate and lower soil moisture may also lead to a northward shift in production patterns and increased demand for irrigation. Changes, however, are likely to vary considerably by region. Geography will play a big role in how agriculture can benefit from climate change. Although forecasts for some areas look favorable, the possibility of increased climate variability and extreme events is not necessarily taken into account. The benefits to agriculture could be offset by increased chances of heatwaves, droughts, severe thunderstorms and tornadoes. Increasing climate variability makes it difficult for farmers to adapt, especially to farming systems, grazing and grazing and animal husbandry [6,7]. We highlight the following issues: With increasing carbon dioxide content and higher temperatures, the life cycle of grains and oilseeds is likely to develop faster. Marketable crops of many horticultural crops, such as tomatoes, onions and fruits, are likely to be more sensitive to climate change than grains and oilseeds. Climate change is likely to lead to northern migration of weeds. Many weeds respond more positively to increased carbon dioxide than most cash crops [8]. Disease pressure on crops and livestock is likely to increase with earlier spring and warmer winters. The projected increase in temperature and lengthening of the growing season is likely to extend fodder production into late autumn and early spring. Pasturelands are already undergoing changes in plant species due to climate change. Planting perennial herbaceous species reduces the availability of soil moisture early in the growing season. Higher temperatures are likely to reduce livestock production during the summer season, but these losses will be partly offset by warmer temperatures during the winter season. Thus, agriculture and forestry can give Russia the opportunity to be not an object, but one of the key subjects of the global climate agenda, offer other countries solutions to the climate challenges they face and not only not lose, but also win in the conditions offered to it [9]. According to the authors of the report, in order to realize the existing potential of Russia, it is necessary to: ensure transparency in the development of the regulatory and legal framework for standards for measuring and reporting on greenhouse gas emissions, including monitoring, verification, certification of projects based on clarifying scientific knowledge about absorptions on agricultural lands and in forests, including within the framework of carbon polygons; revise the national quantitative goal to reduce greenhouse gas emissions in the direction of its tightening; launch a system of voluntary projects to create opportunities for Russian companies interested in reducing their carbon footprint to implement projects in this area (these can be airlines subject to CORSIA or companies subject to border regulation); move towards building a full-fledged regulatory system in the country with incentives for companies to reduce emissions (based on the price of carbon - in the form of an emissions trading system, carbon tax or their hybrid form) with the possibility of embedding voluntary projects to reduce emissions (including in sectors forestry and land use); to intensify the negotiation process with the EU on offsetting units of reductions in the framework of Russian projects to reduce emissions - initially for the purpose of reduction.

III. Results

The widespread recognition of the problem of climate change is forcing scientists and corporations to look for ways to reduce the carbon footprint of the economy, including the extraction of greenhouse gases already in the atmosphere. Modern research highlights a whole range of sequestration strategies: physico-chemical; biological; geological [8]. Physical-chemical approaches are mainly used in industry, energy and transport to reduce new emissions and include the use of adsorbents and separation membranes to capture, compress and transport greenhouse gases. Biological and geological methods make it possible to reduce the volume of gases accumulated in the atmosphere. Geological methods involve the injection of greenhouse gases into underground storage facilities (eg depleted deposits) [4,5,6]. This solution is very reliable from a safety point of view (most storage facilities will not be disturbed by tectonic processes over the next million years), but from an economic point of view, sustainable economic models have not yet been found to build a stable sequestration industry using geological methods. Biological methods involve using the potential of natural living systems to sequester carbon. Plants, algae, bacteria in the soil in the bottom silt are natural “devices” for absorbing greenhouse gases. There are several key areas of application of biological methods: (a) the targeted cultivation of algae and bacteria for the production of biofuels, as well as plant crops for the production of biofuels and biochar (or biochar - coal of vegetable origin with a carbon content of 93-99% and the absence of harmful and toxic impurities); b) restoration of living ecosystems that absorb carbon

[10]. As a result of human economic activity, the volume of plant biomass on the planet has significantly decreased - deforestation and desertification are rapidly taking place, and the adsorption capacity of aquatic ecosystems is decreasing due to pollution of freshwater reservoirs, seas and oceans. Restoring these systems - in particular forests and swamps - is one of the most promising solutions in terms of sequestration. Thus, today the strategy of reducing the carbon footprint through biological methods can be considered dominant. Let's take a look at a few basic ways to implement this strategy. Agricultural activities serve as both a source and sink of greenhouse gases. Agricultural sinks of greenhouse gases are reservoirs of carbon that are removed from the atmosphere through the process of biological carbon sequestration. The main sources of greenhouse gases in agriculture are the production of nitrogen fertilizers; burning fossil fuels such as coal, gasoline, diesel and natural gas; and waste management. The enteric fermentation of livestock or the fermentation that occurs in the digestive system of ruminants results in the release of methane. Carbon dioxide is removed from the atmosphere and converted into organic carbon through photosynthesis. When organic carbon decomposes, it turns back into carbon dioxide through the process of respiration. Protective tillage, organic production, cover crops, and crop rotations can dramatically increase the amount of carbon stored in the soil. Agricultural carbon sequestration refers to the ability of agricultural land and forests to remove carbon dioxide from the atmosphere. Carbon dioxide is taken up by trees, plants and crops through photosynthesis and stored as carbon in biomass in tree trunks, branches, foliage, roots and soil. Forests and grasslands are called carbon sinks because they can store large amounts of carbon in their vegetation and root systems for long periods of time. Soils are the largest terrestrial carbon sink on the planet [8]. The ability of agricultural land to store or sequester carbon depends on several factors, including climate, soil type, type of crop or land cover, and management practices. The amount of carbon stored in soil organic matter is affected by the addition of carbon from dead plant material and the loss of carbon through respiration, decomposition, and both natural and anthropogenic impacts on the soil. By adopting farming practices that minimize soil disturbance and promote carbon sequestration, farmers can slow or even reverse the loss of carbon in their fields. In the United States, forests and arable land currently absorb the equivalent of 12 percent of US carbon dioxide emissions from the energy, transportation, and industrial sectors.

IV. Discussion

The main benefit of a carbon or greenhouse gas tax would be to create a stream of tax revenue that the government could use to further incentivize the practical and technological changes needed to reduce greenhouse gas emissions [4]. For example, many of the current agricultural conservation programs, such as the Environmental Quality Incentive Program and the newer Conservation Management Program, support improving soil quality and can be partly funded by taxes on emissions or carbon emissions, thus providing a source of income to subsidize those that adopt or support emission reduction methods or carbon sequestration activities. For more information, see the ATTRA publication Federal Resources for Sustainable Agriculture and Livestock. Tax revenues could also help support conservation programs such as the Wildlife Conservation Program, which aims to keep sensitive and erosive land from being exploited as these lands sequester soil carbon. Another benefit of this approach is that the tax provides a clear and stable cost to current practices. The tax also makes it easier to identify changes that will be more profitable under new cost conditions. For example, if a concentrated animal feed business understood the cost of its emissions in terms of an emissions tax, it would be easier for it to identify cost-effective alternatives to existing methods. With a sufficiently high tax rate, it would make economic sense to install methane reactors to reduce greenhouse gas emissions [5]. Finally, it has been argued that the carbon tax approach is cost-effective to implement, at least compared to cap-and-trade, to achieve greenhouse gas emission reductions. As a recent report from the Congressional Budget Office puts it: "Available research suggests that in the short term, the net benefits (benefits minus costs) from the tax could be about five times greater than the net benefits from the inflexible cap."

Modern breeding methods make it possible to obtain "regenerative" varieties with a fairly wide range of traits and technical characteristics. Such varieties are able to produce acceptable yields in conditions of minimal use of agrochemicals, ensure the preservation of the genetic diversity necessary to maintain stable yields in unstable climatic conditions. It is necessary to develop varieties and types of agricultural plants, including fundamentally new ones, that would have the ability to suppress weeds, resist pests and diseases without the help of agrochemistry [6]. In addition to increasing nutritional value, the optimization of the interaction of plants with microbial communities in the soil should be taken into account. This applies mainly to the structure and functional features of the root system of cultivated plants [7]. Such varieties may not have the highest yield, but at the same time have the ability to adapt to stressful conditions of both biotic and abiotic nature. In breeding work, it is necessary to pay attention to such criteria for the quality of varieties as delayed leaf aging, nutrient savings, ecological suitability for local conditions, stable yields, resistance to pests and diseases, and overall low production costs. The so-called hit-and-run criterion is becoming popular, which refers to the absence or minimum need for care from the moment of sowing until harvest.

References

[1] Gakaev R.A. Foreign experience of carbon sequestration and its applicability for landscapes of the Chechen Republic, 2021, pp. 60-64

[2] Daukaev A. A., Abumuslimov A. A., Gakaev R. A. Minimization of the Most Prevalent Project Risks in the Oil and Gas Industry, 2020, pp. 64-65

[3] Porfiriev B.N. An effective strategy for action on climate change and its consequences for the Russian economy, 2019. No. 3 (174). pp. 3-16.

[4] Gakaev R.A., Bayrakov I.A., Bagasheva M.I. Ecological foundations of the optimal structure of forest landscapes in the Chechen Republic. In the collection: Environmental problems. A look into the future. Proceedings of the III scientific-practical conference. Executive editor Yu.A. Fedorov. 2006.S. 50-52.

[5] Diane, F.F. Economic growth, full employment and decent work: The means and ends in SDG 8. Int. J. Hum. Rights 2017, 21, 1164–1184.

[6] Männasoo, K.; Hein, H.; Ruubel, R. The contributions of human capital, R&D spending and convergence to total factor productivity growth. Reg. Stud. 2018, 52, 1598–1611.

[7] Boto-Álvarez, A.; García-Fernández, R. Implementation of the 2030 Agenda Sustainable Development Goals in Spain. Sustainability 2020, 12, 2546

[8] Verfaillie, H., and R. Bidwell, Measuring Eco-efficiency: A Guide to Reporting Company Performance, World Business Council for Sustainable Development, Geneva, 2020.

[9] Ionescu, G.H.; Firoiu, D.; Pîrvu, R.; Enescu, M.; Rădoi, M.-I.; Cojocaru, T.M. The Potential for Innovation and Entrepreneurship in EU Countries in the Context of Sustainable Development. Sustainability 2020, 12, 7250.

[10] Kampschreur MJ, Temmink H, Kleerebezem R, Jettena MSM, van Loosdrecht MCM. Nitrous oxide emission during wastewater treatment. Water Res. 2019, pp.4093–410.

FUZZY ASSESSMENT OF OIL SPILLS INTO THE ENVIRONMENT

Hajar Ismailova[1], Mansur Shahlarli[2]

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[1]Azerbaijan State Oil and Industry University
ismayilova.hecer@bk.ru
[2]Oil and Gas Research and Design Institute
mansursahlarli1994@gmail.com

Abstract

It is known that the amount of expected environmental damage with adverse effects is defined as the sum of the individual expected losses for different components of the environment. Estimation of damage caused by oil spills during tragic oil pipeline accidents is based on the existing normative documents and methodological guidance. The basis for developing priority measures to increase the safety of the main pipelines, which are considered a potential source of threat, is the risk assessment in the pipeline. Accidents are mainly associated with oil spills, which have a negative impact on the environment. Therefore, any section of the main oil pipelines should be assessed with certain risk parameters as it can cause accident.

Keywords: risk, oil leakage, corrosion, environment, oil pipeline, fuzzy numbers scale, fuzzy analysis.

I. Introduction

Typical scenarios of pipeline destruction consist of [1]:

- the formation of a persistent environment pollution due to oil blowout from the damaged pipeline;
- oil pool fire, leading to the thermal influences on the environment, material objects and people;
- the explosion of fuel-air compositions;
- the distribution of explosive fuel-air combination clouds with the wind, and possible explosion.

Accident risk assessment of main oil pipelines involves: [2-4]:

- Forecasting of oil leakage rates in the pipeline and estimation of the volume of spilled and lost oil (technological risk);
- Evaluation of the consequences of oil spills for various components of the natural environment;
- Carrying out the hazardous rank of the pipeline route based on risk assessment and prioritizing safety measures for ranging.

The oil pipeline leak prediction is generally based on the combined effects of the groups shown in Table 1.

The relative impact of each group of factors on the intensity of accident changes in the pipelines is considered with weight coefficient.

Each of these groups, based on statistical data on leakage statistics (influencing factors) in relation to accidents on main oil pipelines, has a specific weighting coefficient ("contribution"). It should be noted that weight coefficient are preliminary and can be determined as a rule, taking into account the opinion of specialists (experts).

Table 1: *Total statistics on accident stopping frequencies by factors (weight coefficients)*

№	Name of groups	Shares of group factors
1	External anthropogenic influences (F1)	0,20
2	Corrosion (F2)	0,10
3	Quality of pipe production (F3)	0,05
4	Quality of construction and installation works (F4)	0,10
5	Constructive technological factors (F5)	0,10
6	Natural effects (F6)	0,10
7	Exploitation factors (F7)	0,05
8	Defects in pipe and weld seams (F8)	0.30

II. Methods

Taking into account of weight coefficients in order the assessment of effective parameters, the following ranking was held on a 5-point scale. (Table 2).

Then, the results of evaluating the factors that caused oil leakage from the pipelines to the environment by individual experts were examined. The research (opinions) conducted by three different experts on these factors are shown in Table 3. As can be seen in Table 3, linguistic assessments ("very low", "low", "medium", "high" and "very high") given by experts differ from each other and from the scale adopted so far. So if expert 1 exaggerates factor F8 (defects in pipes and welds) as the most influential factor, experts 2 and 3 focus on factors F7 (operational factors) and F2 (corrosion), respectively. If expert 1 chooses F3 (pipe production quality) and F7 (exploitation factors) as the least effective factor, expert 2 accepts factors F3 , F4 , F5 , F6 and 3rd expert accepts factors F4 and F5 .

Table 2: *Rank classification according to the weight coefficient of the factors by groups*

Weight coefficient change range	Linguistic estimates	Rank
Less than 0,07	“very low”	1
0,7-0,13	“low”	2
0,14-0,20	“medium”	3
0,21-0,27	“high”	4
More than 0,28	“very high”	5

Aggregation of expert opinions on the above 8 factors (Table 3) was carried out for oil leaks. Initially, the linguistic values shown in Table 3 were converted to fuzzy numbers on the scale in Figure. The final vector was determined based on the aggregation of fuzzy numerical vectors.

The values of these final vectors according to factors are given in Table 3. These prices are the general price vector of the group of experts.

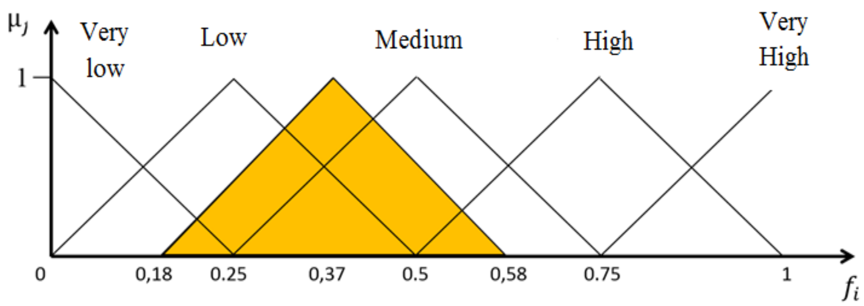

Fig 1: *Fuzzy numbers scale*

Table 3: *Possible risk factors for infield pipeline failures*

Values of factors and risk factors	1st expert score					2nd expert score					3rd expert score					Fuzzy numerical final estimate
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
External anthropogenic influences – F_1			●					●				●				0.17, 0.42, 0.75
Corrosion – F_2		●					●								●	0.25, 0.5, 0.67
Quality of pipe production – F_3	●					●						●				0, 0.17, 0.42
Quality of construction and installation works – F_4		●				●					●					0, 0.17, 0.42
Constructive-technological factors – F_5		●				●					●					0, 0.08, 0.33
Natural influence – F_6				●		●							●			0.25, 0.41, 0.67
Exploitation factors – F_7	●									●		●				0.25, 0.42, 0.58
Defects in pipes and weld seams – F_8					●				●					●		0.58, 0.75, 1

III. Results

Then, according to the method [5], the distance to the highest value vector (in other words, to the "very high" risk factor) of this vector and the sum vectors of the individual experts were calculated. The distances obtained are shown in Table 4. As can be seen from Table 4, these distances were 5.90, 6.39, 5.92 and 5.90, respectively, for the generalized vector of individual experts and the expert group. If we take into account that the distance between the "very weak" indicator and the "very high" indicator is 13.75 and convert the above-mentioned distances to the scale [0, 1], we get the following: 42, 46, 43, 43%.

These estimates indicate the percentage of accident risks far from the "very high" risk, taking into account the opinion of individual experts and expert groups.

Table 4: *Results of fuzzy assessment*

Values of factors and risk factors	Sum values of fuzzy vectors	Distance from "very high" risk	Diverge "too high" risk, %
1st expert score	0.18, 0.37, 0.59	5.90	42
2nd expert score	0.18, 0.31, 0.53	6.39	46
3rd expert score	0.18, 0.37, 0.59	5.92	43
Fuzzy numerical final estimate	0.18, 0.36, 0.58	5.90	43

IV. Discussion

Finally, the final assessment was based on the final vector calculated for individual expert meetings and the expert group. The results were [0.18, 0.37, 0.59], [0.18, 0.31, 0.53], [0.18, 0.37, 0.59] and [0.18, 0.36, 0.58], respectively (Table 4). As can be seen, these indicators do not differ much from each other and can be assessed as “weak” by 0.52 degrees and “moderate” by 0.48 degrees on the scale [0,1] (Figure 1).

Therefore, despite the diversity of initial assessments by experts, the level of technological risk resulting from oil spills for oil pipelines is not very high, mainly can be assessed "weak" risks.

References

[1] Risk Assessment of Oil Pipeline Accidents in Special Climatic Conditions, A N Vtorushinaa , Y V Anishchenko, E D Nikonova, IOP Conf. Ser.: Earth Environ. Sci. 66 012006

[2] Mazur I.I., Ivansov O.M., Moldavanov O.I. Constructive reliability and environmental safety of pipelines. M.: Nedra, 1990, 263 p.

[3] W.Kent Muhibauer. Pipeline Risk Managament Manual / Guff Publishing Company, 1992, 256p.

[4] Guidelines for assessing the risk of accidents on oil pipelines. Volume 27, Issue 1. M.: State Unitary Enterprise "Scientific and Technical Center for Safety in Industry of StateComTechMon. of Russia» 2002, 120 p.

[5] Babanli M.B. Synthesis of new materials by using fuzzy big date concepts. Procedia Computer Science, 120 (2017) pp.104-11

FEATURES OF THE INFLUENCE OF MECHANICAL AND CHEMICAL IMPACT ON THE TREATMENT PROCESS OF OIL CONTAMINATED SOILS

Gahraman Hasanov, Soltan Aliyev, Ruslan Hasanov, Vaqif Valiyev, Ismail Aliyev

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Azerbaijan State Oil and Industry University
gaman51@mail.ru
soltan15041953@gmail.com
gasanov935@gmail.com
vaqifveliyev1953@gmail.com
ismaileliyev51@gmail.com

Abstract

The paper examines the issues of replacing residual oil from fine pores of oil contaminated soil under gradientless pressure conditions. It was shown that the replacement of residual oil from fine pores of oil contaminated soil can be possible because of their unavailability for displacing water. Therefore, in addition to others, destruction degree of the system of pores and capillaries in aggregated structure of oil contaminated soil is considered as an efficiency criterion of an impact on disperse system in oil flushing process, and optimum destruction – as an optimum degree of these impacts. The aim is solved by using the complex methods of joint chemical, physical-chemical and mechanical impact on structured disperse systems of mineral particles of soil. It was shown that in the same chemical-mineralogical composition of oil contaminated soil the efficiency of its treatment increases with the growth of dispersity of its mineral particles. Increasing methods of their dispersity are related to the impact on various forces connecting mineral particles in a single system of structural formations, such as coagulative, condensation-crystalline, and mixed - coagulative -crystalline macro- and microaggregates. To ensure the possibility of realizing mass exchanging processes under the influence on washing water solution on oil surface it is important to destruct the structure, disperse all aggregates from particles by separating them (breaking of contact) and releasing unevenly distributed immobilized liquid phase (oil and water). Under intense mechanical impacts the bond strength between particles is destroyed using adsorption decrease of structure strength in surface-active medium. In this case, aggregates are destroyed into initial particles and structural bonds are broken. Dispersion (peptization) or spraying of microaggregates can be caused by changing the composition of the dispersion medium, using a chemical method of impact. An example of a chemical method of influencing oil contaminated soil is the displacement of Ca^{2+} u Mg^{2+} ions from the exchange complex of clay minerals and their replacement with Na^{+} ions, which leads to the spraying of water-resistant and true aggregates cemented with calcium and magnesium. Increasing the pH of soil suspension medium to 8.0-8.5 and recharging of electropositive hydrates of Al and Fe oxides leads to the destruction of isoelectric aggregates formed by them with electronegative particles such as silica and clay minerals. In the treatment of oil contamınated soil by washing the surface of mineral particles with washıng water solution to prevent oil resorption and coalescence of its droplets, hydrophilization of soil particles is a determining process.

Keywords: oil contamınated soil, mineral particles, aggregation, dispersion, treatment, mechanical and chemical impacts, residual oil.

I. Introduction

Oil contaminated soils consist of mineral particles combined into aggregates with intermediate pores and capillaries partially or completely filled with water and oil. The washing of oil contaminant film from the surface of mineral particles is a result of a complex joint action of molecular surface phenomena (selective wetting, surface energy gradient) and mechanical forces of water washing stream. A washing process is a complex of complicated phenomena with a great variety in the composition and nature of pollution, in the different nature of washed surfaces and a variety of changes in the physicochemical properties of washing agents. General ideas about the role of wetting and adhesion in the washing action are developed and physical and chemical analysis of forces arising at three-phase interface in washing agent-washed surface-oily contamination system is given in the works [1-5].

The quantitative bond of the process energy - necessary mechanical work of treatment - with the main physical and chemical properties of washing agents and washed surfaces is shown. The known results of numerous studies, the conclusions and technical substantiations are related to the study of washing processes of oily contaminants from fabric and polished metal surfaces, washing of bituminous sands, or the processes of oil displacement from oil-saturated sands at deep oil production under conditions of high pressures and temperatures.

A feature of oil-contaminated soils of ecologically unfavorable territories of the oil and gas production division of Apsheron Peninsula is that their components: residual oil, mineral, organomineral and organic particles are in long-term contact of natural occurrence for many decades under climatic conditions of Apsheron. A new substance "oil-contaminated soil of long duration" with features of composition, structure and properties is formed. Utilization of oil-contaminated soils, based on their washing with washing water solution of surfactants using an organic solvent, is a complex of complicated phenomena with a wide variety of composition and nature of contaminants, with a wide variety of nature of washed surfaces and the variety of washing agents.

The methods are based on understanding and knowledge of the nature of oil-contaminated soil and the properties of residual oil, which is part of it and is located on particle surfaces of minerals constituting the soil in the form of a film of a boundary layer with a strong molecular bond and oil coating layer on top of it [6]. Therefore, the restoration of soil ecology destroyed by oil pollution, the development of a treatment technology of oil-contaminated soil require special approaches, considering the characteristics of their composition and properties, and considering the understanding of their formation conditions, the migration of oil-contaminated soil in the soil body, the location of oil-contaminated soil and its location in soil structure.

Displacement of oil with water from the surface of oily soil particles is a complex process, which depends on many factors: on the surface properties and chemical composition of oil and its wash out water; on the granulometric composition of mineral solid phase of soil, especially on the amount of clay fraction in it; on the structure of pore space and a number of other factors. In addition, it is important to break down the aggregated soil structure by available technological methods in order to provide the aqueous detergent solution with maximum access to the oil contaminant of mineral particles. Along with the listed factors, to provide the mineral particles maximum access to oil pollutant, the destruction of the aggregated structure of soil by available technological methods is important. The article presents the results of studies that have formed a rational direction for treatment oil-contaminated soils and determined the necessary methods for influencing them using the technology for their utilization.

II. Methods

For experiments, oil-contaminated soil with a mass fraction of oil of 10% was used as a study object, obtained by applying an oil sample from its benzene solution to clean, dry soil, followed by evaporation of benzene. Granulometric composition of clean soil was determined, according to GOST 12536-79, the chemical composition using an X-ray spectrometer S8 TIGER (Germany, BRUKER), and the mineralogical composition using X-ray diffractometer «MiniFlex 600» (Rigaku Corporation, Japan). Table 1 shows the results of analyses and some physical and chemical properties of pure soil. From the data in Table 1 it can be seen that the pure soil used to obtain the research object is a silty loam containing mainly quartz of various dispersions and up to 15% clay minerals smaller than 0.001 mm.

Pure soil is a polydisperse polymineral mass with a certain water content, and if it is oil-contaminated, then with a certain content of oil and oil products. To maintain the average constancy of the granulometric composition of soil samples in different experiments, they were selected for analysis according to the standard method to obtain a sample with an average particle size distribution. The physical and chemical parameters of oil, which is part of oil-contaminated soil, are presented in Table 2.

Table 1: *Physical and mechanical properties, mineralogical and granulometric composition of pure soil.*

Granulometric composition, mm			Mineralogical composition
Fraction composition, %,			
	1.0 – 0.25	6.43	Quartz
	0.25 – 0.05	57.73	--------
	0.05 – 0.01	11.68	--------
	0.01 – 0.005	5.16	--------
	0.005 – 0.001	4.44	--------
	≤0.001	14.56	montmorillonite
	<0.01	24.16	
Liquid limit, %		33.0	
Amount of carbonates, %		11.25	
Specific surface, m^2/g		3.88	
Specific weight, g/sm^3		2.66	
Volume weight, g/sm^3		1.35	
Porosity, %		49.0	
Full water extract, salt amount, %		0.053	
pH of water extract, unit.		7.9	

The results of analysis of the residual oil that is part of oil-contaminated soil, shows that the oil does not contain light fractions, is weathered, contains resins, asphaltenes, organic acids and hydrocarbons, which boil at a wide temperature range.

III. Results and Discussion

In nature, there are no clean crystal surfaces or soil particles. Finely dispersed particles of clay minerals and larger sandy ones are covered with films of various colloids firmly bound to them: iron hydrates, silicic acid, organic and organomineral substances. Soil formation processes continuously occurring in nature, leading to the destruction of rocks under certain conditions, cause the reverse process of aggregation and cementation of fragments or particles into relatively stable micro- and macroaggregates, characterized by granulometric (aggregate) composition, degree of fragmentation, percentage of particles with different sizes.

Table 2: *Physical and chemical indicators of residual oil released from oil-contaminated soils of Absheron Peninsula in Balakhani region.*

Name	Value	Test method
Fraction composition, ^{0}C/% vol.	100 -260/4,0 >260- destruction 32-110/13 (atm.)	GOST 2177
	110-155/17 155-220/9,5 >225- destruction (3 mm)	ASTMD 1160
Content, % mass:		
asphaltene	6,2	IP143
resin	8,71	GOST 11826
paraffin $C_{19} – C_{35}$	1,16	GOST 11821
Acidity, mgKOH/g	0,168	ASTMD 664
Viscosity at 50^{0}C, kinematic, cSt	76,0	ASTMD 445
Density at 20^{0}C, kg/m^3	955	GOST 3900

The Apsheron Peninsula is characterized by the presence of cohesive clay soils - clay, loam, sandy loam. Much less often in large areas lie incoherent - sands. In this regard, it was shown in [6] that the formation of oil-contaminated soils is caused by the impregnation of crude oil with the main components of the soil body, which are in secular equilibrium—aggregates consisting of cemented natural elementary particles with water on their surface, in their pores and capillaries. Oil coating is layered on the "fur coat" of films consisting of colloids and water on the surface of mineral grains or aggregates cemented from them, Fig. 1 i.e., in the gap between oil layer coating and the surface of the natural elementary particle, there is a water film in the gap between them.

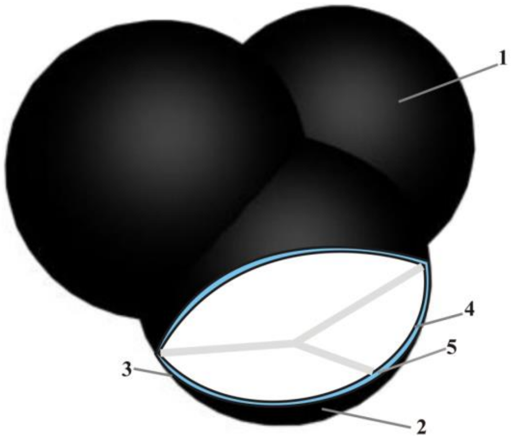


Figure 1: *Scheme of an oil-contaminated aggregate, consisting of cemented natural-elementary particles of chipped soil: 1 - oil-contaminated aggregate; 2 - grain of an oil-contaminated natural elementary chipped particle; 3- oil on the surface of aggregate; 4 - the surface of a natural elementary particle, covered with a colloidal particle film; 5 - gap in the interval between the particle surface and oil shell filled with water film.*

In addition, it was found that in order to effectively clean the surface of aggregated oil contaminated soil particles, it is necessary to provide water-washing solution an access to them. It is necessary to disperse, spray oil contaminated aggregates of dust-clay particles and destroy aggregates consisting of grains of oil polluted natural elementary sand particles.

The oil coating layer of residual oil from the surface of dust and clay particles and grains of natural elementary sand particles is washed out using an organic solvent and an water surfactant solution with destruction of oil polluted aggregates.

To treat the grains of natural-elementary sand particles from boundary layer film of residual oil, it is enough to chip or crush them into two small parts, which occurs due to the established laws of washing oil-contaminated glass and quartz plates. Indeed, it is necessary to disperse the cemented oil-contaminated granules consisting of grains of natural-elementary sand particles and split them, then by wedging action of water-washing stream, with its power vector directed into the intermediate gap between particle surface and the film of residual oil boundary layer, the latter will be torn and is removed from the surface in the form of oil droplets by water-washing stream. The described mechanism of washing the oil-contaminated surface of a soil particle is schematically shown in Fig.2.

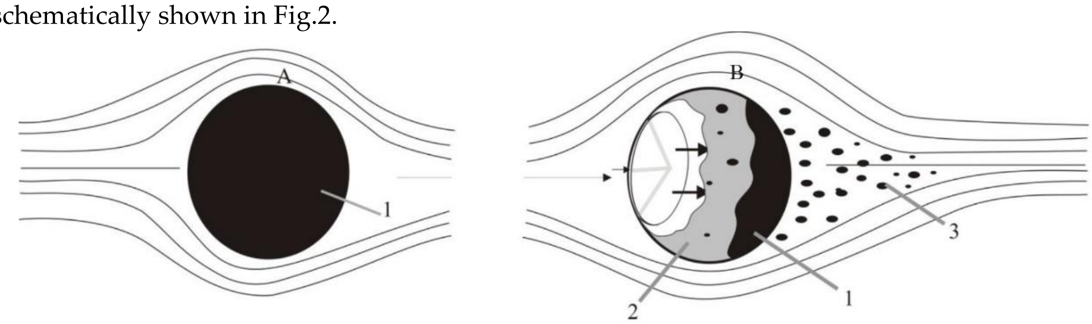


Figure 2: *Scheme of oil-contaminated soil natural-elemental particle and with chip in water-washing solution stream (water + surfactant + organic solvent). A – oil-contaminated particle; B - oil-contaminated chipped particle; 1 - layer of oil coating on particle surface; 2 - film of a boundary layer of residual oil; 3 - oil drops from particle surface chipped during crushing.*

Soils, especially cohesive soils, are polymineral and polydisperse bodies. Its separate particles have a very high strength. Sand particles consisting mainly of quartz are characterized by compression strength ~ 1500-2000 kg/cm^2 [7].

Adsorption of surfactants from environment can significantly reduce the flexibility limit, strength and hardness, facilitate the destruction of fine bodies and increase the flexibility of metals [8]. Water is the most active with respect to quartz surfactant [8]. The existence of three different experimentally established effects of the influence of the environment is stated. Depending on the specific conditions of the experience, the effect of the medium acts either in plasticization, or in increasing brittleness, or gives solids the ability to spontaneously disperse.

The addition of surface-active medium or adsorbent additives can cause spontaneous dispersion of aggregates without external mechanical influences. Such spontaneous dispersion or peptization (with internal stresses in aggregates) leads to a significant increase in the volume of the number of free particles. Fine dispersion is generally impossible without surface-active medium and adsorptive additives [9]. It was found that grinding a quartz powder with water with an optimal content of 30-50% increases specific surface area compared to the specific surface area of powders of the same length in dry air grinding.

Difference in dispersion of powders of dry and wet grinding increases with the growth of dispersion duration (the average optimal value of wet dispersion duration of quartz is 4-8 minutes). Quartz powder crushed with paraffin becomes hydrophobic, but actively disaggregates when it is crushed with water [10]. Water in disaggregation process creates obstacles for close approach of particles and, due to this, reduces the area and number of contacts between them. The specificity of the dispersing action of water is based on its ability to form hydrate shells on particle surfaces, as well as the high wetting energy of many solid (hydrophilic) bodies by it and, the wedging effect. When quartz crystals are destroyed by a split, siloxane groups Si-O-Si, SiO^- and Si^+ ions are exposed on the surface.

During grinding in water, hydrogen ions or hydroxide ions attach to SiO^- and Si^+ ions, forming silanol groups SiOH, [11] fig. 3. Quartz surface is represented by groups interacting with water in different ways: siloxane, silanol, and dissociated silanol. Silanol groups are partially dissociated upon contact with water. Unsaturated bonds of SiO^- groups actively interact with water molecules and mainly determine the wettability of quartz surface with water. All various types of amorphous and crystalline silicas, due to their origin from water solutions (silica gels), when milled in water (crystalline silicas), carry on their surface the so-called "structural water". Based on chemical and adsorption data in [12] this structural water represents silicic acid hydroxyl groups chemically bonded to surface silicon atoms. Structural water is released when silica is heated at 500-700^{0}C.

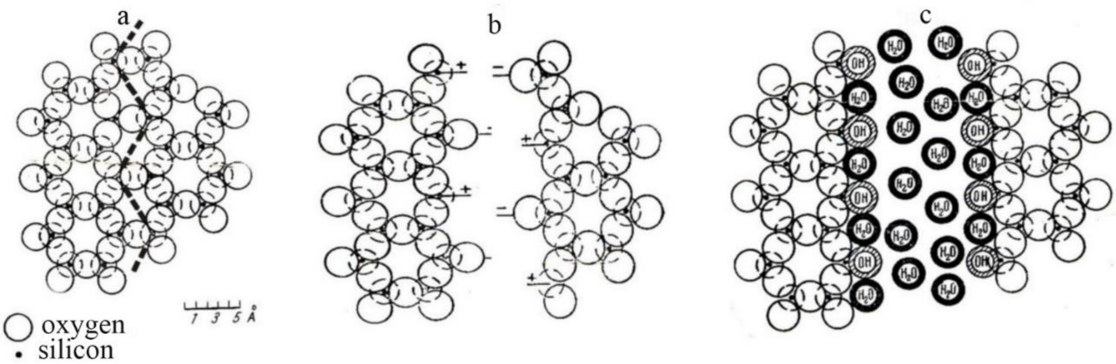
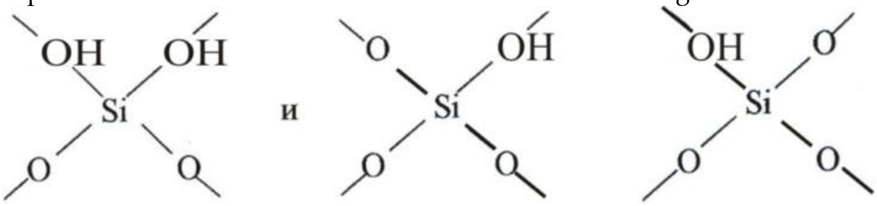


Figure 3: *Scheme of exposure of bonds during splitting of quartz crystals: a - scheme of splitting; b - scheme of a split on air; c - diagram of a split in water.*

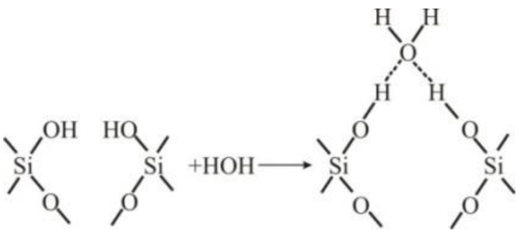
Hydrated silica surface contains mainly silanol groups of two types: [13]. Hydroxyls of these groups, located at suitable distances, partially interact with each other. All this creates a chemical and geometric nonhomogeneity of the surface. As a result, on silica surface there are both "free" hydroxyl groups which are remote from each other and not interacting with each other, as well as



closely spaced and favorably oriented to form a mutual hydrogen bond hydroxyl groups. A hydroxyl cover also exists on the surface of other oxides, such as Al_2O_3 [14] and TiO_2 [15].

Direct and most reliable information on the mechanism of physical adsorption on hydroxylated surfaces was obtained by spectral studies of the interaction of hydroxyl groups on the silica surface with adsorbed molecules. A typical occurrence of adsorption interaction due to the formation of a hydrogen bond with surface hydroxyl groups is observed during the adsorption of water.

The adsorption of water molecules on two adjacent, closely located, and favorably oriented hydroxyl groups of the surface is most energetically favorable [16]. Research results allow us to consider that the hydroxyl groups of fully hydrated silica are the main centers of reversible physical adsorption. Water adsorption is associated with the formation of hydrogen bonds between the hydroxyl groups of the surface and the oxygen of adsorbed water molecules. The predominant interaction of adsorbed water molecules with a hydrated surface is close to that expressed in the scheme [17, 18]:



Protection of the surface of a split quartz particle from resorption of washed oil drops on it and suppression of particle flotation (sticking to air bubbles) can be ensured by introducing colloidal SiO_2 in the form of liquid glass into the composition of the water-washing stream. Facilitating the hydrophilization of a split particle surface, colloidal SiO_2 will give it protective properties from hydrophobic interaction with releasing oil drops.

Processes of dispersion and spraying of aggregates formed by silty-clay particles are traditionally used in soil science for the preparation of soils for granulometric dispersion analysis. When developing the technology for treatment oil-contaminated soil, this experience in the rational use of methods for its dispersion was taken into account. To treat effectively the surface of dusty-clay particles from an oil pollutant, it is necessary to provide a water-washing solution an access to it, by weakening coagulation bonds, dispersing aggregates and releasing particles from an aggregation state.

By controlling hydrophobic coagulation adhesion between particles, peptization and changes in the interaction of water (dispersion medium) with cohesive soil with the addition of electrolytes, surfactants, organic solvent, it is possible to regulate the adhesion properties of dusty clay particles in suspensions by facilitating dispersion process by mechanical interactions into coagulates, particle aggregates.

When the soil is stirred with water, false aggregates formed by the coagulation of particles with Na^+ cation are destroyed. More energetic effect is required for aggregates formed by coagulation of particles with 2^x valent cations. The destruction of such aggregates can be achieved by grinding a highly concentrated water suspension of a soil sample. Thus, with a more energetic mechanical action, in addition to the destruction of false aggregates, water-resistant and true aggregates are sprayed. High dispersing effect is achieved by grinding a thick mass (clay, loam) with liquid glass as a dispersing agent [19].

The efficiency of soil dispersion depends on the stabilization of the suspension of sprayed particles. An increase in the stability of colloidal systems is due to the electric charge of their dispersed phase: colloidal particles, carrying the same charge, repel each other when they meet. Thus, the electric charge is a factor stabilizing the colloidally dispersed state of a substance. Most of the colloids in the soil are negatively charged, so the presence of salt anions is a stabilizing factor for them. Salt cations will reduce or destroy the negative charge of colloidal particles, promoting their coagulation. In this case, cations are a destabilizing factor.

The stabilizing effect of cations depends on their valency and atomic weight. The higher the valency and atomic weight of the cation, the greater its precipitating ability. An exception is H^+, coagulating capacity of which is greater than all other monovalent cations and even surpasses divalent cations in this respect. the calcium ion has the highest coagulating ability among the cations found in natural water in soils. Therefore, in non-saline soils, the main role of the coagulator of colloidally dispersed particles belongs to this cation.

In acidic soils, the hydrogen ion is of great importance. In salina Na^+, Ca^{2+} and Mg^{2+} can be the main coagulators, depending on their predominance in salina. The hydroxyl ion (OH^-) increases the stability of negatively charged atomized colloidal particles and greatly reduces the coagulating ability of electrolytes. Soils containing oxide hydrates of monovalent cations contain colloids in a dispersed state, while divalent cations (especially $Ca(OH)_2$) have colloids in a co-coagulated state.

In granulometric analysis, the physical chemical method of soil preparation is widely used, in which Na^{+} and OH^{-} ions, transforming into an absorbed state, disperse natural soil aggregates according to the reaction:

$$(\text{soil} - Ca^{2+}) + 2NaCl \longrightarrow (2\text{soil } 2Na^{+}) + CaCl_2$$

NaCl is introduced into the soil based on the cation exchange capacity value of soil. At the same time, Na+, passing into the absorbing complex, disperses the soil.

To prepare a soil suspension, low-mineralized waters (dry residue less than 100mg/l) are most favorable, in which the content of monovalent cations is higher than multivalent ones.

An important role in dispersion processes of clay soils can be played by their absorption capacity, based on the formation of low-soluble compounds, as a result of which both anions and cations are absorbed in equivalent amounts. Ca^{2+}, Mg^{2+}, Fe^{3+} and Al^{3+} are most often found in soils from cations that give insoluble compounds. The first two ones (Ca^{2+} and Mg^{2+}) play the most important role. Low-soluble compounds with listed cations can give CO_3^{2-}, PO_4^{3-} and SO_4^{2-}. As a result of the exchange, cations that are in the adsorbed state and capable of forming low-soluble salts with anions of the solution release into the solution.

The action of Na_2CO_3 solution on a carbonate soil and be an example. In this case, the Na^{+} cation will enter the absorbing soil complex and displace an equivalent amount of Ca^{2+} and Mg^{2+} from there. These two cations give with the anion CO_3^{2-} low-soluble carbonates $CaCO_3$ and $MgCO_3$ which precipitate in solid state.

IV. Conclusion

Thus, chemical methods of soil preparation, when combined with methods of mechanical action, it is possible to spray true aggregates with a large yield of fine particles. With dispersion method of analysis all aggregates are destroyed due to:

- displacement of Ca^{2+} and Mg^{2+} cations from the exchange complex and their replacement with Na^{+} cations,

- increase of pH of the suspension above 8.0-8.5 and, as a result, recharging the electropositive hydroxides Al and Fe by destruction of aggregates formed by them with electronegative colloids - silica, humus and clay minerals.

On the basis of the data, the techniques and methods of mechanical, chemical and physico-chemical effects are substantiated, which are the essence of the developed technology for treating oil-contaminated soils, based on the washing off with a water washing solution of an oil pollutant concentrated in hard-to-reach, hydrophobized areas of pores and capillaries of the aggregated structure of soils. The set of techniques and methods of influence used is determined by the necessity of providing the washing agent with favorable conditions for treating the surfaces of soil mineral particles, as well as its maximum access to the oil pollutant, while ensuring high efficiency of mass transfer in dispersed systems.

References

[1] Rebinder P. A. Physics-chemistry of washing agent. M.: Publishing House «Food Industry», 1935. p.210

[2] Adam N. K. (1937) Detergent Action and its Relation to Wetting and Emulsification. *Society of Dyers Colourists*. 53, pp.121-129

[3] Kling W, Longe. (1955) Kolloid Z. Energetik des Waschvorganges bei oligen Anschmutzungen. 1, p.142

[4] Koretskiy A.F., Kolosanova V.A., Smirnova A.V., Koretskaya T. A. (1972). To the theory of washing action. I. Role of energy in treatment processes of surfaces from oily pollutants. *Bulletin of the Russian Academy of Sciences*. Chemistry, issue 1, № 2, p. 32

[5] Koretskiy A.F. (1974). To the energy of washing action. *Bulletin of the Russian Academy of Sciences. Chemistry*, issue 6, № 14, p. 28

[6] Hasanov K.S., Abdullayev F.Z., Latifov F.I. (2006). *Processes of petrochemistry and oil processing*. № 2 (25). p. 62.

[7] Bezruk V.M. Strengthening of soils. M.: Transport. 1965, 340 p.

[8] Shukin E.D., Rebinder P.A. (1958). Formation of new surfaces during deformation and destruction of solid states in surface active medium. *Colloid. journal*. 1958, vol. 20, № 5, p. 645-654

[9] Khodakov G.S., Rebinder P.A. (1960). On the impact of medium on amorphization of quartz in its mechanical dispersion. *Proceedings of the USSR Academy of Sciences*, 131, p. 1316-1318

[10] Khodakov G.S. Fine crushing of construction materials. M.: Stroyizdat, 1972, p. 38

[11] Streltsin G.S. (1968). Surface properties of a quartz. *Colloid. journal.* vol. 30, № 4, p. 592-595

[12] Kiselyov A.V., Ligin V.I. (1962). The use of IR – spectroscopy for the study of compound surfaces and adsorption. *The Russian Chemical Reviews*. vol. 31, issue. 3, p. 351-363

[13] Kiselyov A.V. (1961). Energy of interaction adsorbate-adsorbent and adsorbate-adsorbate in monolayers on surfaces of solids. *Russian Journal of Physical Chemistry*, vol. 35, p. 233-257

[14] Peri J., Hannan R. (1960). Surface hydroxyl groups on γ-alumina. *J. Phys. Chem*., v. 64, pp. 1526-1530

[15] Yates D. (1961). Infrared studies of the surface hydroxyl groups on titanium dioxide, and of the chemisorption of carbon monoxide and carbon dioxide. *J. Phys. Chem*., v. 65 (5), pp. 746-753

[16] Kiselyov A.V., Ligin V.I. (1959). IR-spectra of adsorption and hydroxyl coating in different degrees of hydration. *Colloid journal*,vol. 21, № 5, p. 581-589

[17] Jigit O.M., Kiselyov A.V., Mutik G.G. (1961). Heat of adsorption of water steam on silica gel with hydrated and dehydrated surfaces. *Colloid journal.* 23, p. 553-557

[18] Starshov M.I., Starshov I.M. Certificate of authorship of Method of extracting bitum. 1989

[19] Hasanov G.S., Abdullayev F.Z. (2009). Selection of processing scheme of oil slums and oil-contaminated soils, pilot testing, technology of their utilization and neutralization. Journal of Chemical Problems, № 2, p. 213-227

FORECAST MODELING OF MAN-MADE EMERGENCIES WITH MODERN METHODS

Valery Akimov, Maxim Bedilo, Olga Derendiaeva, Ekaterina Ivanova, Irina Olyan

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All-Russian Research Institute for Civil Defense and Emergency Situations of the Emergencies Ministry of Russia (Federal Center for Science and High Technologies)

akimov@vniigochs.ru
vniigochs@vniigochs.ru
irenaoltyan@mail.ru

Abstract

The article discusses the verbal and mathematical foundations of the forecast modeling of the most catastrophic emergencies of a man-made nature, such as: road traffic accidents, aviation catastrophes, explosions in buildings and structures, radiation and chemical accidents, as well as accidents on housing and utilities systems.

Keywords: emergency situations of man-made nature, traffic accidents, aviation catastrophes, explosions in buildings and structures, radiation and chemical accidents, accidents on housing and utilities systems, modeling methods.

I. Introduction

According to the degree of catastrophicity in the Russian Federation, the following emergencies can be distinguished [1,2]: road traffic accidents (accidents), aviation catastrophes, explosions in buildings and structures, radiation and chemical accidents. Given the importance for the life support of the population of municipal communities, accidents on facilities and networks of heating infrastructure and power supply systems can also be attributed to the most catastrophic emergencies [3].

II. Methods

Accidents with grave consequences, aviation catastrophes, explosions in buildings and structures

Such the most catastrophic emergencies as: road traffic accidents, aviation catastrophes, explosions in buildings and structures and some others can be studied by probabilistic statistical methods, in particular, methods of statistical data processing based on the Bayes theorem [4,5], in accordance with which:

$$P(H|e) = \frac{P(e|H)P(H)}{P(e)}, \tag{1}$$

where:
H — hypothesis;
e — evidence;
$P(H/e)$ — A posteriori probability;
$P(H)$ — A priori probability.

In [6] a typical forecast and analytical model was proposed using the Bayes method for predicting such emergencies. Bayesian networks are used as a mathematical framework of modeling - probabilistic - graph models operating under the conditions of knowledge, intended for the study of probabilistic causal relations between events of the subject area.

In general, the process of developing a typical model based on methods using Bayes methods includes the following steps:

1 stage - meaningful setting of the problem at the conceptual level;

2 stage - training of the learning set;

3 Stage - selection of methods for processing input and output variables.

At the 1st stage, the collection of a priori information about the simulated subject area is carried out.

The features of specific territories should be analyzed: geographical position; climatic conditions; characteristics of the socio-economic system, including (people, organizational and technical systems) and the subject area (residential, public and administrative buildings, industrial and agricultural production, transport, communications, broadcasting, television, technical facilities and utilities systems, watering systems, natural resources, etc.).

When collecting a priori information about the simulated subject area, the established field of application should be analyzed: sources of occurrence; causes of occurrence; the main scenarios of the emergence and development of emergencies; the frequency (statistics) of the occurrence; consequences of impact on various protection objects; means (methods) of control and measurement; impact measures.

According to the results of collecting a priori information, the output variables should be probabilize on the basis of Bayes methods and input variables of the model. The output variables of the models are formed as hypotheses. The assessment and verification of possible events are installed. The variables should be used for indirect judgement of the events possibility corresponding to the established hypotheses.

At the 2nd stage, the training set is prepared. This is a set of structured data, reflecting the states of the input and output variables of the model, ordered by the date and time of observations.

The input variables value should be random. Variables should not changed during observations (the coordinates of measurement points, the constant characteristics of observation objects, etc.), do not affect the output variables.

An objective control system of input and / or output variables, information systems databases, the results of statistical observations of the input and variables in the past, the opinions of the experts – all these may be the sources of learning sets. Data for inclusion in the training set can be obtained using techniques and models which used in practice.

Data quality improving is achieved due to: eliminate duplicate records, contradictory and missed field values; cleaning data from noise and abnormal values; restoration of the structure, completeness and integrity of the data; transformations to installed input formats; elimination of data entry errors; adapt data to a specific task by eliminating their redundancy.

Collecting units of observation for training model should be carried out until sufficient accuracy of the probabilistic assessment of the established hypotheses is achieved. The structure of the learning set should not change during the time interval, within the framework of which the collection and analysis of the values of input variables are carried out, as well as the construction of a probabilistic statistical model on their base.

On the 3rd stage, the model is recommended to use in practice tested Bayesian methods for processing input and output variables.

For each specific model the time interval should be determined.

The obtained values of the probabilistic estimate of the hypotheses (risk - coefficients) are intended for use by relevant officials when making decisions on response to emergencies. The risk of coefficients should establish criteria in accordance with this one can identify the level of technogenic hazards. The coefficient should determine its linear trend and the time to achieve a higher level of danger regarding the current risk. Time is one of the main parameters for making a threat response solution.

Radiation accidents

The threat of an accident on a radiation-hazardous object is a combination of conditions and factors that create the likelihood of ejection or strait of radioactive substances capable of leading to mass radiation damage to people, animals and plants, as well as environmental pollution.

All radiation-hazardous facilities related to the nuclear industry of the economy can be divided into nuclear-dangerous (YAOO) and radiation-dangerous (ROO) objects.

YAOO has the potential danger of the occurrence of spontaneous chain reaction in emergency situations, when processing, storing and transporting nuclear materials. YAOO includes objects of nuclear fuel cycle enterprises: nuclear power plants of various types, enterprises for regeneration of spent fuel and temporal storage of radioactive waste, research organizations with experienced reactors and particle accelerators, sea vessels with nuclear power plants, nuclear ammunition storage facilities and polygons.

ROO includes enterprises using radioactive substances in small quantities, and products based on them (devices and installations that do not represent nuclear hazards). The danger of YAOO and ROO is determined by their possible radiation impact on personnel and the population.

At all phases of the development of emergencies, events on the localization and elimination of the accident are performed in accordance with the pre-developed plan and the resulting radiation situation after the accident. The behavior of personnel and population at the polluted territory is determined by the requirements of the IAEA, NRB-99/2009 [7], OSPORB-99/2010 [8], GOST R 42.4.02-2015 [9] and other regulatory documents.

There is no method that allow promptively in real time to carry out a reliable forecast of the radiation situation and its consequences for various types of ROO and which would be verified and standardized. Existing research techniques require the knowledge of the peculiarities of the flow of physical processes, technology and technical implementation in systems and installations of the ROO, and at the same time are limited to a number of assumptions and a small probability and accuracy of the final results.

As a standardized methodology for operational prediction of the situation during the project development, GOST R 22.2.11-2018 "The methodology for assessing the radiation situation during the projected accident at the nuclear power plant." This technique is intended to evaluate the radiation situation during the projector of the NPP with the VVER-440, VVER-1000 type reactors and RBMK-1000 by forecasting.

With regard to the prediction of radiation consequences at the enterprises of the nuclear cycle, the following guidelines are recommended:

RB-134-17 Safety Guide "Recommended methods for assessing and predicting the radiation consequences of accidents at the nuclear fuel cycle facilities" (approved by the order of the Federal Service for Environmental, Technological and Nuclear Supervision of November 16, 2017 No. 479);

RB-106-15 Security Guide "Recommended methods for calculating the parameters required for the development and establishment of standards for extremely permissible emissions of radioactive substances into atmospheric air" (approved by the order of the Federal Service for Environmental, Technological and Nuclear Supervision of November 11, 2015 № 458).

Chemical accidents

For advanced and operational prediction of infection in the case of emissions of poisonous substances into the environment during accidents (destruction) on chemically hazardous objects and transport used: "Method of predicting the scale of infection with poisonous substances during accidents (destruction) on chemically hazardous facilities and transport (RD 52.04.253-90)" [10].

This technique allows predict the scale of infection zones during accidents on technological containers and storage facilities, during transportation of railway, pipeline and other types of transport, as well as in case of destruction of chemically hazardous objects. The technique applies to the case of emission by driving into the atmosphere in a gaseous, vapor or aerosol state. At the same time, this scale depending on the physical properties and the aggregate state conditions, and calculated for the primary and secondary clouds: for liquefied gases - separately for primary and secondary clouds; for compressed gases - only for the primary cloud; for poisonous liquids, boiling above ambient temperature - only for the secondary cloud.

To predict the scale of possible chemical infection during the accidents on technological containers and storage facilities, during transportation of railway, pipeline and other types of transport, as well as in the case of the destruction of chemically hazardous objects, used "Method of predicting the scale of possible chemical infection of emergency chemically hazardous substances in cases of chemically hazardous objects and transport (application b to SP 165.1325800.2014)"[11]. The technique applies to the event of an emission of emergency chemically hazardous substances into the atmosphere in a gaseous, vapor or aerosol state.

Accidents on heat supply systems

General requirements for the organization and procedure for predicting the consequences of the disconnection of heat supply on the controlled territory are presented in [12].

The main reasons leading to emergency disconnections of heat supply on distribution power grids are [13]: natural phenomena; physical (constructive), including mechanical damage as a result of construction and repair work; actions (inaction) of the service personnel (human factor); technological disorders, including functional failures in the operation of thermal network equipment and thermal energy consumers.

In general, the process of developing this model includes: collecting source information and the formation of a basic learning set; the choice of the Bayesian classifier, the preparation of methods for analyzing and interpreting the results of statistical processing.

The main data for the formation of a basic learning set of models for a separate observed territory, are the following: the overall characteristics of heat supply systems of heat supply organizations; historical data characterizing the emergency and operation of the heat supply system as a whole; historical data of objective control of the heat supply system as a whole; data characterizing heat supply sources; historical data of objective control of the source of heat supply; data characterizing pipelines; historical data of objective control of pipelines; data characterizing thermal chambers; historical data of objective control of thermal chambers; data characterizing thermal points; historical data of objective control of thermal points; data characterizing consumers of thermal energy; historical data of objective control of buildings and structures, characterizing the parameters of heat supply consumers; data on weather stations located within the boundaries of the observed area; Historical data on the meteorological situation at the observed area.

When choosing a Bayesian classifier, it is necessary to take into account that the classification algorithm must be optimized for processing a large amount of input and output data. A probabilistic assessment using the chosen Bayesian classifier is subject to hypotheses given in [12]. The main types of crisis situations and / or incidents associated with the disconnection of heat supply and the directories of individual observed parameters are presented.

Accidents on power supply systems

General requirements for the organization and procedure for predicting the consequences of turning off the power supply on a controlled territory are given in [14].

The main reasons leading to emergency disabling power supply on distribution power grids are [15]: natural phenomena; network overload; Functional failures; human factor; mechanical damage.

In general, the process of developing this model includes the steps described in the previous subsection.

The main data for the formation of a basic training set of the model, are the following: historical data characterizing the emergency room on the power supply; data characterizing the power grid organization; data characterizing the power centers of distribution electrical networks; data characterizing the sections of the supply air (cable) lines; data characterizing 6-10 kW camshafts; data characterizing the section of the supply air (cable) lines from the distribution device to the consumer distribution point; data characterizing the consumer distribution point and the main reduction substation of the enterprise; data characterizing the distribution (cable) line from the distribution point to transformer substations; data characterizing distribution reductions transformer substations of the power supply; data characterizing cable lines with a voltage of 0.4 kV from the transformer substation to the introductory and distribution devices; data characterizing input and distribution devices; data characterizing consumers of electrical energy; historical data characterizing the consequences of emergencies; data on weather stations located within the boundaries of the observed area; historical data on meteorological setting.

At the same time, the probability of trouble-free operation of objects (sections) of distribution power grids (P(t)) should be determined by the equation:

$$P(t) = \frac{N_0 - n(t)}{N_0} = 1 - \frac{n(t)}{N_0}, \tag{2}$$

where:

N_0— the number of objects at the beginning of the test;

n(t) — the number of refusal objects for the observable time.

The probability of trouble-free operation of objects (sections) of distribution power grids ($P(t)$) is allowed to be determined by the formula:

$$\mathrm{P}(t) = \mathrm{e}^{-\omega\mathrm{t}}, \tag{3}$$

where: t — settlement period, years;

ω — parameter of the failure of objects (sections) of distribution power grids, 1 / year.

A probabilistic assessment using the chosen Bayesian classifier is subject to hypotheses given in [14]. There are also presented the main types of crisis situations and / or incidents associated with the disconnection of power supply, and the directories of individual observed parameters.

III Results

Thus, this article presents the verbal and mathematical foundations of modeling the most catastrophic emergencies of a technogenic nature, such as: road traffic accidents, aviation catastrophes, explosions in buildings and structures, radiation and chemical accidents, as well as accidents on housing and utilities systems.

IV Discussion

The verbal and mathematical foundations of the forecast modeling of the most catastrophic emergencies of a technogenic nature are actively discussed in recent years on the pages of scientific literature [1, 2, 4, 5]. Classic mathematical models for predicting emergency situations of a technogenic nature are described in [16 - 20].

References

[1] Akimov V.A., Olyan I.Yu., Ivanova E.O. Methods of ranking emergencies of natural, technogenic and biological and social character in the degree of their catastrophicity // Scientific and Technical Journal of Civil Security Technologies, No. 1 (67), 2021. - PP. 4 - 7.

[2] Akimov V.A., Olyan I.Yu., Ivanova E.O. Range of emergency situations of a natural and technogenic nature of socially - economic indicators of their catastrophicity // Materials V MNPC on go. Ch. IV. - M.: Academy of GPS Emergencies Ministry of Russia, 2021. - PP. 199 - 204.

[3] State reports on the state of protection of the population and territories of the Russian Federation from natural and technogenic emergencies in 2010 - 2020. M.: EMERCOM of Russia. 2011 - 2021 years.

[4] Akimov V.A., Bedilo M.V., Study of emergency situations of natural, technogenic and biological and social nature by modern scientific methods: monograph. M.: FSBI VNII GOCC (FC), 2021. 180 p.

[5] Akimov V.A. Applications of the general theory of security to the study of emergency situations of natural, technogenic and biological and social character // Scientific and Technical Journal of Civil Security Technologies, Volume 18, 2021 (Special Education) - PP. 12 - 27.

[6] GOST R 22.1.Hh-202x. Safety in emergency situations. Safe city. Typical forecast and analytical model using the Bayes method. General requirements.

[7] Radiation safety standards (NRB-99/2009). Sanitary rules and standards of SanPiN 2.6.1.2523-09 (approved by the Resolution of the Chief State Sanitary Doctor of the Russian Federation of July 7, 2009 No. 47).

[8] The main sanitary regulations for the provision of radiation safety (Singing - 99/2010). Sanitary rules and regulations SP 2.6.1.2612-10 (approved by the Resolution of the Chief State Sanitary Doctor of the Russian Federation of April 26, 2010 No. 40).

[9] GOST R 42.4.02-2015. Civil defense. Radiation protection regimes on the territory subjected to radioactive contamination.

[10] RD 52.04.253-90. Steering document. The method of predicting the scale of infection with potent poisonous substances during accidents (destruction) on chemically hazardous facilities and transport (approved by the chairman of Roshydromet of the USSR 13.03.90 and the head of civil defense of the USSR 24.03.90).

[11] SP 165.1325800.2014. Set of rules. Engineering and technical measures for civil defense. Actualized edition SNiP 2.01.51-90 (approved by the Order of the Ministry of Construction and Housing and Communal Services of the Russian Federation of November 12, 2014 No. 705 / PR).

[12] GOST R 22.1.Hh-202x. Safety in emergency situations. Safe city. Forecasting the effects of turning off heat supply. General requirements.

[13] Federal Law of July 27, 2010 No. 190-FZ "On Heat Supplying".

[14] GOST R 22.1.Hh-202x. Safety in emergency situations. Safe city. Forecasting the effects of power outage. General requirements.

[15] Federal Law of March 26, 20000 No. 35-ФЗ "On Electrical Engineering".

[16] Safety of Russia. Legal, socio-economic and scientific and technical aspects. Systems of emergency situations. M.: Society "Knowledge", 2015. - 864 p.

[17] Safety of Russia. Legal, socio-economic and scientific and technical aspects. Scientific basis for technogenic security. M.: MGF "Knowledge", 2015. - 936 p.

[18] Safety of Russia. Legal, socio-economic and scientific and technical aspects. Consolidated volume. Fundamental and applied problems of integrated security. M.: "Knowledge", 2017. – 992p.

[19] Safety of Russia. Legal, socio-economic and scientific and technical aspects. Technogenic, technological and technospheric safety. M.: MGF "Knowledge", 2018. - 1016 p.

[20] Safety of Russia. Legal, socio-economic and scientific and technical aspects. Analysis and provision of protection against emergency situations. M.: MGF "Knowledge", 2021. - 500 p.

RISK ASSESSMENT OF APSHERON PENINSULA OIL AND GAS FIELD USING MICROWAVE SENSING TECHNOLOGIES

Emil Bayramov[1,2]

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[1]Nazarbayev University, Kazakhstan
[2]Technical University of Berlin, Germany
emil.bayramov@nu.edu.kz

Abstract

A number of productive oil and gas fields are located in the Apsheron Peninsula of Azerbaijan. The primary goal of the presented study was to quantitatively assess the ground deformation rates of oil and gas fields, determine natural and man-made influencing factors and predict deformation trends. The determined maximum displacement rates of subsidence and uplift processes were −26 mm/y and +23 mm/y, respectively. However spatial density analysis of deformation velocity presented the natural patterns of uplift and subsidence tectonic processes. This allowed to determine that two oil and gas fields hold a higher probability of being affected by man-made oil and gas exploration activities, whereas the one oil field is affected by both natural and man-made processes.

Keywords: PS-InSAR; SBAS; remote sensing; geospatial; pipelines; oil and gas; radar; interferometry

I. Introduction

Possible causes of surface deformation are earthquakes, mud volcanism, groundwater changes, and man-made activities for hydrocarbon or gas withdrawal. Among these ground deformation causing factors, it is well known that hydrocarbon fluid or gas withdrawal activities have a direct impact to the subsidence and uplifts processes of oil and gas fields. Traditional ground surveying methods are important to accurately assess the subsidence and uplift rates, however, they are costly in terms of necessary equipment, human involvement, availability of historical baseline as a reference for the detection of continuous ground movement rates and velocity and limited territorial coverage for the assessment of spatial ground movement patterns. This research is focusing on the quantitative assessment of ground movements caused by petroleum and gas activities. Interferometric Synthetic Aperture Radar (InSAR) is a well-known and proven remote sensing technique that uses the phase information of SAR images to measure ground surface displacements. For the Apsheron Peninsula, the first studies based on InSAR were performed by Mellors *et al.* [1]. These studies used the SAR images to generate Digital Elevation Models which have been compared with topographic maps and independently derived topographic information. Feyzullayev *et al.* [2] developed the scheme of vertical movements in the Apsheron Peninsula based on results of repeated ground-based geodetic levelling and indicated that the intensive development of oil-and-gas fields causes natural disbalance and wide progress of deformation processes. Yaschenko [3] conducted repeated ground levelling in the Apsheron Peninsula during 1977–1984 and indicated that the annual velocity of subsidence was 0.21–5.6 mm/year in the southern part of the Apsheron Peninsulla, whereas maximal subsidence rates were observed for Syrakhany (−18 mm/year), Baladjary and (12 mm/year), Bibi-Heybat (12 mm/year) oil and gas fields [4, 5]. The main goals of the present study are the following:

a. Detect ground deformations (subsidence and uplift) of oil and gas fields in the Apsheron Peninsula

b. Assess the natural and anthropogenic factors influencing these deformation processes

c. Predict the liner trends of ground deformation

The present research holds novelty insofar as PS-InSAR technique has never been used for this part of the globe. Besides, our approach considers the advanced geospatial statistical analysis of PS-InSAR ground movement derivatives, quantitative assessment of natural and anthropogenic factors influencing the ground deformation processes and also the forecast of vertical movement trends and rates.

II. Methods

The Apsheron Peninsula is of the world's most ancient oil and gas producing regions. In 1846, Azerbaijan drilled its first oil well in Bibi-Heybat oil field. The Apsheron Peninsula extends 60 km eastward into the Caspian Sea, and reaches a maximum width of 30 km (Figure 1a). As can be seen in Figure 1(b), there are 11 oil and gas and 17 oil fields under exploitation [6]. The Apsheron Peninsula has a temperate semi-arid climate with warm and dry summers, cool and occasionally wet winters, and strong winds all year long. The peninsula is the most arid part of Azerbaijan with an average precipitation of 263 mm per year. The annual mean air temperature is approximately 14°C. Summers are warm with typical maximum air temperatures in the order of 35–40°C. January is the coldest month with an average of 0°C. Wind speeds typically range from 0.5 to 12 m/s. Based on the past historical records of earthquakes (1950–2020) from United States Geological Survey (USGS), the Apsheron peninsula is an active seismic area with surrounding faults. Rapid population growth, increasing social and industrial infrastructure and intensive oil and gas exploration activities significantly raised the seismic vulnerability of the Apsheron peninsula and natural hazards consequences [7].

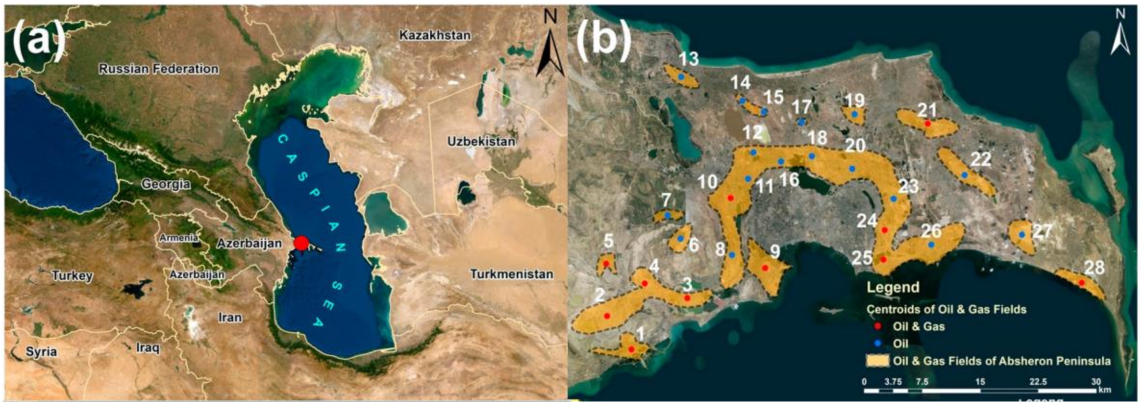

Fig. 1: (a) *Geographic location of the Apsheron Peninsula; (b) Oil and gas fields of Apsheron Peninsula*

Persistent Scatterer Interferometry (PSI) is a proven differential interferometric technique which involves processing of multi-temporal Synthetic Aperture Radar (SAR) data to identify persistently reflecting ground features and their motion rates with millimetre precision [8]. The PS-InSAR concept for the measurement of precise displacement is based on finding of permanent scatters with phase stability over a long period of time, removal of atmospheric phase contribution, DEM error and system/thermal noise etc. [9]. Monitoring and characterisation of the ground deformation processes of oil and gas fields of the Apsheron Peninsula have been carried out by using a stack of 28 Sentinel-1 Synthetic Aperture Radar (SAR) satellite images from

European Space Agency (ESA) acquired for the period of 2015–2017. The Sentinel-1 SAR instrument operates at 5.405 GHz (C-band, corresponding to a radar wavelength of about 5.6 cm). Sentinel-1 VV polarization bands were used since co-polarized bands provide higher coherency [10]. The following workflow shown in Figure 2 was used for the Persistent Scatterer PS-InSAR, geospatial and statistical analysis. The main processing steps of PS-InSAR consist of interferogram generation, multi-temporal persistent scatterers (PS) processing and removal of atmospheric phase screen [11].

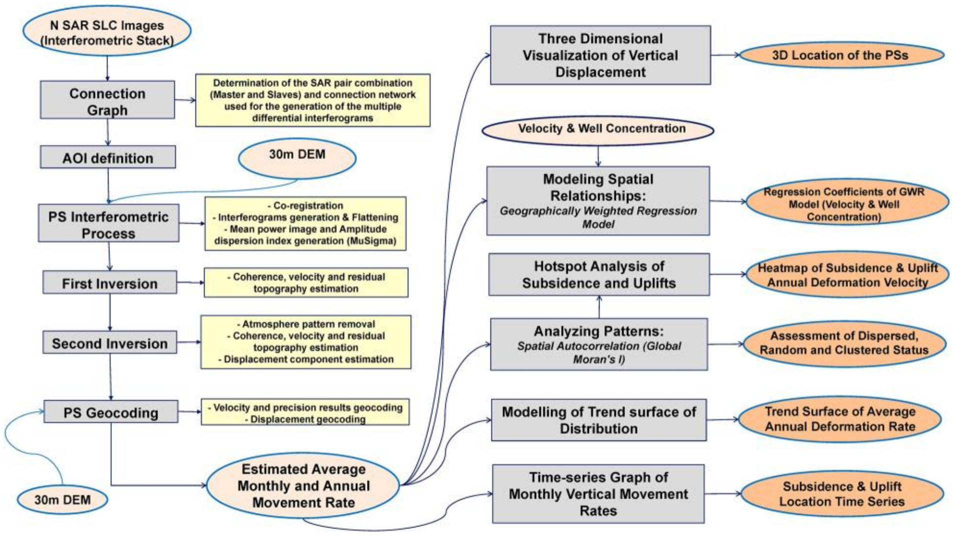

Fig. 2: *Workflow of PS-InSAR, geospatial analysis and predictions of ground deformation processes.*

III. Results and Conclusions

The present studies allowed to primarily determine the hotspots, controlling factors and spatiotemporal trends of ground movements for the oil and gas fields of the Apsheron peninsula (Figure 3a-f). The present research demonstrated the capacity of low-cost and safe technology to monitor the ground movements of the oil and gas fields. Besides, the produced results contribute to the larger scale and reliability of observations with enhanced clarity of ground deformations rather than measurements for single points. The presence of ground-deformation processes in the Apsheron oil and gas fields was observed with the highest rates of subsidence processes at the Hotspots A5 (Bibiheybat), A6 (Zigh) and A7 (Balakhani-Sabunchi-Ramani) and the highest rates of uplifts in Hotspot A1 (Garadagh), Hotspot A2 (Kergez-Giziltepe-Shongar) and A4 (Bibi-heibat). Determined maximum movement rates of subsidence and uplift processes were −26 and 23 mm/y, respectively (Figure 3a-f). Trend and concentration analysis of deformation velocity presented the natural patterns of uplift and subsidence tectonic processes from west to North-East and South-East. Among the detected hotspots of uplifts, Hotspot A1 (Garadagh) and Hotspot A2 (Kergez-Giziltepe-Shongar) were observed to be within the detected natural tectonic process of uplift and Hotspot A7 (Balakhany- Sabunchi-Ramani) is within the detected natural subsidence processes. Hotspot A4 (Bibi-heibat) did not reveal any regression with either concentration of wells or elevation factors and requires further in-situ investigations to understand the controlling factors and causes of ground uplifting processes. The ground-based geodetic levelling in the Apsheron Peninsula conducted during 1977-1984 allowed to validate that the Hotspots of A3, A5 and A7 continue to subside. The subsidence of Oil Field 23 (Surakhani) was not detected, instead the uplift process was observed in this area and this uncertainty may be related to several reasons as follows: discontinuation of subsidence processes in this area, failure in the in-situ ground measurements, interferometry calculations and applied injection technology. The present research demonstrated the contribution of SAR technologies to the safe operational monitoring of petroleum and gas fields without human ground-based measurements, significant cost reduction, reliability and broad scale of observations. The present study allowed to perform combined Persistent Scatterer Interferometry and the geospatial machine learning - based geostatistical analysis which allowed to develop and understand broader picture of the ground deformation processes over the oil and gas fields of the Apsheron Peninsula.

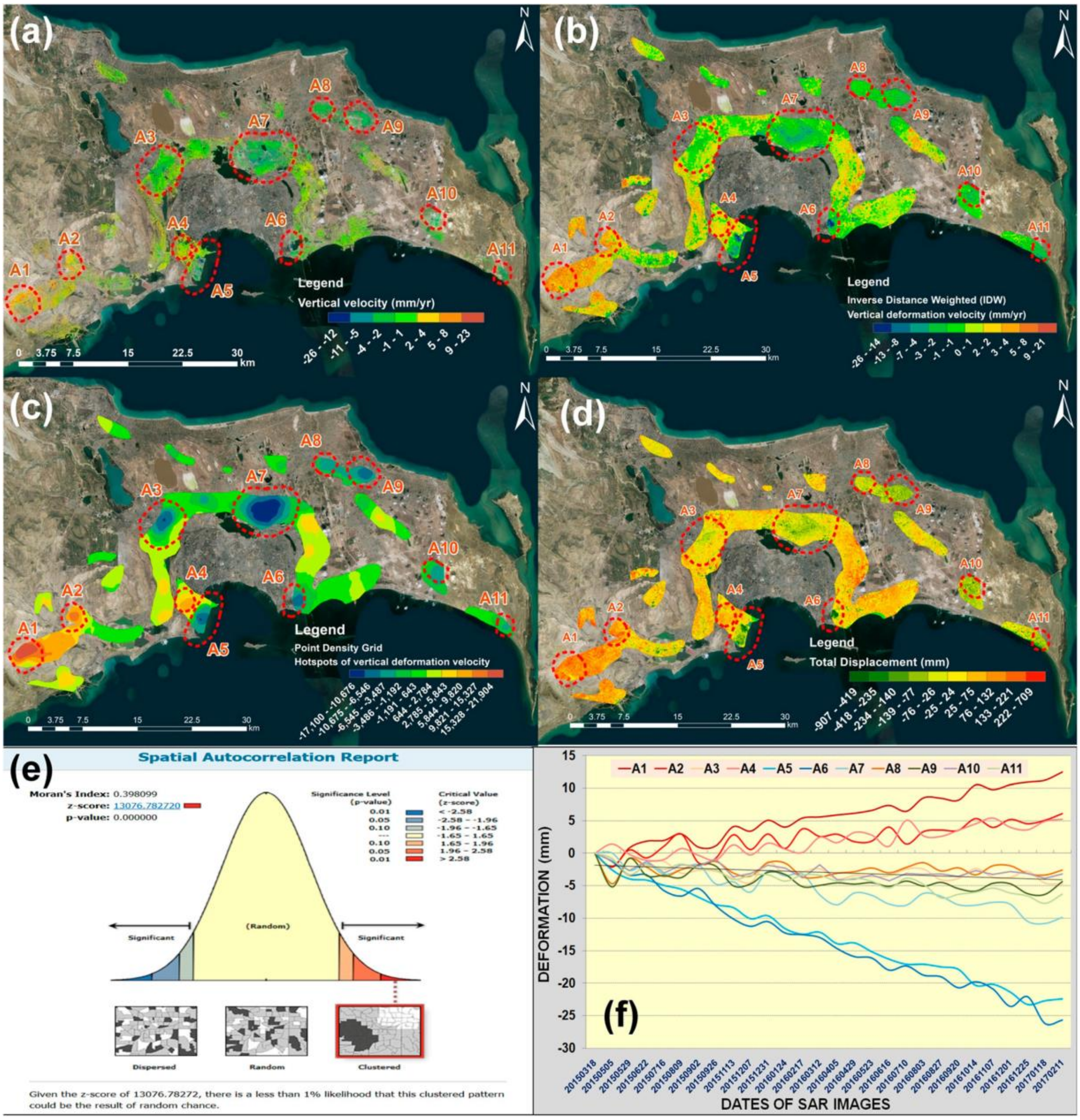

Fig. 3: *(a) Deformation map of subsidence and uplifts of the Apsheron oil and gas fields; (b) Inverse Distance Weighted interpolation of deformation values of persistent scatterers; (c) hotspots of vertical deformation velocity; (d) Inverse Distance Weighted interpolation of total deformation values of persistent scatterers; (e) Spatial autocorrelation of deformation velocities; (f) time series deformation curves of Hotspot A1–11 in millimetres.*

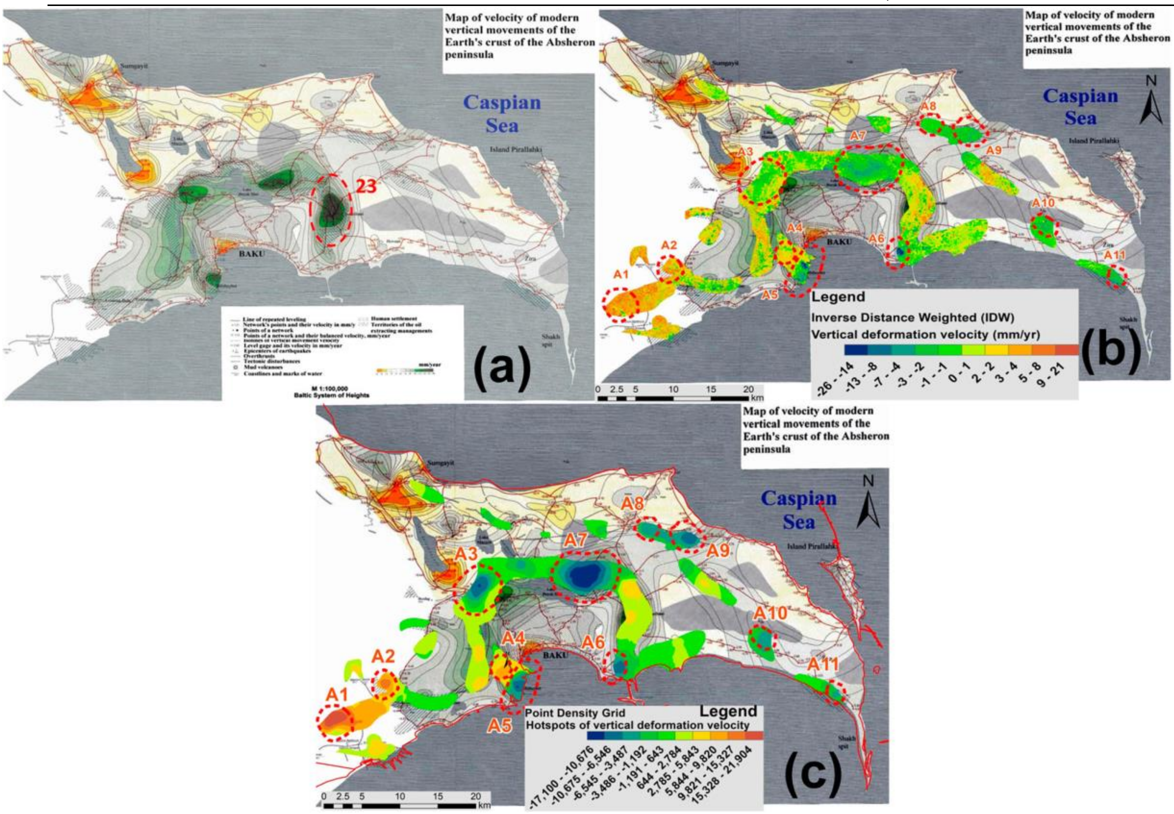

Fig. 4: (a) *Subsidence map of oil and gas fields developed as a result of ground levelling measurements conducted during 1977–1984 (Yaschenko 1989; Alizadeh et al. 2016a, 2016b) and indication of oil field not detected by PS-InSAR technology; (b) detected vertical deformation velocity using PS-InSAR technology; (c) hotspots of detected vertical deformation velocity using PS-InSAR technology.*

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References

[1] Mellors R. J., Bunyapanasarn T., and Panahi B. (2005). Insar Analysis of the Apsheron Peninsula and Nearby Areas, Azerbaijan. In Mud Volcanoes. Geodynamics and Seismicity. Vol. 51., edited by G. Martinelli and B. Panahi, 201–209. Dordrecht: Springer. NATO Science Series (Series IV: Earth and Environmental Series).

[2] Feyzullayev A. A., and Ibragimov V. B. (2014). Environmental Consequences of Long-Term Development of Petroleum Fields, Apsheron p-la, Azerbaijan, Case History.” Journal of Environmental Protection 5: 1603–1610.

[3] Yaschenko V. R. (1989). Geodetic Investigation of Earth Crust Vertical Movements. Nedra, Moscow (in Russian).

[4] Alizadeh A. M., Guliyev I. S., Kadirov F. A., and Eppelbaum L. V. (2016a). Geosciences of Azerbaijan. Vol. I. Springer. Geology, 239 p.

[5] Alizadeh A. M., Guliyev I. S., Kadirov F. A., and Eppelbaum L. V. (2016b). Geosciences of Azerbaijan. Vol. II. Springer. Economic Geology and Applied Geophysics, 348 p.

[6] Humbatov F. Y., Suleymanov B. A., Ahmedov M. M., and Balayev V. S. (2016). Radium Isotopes in an Oil-Field Produced Lake Near Baku, Azerbaijan. Journal of Environmental

Protection 7: 1149–1156.

[7] Babayev G., Ismail-Zadeh A., and Le Mouel J.-L. (2010). Scenario-based Earthquake Hazard and Risk Assessment for Baku (Azerbaijan). Natural Hazards and Earth System Sciences 10: 2697–2712.

[8] Ferretti, A., Prati C., and Rocca F. (2001). Permanent Scatterers in SAR Interferometry. IEEE Transactions on Geoscience and Remote Sensing 39 (I): 8–20.

[9] Lu L. and Liao M. (2008). Subsidence Measurement with PS-InSAR Techniques in Shanghai Urban. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 37: B7. Beijing.

[10] Imamoglu, M., Kahraman F., Cakir Z., and Sanli F. B. (2019). Ground Deformation Analysis of Bolvadin (W. Turkey) by Means of Multi-Temporal InSAR Techniques and Sentinel-1 Data. *Remote Sensing* 11: 1069.

[11] Osmanoglu, B., Sunar F., Wdowinski S., and Cabral-Cano E. (2016). Time Series Analysis of InSAR Data: Methods and Trends. ISPRS Journal of Photogrammetry and Remote Sensing 115: 90–102.

METHOD OF STUDYING THE REDUCTION AND SEQUESTRATION OF GREENHOUSE GASES ON CARBON FARMS

Sergey Mashkov[1], Kheda Murtazova[2]

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[1]Samara State Agricultural University, Russia
[2]Chechen State University named after A.A. Kadyrov, Russia
mash_ser@mail.ru
fu.ggni@mail.ru

Abstract

Methodological approaches to the formation of a unified National system for monitoring and recording the balance of carbon and greenhouse gas emissions are considered, as well as the purpose, typification, requirements for the spatial distribution of "carbon" landfills, assessment of the carbon absorption capacity of forests and agricultural ecosystems of the Russian Federation, a standard methodology recommended by the international community for assessment of carbon stocks in soils, which should be applied in the Russian Federation to ensure comparability of greenhouse gas accounting results between countries, determination of carbon absorption capacity of natural ecosystems and soils. The carbon uptake potential of agricultural soils is shown. A list of indicators for assessing soil carbon according to the methodology of the Intergovernmental Panel on Climate Change (IPCC Guidelines for National Greenhouse Gas Inventories) is given.

Keywords: carbon polygons, greenhouse, carbon farms, agricultural ecosystems, environmental protection, carbon dioxide

I. Introduction

Carbon farming is an effective strategy for more sustainable production of food and other related products. It aims to simultaneously produce a variety of natural farming practices and marketable products[1]. According to the Food and Agriculture Organization (FAO), agriculture, forestry and other land uses account for 24% of global greenhouse gas (GHG) emissions, and total global emissions from livestock production are 7.1 gigatonnes of CO2 equivalent per year, which is 14 .5 gigatons. % of total anthropogenic GHG emissions [2]. For example, an agroforestry system that deliberately combines trees and crops with livestock in agricultural production has the potential to increase carbon sequestration and reduce greenhouse gas emissions from terrestrial ecosystems, thereby helping to mitigate global climate change. In addition, agroforestry has the potential to generate vast amounts of biomass and is considered particularly suitable for replenishing soil organic carbon (SOC). SOC is an important indicator of soil fertility, as change in SOC can explain whether land-use patterns of soil fertility are deteriorating or improving [2,3]. What's more, SOC, found in soil as soil organic matter (SOM), directly or indirectly helps improve soil health. Thus, efforts must be made to convince farmers to improve resource efficiency and soil conservation in order to maximize the benefits of agriculture. Therefore, this review aimed to clarify the issues of carbon farming, changes in the carbon cycle and carbon sequestration during agricultural development, and the benefits of agroforestry. A clear trend towards bringing climate change issues to the forefront of the global political and economic agenda has emerged in the past few months. The growing consensus in global economic centers on the legitimacy of trade restrictions on goods with a high carbon footprint is a real threat to Russian exports. Already today, some world exchanges require issuers to report on greenhouse gas emissions. The mining and metals industries, fertilizer producers, and subsequently other sectors of the economy, including agriculture, are at risk of constantly shrinking export markets as more countries move to the standards of the leaders in the climate race. We are talking about the prospect of erecting barriers not only in the EU or US markets, but also in all markets that are actively trading with them [4]. However, natural and climatic conditions allow Russia to be not an object, but an active subject of the global carbon policy. The vast forest areas of our country, tens of millions of hectares of agricultural land taken out of circulation, with proper preparation (fire prevention, building protective forest belts, etc.) can become huge carbon storage factories capable of absorbing, according to some estimates, hundreds of millions of tons of carbon dioxide in year. The transition of agriculture to resource-saving practices, the introduction of carbon farming methods will significantly reduce the carbon footprint of Russian agricultural products, turn the Russian agricultural producer, land user into a provider of carbon absorption services [3]. Russia can and should become a leader in carbon credit trading within the global sequestration industry. The introduction of new management methods will also require new approaches to the selection of agricultural and forest plants, reorientation of breeding work to new characteristics, including increasing the ability to absorb atmospheric carbon and reducing the need for the use of fertilizers and plant protection products. The invitation of the authors of the report to talk about Russia's possible strategy in the new "carbon reality" can only be welcomed. The spread of carbon farming and forest management practices will directly contribute to the achievement of this goal by enhancing the protection, protection and reproduction of forests, reducing the area of forest fires, and increasing the absorption capacity of forests. The organization in Russia of carbon farms, adapted to the characteristics of specific territories and ecosystems, will make it possible to work out forestry and agricultural technologies aimed at the most active absorption of carbon dioxide from the atmosphere.

II. Methods

New approaches to farming systems and soil management are being developed to manage excess CO2 in the environment while improving water use efficiency and soil quality. Various management practices affect the amount of soil organic matter, composition and water retention capacity [1,2]. However, meeting human needs and protecting environmental resources at the same time is the key to effective planning strategies. Soil quality research aims to understand how to manage soil in order to take advantage of its inherent qualities. Therefore, it becomes necessary to recognize the factors influencing soil health, among which organic matter is crucial [3,4]. Organic matter that is easy to handle in land management can be found in most agricultural land. Since organic matter increases water-holding capacity and strengthens soil structure [5,6], it contributes to increased agricultural productivity as well as reduced incidence of drought and disease [7,8]. In addition, agricultural activities that release organic matter into the soil are necessary to limit CO2 emissions into the environment [9,10].Soil management activities have also been shown to be necessary to conserve and restore soil carbon. However, many agricultural lands, although not all, have a significant carbon deficiency due to erosion and soil destruction [10]. It is widely recognized that various governments are taking possible measures to encourage environmentally sustainable agricultural practices to conserve soil carbon. In low-cost areas, agroforests fight to increase crop productivity and help farmers maintain soil quality. In combination with crops, certain types of trees in agroforest management systems can be suitable for solving numerous agricultural problems [4]. Another government project is the implementation of an environmental policy aimed at reducing the carbon footprint. In addition to traditional tillage, terracing and no-mulching systems, farmers are encouraged to use other systems such as bio-fertilizers, no-till and plant mulch, along with systems operating under agroforestry [6]. Forest density is another important factor influencing soil carbon content. On the other hand, deforestation significantly affects river flow and land use patterns. Agriculture, forestry and other land use practices account for 24 percent of global greenhouse gas (GHG) emissions, with total global livestock emissions of 7.1 gigatonnes of CO2 equivalent per year, representing 14.5 percent of total anthropogenic GHG emissions, according to the Food and Agriculture Organization (FAO) [9]. Forests, however, provide significant opportunities for a net reduction in global warming (as a consequence of greenhouse gas emissions) through CO2 sequestration [10]. Since the injection of flue gases into aquifers to store and utilize CO2 poses a risk of carbon leakage over time, it offers few economic benefits, making the carbon sequestration method more attractive [8]. In addition, the planning and management of forests must also consider how they relate to other aspects of the ecosystem. In addition, microalgae demonstrate highly productive photosynthesis, as a result of which a large amount of CO2 is formed in their cells in the form of organically bound carbon [10]. Therefore, for biomass derived from fossil fuels, CO2 pollution per unit can be reduced by having CO2 recycled and then reused by algae.

III. Results

The EU's plans to introduce a frontier carbon adjustment mechanism have prompted many manufacturers of carbon-intensive products exported to the EU to rethink their carbon strategy. Over the past few months, it has become clear that the emergence of such a mechanism in one form or another is inevitable. Moreover, similar measures can be taken in the United States: the program of the new president directly provides for the introduction of a "corrective carbon levy" in relation to countries "not fulfilling their obligations on climate and environmental protection." If this scenario materializes, there is a high probability of a domino effect triggering: exporters to these markets will be forced to switch to higher carbon standards of importing countries, and therefore protect their producers with similar measures. Russia's failure to take steps to develop and implement a strategy to reduce greenhouse gas emissions will mean a gradual narrowing of export markets. It may turn out that there will simply be nowhere to switch from the EU market: similar barriers will be erected in other markets [6,7]. Challenging "carbon adjustments" in the World Trade Organization is unlikely to lead to the desired results: if specific forms of implementation of the mechanism can be found to be inconsistent with certain WTO rules (for example, on the prohibition of discrimination), the very idea of such a mechanism is subject to its support economic centers of the world, including the EU and the USA, and the emergence of climate change issues at the forefront of the international agenda - with a high probability will be recognized as legitimate. In addition, the WTO dispute resolution system remains blocked today (the US is preventing the appointment of members of the Appellate Body, citing irregularities in its work; the new administration has not yet demonstrated a willingness to change the situation in the foreseeable future), so filing a complaint in the near future is futile [8]. Thus, having won a dispute with the EU over energy adjustments last year, Russia cannot enforce the decision of the arbitration panel, since the EU filed an appeal with the non-functioning Appellate Body, thereby maintaining the status quo indefinitely. Carbon pricing initiatives—in the form of a carbon tax or an emissions trading system—are on the rise around the world, with about 60 of them now. years before. Africa's first carbon tax was introduced in the Republic of South Africa (SAR), with Singapore pioneering in Asia. On February 1, 2021, the national emissions trading system began to operate in China. In these circumstances, one of the key elements of Russia's response to climate threats and related trade barriers could be agriculture and forestry [8].

Forest farms focus on growing special forest and non-timber forest products, including such valuable ones as mushrooms, ginseng, nuts, herbs and dyes. The activities of such a farm change the forest ecosystem, but do not violate such important functions as soil erosion control, microclimate regulation and the creation of wildlife habitats. Windbreaks are strips of trees and/or shrubs that are maintained to change the wind flow and affect the microclimate. Such strips can protect sensitive crop species, improve water use efficiency, better control wind erosion, and increase bee and pesticide pollination efficiency. These ecosystem services can improve soil health by increasing soil diversity, reducing soil disturbance, and providing year-round soil cover [5,6]. Coastal (tugai) forest buffers consist of strips of grass, shrubs, and trees between the shore, just below the water's edge, and arable land. Trees and shrubs stabilize the coast, improve and protect the aquatic environment, and protect arable land from water erosion and weeding. Grass slows and disperses runoff from arable fields, promoting sedimentation and infiltration of nutrients and pesticides. Finally, silvopasture agriculture is the deliberate use of a forest area as a pasture. Typically, this system includes seeding with native pasture grasses, fertilization and nitrogen-fixing legumes, and rotational grazing. Potential benefits of this system include a cooler environment for livestock, shorter logging cycles due to higher levels of nitrogen fertilizer and control of competition, and more efficient uptake of nutrients by plants. The costs and challenges associated with setting up a silvopastoral irrigation system include the high capital costs associated with planting trees, the need for fencing and monitoring of livestock, and ensuring correlation between livestock and plant species [7,8].

Forests cover about 30% of the total land area and play an important role as carbon sinks in both the atmosphere and soil. The current area of forest cover is dynamic and will be largely affected by land use and climate change in the future. Rising temperatures, more frequent droughts and wildfires are some of the factors that can transform forests from net carbon sinks to net CO2 sources. Natural solutions to climate change will require significant contributions from afforestation, reforestation and the prevention of deforestation. For such measures to be effective, it will be necessary, among other things, to undertake a concerted plant breeding effort. Paulownia, a tree widely used in agroforestry and as a biomass for energy generation, shows the highest rate of carbon sequestration among all species [4]. The volume of its sequestration is about 9 tons of CO2-eq./ha per year. Another plus is the fast growth rate - 3.6-5.0 m per year, a relatively short harvest cycle - starting from 8-10 years in the most favorable conditions. These characteristics require a lot of nutrients and water, which can be costly and affect soil quality and fertility. Paulownia is quite adapted to various climatic conditions: being endemic to Asia, it can tolerate temperatures as low as -15ºC and therefore has the potential to adapt to colder climates. Experimental paulownia plantations have been established in a number of countries of Central Asia - in Uzbekistan, Kyrgyzstan, and Kazakhstan. However, a wide distribution in new regions for this family can lead to consequences that have not been studied so far. In a number of US states, the distribution of paulownia is prohibited by local law [9].

Poplar (Populusspp) and its hybrids have been identified as a promising species for carbon sequestration in colder, northern and continental climates. Poplar is distributed throughout most of Russia and is found in many Russian cities. It has a relatively high carbon sequestration potential of 1.8–6.35 tCO2-eq/ha per year, high growth rates of 1.524–3.6 m/year, and a short productive cycle of 10–15 years [10]. Poplar can be used in agroforestry, bioenergy, pulp production. Several hybrids have been created in Russia: Breeze, Voronezh Giant, Veduga, Surprise. To maximize the effectiveness of future poplar afforestation and reforestation initiatives, selection of genotypes with high growth, biomass and disease resistance will be required. The specificity of the planting region is also an important characteristic for the selection of the genotype [6]. A number of foreign forestry companies, such as Alberta-Pacific (ALPAC) in Canada, are experimenting with poplar-aspen hybrid plantations. In the process of experimental cultivation, not only positive, but also a number of negative points were revealed - for example, a high degree of damage to poplars by various phytopathologies [7]. Before widespread introduction into practice, it is necessary to conduct experimental plantings of this kind of plantings. Although the range of eucalyptus (Saligna) and bamboo (Phyllostachys pubescens) is far from cold regions, they deserve attention due to their extremely high potential for carbon sequestration. Eucalyptus is a fast growing species (1.8–3.6 m/yr) with a high carbon sequestration potential (8 tCO2e/ha/yr), a short harvest cycle (8–12 years) and reusability of its wood [9]. The homeland of eucalyptus is Australia, the local habitat is from tropical to subtropical. The paper describes the crossing of Eucalyptus grandis with Eucalyptus urophylla, which allows the plant to be resistant to freezing. Such studies offer interesting opportunities for adapting eucalyptus to carbon sequestration initiatives in colder regions. Several decades ago, eucalyptus trees were planted in the Colchis lowland in Georgia, took root and became an element of the natural environment. Due to the low resistance to frost, further expansion of common eucalyptus to the north did not occur. As for bamboo, several of its species are cold-resistant (Phyllostachys Aurea, Phyllostachys bissetii) and can tolerate temperatures up to 15°C. Bamboo has an extremely fast growth rate (5.0–10.0 m/year) with a high carbon sequestration potential (8.5 tCO2-eq/ha/year) and can be used as a raw material for production as well as for food [3,4]. Not classified as a tree, bamboo reaches a height comparable to a tree (up to 15–20 m) and also has a biomass structure similar to trees. Bamboo reforestation initiatives have been observed to promote the accumulation of organic matter in the soil, counteract erosion, promote the restoration of exploited landscapes, reduce sedimentation and pollution from agricultural runoff, and even filter sewage. It should be noted that the rate and magnitude of growth of forest stands depend not only and even not so much on the presence of fast-growing species, but on the quality of care. Forestry requires planting a much larger number of seedlings than the total number of mature trees per unit area. So, based on the rules of reforestation, it is necessary to plant at least 3,000 seedlings per 1 ha, while about 250–300 survive to the age of 100 years. This means that 90% of trees die due to natural causes - due to competition or as a result of natural death.

IV. Discussion

It is very likely that in the future, agricultural products will somehow fall under the EU's corrective mechanism [8]. Given that the agricultural sector is the subject of special protection in the EU, there is no reason to believe that, by protecting competition in its market with a carbon corrective mechanism, the European Commission will refuse to use this tool to protect the European agricultural producer. Moreover, at the international level, an understanding is beginning to form that, in the issue of climate change, agricultural production "is not only the source of the problem, but also a key element of the solution [9]." If earlier agriculture was perceived, on the one hand, as one of the causes of climate change, and on the other hand, as one of its main victims, and the question was raised only about reducing the impact of climate change on agricultural production and its adaptation to a changing climate, today it is that agriculture can become a source of technologies that ensure the removal (sequestration) of greenhouse gases from the atmosphere. Farming methods aimed at capturing carbon from the atmosphere are known as carbon (or carbon) farming (carbon farming). The essence of carbon farming is to increase soil carbon by increasing the amount of carbon put into the soil and reducing the rate of carbon loss through respiration and soil erosion. The reduction of greenhouse gas emissions associated with agriculture is achieved, among other things, by minimizing the use of agrochemicals (fertilizers, plant protection products).In recent years, along with the active spread of state regulation systems for greenhouse gas emissions (including emission trading systems in Europe, China, California and carbon taxes in European and Asian countries), as well as various sectoral emission regulation systems (including the system Corsia on the basis of ICAO), voluntary carbon offsetting schemes are rapidly developing based on the implementation of investment projects. Voluntary carbon markets are platforms for transactions for the sale and purchase of greenhouse gas emission reduction units. Companies come to participate in voluntary emission reduction schemes both out of a desire to increase their attractiveness for investors, and based on some associated benefits, including to strengthen their positions in certain local markets where the company's products are supplied 7,8]. Projects cover a range of activities, from reducing agricultural emissions by reducing the amount of chemical fertilizers used, to improving the energy efficiency of production and switching to cleaner energy sources. Recently, projects in the field of forestry and land use have become increasingly popular. Your projects have a fairly wide geography and are being implemented in more than 80 countries, but the majority are concentrated in India, China, the USA, Turkey and Brazil.

In many ways synonymous with carbon farming is the concept of "regenerative" (i.e. restorative) agriculture (regenerative agriculture), which is understood as a set of non-destructive agricultural practices that ensure soil restoration in the process of managing. With the help of modern breeding methods, it is possible to obtain regenerative varieties with the appropriate characteristics and technical characteristics [8,9]. As part of the new climate agenda, it is necessary to develop varieties and types of agricultural plants, including fundamentally new ones, that would have the ability to suppress weeds, resist pests and diseases without the help of agrochemistry. Breeding these kinds of varieties and species is more complex than breeding for homogeneous, manageable, high-yielding systems. But it is necessary in the face of declining global resources with a growing population of the planet, as well as taking into account the inevitable introduction of strict carbon standards, fines, and quotas into the agricultural industry. The subject of breeding work should be non-obvious properties and point effects on molecular mechanisms, and not simple formulas like "yield / cost". Forests, in turn, are the main natural sink of greenhouse gases in terrestrial ecosystems in the world. As the world's leading forest power, Russia has natural capital in the form of forests accumulating 625 million tons of greenhouse gases annually. This gives Russia significant competitive advantages, since the absorption of greenhouse gas emissions by forests occurs without significant costs from the state, the cost of measures to reduce emissions - for example, to extinguish forest fires - is moderate (3 billion rubles per year) compared to other types of measures, for example, to improve energy efficiency in industry [7]. In general, in Russia there is a huge and still not used reserve for reducing the carbon footprint of products due to the existing protective and other categories of forests on agricultural lands. Forests located on agricultural land are of great importance for the absorption of greenhouse gases. If 1 hectare of forests on the lands of the forest fund absorbs on average about 1 ton of greenhouse gases per year, then 1 ha of protective and anti-erosion forests on agricultural lands - about 7 tons per year, i.e. 7 times more. At the same time, according to various estimates, from 40 to 90 million hectares of agricultural land in Russia are overgrown with forests, which are not yet taken into account in the national statistics of greenhouse gas absorption due to the fact that they do not belong to managed forests. Forest breeding should be aimed at obtaining varieties and species with high growth rates and high potential for carbon sequestration in the climatic conditions of Russia.

References

[1] Ivanov A.L., SavinI.Yu., Stolbovoy V.S., DukhaninYu.A., Kozlov D.N., Bamatov I.M. Global climate and land cover - implications for Russian land use, 2021, 107, pp. 5–32.

[2] Minutes of the meeting with the Deputy Prime Minister of the Russian Federation V.V. Abramchenko dated September 18, 2020 No. VAP1-68Pr.

[3] Paris Agreement. UN. 2015. 30 p. URL: http://unfccc.int/files/essential_background/convention/application/pdf/Russian_Paris_agreement.pdf (accessed 01/08/2022).

[4] Gakaev, R. Carbon sequestration in landscapes of the Chechen Republic. Reliability: Theory & Applications, 2022, 17, 3(66), pp.193-196.

[5] Rai, S.M., True, J., Tanyag, M. From Depletion to Regeneration: Addressing Structural and Physical Violence in Post-Conflict Economies. Soc. Politics Int. Stud. Gender State Soc. 2019, 26, 561–585.

[6] Van Heijster, H., van Berkel, J., Abma, T., Boot, C., de Vet, E. Responsive evaluation of stakeholder dialogue as a worksite health promotion intervention to contribute to the reduction of SEP related health inequalities: A study protocol. BMC Health Serv. Res. 2020, 20, 196.

[7] Psaradakis, Z. Vávra, M. Normality tests for dependent data: Large-sample and bootstrap approaches. Commun. Stat. Simul. Comput. 2020, 49, 283–304.

[8] Verfaillie, H., and R. Bidwell, Measuring Eco-efficiency: AGuide to Reporting Company Performance, World BusinessCouncil for Sustainable Development, Geneva, 2020.

[9] Andrijasevic, R.; Novitz, T. Supply Chains and Unfree Labor: Regulatory Failure in the Case of Samsung Electronics in Slovakia. J. Hum. Traffick. 2020, 6, 195–208.

[10] Kampschreur MJ, Temmink H, Kleerebezem R, Jettena MSM, van Loosdrecht MCM. Nitrous oxide emission during waste water treatment. WaterRes. 2019, pp.4093–4103.

INVESTIGATION OF GRANULOMETRIC AND CHEMICAL COMPOSITION OF SAMPLES OF UNDERWATER WELDING

Konstantin Kirichenko[1,2], Evgeniy Elovskiy[4], Kirill Golokhvast [1,2,3]

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[1] Siberian Federal Research Center for Agrobiotechnologies, RAS, r.p. Krasnoobsk, Russia
[2] Far Eastern Federal University, Vladivostok, Russia
[3] Pacific Institute of Geography FEB RAS, Vladivostok, Russia
[4] Far Eastern Geological Institute FEB RAS
kirichenko@sfsca.ru
golokhvast@sfsca.ru
yarovaya@sfsca.ru

Abstract

The article is devoted to the study of granulometric characteristics and chemical composition of samples of underwater welding for sea water from the water area from Ajax Bay (Sea of Japan) and fresh water. A high content of the smallest particles of metal oxides with a dimension of less than 10 μm was revealed.

Keywords: underwater welding, nano- and microparticles, ecology

I. Introduction

The first mention of underwater arc welding and metal cutting using an electrode date back to 1887. However, the laboratory experiments of Professor D. A. Lachinov and N. N. Benardos have not received practical application. They were remembered only by the beginning of the 30s of the twentieth century. K. K. Khrenov managed to create special electrodes suitable for underwater welding and metal cutting, both in fresh and salt water, which was confirmed by natural tests in the Black Sea [1].

At the beginning of 1932, Academician K.K. Khrenov conducted underwater experiments of electric welding with a metal electrode for the first time. On the basis of these studies, the main characteristics of the underwater welding process, the technology of execution were obtained, and electrodes for welding structures under water were developed. In 1936, underwater welding of metal structures was used in practice for the first time on the Black Sea, when the Boris steamer was lifted from a depth of 48 meters.

Welding of metals under water is the main way to obtain a non-split joint of two or more solids, characterized by interatomic bonding and continuity of the structure [2]. Underwater welding and metal cutting is widely used in the construction of modern oil and gas pipelines, as well as during repair and rescue operations on the water.

Nowadays, the need to extract and transport oil and gas along the seabed has led to the creation of underwater marine structures [3]. During construction, and especially during their operation, as a result of the effects of storms and corrosion, metal structural elements require repair. Given the size of oil producing offshore structures, or offshore gas pipelines, it is not possible to raise them to the surface or repair them in a dry underwater chamber, therefore it is necessary to conduct high-quality welding under water.

It should be noted that the technological process of welding under water includes the gorenje electric arc, as a result of which, the products of metal combustion and electrode coating get into the water. When they come into contact with water, they turn into suspended particles that form a cloud of turbidity around the burning arc. In this article, the dependence of the dynamics of particle size change on the arc burning time is investigated and a chemical analysis of emissions of underwater welding derivatives into the aquatic environment is carried out.

II. Experimental

Seawater for experiments was taken from the water area of Ajax Bay (Sea of Japan), near the FEFU campus. To measure the quantitative composition of suspended particles, a manual laser particle counter AeroTrak Handheld Particle Counter 9306 (manufactured in the USA) was used, which meets all the requirements of ISO 21501-4.

In continuation of the previously conducted studies [4] on atmospheric air pollution by welding and electrochemical industries for the most dangerous processes from a hygienic point of view – depending on the level of the smallest particles of the fraction PM0,3 and PM10 for further studies to measure the fractional composition of suspended particles formed during underwater welding (Fig. 1). The process of manual electric arc welding under water was chosen. This is a process for welding ferrous metal products (metal plate VSt-3sp, S= 8 mm) by manual electric arc welding using Kiswel KR-3000 electrodes with a rutile coating type, diameter 3 mm.

Atmospheric air sampling was carried out in the immediate vicinity at a distance of 1 m from the source of pollution (Fig.1) and at a height of 1.5 m, which corresponds to the level of human respiration.

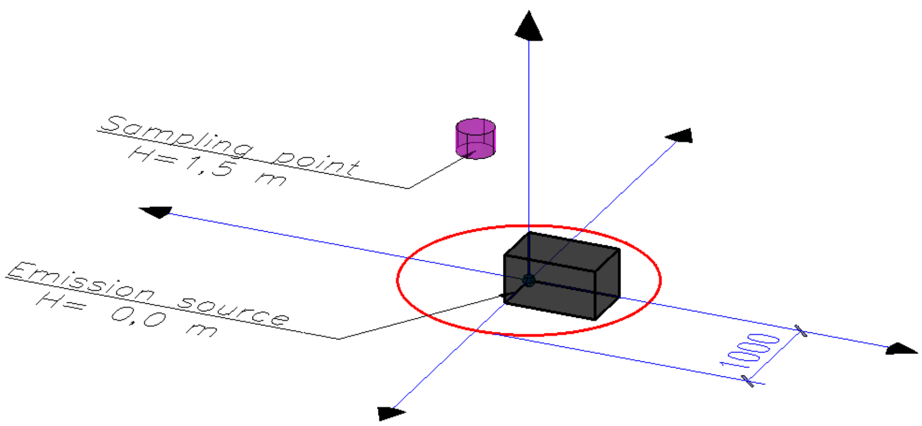

Fig. 1: *Location of sampling points when using the aquarium*

Particle size analysis

To measure the quantitative composition of particles, the laser diffraction method was used, which was used to determine the size of particles and study the dynamics of particle size changes over time. The analysis was carried out on a laser particle analyzer Analysette 22 NanoTec plus (Fritsch GmbH, Germany). The measurements were carried out with a range of fixed particles of 0.01-2000 microns, in 5 repetitions. MaS control software (Fritsch GmbH, Germany) was used to obtain the analysis results. The Mie scattering theory was used to calculate the particle distribution.

RT&A, Special Issue № 4 (70)
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Chemical analysis of particles

MS ISP method of water analysis after underwater welding.

After a laboratory experiment on underwater welding of materials, small dark-colored particles formed as a result of this process were clearly observed in seawater samples. The transfer to the dissolved state of these particles consisted of the following steps.

Step-1. Concentrated HNO3 (distilled near the boiling point) up to 5% by volume and concentrated HF (suprapur class) up to 0.25% by volume were added to a 50 ml test tube with seawater after underwater welding.

Step-2. A week later, the acidified aqueous solution was placed in an ultrasonic bath, where the temperature rose under ultrasonic exposure. At a temperature of 45-55 ° C and exposure to ultrasound, the acidified aqueous solution was kept for about 2 hours. When the temperature increased, the ultrasonic bath was turned off until the set temperature was reached, and the downtime was not taken into account. As a result of the procedure, small solid particles were dissolved.

Step-3. After cooling the solution to room temperature, its aliquot was diluted five times with deionized water.

Similarly, blank samples were exposed, which were samples of seawater prior to the relevant underwater welding experiments.

Further, on the Agilent 7700x device, in the mode of high-salt introduction "HMI" (High Matrix Introduction), mass spectrometric with inductively coupled plasma (MS ICP) determination of the following elements by the corresponding analytical masses took place:

– Group-1: Li (7), Be (9), B (11), Co (59), Ni (60), Cu (63), Zn (66), Ga (71), Rb (85), Sr (88), Y (89), Zr (90), Nb (93), Mo (98), Ag (107), Pd (108, to adjust the overlay on Mo), Cd (114), In – internal standard (115), Sn (118), Sb (121), Te (125), Cs (133), Ba (137), La (139), Ce (140), Pr (141), Nd (146), Sm (147), Eu (151), "BaO"-interference (154, for Eu overlay correction), "BaOH"-interference (155, for Eu overlay correction), Gd (157), Tb (159), Dy (163), Ho (165), Er (166), Tm (169), Yb (172), Lu (175), Hf (178), Ta (181), W (184), Re (187), Tl (205), Pb (208), Bi (209), Th (232) and U (238);

– Group-2: Al (27), Si (28), Sc (45), Ti (47), V (51), Cr (52), Mn (55), Ge (72), As (75) and In – internal standard (115);

– Group-3: Na (23), Mg (24), P (31), S (34), K (39), Ca (44), Fe (56), Se (78) and In – internal standard (115).

Group-1 was filmed in c mode passively operating octopole reaction system, that is, without the introduction of any collision and (or) reaction gas. Group-2 and group-3 are in low–energy helium (4.3 ml/min – helium flow; 3 V – potential barrier) and high-energy (10 ml/min – helium flow; 7 V – potential barrier) modes, respectively.

The following mathematical adjustments of mass spectral overlays were carried out:

– By finding the correction coefficient for Ru-containing and Mo-free solution, Ru isobars were subtracted at the 98th mass of Mo. Similarly, Sn isobars were taken into account at the 114th mass of Cd.

– At the 115th mass In, Sn overlays were adjusted based on the theoretical coefficients of the prevalence of Sn isotopes at the 115th and 118th masses.

– Isobaric overlays of oxides and hydroxides of Ba on the 151st analytical mass of Eu were taken into account according to the principles described in the work [7] with the following changes.

1. By obtaining the actual coefficients, the technique was adapted for the "HMI" mode from the mode focused on the introduction of low-mineralized samples.

2. Instead of the matrix approach, based on five equations (masses: 151-155), a matrix approach with three equations (masses) was used (as it turned out to be more accurate).: 151, 154 and 155).

3. The coefficients of formation of barium oxides and hydroxides were not found for each sample separately, but were calculated for Ba-containing and Eu-free solutions and transferred to other analytical solutions without changes.

The statistical sample consisted of 3 measurements for each experiment. Then the samples were transported to the laboratory of the REC "Nanotechnology" of the FEFU Polytechnic Institute for further research.

III. Results and discussion

It is known that the penetration of industrial aerosol particles through respirators increases with increasing flow velocity regardless of the type of particles and that the particle size is a significant factor affecting the penetration of combustible particles [5]. That is why the experimental work considered particles with a dimension of up to 10 microns, which have the greatest penetrating power [6] and are able to settle deep into the lungs of welders and workers of related specialties. Table 3 shows data on the mass and quantitative composition of suspended solid particles of welding aerosol during an experiment with seawater.

Table 1: *Welding spray. Quantitative composition of suspended particles (qty/cubic meter)*

Respirator number	**PM 0,3**	**PM 0,5**	**PM 1**	**PM 3**	**PM 5**	**PM 10**
◎	◎◎◎◎◎◎	◎◎◎◎◎	◎◎◎◎	◎◎◎	◎◎◎	◎◎

Table 2: *Particle size analysis. Results of granulometric analysis of welding aerosol samples*

Particle fraction range	0	15	30	45	60	exp	ctrl
	Particle size distribution, %						
<0,1 μM	15,36	9,67	9,01	13,96	5,46	0,00	0,00
0,1-1 μM	11,26	12,17	7,63	11,43	11,56	0,00	0,00
1-10 μM	34,49	32,68	16,79	36,34	25,32	0,01	7,84
10-50 μM	38,58	3,05	22,05	18,15	49,62	0,23	18,41
50-100 μM	0,02	0,00	0,00	0,01	0,58	0,18	0,09
100-250 μM	0,00	0,00	0,00	0,00	0,00	1,14	0,75
250-500 μM	0,00	0,01	0,00	0,00	0,00	4,57	4,68
500-1000 μM	0,28	23,60	21,25	10,86	2,39	4,82	6,22
1000-1500 μM	0,01	17,91	21,81	8,80	4,57	12,05	4,23
>1500 μM	0,00	0,92	1,46	0,45	0,51	77,02	57,77

Chemical analysis of particles

Results of determination of the concentration of elements in seawater, mcg/l (ppb). The concentrations were determined by inductively coupled plasma mass spectrometry on an Agilent 7700 x spectrometer (Agilent Techn., USA) [5]

Table 3: *Chemical composition*

Concentration, ppb	Svarka*1	Svarka*2	Fon
7 Li	144	150	140
9 Be	≤ 0,057	≤ 0,057	0
11 B	4815	5944	4849
23 Na	9020554	9773710	9398281
24 Mg	1119792	1181197	1166314
27 Al	487	492	92

28 Si	≤ 16000	28697	16578
31 P	86	145	123
34 S	533411	559774	562796
39 K	346340	368331	359836
44 Ca	434272	454397	457236
45 Sc	0	0	0
47 Ti	778	788	2
51 V	4	5	2
52 Cr	5	6	2
55 Mn	291	294	7
56 Fe	5671	5813	99
59 Co	1	1	1
60 Ni	8	9	6
63 Cu	71	67	59
66 Zn	538	519	33
71 Ga	0	0	0
72 Ge	0	1	0
75 As	2	2	2
78 Se	1	0	1
85 Rb	101	95	97
88 Sr	7418	7141	7304
89 Y	0	0	0
90 Zr	6	5	0
93 Nb	3	3	0
98 Mo	12	11	11
107 Ag	0	0	0
114 Cd	2	2	0
118 Sn	5	4	1
121 Sb	1	1	1
125 Te	≤ 0,19	0	≤ 0,19
133 Cs	0	0	0
137 Ba	17	16	9
139 La	0	0	0
140 Ce	0	0	0
141 Pr	0	0	0
146 Nd	0	0	0
147 Sm	0	0	0
151 Eu	0	0	0
157 Gd	0	0	0
159 Tb	0	0	0
163 Dy	0	0	0
165 Ho	0	0	0
166 Er	0	0	0
169 Tm	0	0	≤ 0,00044
172 Yb	0	0	≤ 0,0022
175 Lu	0	0	0
178 Hf	0	0	0
181 Ta	0	0	≤ 0,027
184 W	1	1	0
187 Re	0	0	0
205 Tl	0	0	0
208 Pb	4	3	1
209 Bi	0	0	0

232 Th	0	0	0
238 U	3	3	3

V. Conclusions

The results obtained indicate further work will be continued in the field of studying the toxicological effects of solid particles of underwater welding on representatives of marine biota and hydrobionts.

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References

[1] Shaferovsky, V. A. Welding and cutting of metal under water. Brief history / V. A. Shaferovsky // Modern problems of welding and related technologies, improvement of personnel training. pp.39-42.

[2] Shestakov S.A., Underwater welding and cutting of metal structures of offshore oil and gas facilities.// Volgograd : VolGASU, 2008.

[3] Kapustin K.Ya. Construction of offshore pipelines/ K.Ya. Kapustin, M.A. Kamyshev. M.:Nedra, 1982.

[4] Kirichenko K.Y., Pikula K.S., Zakharenko A.M., Gridasov A.V., Parshin S.G., Medvedev S.A.,Vakhniuk I.A., Golokhvast K.S. Ecotoxicological assessment of underwater welding impact during the construction of marine pipelines. Advances in Raw Material Industries for Sustainable Development GoalsPages 222 - 2292021 Advances in Raw Material Industries for Sustainable Development GoalsSaint-Petersburg27 November 2019 through 29 November 2019Code 172332.

[5] Penetration of combustion aerosol particles through filters of NIOSH-certified filtering facepiece respirators (FFRs). Gao, S., Kim, J., Yermakov, M., Elmashae, Y., He, X., Reponen, T., Grinshpun, S.A. (2015) Journal of Occupational and Environmental Hygiene, 12 (10), pp. 678-685.

[6] Popova S.Yu. "The results of using a device to reduce the level of dust in the workplaces of welders." Agro-industrial complex of Russia. 2010. Vol. 56. pp. 71-74.

[7] Elovskiy E. V. Mathematical elimination of spectral interferences in the direct determination of rare-earth elements in natural waters by inductively coupled plasma quadrupole mass spectrometry / E. V. Elovskiy // Journal of Analytical Chemistry. 2015. V. 70, n. 14. P. 1654–1663. DOI: 10.1134/S1061934815140063.

CHANGES IN THE HABITATS OF THE UNIONIDAE, EUGLESIDAE, PISIDIDAE AND SORBICULIDAE SPECIES WITH THE CONSTRUCTION OF RESERVOIRS IN THE KASHKADARYA BASIN DUE TO CLIMATE CHANGE

Husniddin Boymurodov[1], Khojamurod Jabborov[2], Tozagul Jabbarova[2], Bakhtiyor Aliyev[3], Omon Mirzamurodov[3], Azamat Egamqulov[3]

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[1]Samarkand Institute of Veterinary and Medicin, Uzbekistan
boymurodov1971@mail.ru
[2]Karshi State University, Uzbekistan
kardu@mail.ru
[3]Samarkand State University, Uzbekistan
monitor@samdu.uz

Abstract

In the Kashkadarya basin, the destruction of natural zoogeographic barriers under the influence of anthropogenic factors has led to the expansion of the range of invasive species. With the construction of reservoirs in the Kashkadarya basin, the range of Unionidae, Euglesidae, Pisididae and Sorbiculidae families has been expanded. There are 9 species and 1 subspecies of bivalve mollusks were found in Pachkamar, 11 species and 2 subspecies in Chimkurgan, 5 species and 1 subspecies in Kamashi, 7 species in Hisorak, 5 species in Dehkanabad, 3 species in Nugayli and 5 species in Yangikurgan.

Keywords: water reservoir, aquatic ecosystems, Unionidae and Corbiculidae families, *Colletopterum cyreum sogdianum, C. bacterianum,*

I. Introduction

The development of agriculture and industrial production in the world is also leading to an increase in demand for water resources. In this context, mollusks, which are an integral part of aquatic ecosystems, are of particular importance, as their diversity has been declining in recent years as a result of water misuse. Accordingly, it is important to determine the species composition of mollusks distributed in reservoirs, to determine the factors affecting their populations, and to develop measures for the conservation of rare species.

Much attention is paid to the inventory of mollusks in the watersheds of natural and geographical regions of the world, the identification of promising species and their introduction into production. In this regard, in particular, the status of the malafauna of water bodies of different continents was determined, their natural-geographical distribution and distribution depending on the characteristics of water bodies were assessed, measures were developed to preserve rare and endangered species. It should be noted that, unlike marine mollusks, the condition of freshwater basin mollusks, including biphasic mollusk populations and their survival are directly dependent on the variability and level of impact of environmental factors. In particular, the seasonality of the water level in the freshwater basins of the southern continent, the diversity of the source of saturation and their hydrological regimes are one of the main factors determining the distribution, viability and transformation of bivalve mollusks in different biotopes. However, in recent years, the depletion and pollution of freshwater sources has led to the crisis of biota of bivalve mollusks and the loss of species. Accordingly, it is of great scientific and practical importance to assess the status of biphasic mollusks distributed in different freshwater basin water types, to identify abiotic factors affecting their populations, and to develop conservation measures.

At present, special attention is paid to the protection and rational use of water resources in the country. In this regard, in particular, the state of the fauna of water bodies was assessed, the sources and scale of anthropogenic pollution were identified and measures to eliminate them were developed. The Action Strategy[1] for the further development of the Republic of Uzbekistan defines the tasks of "... prevention of environmental problems that harm the environment." Based on these tasks, it is important to determine the diversity of bivalve mollusks distributed in different water types of the Kashkadarya coast, to assess the impact of abiotic factors on their distribution, to introduce promising species into production.

Currently, one of the most pressing issues in the Kashkadarya Basin is the study of changes in the habitats of the families Unionidae, Euglesidae, Pisididae and Sorbiculidae with the construction of reservoirs in the context of climate change.

II. The level of the studied issue

In Uzbekistan, there is insufficient information on the distribution, morphology and resources of bivalve mollusks in different water bodies. This information is reflected only in the research of Z.I. Izzatullaev [1-5], H.T. Boymurodov [6-12] in which information on certain species in some water bodies of Uzbekistan can be found. These data could not provide sufficient conclusions on the modern species composition of mollusks of the families *Unionidae, Corbisulidae, Pisididae* and *Euglisidae*, which are ecologically important among the organisms of water basins macrobenthos, the influence of abiotic factors on their distribution. In this regard, an inventory of bivalve mollusks found in the aquatic ecosystems of the Kashkadarya coast, to determine the impact of abiotic factors on their distribution in water bodies and to study the prospects for their use in economic sectors is of great scientific and practical importance.

Today, the detection of new species in coastal marine, brackish and freshwater ecosystems around the world has increased significantly. In 1970, Starobogatov conducted research on the distribution and zoogeographic direction of species under the influence of anthropogenic factors. In addition to the natural causes of the distribution of different groups of mollusks in mainland watersheds, the importance of anthropogenic factors has also been highlighted. The presence of geographical barriers and zones influences the distribution of species, anthropogenic factors play a major role in the historical period in overcoming them mechanically.

III. Materials and learning methods

The study of mollusks and collection of materials from the aquatic ecosystems of the Kashkadarya Reservoir began in 2004. Changes in the habitats of the *Unionidae, Euglesidae, Pisididae* and *Sorbiculidae* families with the construction of reservoirs in the Kashkadarya basin in the context of climate change have not been sufficiently studied. Materials for research were

[1]Decree of the President of the Republic of Uzbekistan dated February 7, 2017 No. PF-4947 "On the Action Strategy for further development of the Republic of Uzbekistan".

collected in spring, summer and autumn of 2004-2021. A total of 2162 mollusks were studied. Specimens of these mollusks were studied by the methods given by different authors.

IV. Analysis and results

Reservoirs, fisheries and canals built under the influence of anthropogenic factors in the Kashkadarya basin have led to the destruction of natural zoogeographic barriers under the influence of anthropogenic factors and the expansion of the range of invasive species. With the construction of reservoirs in the Kashkadarya basin, the expansion of the range of species of the families Unionidae, Euglesidae, Pisididae and Sorbiculidae was revealed. Chimkurgan Reservoir was built in 1960 on the territory of Karshi and Chirakchi districts of Kashkadarya region, on the Kashkadarya River, the area of the reservoir is 49,2 km^2, length 17,5 km, width 7 km. The total capacity of 500 million m^3 of water surface level varies throughout the year.

Irrigated area is 38 thousand h. forms. Chinese complex fish are *Colletopterum ponderosum volgense* and Chinese toothless mollusks with fish in the reservoir as a result of acclimatization of white amur (*Ctenopharyngodon idella*) and white-tailed deer (*Hypophthalmichthys molitrix*) to the Chimkurgan Reservoir.

Sinanodonta gibba, S. orbicularis, S. ruerorum are widespread and habitats are expanded. *Sinanodonta orbicularis, S. puerorum, Colletopterum cyreum sogdianum* from the Unionidae family, *Euglesa hissarica* from the Euglesidae family, *Odhneripisidium terekense* from the Pisididae family, *Corbicula cor, C. fluminalis, C. purpurea, Corbiculina tibetensis, C. ferghanensis* were found in the Corbiculidae family. The long existence of the reservoir has had an impact on species diversity. With the waters and fish of the Chimkurgan Reservoir, the distribution of species of the *Unionidae* and *Sorbiculidae* families to fisheries, canals and ponds receiving water from this reservoir and the expansion of the range of these species was observed. Pachkamar Reservoir was built in 1967 on the Guzar River. The reservoir area is 16,8 km^2, the water volume is 260,0 million m^3, the irrigated area is 15,5 thousand h. Currently in the ecosystems of the reservoir *Sinanodonta gibba* from the family Unionidae, *S. orbicularis, S. puerorum, Colletopterum bactrianum, C.cyreum sogdianum, C. ponderosum volgense*, *Euglesa obliquata* from the family Euglesidae, *Odhneripisidium sogdianum* from the family Pisididae, *Odhnerip* from the family Pisididae, *C. purpurea, Corbiculina tibetensis, C. ferghanensis* from the Corbiculidae family species distribution are studied.

Prior to the construction of the reservoir, it was noted that only species of the Corbiculidae family were distributed in the aquatic ecosystems of this area of the Guzar River. Kamashi Reservoir was built in 1957 in the Shurchasoy natural basin, 4 km from Kamashi city. The total volume is 17,3 million m^3 and the useful volume is 16 million m^3. The maximum depth is 12,0 meters and the average depth is 6,0 meters. The surface area is 1,5 km^2. Irrigated area is 1,6 thousand h. After the construction of the reservoir, *Sinanodonta gibba* from the Unionidae family, *Colletopterum.cyreum sogdianum, Corbicula cor, Corbiculina tibetensis, C. ferghanensis* from the Sorbiculidae family led to the spread in the waters of this region. Hisorak Reservoir was built on the Aksuv River, a tributary of the Kashkadarya River in the Kashkadarya region. Built in 1983-1988. The total volume is 170 million m^3, useful volume is 161,6 million m^3. The length of the rocky dam is 666 m. height 138 m, water surface 4,2 km^2, water discharge capacity 200 m^3/s, drainage structure 130 m^3/s. It is not indicated that species of the Unionidae and Sorbiculidae families were distributed before the construction of the reservoir on the Aksu River. Currently, the reservoir is home to *Sinanodonta orbicularis, S. puerorum* from the Unionidae family, *Euglesa turkestanica* from the Euglesidae family, *Kuiperipisidium sogdianum* from the Pisididae family, *Corbicula fluminalis,* C. purpurea, *Corbiculina tibetensis* species from the Corbiculidae family.

The Dehkanabad Reservoir was established to ensure a certain flow of the Uradarya River. The reservoir was established in 1981 and has a total capacity of 27,2 million m^3. The maximum height of the dam is 36,2 m, the maximum discharge capacity is 12,0 m^3/sec. *Euglesa hissarica, E. turkestanica* from the family Euglesidae, *Corbicula fluminalis, C. purpurea, Corbiculina tibetensis* from the family Corbiculidae are distributed in aquatic ecosystems.

Nugayli reservoir is located in the Kashkadarya basin and has an area of 0,587 km^2 and a volume of 0,50 million m^2. Founded in 1975, the irrigated area is 1,8 thousand h. forms. The species *Corbicula cor, C. fluminalis, Corbiculina ferghanensis* from the family Corbiculidae are widespread in the reservoir and their habitats have expanded. Yangikurgan Reservoir - The Yangikurgan Reservoir was built in 1975 on the banks of the Yakkabogdarya River and covers an area of 1,5 km2. The annual water volume is 1,62 million m3. The construction of the reservoir led to the spread of *Euglesa obliquata* from the family Euglesidae, *Kuiperipisidium terekense* from the family Pisididae, *Corbicula purpurea, Corbiculina tibetensis, C. ferghanensis* from the family Corbiculidae. With the establishment of artificial water types in the Kashkadarya basin, the distribution of the distribution areas of bivalve mollusks of the families Unionidae, Euglesidae, Pisididae and Corbiculidae is expanding under the influence of anthropogenic factors. Seed species of *Sinanodonta, Colletopterum, Euglesia, Kuiperipisidium, Corbicula* and *Corbiculina* are distributed in canals, fisheries and ponds with water and fish from reservoirs in the river basin. Reservoirs and canals Unionidae and Corbiculidae families are reservoirs that are suitable for the distribution of species. The canals that flow into and out of the reservoir are the source and route of interfacial distribution of bivalve mollusks in the Unionidae, Euglesidae, Pisididae, and Sorbiculidae.

The disturbance of the balance of the aquatic ecosystem of the Kashkadarya basin, in particular, the disturbance of the water regime, to some extent affects the number and density of bivalve mollusk species studied in new areas. Under unstable ecosystem conditions, natural changes in the number of typical species of mollusks are observed. Changes in the taxonomic composition of the fauna of bivalve molluscs (stenabiosis prone to anthropogenic factors and a decrease in the number of rare, endangered species in a narrow range) are observed under changing environmental conditions.

In the Kashkadarya reservoirs, the density of mollusks has been observed to increase over the years. The scientific results of the distribution of bivalve mollusks in the Kashkadarya basin and their use in various sectors of the economy are important. Corbicula corbicula, Corbicula fluminalis, Corbicula purpurea, Solletopterum bactrianum, Colletopterum cureum sogdianum, distributed in the Kashkadarya basin, are included in the Red Data Book of Uzbekistan as endemic and rare species.

V. Conclusions

Reservoirs, fisheries and canals built under the influence of anthropogenic factors in the Kashkadarya basin have led to the destruction of natural zoogeographic barriers under the influence of anthropogenic factors and the expansion of the range of invasive species. With the construction of reservoirs in the Kashkadarya basin, the range of Unionidae, Euglesidae, Pisididae and Corbiculidae families has been expanded. There are 9 species and 1 subspecies of bivalve mollusks were found in Pachkamar, 11 species and 2 subspecies in Chimkurgan, 5 species and 1 subspecies in Kamashi, 7 species in Hisorak, 5 species in Dehkanabad, 3 species in Nugayli and 5 species in Yangikurgan are studied first time by us.

References

[1] Izzatullaev Z.I., Boymurodov X.T. Results of the development of two-limbed preservative mollusks (Bivalvia: Unionidae, Anadontinae) in Uzbekistan // Journal of the Moscow Society of Experimental Nature. – Moscow, 2016. p.16-19.

[2] Izzatullaev Z.I., Boymurodov H.T., Egamqulov A,N., Otaqulov B.N, Hojiyev M.B., Bobomurodov Z.A., and Suyarov S.A., Freshwater Bivalve Molluscs in Artificial Reservoirs of Uzbekistan // International journal of current microbiology and applied sciences 2019.-2184-2188.

[3] Izzatullaev Z.I. Mollyuski vodnikh ekosistem Sredney Azii. // Monografiya. – Toshkent: Lessonpress, 2018. 109-121 c.

[4] Izzatullaev Z.I. Fauna mollyuskov vodnых ekosistem Sredney Azii i sopredel'nikh territoriy. Monografiya. Toshkent: «LESSON PRESS», 2019. – 420 s. (v pechati).

[5] Boymurodov X.T., Izzatullaev Z.I., Egamqulov A.N., Otaqulov B.N., Hojiev M.B., Bobomurodov Z.S., Sovremennoe sostoyanie populyatsii Colletopterum baktrianum rolle 1897 v vodoemax Uzbekistana // Bulletin of Science and Practice Scientific Journal.- 2020.-28-34 b.

[6] Boymurodov Kh.T., Khasanov N. Influence of abiotic factors on biodiversity of the populations of bivalve molluscs of the Lower Zarafshan reservoirs. E3S Web of Conferences 265, 01012 2021 https://doi.org/10.1051/e3sconf/202126501012 RUDN 2021

[7] Baymurodov Kh. T. Advanced studies in science: theory and practice, The Collection of Scholarly Papers Materials of the International Scientific Conference, 239-242 (2016)

[8] Baymurodov Kh. T. The Significance of Dicotyledonous Mollusks of the Unionidae Family in the Aquatic Ecosystems of Uzbekistan in Food and Economy Bulletin of Pure and Applied Sciences. Vol.40 B (Botany), No.1. January-June 2021: P.8-12. Orginal Research Article

[9] Baymurodov Kh. T., Suyarov S.A.Bivalve mollusk fauna and ecological groups of Unionidae and Corbiculidae families in natural and artificial reservoirs of Uzbekistan E3S Web of Conferences 265, 01014 (2021) https://doi.org/10.1051/e3sconf/202126501014. RUDN 2021.

[10] Boymurodov X.T. Ikkipallali mollyuskalarning inson tomonidan barpo etilgan suv havzalarida tarqalishi va biologik xilma-xilligi // O'zbekiston biologiya jurnali. –Toshkent, 2010.–№6.–B.41-44.

[11] Boymurodov X.T. Ikkipallali mollyuskalarning adir mintaqasida barpo etilgan suv omborlarida tarqalishi va biologik xilma-xilligi // O'zbekiston biologiya jurnali. –Toshkent, 2013.–№2. –B.29-32.

[12] Boymurodov X.T. Amudaryo sohili suv omborlari ikkipallali mollyuskalari faunasining shakllanishi, biologik xilma-xilligi va ekologik komplekslari // O'zbekiston biologiya jurnali. –Toshkent. 2013. –№ 4. –B. 38-41.

RISK MANAGEMENT ANALYSIS

Deshy Musostova[1], Valentina Dzobelova[2], Varvara Markaryan[3]

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[1]Chechen State University, Grozny named after A.A. Kadyrov, Russia
goldzr@yandex.ru
[2]North-Ossetian State University named after K.L. Khetagurov, Russia
dzobelova@mail.ru
[3]Krasnodar Branch of Financial University under the Government of the Russia
markarianvr@gmail.com

Abstract

Risk as an integral part of the political, economic and social life of society invariably accompanies absolutely all spheres and activities of any corporation operating in market conditions. Risk management is especially relevant in the face of economic uncertainty, the volatility of the national currency, active technological development and tougher competition. In 2020, the Russian risk management standard for a commercial company based on ISO 31000 was developed, but the procedure for its application has not yet received a comprehensive study, which determines the relevance of the chosen research topic.

Keywords: risk, risk management, risk analysis, risk management, risk management standard

I. Introduction

Risk management (risk management) is an integral structural element of corporate management, implemented at all levels of the management system and contributing to the sustainability and efficiency of the organization. The principles, infrastructure and process of risk management are described in the new Russian standard GOST R ISO 31000-2019 [1], which is completely identical to the international standard ISO 31000:2009 Risk management - Principles and guidelines.

In accordance with the specified standard, the risk management system includes the following structural elements (Fig. 1).

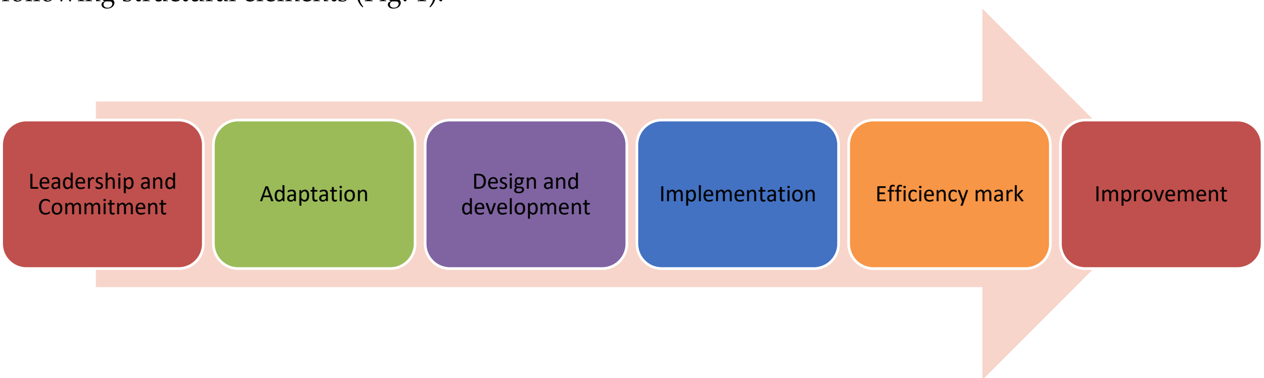

Figure 1: *Structural elements in the risk management system*

The Leadership and Commitment component is the basic structural element of risk management that influences all other aspects of risk management in the organization. Senior managers are responsible for implementing risk management in all areas of the company, while the main tasks are the following:

- integration of all components of the risk management structure;
- establishment of a clear procedure for the implementation of risk management;
- allocation of resources for the organization of risk management;
- distribution of powers and responsibilities at all levels of the company's functioning.

Carrying out these activities will allow the company to solve a number of issues, including: bring risk management in line with the goals and objectives facing the company, ensure the fulfillment of obligations assumed by the company, choose a risk level acceptable to the company and corresponding to the risk criteria used, implement systematic monitoring of risks, demonstrating its benefits to company employees and stakeholders.

Risk management activities are organized by senior managers, while the owners of the corporation may appoint supervisory authorities that may require the company to comply with the following points:

- consideration of risks in accordance with the goals and objectives of the company;
- assessment of risks arising in the course of the company's activities;
- ensuring the effectiveness of the implementation of risk management systems;
- timely exchange of up-to-date information on the state of risks and the effectiveness of their management.

Adaptation in the risk management system involves ensuring the comparability of the risk management system with industry specifics, organizational structure and the current state of the company. At this stage, it is supposed to determine the optimal management methods, the distribution of responsibility, and the development of an adequate system of control over risk management. Adaptation is a dynamic process that is implemented not only at the stage of risk management implementation, but also at all bifurcation points that cause a change in the standard state of the business system.

II. Methods

Designing and developing a risk management system at the corporate level involves a comprehensive analysis of its external and internal environment. The study of the external environment can be carried out using the PEST-analysis method, which involves an assessment of the political, macroeconomic, social and technological aspects of the functioning of the organization. Also at this stage, an industry analysis is carried out to compare the potential risks of the organization with the closest competitors in the industry and region. Analysis of the internal environment involves a detailed study of the production, financial and marketing subsystem of an economic entity using methods such as SNW analysis, SWOT analysis and others. Model 7S McKinsey allows you to identify the risks emanating from the seven basic organizational components of the company.

III. Results

Top managers of the company must ensure that the necessary resources are available to provide the system, which include appropriate technology, staffing and an information system that provides automation of risk management. At the design stage of the risk management system, mechanisms for data exchange and consultative interaction between departments should also be developed and approved, ensuring the generation and neutralization of risks.

Corporations implement a risk management system by developing a plan indicating the necessary resource and time costs, allocating responsibility in the field of risk management, as well as ensuring a clear understanding of the methods and risk management mechanisms that can be used within a particular organization. An adequate risk management system should be integrated into the corporate governance system and have a high degree of efficiency in terms of the ratio of returns and costs incurred.

To assess the effectiveness of the risk management system, the following is carried out:

- regular comparison of plans and actual indicators of the functioning of the economic system;
- analysis of the relationship between the functioning of the risk management system and the achievement of specific goals of the corporation.

Based on the results of monitoring the effectiveness of the risk management system, directions for its improvement are developed. In accordance with GOST R ISO 31000-2019management should continuously improve the applicability, adequacy and effectiveness of the risk management framework, as well as the tools for integrating the risk management process within the corporation.

The project risk management process is based on four basic principles. The first principle is the awareness of making a risky decision. This principle means accepting the existence of risks, working on their analysis and developing measures to reduce and neutralize risks. The second principle is the correlation of the level of risks of economic activity with the size of the expected profitability. This principle means that decisions should not be made, the costs of implementation of which may be higher than the expected profit. The third principle is reasonable economy. The cost of activities should not exceed the potential adverse effects. The fourth principle is taking into account the time factor and its influence on the nature of financial and business operations.

Risk management is carried out on the basis of their classification by time, place of occurrence, form of manifestation and impact on the activities of the economic entity. The negative results of the impact of risks are the occurrence of a direct loss, lost profit or lack of the desired result of the committed economic actions (for example, the inefficiency of an investment project). Within the framework of risk management, typical varieties of risk can be differentiated according to the source of occurrence (internal or external environment), as well as the priority of analysis and management impact.

So, the category of financial risks includes market, credit and investment risks. Market risk is the risk of financial losses of the organization associated with the transformation of product prices due to changes in the interest rate, volatility of the national currency, various fluctuations in the commodity and stock markets. Credit risk is associated with the possibility of a borrower's refusal to repay obligations, as well as a decrease in the cost of debt security due to various external circumstances.

Investment risk is determined by the possibility of not obtaining the expected effect from investing resources in a specific investment project for upgrading equipment, expanding production, diversifying activities or opening a new business. The probability of negative consequences of investing in proven goods and services is much lower than the risks associated with the introduction of fundamentally new products to the market, therefore, innovative risks are often distinguished in the structure of investment risks.

Operational risk is determined by the possibility of losses due to the poor quality of the organizational structure, errors or fraudulent actions of employees, problems in interaction with counterparties. Production risks are associated with equipment breakdowns, technology violations, software failures and other similar factors.

The risks of the external environment are associated with changes in the situation in the industry, country or region, the transformation of the political course, the increase in tax burden and changes in legislation, including those regulating licensing and standardization in the field in which the company operates.

The listed categories of risks are subject to further detailing. According to the Aon global risk management study, the most serious risks threatening modern enterprises are the following categories of risks (Fig. 2).

Figure 2: *The most serious risks of modern enterprises according to Aon [3]*

Risk management in business systems involves the choice of one of the four basic models to counteract the negative consequences of decisions (Fig. 3).

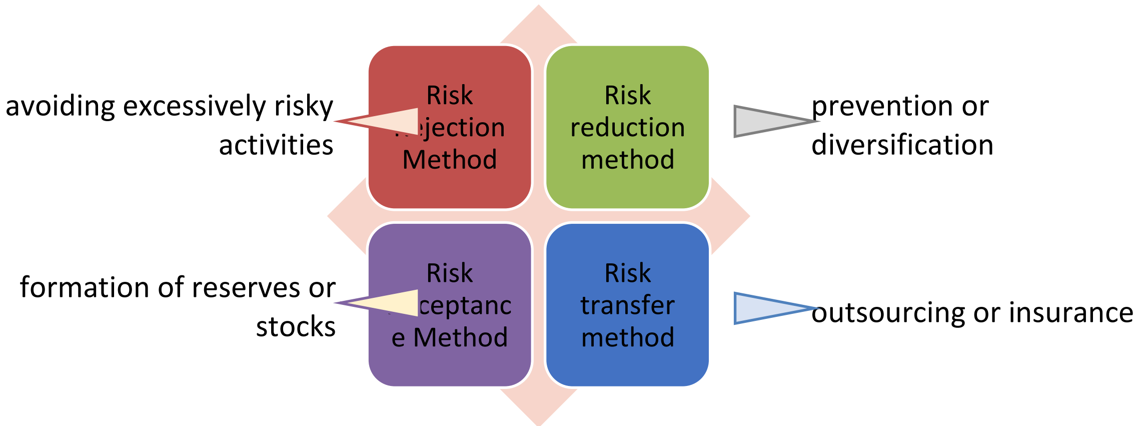

Figure 3: *Methods of risk management in modern business systems [2]*

IV. Discussion

The risk rejection method is a universal management tool in risk management, which consists in rejecting unreasonable investment in high-risk assets, cooperation with an unreliable counterparty, and the use of borrowed capital in an economic downturn. The presented method allows you to fully eliminate financial losses, while its use does not allow you to acquire additional income. The rejection of all categories of risks leads to the loss of efficiency in the use of equity capital and, ultimately, to the bankruptcy of the company.

The risk reduction method is provided through such tools as cost limits, careful analysis and control of ongoing projects, diversification of activities and the formation of an optimal portfolio of projects in order to reduce the likelihood of a complete loss of funds invested in their implementation. The company can diversify its products, investments, securities, portfolio of loans and deposits. Diversification can be carried out both on the scale of all activities and individual projects, which allows you to neutralize the consequences of management errors and underestimation of the negative consequences of individual management decisions. This tool is of the greatest importance for neutralizing technical, technological, marketing, financial and complex risks, while diversification is completely ineffective against political, legal, inflation and tax risks affecting all areas of the organization. Risk reduction can be achieved through hedging - "opening transactions in one market to compensate for the impact of price risks of an equal but opposite position in another market" [2].

Minimization of risks in the financial and economic activities of the company can be ensured by their partial transfer to a third party - an insurance company or partner. So, for example, in exchange for appropriate financing, partners are transferred part of the risks, for which they have the appropriate tools to neutralize. In particular, to reduce the risks of settlements with debtors, such a tool as factoring is used - a type of trade and commission operation, combined with financing of the client's working capital against the assignment of a monetary claim.

Currently, it is customary to differentiate factoring with the right and without the right of recourse. The first option implies that the factoring company (usually a bank) acquires the right to the full amount of debt obligations from the creditor, but if it is completely impossible to collect it, the bank will demand it from the client. In the second case, the risk of non-payment is fully borne by the bank, therefore the price of this service increases significantly. Insurance allows you to avoid the risks associated with various force majeure circumstances - loss of property as a result of theft, fire, traffic accidents. Risk outsourcing involves the transfer of risk assessment and management functions to a specialized organization (for example, a broker).

The risk acceptance method involves independent management of existing risks by creating additional reserves to compensate for the negative consequences of uncertainty. In accordance with the current legislation, the organization has the right to create and reflect the following types of reserves in accounting:

- allowance for doubtful debts (clause 70 of the Order of the Ministry of Finance of July 29, 1998 No. 34n);
- reserve for depreciation of inventories (clause 30 of FSBU 5/2019);
- provision for depreciation of financial investments (clause 38 PBU 19/02).

Other types of reserves and stocks can also be formed to maintain the company's stability in the face of risk.

This category also includes the method of localization, which is most applicable to project risks. So, for example, to manage innovation risks, independent venture companies can be established that accumulate project resources received from the parent company and investors. Venture companies assume all the risks associated with the implementation of a particular project, while the founders are liable in case of project failure only within the amount spent on its financing.

Thus, risk management of financial and economic activities is a complexly organized system that uses certain principles, methods and technologies that ensure the sustainability and efficiency of the company in the long term.

References

[1] GOST R ISO 31000-2019 Risk management. Principles and Guidance: Official publication. – M.: Standartinform, 2021.

[2] Vyatkin, V. N. Risk management: textbook / V. N. Vyatkin, V. A. Gamza, F. V. Maevsky. - 2nd ed., revised. and additional - Moscow: Yurayt Publishing House, 2021. - 365 p.

[3] Global Risk Management Solutions 2021. - URL: https://www.aon.com/ (Accessed: 07/10/2022).

POLLUTION AND RISKS IN PAMIRO-TIENSHEN-BURIAL GROUNDS OF URANIUM AND OBSOLETE PECTICIDES

Igor Hadjamberdiev[1], Ibragimjon Domulajanov[2], Ikromjon Mamadov[3]

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[1]International University of Kyrgyzstan – High Medical School, Bishkek, Kyrgyzstan
igorho@mail.ru
[2] Polytechnical Institute of Ferghana and Society Eco Ferghana, Uzbekistan
domulajanovi@mail.ru
[3]Youth group for Environment Safety, Khujand, Tajikistan
info@ygpe.tj

Abstract

There are huge environmental problems in Central Asia (CA) due to dozens of former USSR uranium tailings and abandoned obsolete pesticides warehouses. 17% of TienShan-Pamir territory (Kyrgyzstan, Tajikistan, Uzbekistan) is considered to be the worst polluted areas. We studied radioactivity in uranium area and radiation absorbed by humans in these areas. We have determined the other harmful toxicants - obsolete pesticides which still being used illegally. It has been concludes that immunity system are very vulnerable to combined harmful impacts mentioned above. Scientific studies were conducted in local settlements - school workshops in local languages including videos, presentations and leaflets.

Keywords: uranium burial ground, obsolete pesicides, immunity, health, radioactivity

I. Introduction

The complex of USSR uranium mines-tailings-dums includes: Taboshar, Adrasman, former Chkalovsk – Tadjikistan; Cherkesar [1], Jangiabad- Uzbekistan; Sumsar, Shekaftar, and Mailuu-Suu area. Latest one - huge complex consists of 23 tailings and 13 dumps (total volume of 2 million cubic meters, weighing more than 4 million tons).

Taboshar has radiation of 350 μR/hour in many areas. In addition, there is an artificial lake above the city filled with water and acid from the nearby mines. The level of background radiation there is 200-300 mcr/hour. The acid used is a highly potent underground leaching agent for uranium ore. The main "tailing dump" in the area of Goziyon village. According to experts, there are open highly radioactive sites in this territory, where sanitary-permissible standards are exceeded 10 times. The situation is even more depressing in the storage facility itself, in the Degmay area, where about 20 million tons of uranium ore processing waste has been collected to date. In some parts of the Taboshar, and in Adrasman level of radiation background reaches 1590 microroentgens/hour and even 1700 microroentgens/hour

Outdated technology in the 50s and 60s resulted in the sludge containing high concentrations of uranium. Poorly made tailings beds led to continuous infiltration and washout of uranium into the water of the river - which is the source of drinking water for the inhabitants. The following samples were examined: the content of uranium in open water sources and drinking water in the region and the content of uranium in food products. One of the most dangerous was the water-food route of radionuclides. In some areas of the city and houses, radon exposure was very dangerous.

Obsolete pesticides in Central Asia land are infiltrated from more than 360 warehouses and more than 200 old fly grounds for micro-planes (which had used for DDT pulverizing in 60th-70th). This leads to rise, crop and cotton lands pollution due to the outdated agricultural technologies. Water pollution comes from upper layer (Tien-Shen, Kyrgyzstan) to Uzbekistan. There were several accidents in 2013 on the South-East of Tien-Shen (Kyrgyzstan and Uzbekistan) when many domestic animal died.

The main sources of obsolete POP pollution are: old abandoned warehouse that has been ransacking by inhabitants, additionally POP (include DDT) imported illegally from India and China. There is a huge problem of finding correlation between the level of pollution and health status. Because: a) there are several different (not one) illnesses; b) the illnesses can come out in tenth years after body intake. So, we decided studying essential/basic health status: a) pre-illness state by compliance, b) base-immunity levels (blood cells and CD proteins).

II. Methods

Our study is based on chemical pollution health estimation by original medico-geographical ranking [2] and methods of health-area calculation [3]. Laboratory determination is based on Manual book [4], POP determination is done in accordance with recommendation of EPA US (devices: HP 5890 II Gas Chromatograph, Mass Spectrometer with HP MS Chemstation, etc). Selective determination was done for chromosomal-crash test [5]. Ordinary clinical data**:** clearance of urine; goiter 4 hormones, ALT/AST liver-mark ferments. We chooses for study most vulnerable groups: women 20-35 years, teenagers 11-16 years.

III. Results

A survey of residents showed that the content of leukocytes in 32% of schoolchildren was reduced due to neutrophils, while toxic granularity of neutrophils was registered in 14%, and thrombocytopenia in 18% - such shifts are characteristic of chronic diseases, including a mild form of radiation sickness. There are a number of other indicators of adolescents that indicate a low basic level of health: weakness of the immune system (IgA, IgG proteins) and a decrease in the functional activity of the thyroid gland.

Table 1: *Radiation background rate in Mailusuu uranium area*

Place of survey	Radiation rate mcRn/h
In the office premise of the combine On the territory of combine	16-40 18-22
Tailing dump N8 on average On soil cut and on hatch	20-30 50- 120
Tailing dump N3 on average On soil cut and in the hatch On 2 abnormal sites at the end of the tailing dump	25-30 180 – 120 500
Tailing dump N9 on average On soil cut and in the underground water	18-40 60
Tailing dump N22, in the adit N51 Inside the adit (7 m)	100 – 240 240
At the entry to adit N1 Inside the adit (10 m)	600 150
“Intourist” hotel	18-22

POP in waters by study 2015-2020. North Tien-Shen Chui river (Kyrgyzstan) the sum of alfa-, beta-, gamma-, delta HCH 8,5x10^{-3} mg/litre, Aldrin 1,5x10^{-3}, sum of DDT-DDE group 13,6x10^{-2} mg/l; Board South Tien-Shen and Pamir Vakhsh river, point intern to Amu-Darja - the sum of HCH 1,45x10^{-2} mg/l, Aldrin 9,0x10 $^{-3}$, DDT-DDE group 4,64x10^{-2} mg/l.

Woman milk WHO- TEQ values were observed (median: 36.0v44.1 pg/g fat) and the highest PCDD-TEQ was in Jalal-Abad rural region hot spots (Kyrgyzstan). The calculated median daily intake of the total TEQ for breast-fed infants ranged from 391 pg/kg b.w./day in the vulnerable region, but more less in Aravan and Osh regions (117 pg/kg b.w./day). It has been counting daily income of POP, they over permitted level (EU and EPA) 3-5 times. Polyaromatic hydrocarbonates (PAHs) were determining in home dust latest year only. We did previous/screening analysis in several rooms in two areas (previous results: 36 μg/m2 and 90 μg/m^2).

Health markers

Many inhabitants has answer special questionnaire – complain cardiovascular-breath systems, allergic reaction, etc. There are 10-22% of hepatic disturbance tests in studying groups. Blood analysis of women and teenagers show low level of immune proteins. Ethnic factor did not influence results. Cells immunity of teenagers: phagocytes activity tests from clear area 40,67±2,23; fall in to two unfortunate areas 32,06±1,85; 33,29±1,98. The protein immunity shown in table 2.

Table 2: *Teenagers protein immunity in POP polluted area*

Indicators	Data of inhabitants in polluted area	Control set
CD3, %	32,55±0,89*	45,9±0,95
CD4, %	18,70±0,51	27,1±0,83
CD8, %	17,14±0,45*	20,1±0,92
CD4/CD8	1,05±0,08*	1,61±0,05
CD19, %	20,61±0,30*	15,6±0,72
IgA, g/l	2,23±0,11	2,55±0,14
IgM, g/l	1,08±0,09*	1,88±0,22
IgG, g/l	11,50±0,68*	15,02±0,59

Foot note: *statistical validity of difference (P<0,5) compare with control set

IV. Discussion

However, few scientific paper on oncology in the polluted areas were published. One of them named "Women uterus cancer level in Kyrgyzstan". Authors studied the most polluted rural areas of Jalal-Abad oblast – 14,98 /for 100 thousands, second level - Osh oblast 11,8. The authors predict the rise of oncology illnesses [6]. We are completely agree with the authors because there are common impacts of two toxicants should be more dangerous [7;8].

Concerning juridical fields. The Stockholm`s, OPCW`s, Rotterdam`s, Aarhus`s Convention was officially adopter in four CA states. But there are big problems with the implementation of treaties mentioned above. The obstacles are: lack of wide net of points for analyzing, lack of contemporary devices; misunderstanding and confusion by big international documents of people in rural areas, people national features. Short color leaflets and movies (that we had done) are found useful [9]. Our work has been supporting by Swiss Green Cross and IPEN.

References

[1] Aitmatov J.I., Aparin K.B. "Tailing dumps of radioactive wastes and their effect on the environmental components, on the territories of U mines Mailusuu and Charkesar". "Science & New technologies", N3, 2003.

[2] Hadjamberdiev I. Computer-cartography estimation of health-dangerous locus in Tien-Shan. In: 3rd Intern. Conf. Env. Impact Assessment, Prague 23-26 Sept 1996. Prague: Czech Technical univ, 1996, v.4, p.703-705.

[3] Disease Mapping and Risk Assessment for Public Health, Chichester - N.Y., Wiley 1999, 482p.

[4] A Laboratory Manual of Analytical Methods of Protein Chemistry (Eds: P. Alexander,H. P. Lundgren) London: Pergamon Press, 2014, 244pp.

[5] Method chromosomal aberration as biological indicator environment impact on human. Genetic Inst. Moscow, 1974, 42 pp. (in Russ).

[6] Ormonov J.A., Kamarly Z.P., Jumabaev A.R. Oncology in Jalal-Abad area. In: Physiol, morphol. and pathology of human in Kyrgyzstan. Special vol. of Medical Faculty of Kyrg. – Russ. Univ., Bishkek, 2012, p.183-185.

[7] Hadjamberdiev I., Prokhorenko V., Tukhvatshin R., Zhakipova I. Common Radioactivity and Pesticides Health Impact in Central Asia Abstr. Glasgow SETAC meeting, 2013, sect 3.

[8] Hadjamberdiev I**.,** *S*.Begaliev, A.Husainov Pesticides – danger! Bishkek, booklet, 2014, 38 pp., (in Russ, Kyrgyz, Uzbek), IPEN-IPEP supporting.

GEOPHYSICAL AND GEOCHEMICAL STUDIES ON AN ACTIVE VOLCANO (EBEKO VOLCANO, PARAMUSHIR ISLAND)

Sofiya Kokhanova, Dmitry Kucher, Sergey Volynkin
•
Trofimuk Institute of Petroleum Geology and Geophysics SB RAS, Russia
KokhanovaSP@ipgg.sbras.ru
infor@ipgg.sbras.ru
volyunkin@ipgg.sbras.ru

Abstract

Investigations on Ebeko volcano, Paramushir island are presented: microelectrotomography on a thermal field, and the results of a mercury survey in a nearby city after an ash fall. High levels of mercury vapor in the air indicate the unfavorable ecological situation of the settlement. According to the results of electrotomography, we can talk about the thermal field subsurface space: the structure of the boiling mud pots and the presence of the gas phase.

Keywords: electrotomography, gas analytics, modern volcanology, mercury observation

I. Introduction

There are not many cities in close proximity to modern active volcanoes. And, despite the small number of objects, they are not studied so well [1, 4]. In this paper the city of Severo-Kurilsk on the Paramushir island studied, with a registered population over 3000 people. Ebeko volcano is located about 7 km from the city.

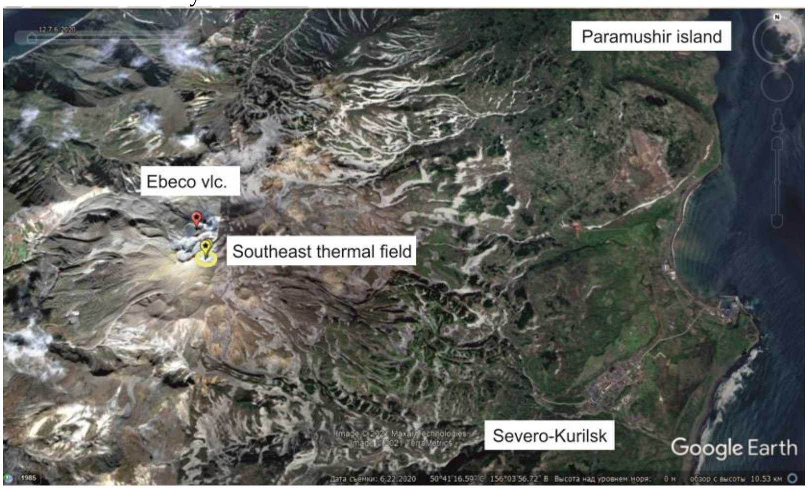

Figure 1: *Schematic map of the study area*

II. Methods

The electrical resistivity tomography (ERT) and mercury observation were carried out at the Ebeco volcano at 2021 [2].

ERT was carried out by the multi-electrode electrical resistivity and induced polarization imaging instruments «SibER-48» (LLC «KB Electrometry», Novosibirsk, Figure 2 left) in cloudless weather with a slight wind. Directly on the Southeast thermal field of the Ebeko volcano, above the thermal cauldron, a microelectrotomography profile was made. The distance between the electrodes was 0.3 m, the profile length was ~14 m, and the effective observation depth was up to 2.5 m.

Portable automatic gas analyzer GANK-4 (LLC NPO PRIBOR GANK, Moscow, Russia, Figure 2 right) with forced air sampling is designed to measure the concentration of polluting and harmful chemicals contained in the atmosphere, in the air of the working area, in enclosed spaces and in industrial emissions [3]. GANK made a list of air analyzes directly on the thermal field of the volcano, as well as near Severo-Kurilsk.

Figure 2: *SibER-48 (left) and GANK (right)*

III. Results

July 7, 2021 at the South-Western thermal field of Ebeko volcano two microelectrotomography profiles were made. Good grounding <0.1kΩ. The sounding was carried out by the Schlumberger and dipole-dipole sequence. During further processing, despite the high-quality equipment and good grounding, the sounding data from the dipole-dipole sequence were rejected due to the large number of "overshoots" in the sounding curves.

The first profile was laid on the thermal field, the center of the arrangement was on the large fumarole (Figure 3). A gas analytical survey was also carried out there, samples of fumarolic sulfur and efflorescences around the fumaroles were taken.

Both microelectrotomography profiles are very low-resistance, which is due to the high conductivity of the medium - hydrothermally altered rocks saturated with liquid and gases.

Despite this, the most conductive zone can be distinguished in the middle of the profile: apparently, it includes a channel that feeds a large fumarole.

Based on the results of the background gas survey in Severo-Kurilsk and its environs, which was carried out for 3 days, no complex anomalies in gas content were recorded, but local excesses were recorded for some components in a number of peripheral points. At the main points, a full set of gases was measured, at the rest, a reduced list. In the area of the port and the nearby cape, elevated levels of CS_2 0.023 (port) and 0.045 (cape) mg/m^3, and phenol 0.01275 mg/m^3 (cape) were recorded (points svg-12 and svg-13). On the river bank, near the dam to the west of Severo-Kurilsk, elevated levels of mercury and phenol (0.0108 mg/m^3) were recorded (point svg-15). In the kindergarten area, elevated levels of hydrogen sulfide and phenol were recorded, 0.012 and 0.0050 mg/m^3, respectively.

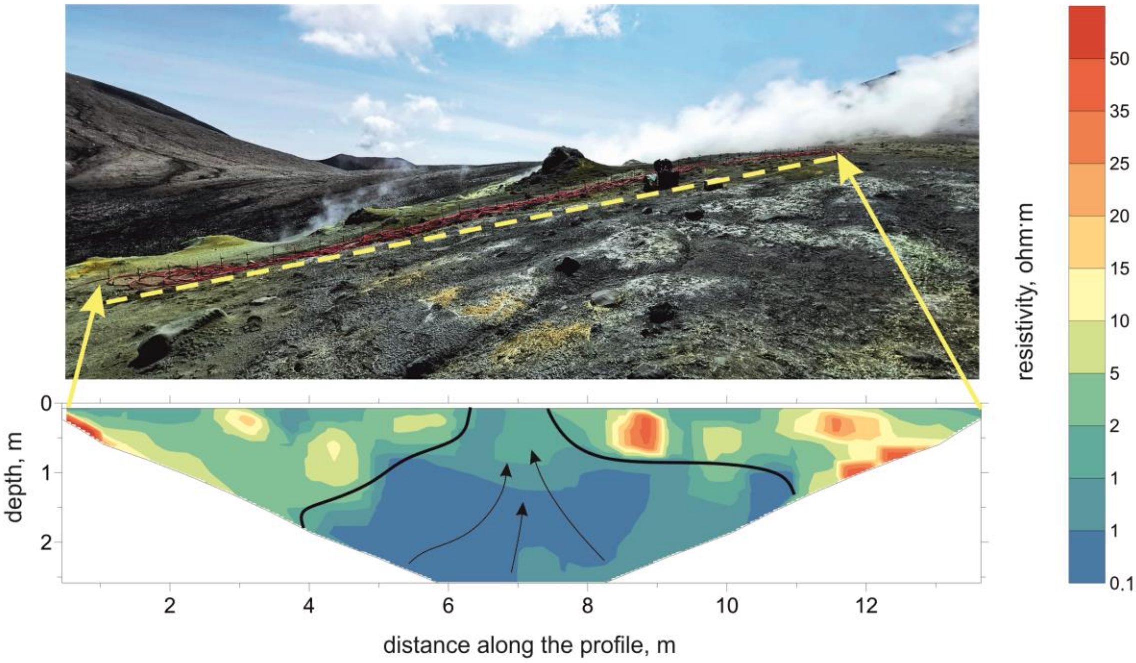

Figure 3: *Profile of microtomography No. 1. Schlumberger sequence, robust inversion*

In general, during the observation days, no increase in the content of various gases, with the exception of mercury, in the air of the city of Severo-Kurilsk associated with emissions from the active Ebeko volcano was recorded (but they are not excluded, monitoring was not round-the-clock). On the days when the survey of the background concentrations of gases was carried out, the weather conditions contributed to the demolition of the ejected materials of the volcano away from the city of Severo-Kurilsk.

An exception was an ash ejection to a height of up to 3 km, which occurred on the evening of July 12, 2021. The plume spread in a southeast direction from the volcano, and ashfall was observed on the territory of the city of Severo-Kurilsk. On the morning after the ash fall, it was decided to conduct an areal mercury survey in the city of Severo-Kurilsk. The survey was carried out during July 13, 2021. The data obtained are given in Appendix 2. and in Figures No. 6 and No. 7. An increase in the content of other gases at the site near the kindergarten was not recorded. The survey was carried out during July 13, 2021, at a height of 30 cm from the surface on roadsides, sidewalks, paths, in courtyards of houses, in areas in front of various objects.

In the case of mercury, we observe the emanation of its vapor from the fallen ash, both immediately during the ashfall and after it, and the next day after the ashfall. As a result, a critical increase in the content of mercury vapor in the air was recorded, up to 10 times the MAC of mercury in the air of populated areas (300 ng/m3).

IV. Discussion

4.1. Microelectrotomography

Based on the results of microelectromography, it can be concluded that the thermal field has a general low-resistivity setting: highly mineralized solutions are the most conductive medium, while hydrothermally altered host rocks are hardly characterized by increased resistance.

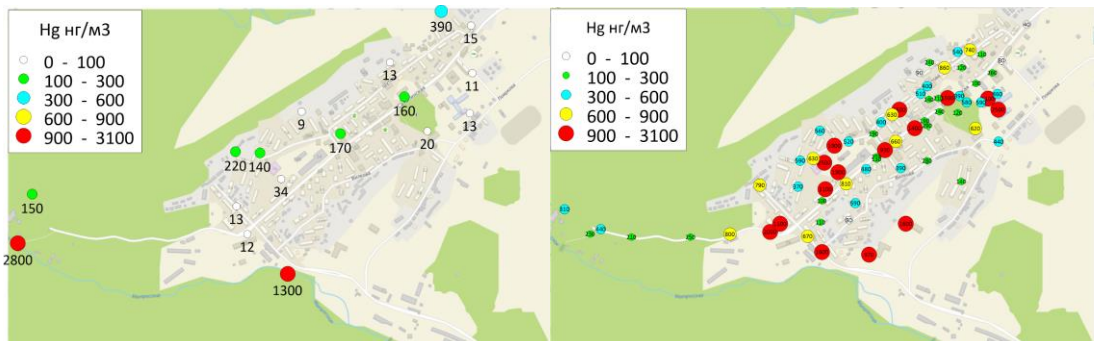

Figure 4. *The content of mercury vapor in the air in Severo-Kurilsk before (left) and after ash fall (right).*

4.2. Mercury observation

The results obtained allow us to judge the unfavorable environmental situation in the city. As a result of ashfalls, elevated levels of mercury vapor are observed in the city, of course, for a long time after the ashfall, the contents decrease to background values, but in the presence of a periodic source of pollution, it is difficult to talk about permanent pollution. An additional factor is the ash itself, which also carries potential harm. Further plans include monitoring the content of mercury vapor in the air of Severo-Kurilsk depending on ashfalls and time of day.

Acknowledgements

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References

[1] Bortnikova S.B., Shevko A.A., Gora M., Eltsov I.N., Grakhova S.P., Panin G.L., Pospeeva E.V. Evidence of mineralization of the platinum group of elements on the Mutnovsky volcano (hydrochemical, mineralogical and geophysical data). 16th International Workshop on WATER DYNAMICS Sendai, Japan. Report. 2019-0175.

[2] Grakhova S.P., Bortnikova S.B., Panin G.L. The results of three-dimensional electrical tomography of the Tokarev crater (Karymsky volcanic center, Kamchatka Interexpo GEO-Siberia - "Subsoil use. Mining. Directions and technologies for prospecting, exploration and development of mineral deposits. Economics. Geoecology": Proceedings of the XVI International Scientific Conference (Novosibirsk, 20 - April 24, 2020) - IPGG SB RAS - Novosibirsk - pp. 373-384 - 2020.

[3] Grakhova S.P., Eltsov I.N., Fage A.N. Comprehensive description of geothermal fields of Mutnovsky and Ebeko volcanoes based on geochemical and geophysical studies – 2018.

[4] Shevko E.P., Bortnikova S.B., Abrosimova N.A., Kamenetsky V.S., Bortnikova S.P., Panin G.L., Zelenski M. Trace Elements and Minerals in Fumarolic Sulfur: The Case of Ebeko Volcano, Kuriles Geofluids – 2018

ANALYSIS OF THE POSSIBILITIES OF APPLYING MODERN INFORMATION TECHNOLOGIES IN ENERGY EFFICIENT URBAN DEVELOPMENT (on the example of Karabakh region)

Nurmammad Mammadov, Samira Akbarova, Gulnar Feyzieva

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Azerbaijan University of Architecture and Construction
sqiom@yahoo.com
samira.akbarova@azmiu.edu.az
gulnar0903@gmail.com

Abstract

Solving the problems of energy saving and efficient use of thermal energy in the construction industry is primarily associated with a number of insufficiently developed scientific and technical problems of urban planning, infrastructure, building thermal physics, such as thermal conductivity and humidity conditions of complex outdoor structures, heat resistance and general heat exchange of a room, air regime buildings, non-stationary joint heat, moisture and air exchange, as well as the durability of the external building envelope. Today, energy saving in urban planning, in the restoration of the destroyed cities and towns of Karabakh, as well as in their further operation, is increasingly relevant due to the high rate of construction of buildings for various purposes, with the deterioration of the environment, the rise in the cost of energy, material and labor resources. Today, world energy is one of the most powerful, actively functioning global systems that determines the most diverse aspects of the life of human society and largely determines the direction and pace of development of the world economy. The paper discusses the application of modern information technologies in solving issues of urban planning, construction and operation of buildings and structures in Karabakh.

Keywords: urban planning, outdoor structures, thermal energy, energy efficiency, operating conditions, optimal control

I. Introduction

In many countries of the world, a huge amount of thermal energy is wasted due to inefficient and irrational design of new cities and towns, the choice of external building envelopes, irrational distribution of thermal energy among consumers, mismanagement of the mode of consumption of thermal energy, etc.

These countries, unfortunately, include Azerbaijan and other CIS countries that developed their economies on the principles of extensive use, and not on the principles of rational use of thermal energy, which became inherent in the economies of the developed countries of the world after the first energy crisis in 1973.

An analysis of the state of affairs in the thermal economy of cities and towns of the republic showed a lot of pressing problems. The current situation in the heat supply system of the cities of Baku, Sumgayit, Ganja and other regions of the republic is characterized by technical, technological and organizational backwardness, low efficiency, inconsistency and unreliability in the most extreme situations. Therefore, increasing the share of volumes of the structure of the heat and power system with the simultaneous design of potential and energy-efficient buildings and increasing the quality of their energy supply is the first step in solving the problem of increasing the efficiency of the energy sector of Karabakh.

II. Methodology

Currently, there are many mathematical models for optimal control, planning and distribution of thermal energy, but in real conditions their use is often difficult. First of all, this concerns the operational management and distribution of thermal energy between consumers, when there is a problem of prompt adjustment of the initial information and feedback on actual consumption. At the same time, one has to deal with the uncertainty of goals that arise when simultaneously performing different tasks for managing and providing the required amount of thermal energy in extreme climatic conditions or emergency situations. As a result of the influence of disturbing factors (climatic parameters of the environment, operating conditions of buildings, organizational factors, emergency situations, etc.), as well as incompleteness and inaccuracies of the initial information, the main controlled parameters turn out to be fuzzy. In this regard, today, in almost all operational control rooms, operators mainly use their own decision rules based on their own experience and intuition. Such actions do not guarantee mathematical optimality, they are not always adequate to real conditions and are not implemented in practice.

It is obvious that further improvement of the system of planning, management and distribution of thermal energy between consumers of different categories, increasing the efficiency and reliability of the operation of newly built buildings, especially for the climatic zone of Karabakh, is associated with the transition to a new modeling system, in particular to a new information technology, and the creation based on it qualitatively new systems of optimal and operational management, distribution and operation.

With the advent of "intelligent" technologies in the construction industry, it became possible to raise quality and energy efficiency indicators (safety, optimal comfort, information service, optimal management, efficient use of thermal energy, etc.). All engineering systems of newly built cities and settlements in the Karabakh zone should be managed by a single center, which allows reducing heat and power resources, saving costs for maintenance personnel, reducing the likelihood of accidents, predicting and planning the mode of consumption of thermal energy [1].

III. Results

Profound changes in the global construction market, and in connection with this, the need to develop modern energy-saving technologies are forcing enterprises and companies in this industry to introduce more and more powerful control systems into production at all information levels, while ensuring the optimal use of energy resources and other potentials. And this defines a new stage in the development of the scientific concept of managing the indoor microclimate and energy consumption, which ensures the possibility of efficient use of energy resources.

At present, the intensive growth of thermal energy consumption necessitates the development of modern schemes for automatic control of the technological regime of the system, data collection from measuring sensors and computer systems, their storage, display and processing based on the use of information technologies [2, 3].

These systems should implement the following main functions:

- information support for control and management at all levels;
- processing of measurement data and solution of various tasks of automatic and dispatch control;
- implementation of control functions;
- emergency protection of technological process and equipment.

Currently, domestic and foreign experts have carried out a significant amount of research on modeling and optimizing the mode of distribution of thermal energy in cities and towns, as well as on ensuring the microclimate in buildings [4, 5]. However, the developed methods are deterministic and do not take into account the actual operating conditions of the entire system of cities and individual buildings.

The solutions obtained with the help of these developments on the distribution of thermal energy between consumers of cities and regions of Karabakh and the provision of individual buildings with high-quality air correspond only to specific boundary conditions and are on the border of the permissible area. Therefore, even minor changes in the boundary conditions can not only significantly change the optimal solution, but also take it out of the region of technologically acceptable modes and lead to an emergency. Such solutions may not always be acceptable for practice, because they are often inoperable in real conditions.

Planning and production as well as dispatching services, specialists usually use their own solutions in practice, based on their experience and intuition. Such rules, although they do not guarantee mathematical optimality, sometimes turn out to be adequate to real conditions.

Modern cities with a continuous nature of operation are complex systems consisting of dozens of subsystems, which in turn are interconnected and characterized by dozens of parameters. The use of modern information technologies for the operation and management of these cities and the microclimate of individual buildings, and the consumption of thermal energy allows raising the social conditions of the city to a new qualitative level and will help solve the problem of optimizing energy saving in the region.

We assume that modern information technology management of the microclimate and thermal energy consumption for buildings can develop in two interrelated directions.

The first direction is determined by the effectiveness of the implementation of the theoretical knowledge base of technological processes, which create the basis for the dynamic development of indicators of the organizational and economic system of enterprises for the production of thermal energy.

The second direction is the use of efficient and optimal control systems to control the systems to provide thermal energy to cities, combining not only all levels and components of automated and automatic control, but also technical systems with the help of which the technological processes of these systems are implemented.

In our opinion, in the systems to ensure the microclimate of an environmentally friendly building with efficient use of thermal energy, it is necessary to introduce: complexes for modeling and optimizing the operating modes of these systems, electronic dispatch logs, systems for collecting and processing regime-technological and climatological (outdoor and indoor air) information , real-time systems, systems for graphical representation of objects (general plan of the territory and floor plans of individual buildings), various complexes of regime and technological tasks, control subsystems for individual buildings or premises.

These software tools make it possible to model complex multifunctional systems to ensure the optimal distribution of thermal energy between consumers of the city, to evaluate possible management and dispatching decisions not only in the conditions of normal operation of the system, but also in case of significant changes affecting the system of factors (a sharp change in climatic indicators of the environment, change in operating conditions, occurrence of an emergency, etc.).

To automate the control and regulation of systems for providing thermal energy to cities and towns of Karabakh, geoinformation software and hardware complexes that select, display, process, analyze and disseminate information about spatially distributed objects based on electronic maps, related databases and technologies can be used. Such technologies provide computer support for regulation, efficiency of data processing, provide high accuracy, as well as computer simulation of the system with hydraulic calculation and analysis of the mode of operation of the entire system [6].

However, control systems and optimal distribution of thermal energy between consumers should not only have interfaces for receiving and sending information, but also be able to automatically process the information received. At the same time, the degree of usefulness of software systems for controlling technological regimes is determined not only by the reliability of the initial information, but also by the adequacy of the mathematical models used for objects of central systems (climatization and distribution of thermal energy).

Despite the fact that in the modern world of information technology a decade is comparable to a century of progress in traditional technologies, models and solutions of the 60s of the last century are still used in the development of models of central air conditioning and heat distribution systems.

At present, the problem of mathematical modeling of these systems has become aggravated due to the use of new technologies, as well as the need to justify the economic efficiency of the methods used to control new energy-saving technologies in systems for providing a microclimate and optimal distribution of thermal energy between consumers.

In any information technology control system, it is necessary to provide for the accumulation, transmission, processing of primary information and a system for presenting information about decisions made in the required form and, based on these decisions, a system for reliably performing technological operations for processing, transporting and supplying heat energy to buildings in the required amount [6].

However, the environment of Karabakh and the internal climate of the buildings being built there are complicated complexes, for which it is practically impossible to conduct a full and comprehensive scope of full-scale tests. Moreover, the objective unattainability of the full scope of tests is associated with infinite sets of various unpredictable changes in environmental parameters and possible scenarios for operating systems (maintaining the required parameters of indoor air), the semantic variety of initial information that is subject to operational processing in real time and a lot of software functions that are subject to appropriate checks for tests. Therefore, before the introduction of such systems, such tasks as:

- system analysis of outdoor climatic parameters of construction areas and indoor air
- development of effective algorithms and mathematical models for making managerial decisions during the operation of heat supply systems for individual buildings;
- development of unified object-oriented models for simulating and optimizing technological facilities to ensure the microclimate of buildings (premises) and the optimal distribution of thermal energy between consumers of different categories;
- development of methodology and corresponding mathematical models for assessing and monitoring the reliability of automated control systems, etc. should be solved.

Simulation modeling is designed to study a system with a fixed topology and a given configuration of parameters. It can also be used to test the validity of a specific combination of external and internal environment parameters, i.e. as a means of testing and comparing analysis of technical solutions for managing the microclimate of buildings.

When compiling mathematical models, it is necessary to strive to obtain the simplest models with sufficient accuracy of the calculated data.

One of the common shortcomings in the practice of creating microclimate control systems for multifunctional buildings is a deterministic software approach to this problem. In this case, various classical approaches are used to model physical processes in technical systems with certain, sometimes significant, assumptions. As a result, the model is described by linear or non-linear mathematical equations, which are solved by analytical, numerical or probabilistic-statistical methods. As a result, the resulting solutions do not always provide sufficient flexibility to the requirements of the microclimate. This is due to the fact that: firstly, many random factors influence the functioning of the microclimate, and it is practically impossible to take into account all these factors in the model. Secondly, these systems are open systems, with unclearly predictable air parameters, with periodically changing operating conditions and parameters of the state of the buildings (or premises) themselves. As a result, the solution is accompanied by large computational difficulties:

- there is a large area of uncertainty for many model parameters;
- high inaccuracy of measured parameters;

● inadequate consideration of process parameters in the model, in particular at the junction of different technological solutions;

● presence of empirical coefficients and dependencies in the model;

● to identify model parameters, it is not possible to obtain real-time data at a given frequency, etc.

To get out of this situation, various modeling and optimization methods are used, which take into account the stochastic nature of the change in environmental parameters, as well as the random nature of the operation of the air conditioning system and the optimal distribution of thermal energy between consumers. Sometimes the model is a controlled non-stationary Markov process in which the control affects the probability of the system transition from one state to another [6]. If air conditioning and heat distribution systems are considered as technical systems, and design and optimization tasks are formulated as the choice of the most economical option that meets the established norm, reliability and probability of fulfilling certain ratios, then the model does not allow taking into account the material damage to consumers.

IV. Conclusion

Solar energy use becomes more and more globally. Like other countries, Azerbaijan is trying to meet its thermal energy and electricity needs by applying renewable energy sources. It is predicted that by 2050, about 50% of the total amount of energy will be produced by "green" energy technologies. At present time Azerbaijan meets only 8% of energy consumption needs with renewable energy.

The obtained results of the study allow making the next conclusions on an initial assessment of Under the new conditions, which were formed as a result of the introduction of various information and technological systems for managing the microclimate of buildings, there appeared both a necessary and a real opportunity to use neural networks and fuzzy controllers for analyzing and processing information when solving management problems.

Methods for interpreting and representing trained neural networks are currently being developed in various directions. The wide possibilities of using neural networks in production management are due to the fact that the technology for applying this technique forms a structure in which all types of imperfect knowledge (inaccuracies, uncertainties, etc.) can be represented in an appropriate way and combined for processing. In addition, with the use of various SCADA-type control software systems, a huge amount of information about control objects is accumulated, and they can be used to adapt models [6].

It should be noted that neural networks can be used with great success for diagnosing building climate parameters, microclimate control, and also for optimal distribution of thermal energy between consumers. Since the information environment for diagnosing and managing the climate of buildings should provide the necessary accuracy and reliability of detection, identification, and determination of air parameters. Neural network algorithms make it possible to eliminate redundancy and inconsistency of information, and also work in conditions of incomplete information.

Thus, when solving the problems of urban planning, as well as the efficient and rational distribution of thermal energy between consumers in the Karabakh zone, in order to provide consumers with quality air, it is necessary to consider the problem not in a narrow, but in a global sense, through the use of modern and economically cost-effective technologies.

References

[1] Tabunshchikov Yu.A., Brodach M.M., Shilkin N.V. Energy efficient buildings. M.: AVOK - PRESS, 2003, 200 p.

[2] Mamedov N.Ya. Probabilistic-statistical characteristics of the regime of uneven consumption of thermal energy for buildings // Bulletin of the Tomsk State Construction

University, 2009, No. 2.

[3] Mamedov N.Ya. Modeling the mode of consumption of thermal energy for buildings, taking into account the influence of meteorological and operational factors // Teoreticheskayaiprikladnayamekhanika, Baku: 2009, no. 2, p. 119-124.

[4] Mamedov N.Ya., Zhila V.A., Solovieva E.B. Application of the theory of intelligent systems to control the mode of consumption of thermal energy in buildings // Vestnik MGSU, M: 2009, No. 1, p. 188-193.

[5] Brodach M.M. Improving the thermal efficiency of buildings by optimization methods. Abstract dis. cand. those. Sciences. M.: NIISF, 1988, 22 p.

[6] Aliev R.A., Aliev R.R., Theory of intelligent systems and its application. Baku: Çaşıoğlu, 2001, 720 p.

ON THE CONSTRUCTION OF MEMBERSHIP FUNCTIONS FOR FUZZY SETS ASSOCIATED WITH RISKS

Reshad Ismibayli[1], Pünar Guliyeva[1], Nigar Ahmadli[2]

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[1]Azerbaijan University of Architecture and Construction
reshadismibayli@gmail.com
punar.guliyeva@gmail.com
[2]Institute of Control Systems of NAS Azerbaijan
a.nigar.zadeh@gmail.com

Abstract

The paper analyzes the methods for constructing membership functions on the example of fuzzy sets associated with risks using expert information. Methods of approximation and interpolation are used. The influence of noise in expert data on the accuracy of the obtained membership functions is analyzed.

Keywords: fuzzy sets, membership function, method of penalty function, approximation

I. Introduction

It is known that both at the design stage and in the management of complex processes, decision-making problems occupy an important place. These problems, as a rule, are associated with an assessment of the risks that the decisions taken lead to. Of great importance is the choice of specific values of the parameters that determine the chosen decision, in which the consequences of the decision lead to fewer risks, and even better - to their absence.

Many real problems cannot be formalized mathematically because of their complexity. This is due to the impossibility of constructing appropriate adequate mathematical models, objective functions and functions that describe constraints.

Given the above, to solve complex decision-making problems that are difficult to formalize and can be solved in the framework of classical mathematics, relatively new approaches based on the construction of intelligent systems are used. Examples of such approaches are theories of expert systems, fuzzy sets, theories of neural and neurophase networks. This work is devoted to an approach based on the theory of fuzzy sets, which is currently widely used in mathematical modeling of the functioning of complex technological processes and technical objects. The main characteristic of fuzzy sets is their membership functions. In practice, such functions as triangular, trapezoidal, Gaussian, bell-shaped and some other types of functions. Each of these classes of functions is characterized by a number of parameters that can be used to construct the membership function (FC) of a specific fuzzy set. The number of parameters of the known classes listed above is in many cases small to construct a sufficient adequate FP for specifically given fuzzy sets [1]-[5].

In this paper, the analysis of methods for constructing an FP from various classes of known functions is carried out. Thus, the analysis of functions from the class of piecewise continuous functions proposed in this paper is carried out. To construct functions, expert information about the degree of belonging to a fuzzy set of some given elements of the universal set is used.

To construct membership functions, namely, to determine the values of their parameters, mathematical methods such as various interpolation methods, approximation methods based on conditional and unconditional optimization methods are used.

The paper presents the results of numerical experiments using various approaches to constructing the FP, and analyzes and compares the results obtained.

II. Statement of the problem

Let there be expert information about the degree of membership of the elements $\bar{x}_i \in X, i = 1, \dots, n,$ to the fuzzy set A, here X is a universal set. Thus, $\bar{x}_i$ and $\bar{\mu}_i$are given, such that it is desirable to fulfill the conditions:

$$\bar{\mu}_i = \mu_A(\bar{x}_i; P), \quad i = 1 \dots, n. \tag{1}$$

Here the $\mu_A(\bar{x}_i; P) -$ is a membership function of the fuzzy set A; $P -$ is a vector of parameters of this membership function.

It is required, firstly, to determine the type of MF $\mu_A(x, p)$, i.e. to determine what class it is from (we call this problem the problem of structural identification). Secondly, it is required to determine the values of the r-dimensional vector of parameters $P \in R^r$, participating as coefficients in the function $\mu_A(x, p), r -$ is the dimension of the vector of parameters (we call this problem the problem of parametric identification).

There are no mathematical methods to solve the problem of structural identification, i.e. to choose the form of the function $\mu_A(x_i, p)$ when choosing a class of functions, it is necessary to consider:

1) the specifics of the fuzzy set itself;

2) $r -$the number is the dimension of the vector of parameters of functions participating in the membership functions of a given class;

3) $n -$ the number of elements, which have expert information about the membership degree to the fuzzy set [6]-[9].

To carry out parametric identification, such mathematical methods can be used, such as, for example, the Lagrange interpolation method when the condition $r = n$ is satisfied. In the case, if $n < r$ condition of uniqueness of the constructed membership function is not satisfied. The use of interpolation methods is also incorrect for $n > r$, due to the impossibility of constructing (non-existence) of such a membership function.

The application of approximation methods using methods, for example, minimizing the standard deviation, leads the original problem to the following:

$$S(P) = \frac{1}{n}\sum_{i=1}^{n}[\mu_A(\bar{x}_i; P) - \bar{\mu}_i]^2 + \varepsilon\left\|P - \tilde{P}\right\|_R^2 \to \min_{P\in R^r} \tag{2}$$

Here it is assumed that the condition $r < n$ is satisfied. This is necessary for the uniqueness of the solution of the problem (2). The second term in (2) is introduced to regularize the optimization problem; $\varepsilon > 0, p \in R^r -$ regularization parameters [10]-[12].

The problem (2) belongs to finite-dimensional optimization problems. To solve it, you can use well-known effective optimization methods such as conjugate gradient methods, variable metrics, and others. To solve it, there are ready-made packages of applied programs.

As a rule, membership functions are required to fulfill the following condition:

$$\mu_A(x; P) \le 1, \qquad x \in X, \tag{3}$$

$$\mu_A(x; P) \ge 0, \qquad x \in X, \tag{4}$$

The condition (3), called the normalization condition, is optional in some problems. However, after solving the problem of parametric identification and determining the parameters P, the resulting function can be normalized by the formula:

$$\bar{\mu}_A(x) = \frac{\mu_A(x;P)}{\max_{y\in X}\mu_A(y;P)},\quad x\in X. \tag{5}$$

It is easy to check that the (5) function $\bar{\mu}_A(x)$ reduced to satisfies the (3) condition. If the obtained function violates condition (4), then it can be transformed as follows:

$$\bar{\bar{\mu}}_A(x) = \frac{\mu_A(x;P) - \min_{y\in X}\mu_A(y;P)}{\max_{y\in X}\mu_A(y;P) - \min_{y\in X}\mu_A(y;P)},\quad x\in X. \tag{6}$$

It is easy to check that the (6) function $\bar{\bar{\mu}}_A(x)$reduced to satisfies the conditions(3), (4).

You can do it in another way. Namely, to solve the problem of minimizing a function (2) under restrictions (3), (4). For this, for example, methods of penalty functions can be used. But in this case, constraints (3), (4) on the parameters P must be discretized with respect to $x \in X$. Namely, enter, for example, a grid with a given step h: $x_j = x_0 + jh$, $j = 1, \dots, M$, and require the fulfillment of the conditions (3), (4) at all points of the grid:

$$\mu_A(x_j;P) \le 1,\qquad j = 1,\dots,M, \tag{7}$$

$$\mu_A(x_j;P) \ge 0,\qquad j = 1,\dots,M. \tag{8}$$

To determine the parameter vector P minimizing the function (2), it is necessary to add $2M$ constraints (7), (8).

III. Results of numerical experiments

Let us present some of the results of computer experiments carried out on examples of hypothetical expert data.

Tables 1, 2, 3 show exact expert data on the degree of belonging of elements to some fuzzy sets. The fourth rows of these tables contain data on the degree of membership of the same elements with noises $\xi = 10\%$, i.e. $\bar{\mu}_i^{\xi} = (1+\xi)\bar{\mu}_i$. Noises are random variables that have a uniform distribution on the interval$[-1;1]$.

Table 1: *Expert data for triangular membership function*

No.	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
$\bar{\mathbf{x}}_\mathbf{i}$	0.1	0.21	0.3	0.38	0.48	0.65	0.71	0.83	0.88	0.9
$\bar{\boldsymbol{\mu}}_\mathbf{i}$	0	0.2749	0.4999	0.7	0.95	0.625	0.475	0.175	0.05	0
$\bar{\mu}_i^{\xi}$	0	0.2954	0.5372	0.7522	1	0.6716	0.5104	0.188	0.0537	0

Table 2: *Expert data for the trapezoidal membership function*

No.	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
$\bar{\mathbf{x}}_\mathbf{i}$	0.1	0.21	0.3	0.38	0.48	0.65	0.71	0.83	0.88	0.9
$\bar{\boldsymbol{\mu}}_\mathbf{i}$	0	0.36	0.66	0.93	1	1	0.95	0.35	0.1	0
$\bar{\mu}_i^{\xi}$	0	0.39	0.71	1	1	1	1	0.37	0.1	0

Table 3: *Expert data for the Gaussian membership function*

No.	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
$\bar{\mathbf{x}}_\mathbf{i}$	0.1	0.21	0.3	0.38	0.48	0.65	0.71	0.83	0.88	0.9
$\bar{\boldsymbol{\mu}}_\mathbf{i}$	0	0.01	0.14	0.49	0.98	0.32	0.11	0	0	0
$\bar{\mu}_i^{\xi}$	0	0	0.1	0.5	1	0.3	0.1	0	0	0

Figure 1 shows graphs of membership functions from a triangular class of functions, the parameters of which were obtained using the above methods.

Figure 2 shows similar results for the trapezoidal membership function.

Figure 3 shows similar results for the Gaussian membership function.

In these figures, solid graphs are obtained for the exact values of expert data, dotted graphs correspond to expert data with noises given in the fourth rows of tables 1-3.

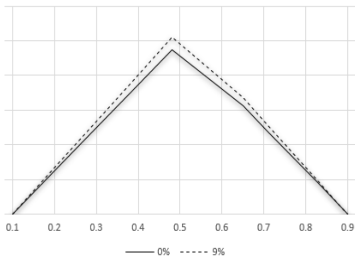

Fig.1: *Results for triangular function accessories*

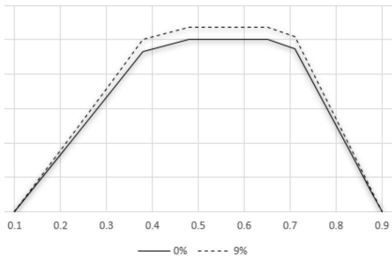

Fig.2: *Results for the trapezoidal function accessories*

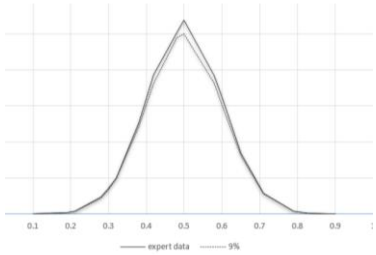

Fig.3: *Results for the Gaussian function accessories*

As can be seen from the figures, the quality of the approximation of expert data significantly depends on the chosen class of the membership function. Noises in expert data have a comparatively small effect, since they are smoothed out in the process of approximation.

IV. Conclusion

In recent years, much attention of researchers has been paid to the application of the theory of fuzzy sets in solving problems that are difficult to formalize. The main characteristic of fuzzy sets is the corresponding membership functions.

In this work, on the basis of expert data on the degree of risk of the decision being made for various values of the parameters on which the decision depends, an approach to the construction of membership functions of fuzzy sets is investigated. The approach is based on approximate methods of approximation.

The use of a class of triangular-like, trapezoidal, functions and Gaussian functions for the approximation of membership functions has been carried out. To determine the parameters of membership functions, approximation methods were used, leading to the problem of unconditional optimization of the mean square criterion.

An analysis of the stability of the constructed membership functions to the noise of expert data assignment is carried out.

References

[1] Aida-Zade KR, Alieva NT, Automatic Control and Computer Sciences, Study of one class of membership functions of fuzzy sets, 2011, Vol 45, No. 3, pp. 142-152.

[2] Aida-Zade KR, Alieva NT, On class of smoth membership functions, journal of Avtomation and Information Sciences, Beggel House, Inc., New York, 2012, No2, pp.60-71324

[3] Gottwald, S. Universes of Fuzzy Sets and Axiomatizations of Fuzzy Set Theory. Part I: Model-Based and Axiomatic Approaches. Studio Logic. 2006, pp. 211–244

[4] LA Zadeh, Fuzzy sets as a basis for a theory of possibility, Fuzzy Sets and Systems, 1999, pp.9-34.

[5] Zadeh, L.A., Fuzzy Set, Inform.Cont., 1965, No.8, pp. 338-353.

[6] Liou, TS and Wang, MJJ, Ranking Fuzzy Numbers with Integral Values, Fuzzy Sets and Systems, 1992, No.55, pp. 247-255.

[7] Kaufmann, A. and Gupta, MM, Introduction to Fuzzy Arithmetic Theory and Applications, New York: Van Nostrand Reinhold, 1991.

[8] Jang, S., Sun, C.-T., and Mizutani, E., Neuro-Fuzzy and Soft Computing, New York: Prentice Hall, 2001.

[9] Baruah, Hemanta K. The Theory of Fuzzy Sets: Beliefs and Realities // International Journal of Energy, Information and Communications, 2011, Vol, 2, Issue 2, 1 – 22

[10] Gill, P.E., Murray, W., and Wright, M.H., Practical Optimization, London: Academic Press, 1981. George M. Phillips Interpolation and Approximation by Polynomials.

[11] Vasiliev F.P. Methods of optimization M.Factorial Press, 2002, 824 pp.(in russian)

[12] Ismibayli R.E.. A.B.Rahimov Optimization of the number of constancy intervals of piece wise constant control functions with uncertain information. Proceedings of The Third Intern.Conf. “Problems of Cybernetics and Informatics” Vol. III, September 6-8, 2010, Baku, pp. 152-155

[13] Ismibayli R.E., K.R.Aida-Zade, P.S.Guliyeva Analysis of the methods for constructing membership functions using expert data. The 8-th World Conference on Soft Computing. February 03-05, Baku 2022

ANALYSIS OF THE SPECIFICS OF INNOVATIVE ACTIVITY IN THE CONSTRUCTION INDUSTRY IN ASSESSING ECONOMIC RISKS

Fatima Dakhaeva[1], Tamerlan Magomaev[2]
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[1]Chechen State University named after A.A. Kadyrov, Russia
[2]Grozny State Oil Technical University named after Acad. M.D. Millionshchikov, Russia
dahaevaf@mail.ru
medic86@mail.ru

Abstract

At present, increasing the efficiency of involving new technologies in economic circulation is impossible without analyzing the effectiveness of innovative activity. Considering the issue of innovation management, it is necessary not only to take into account the multi-level approach and positioning of the methodology of innovation analysis, depending on the adoption of economic decisions, but also to take into account the very nature of innovation as the basis for building valuation activities. A deterrent to the diffusion of innovations is the lack of methods for analyzing and improving the efficiency of innovative projects. Their development continues to be carried out largely without regard to the type and scale of technologies being introduced. The lack of an appropriate methodology leads to the fact that enterprises often refuse to introduce innovations due to the uncertainty of their final results.

Keywords: innovative activity, economic risks, natural resources, innovative projects, risk management

I. Introduction

The term «innovation» comes from the Latin «novation», which means «update», and the prefix «in», which is translated from Latin as «in the direction», if translated literally «Innovatio» «in the direction of change». This concept first appeared in the 19th century, but received a new life at the beginning of the 20th century. In 1900, the Austrian and American economist J. Schumpeter first used this term in economics [1]. Innovation is understood as the result of an intelligent solution that has not been used before, an idea that is invested in the development and acquisition of new knowledge, updating various areas of people's lives, such as technology, products, science, informatization, etc., the subsequent process of introducing this innovation with obtaining additional values (profit, lead, leadership, priority) [2]. Among the scientists of our time, there are many supporters of the classical theory of I. Schumpeter, such as V.P. Loginova and A.S. Kulagin, who understand «innovation» as an object, result, product obtained as a result of the commercialization of scientific and technical activities. At its core, the concept of «innovation» is an economic phenomenon, which is characterized by a process: investment - development - implementation process - obtaining a qualitative improvement. Based on the foregoing, the author believes that «innovation» is the result of any type of activity aimed at improving, developing and achieving something new.

Differences in the identification of innovation as an object of evaluation predetermine the features of the analysis. If innovation is considered as an innovation, a formalized result of scientific research and development [1, 2], then the assessment of innovation will be reduced to an analysis of the costs and results of R&D and patent analysis (academic approach in analysis). Considering innovation utilitarianly as a new utility to meet new consumer needs [3], the assessment of innovation will be reduced to marketing analysis and commodity assessments (market approach). If we imagine innovation as the production introduction of new or improved equipment or technology [4, 5], then the assessment of innovation is reduced to a technical and economic analysis of the costs of updating production (technocratic or cost-resource approach in the analysis). Identification of innovation as the use of new or improved forms and methods of organizing management [6], including methods of remuneration and incentives, customer service, accounting and control, forecasting and planning, analysis techniques, boils down to the fact that the evaluation of innovation turns into an organizational managerial analysis (managerial approach in analysis). Consideration of innovation from the perspective of an intellectual property object or an intangible asset determines the assessment through property analysis (accounting or accounting approach in the analysis). If innovation means getting high profits from the use of a monopoly of novelty in the market, then the entire assessment of innovation turns into an analysis of the monopoly conditions for obtaining excess profits (commercial or income approach in the analysis). If innovation means obtaining a social or environmental effect from the use of a new or improved social service as a «public good», then the entire assessment of innovation becomes a socio-psychological analysis (non-commercial social approach in analysis). If innovation means a new or improved combination of production factors [7] to minimize costs and maximize results, then the entire assessment of innovation comes down to an analysis of the costs and benefits of a new or modified production function (neoclassical approach in analysis). If innovation is understood as the process of creating and increasing the value of a high-tech business through new added value and reinvestment of profits when using innovations, then the assessment of innovation leads to an analysis of the capitalization of a high-tech business (cost approach or business capitalization approach in the analysis). If innovation is understood as the process of introducing an intellectual property object into economic circulation through the sale and purchase of an innovation with its subsequent use or non-use by the buyer, then the assessment of innovation is reduced to the analysis of the pricing of an intellectual property object for sale or resale (price approach or commercialization approach in the analysis).

II. Methods

In the proposed reporting forms, the information base on innovation activities is mainly limited to patent statistics, which reflects only the initial stage of the innovation cycle - the process of producing new knowledge. In addition, the available statistical forms are a collection of only quantitative indicators, the use of which for the management of innovation activity without additional information will give a one-sided assessment. This situation is a consequence of the opinion that existed for a long time, according to which innovation activity was considered as integral to scientific activity. This approach considers a linear model of the innovation cycle, consisting of the following stages: scientific research, inventions, innovations and diffusion of technological innovations. The linear model justified the use of indicators of science statistics as the main indicators of innovation activity. In this case, the innovation policy was limited to accelerating the promotion of innovations at all stages of the innovation cycle. Forms for the collection and analysis of information on innovation activity, submitted both by official statistical organizations and industrial enterprises, do not allow an objective assessment of the potential for the application of innovative solutions of individual enterprises. In addition, in Russian statistics, organizations that have introduced (completed) innovations in the last three years are declared to be innovatively active organizations, and on the other hand, all organizations that showed the presence of innovation costs in the reporting year are classified as innovatively active. In our opinion, it is advisable to determine the innovativeness of organizations using two indicators [7]: 1) innovative organizations - organizations that have introduced (completed) innovations in the last three years; 2) innovatively active organizations - organizations that carried out innovative activities in the reporting period (three years, a year), regardless of the degree of its completion (the criterion for classifying this type of organization is the presence of innovation costs in the reporting period). In addition, it should be borne in mind that the reporting period in the Frascati Manual is three years. Therefore, for international comparability, indicators characterizing innovative organizations should cover a three-year period of the organization's activity (and not predominantly a year, as it is now).

There are three logical forms of the innovation process [7-8]: 1) simple intra-organizational (natural) involves the creation and use of innovation within the same organization, innovation in this case does not take a direct commodity form; 2) simple interorganizational (commodity) means the separation of the function of the creator and producer of innovation from the function of its consumer, innovation acts as an object of sale; 3) extended is used in the creation of new producers of innovation, in violation of the monopoly of production of the pioneer manufacturer, which contributes through mutual competition to the improvement of the consumer properties of the manufactured goods [4]. Consequently, not every innovative process involves commercial use (see item 1. no product - no commercial use). The innovation process covers a sequential chain of events during which an innovation matures from an idea to a specific product, technology or service and is disseminated through practical use on a commercial basis. Unlike scientific and technological progress, the innovation process does not end with the so-called introduction - the first appearance on the market of a new product, service or bringing a new technology to its design capacity. This process is not interrupted even after implementation, because as it spreads (diffusion), the innovation improves, becomes more efficient, and acquires new consumer properties. This opens up new areas of application for it, new markets, and, consequently, new consumers who perceive this product, technology or service as new for themselves. Thus, this process is aimed at creating the required markets for products, technologies or services and is carried out in close unity with the environment: its direction, pace, goals depend on the socio-economic environment in which it functions and develops. The period that begins with the implementation of theoretical and industrial innovations and includes the subsequent development, development and application of a new scientific and technical idea, improvement of the technical and economic parameters of the manufactured equipment, its repair and other maintenance, and ends with the moment when this equipment is to be replaced with a qualitatively new one, more efficient is called the innovation life cycle.

III. Results

Most scientists involved in innovation development note that innovation policy is dominated by less risky and inexpensive innovations that reduce the level of efficiency of ongoing technological and production changes [6,7]. Due to the fact that many construction companies operate in accordance with the strategy of "skimming the cream", i.e. in their economic activities are guided by momentary benefits, and this, in turn, is a factor that weakens the innovation process. Given the fact that short-term interests will prevail over long-term ones, investors prefer to implement small-scale measures, rather than actions that give a more significant, but long-term effect. As a result of such actions, innovations take the form of spasmodic reproduction, including in investment and construction activities. At the same time, one should not forget that the effectiveness of innovative processes depends on complex reproduction and technical reorganization, at the same time costs, in addition, there is a time gap between the introduction of innovations and obtaining an economic result. In this regard, it is necessary to carry out a risk assessment in the implementation of innovative solutions, as well as to predict the probability of profits and losses. It should also be pointed out that when implementing innovative construction projects, it is possible to receive not only losses, but also losses. The monetary value of damage is considered to be loss. Unforeseen losses associated with the influence of the factor of uncertainty, inconsistency and alternativeness can be assessed as probable losses from the implementation of the project. In order to accurately assess the feasibility of implementing innovative construction projects, there is a need to improve the classification of risk factors due to the introduction of innovations [9]. With an increase in the number of specific factors that are taken into account when calculating the magnitude of the risk, the accuracy of the results of assessing the economic efficiency and the effect of the implementation of innovative construction projects increases. The classification of factors that influence the formation of risks of innovative construction projects is shown in the figure. The presented classification, based on the characteristics of individual innovation processes, may additionally include other specific factors. External factors have a significant impact on the development of innovations. In particular, the state taxation system, contractors, suppliers, banks and lenders are the main partners in the implementation of construction projects. As a result, unstable interest rates on credit resources increase the level of banking risk from the implementation of innovative projects. An important factor of investment risk is the instability of taxation. Since often the tax benefits that are provided at the initial stage of the project may change for the worse in the process of implementation and operation of the facility. This trend makes it difficult to invest in large-scale construction projects. The supply risk appears with the instability of supplies, with a disruption in the supply of material and technical resources. This risk also complicates the effective implementation of the project. The levers of state protection of the domestic market are also not effective enough. Local investments in the conditions of strong external competition become risky, therefore, there is a decrease in the degree of interest of domestic investors in large-scale investments in construction. Insufficient space [8-9] for domestic entrepreneurs in the market leads to a violation of the balance of supply and demand in the domestic market. Therefore, the expediency of implementing innovative projects is called into question, because. it is difficult to predict the final result of investing. The risk factor from a decrease in market demand and interest in the final results of investing influences the decision to invest in large-scale innovative projects. A significant influence is exerted by specific internal conditions that impede the development of innovation activity and increase the degree of risk of innovation at the level of specific investment projects, along with external factors of innovation risk. This concerns the leakage of personnel from the sphere of scientific and technical activity outside the state. At the same time, there are difficulties in training personnel in the field of innovation [10]. The risk of a lack of scientific and human resources for managing innovative projects is formed by the slow replenishment of the administrative apparatus with personnel oriented towards market management, while reducing the composition of the former scientific and production personnel. With the reduction in financing of investment activities from the own sources of construction companies, there is an internal risk of underperformance of innovative programs and projects. In the field of logistics, there may be disruptions and late payments. This combination of factors is the reason for the reduction of own funds allocated for investment in innovative construction projects. When assessing the feasibility of implementing innovative projects and programs, losses from errors in forecasting the expected beneficial results of investments should be taken into account. Often, in prospective economic calculations, it is not possible to determine with high accuracy the expected positive and negative results of the planned investments. Therefore, it is necessary to use the risk coefficient to analyze the effectiveness of the proposed innovative construction projects. With the growth of the volume of innovative projects and programs, this ratio tends to increase. Specific factors that increase the degree of risk of innovative construction projects must be taken into account when developing a risk management mechanism for the implementation of innovative construction projects. The development of an appropriate mechanism will make it possible to make decisions on the most beneficial use of economic resources and increase the socio-economic potential of the territory, its sustainable and safe development. In turn, risk management in the implementation of innovative construction projects should be understood as a set of scientifically based principles, forms, methods, techniques and means of managing innovations in the field of their creation, development in production and promotion to the market in order to make a profit. Risk management in the implementation of innovative construction projects must be carried out in several stages. At the first stage, the classification and structuring of risks is carried out. At the second stage, risk response planning is carried out, and at the third stage, the results of the risk management system are monitored. Terms of use of the property. Based on the existing state of each specific building, various hazards arise during its operation, which can have a negative impact on the state of the housing stock as a whole. When assessing the conditions of use, a database of the study area is formed, which includes information on the geography of the territory, meteorology, infrastructure, distribution of the population by areas of residence, location of industrial and other hazardous industries and facilities, main traffic flows, etc. Pressure factors for new construction, which may include both external and internal pressures. It is important to identify such factors that can have a negative impact on the object and pose a certain danger to it.

The reproduction process, as noted earlier, includes current repairs, major repairs, reconstruction, modernization and new construction. It is important to identify the risks associated with the implementation of these works and which can become a threat to the reproduction process as a whole. The mechanism of state regulation includes various tools, including the development and examination of regulations aimed at understanding possible hazards and ensuring the safety of the territory as a whole, analyzing fire safety systems and services, taking into account the fire hazard of residential buildings, high-risk facilities, systems transportation of gas and electricity. Risk analysis block. After the preliminary monitoring of possible hazards and their classification, using the methods of qualitative and quantitative analysis, the most serious of them are identified. The risks are assessed in terms of their danger and vulnerability of the object to these impact factors. A quantitative analysis of the impact of hazards is carried out throughout the life of the property. The most widely used among the quantitative methods of risk analysis is the probabilistic method, which makes it possible to estimate the probability of relevant events and the potential damage associated with them. The study of risks based on the probabilistic method makes it possible to build various risk assessment methods. Depending on the available (used) initial information, these can be methods of the following types: - statistical, when the probabilities of risk occurrence are determined according to the available statistical data (if available); - probabilistic, used to assess risks from rare events, when statistics are practically absent; - heuristic, based on the use of subjective assessments of the probability of occurrence of risks obtained with the help of expert assessment (used in assessing complex risks from various hazards, when not only statistical data are missing, but also mathematical models or models are too rough, i.e. their accuracy is low). Testing risks, evaluating various alternatives for the impact of the risks under study and predicting its consequences. Methods for predicting the extent of damage over time of use can be divided into two groups: 1) methods based on a priori (estimated) estimates obtained using theoretical models and analogies; 2) methods based on a posteriori estimates (assessment of the extent of an emergency that has already occurred). Taking into account the influence of various factors on individual risk: types of negative events, their frequency, strength, mutual arrangement of sources of danger and objects of influence, the security and vulnerability of innovative objects in relation to the damaging factors of sources of danger, the costs of implementing measures to reduce the negative impact of individual factors - justified rational measures to reduce natural and man-made risks to the lowest possible level. Separate hazardous phenomena, potentially hazardous objects are compared with each other in terms of the magnitude of the individual risk, and critical risks are identified [8-9].

Planning for response to identified risks. This block includes the development and justification of strategies and operational action plans designed to effectively implement decisions to neutralize the identified risks and ensure the achievement of the set goals. Initially, based on the rational distribution of financial resources generated from the funds of the budgets of various levels, the population and business, it is necessary to determine the order of implementation of organizational measures to improve the sustainability of the functioning of the housing stock. Of greatest interest is the use of such tools as [7-8]: - rational placement of objects serving the property. It is necessary to place hazardous production facilities (gas boilers, electrical substations, gas-balloon equipment, etc.) in such a way that the possible harm caused by them is minimal; - risk insurance. It is possible to use various types of insurance, including insurance of property risks and liability insurance for causing harm to life, health and property of citizens and the environment; - development and implementation of preventive measures to reduce risks and reduce their consequences. An important role in the prevention of emergency situations is assigned to national, departmental and territorial organizational and economic measures. They allow, through the application of administrative measures (penalties), to stimulate work to reduce the risks of emergencies and manage them with the help of a tax mechanism and concessional lending; - introduction of an emergency response mechanism. Includes planning of actions in case of an emergency, taking into account the interaction of various services with state administration and control bodies, as well as members of the public and the population. Monitoring the results of risk management is a process that must be carried out regularly to identify weaknesses in this system, track the results and make certain adjustments to the risk management process aimed at ensuring the most effective implementation of an innovative construction project.

IV. Discussion

In modern conditions, there are specific factors that increase the degree of risk of innovative construction projects. Such factors must be taken into account when developing a risk management mechanism for the implementation of innovative construction projects [6]. The developed and substantiated risk management mechanism in the implementation of innovative construction projects will make it possible to make decisions on the most beneficial use of economic resources and increase the socio-economic potential of the territory, its sustainable and safe development. Risk management in the implementation of innovative construction projects must be carried out in several stages. At the first stage, the classification and structuring of risks is carried out. At the second stage, risk response planning is carried out, and at the third stage, the results of the risk management system are monitored.

In general, the problem of determining the economic effect and choosing the most preferable options for implementing an innovation requires, on the one hand, the excess of the final direct and indirect, pure and explicit effects of using the innovation over the full costs, taking into account the payback period, and on the other hand, comparison with the same in nature. effect and cost of similar innovation options. Another problem of determining economic efficiency is related to the need to distinguish between the effectiveness of innovation activity among producers and buyers [4, 5]. The main criteria for substantiating the economic efficiency of innovative activities for manufacturers are the accounting rate of return on investment, simple and discounted payback periods, net present value, profitability index and internal rate of return. The assessment is completed by determining the stability and sensitivity of these indicators to changes in internal and external parameters. The cost-effectiveness of innovation activities for buyers needs to be considered differently. The buyer, acquiring innovations, improves his material and technical base, production and management technology. He bears the costs associated with the purchase of innovation, its transportation, development, etc. The cost effectiveness of the buyer for the use of innovations can be determined by comparing the following indicators [7]: - the cost of production and sales of products before and after the introduction of innovations (cost savings); - proceeds from the sale of products before and after the introduction of innovations (increase in revenue); - the cost of consumed resources before and after the introduction of innovations (resource conservation); - the average number of personnel (saving of living labor); - labor productivity before and after the introduction of innovations (increase in productivity); - the ratio of the operational effects of innovation consumption and own costs, including the costs of after-sales service or maintenance of operation, especially for science-intensive and technically complex innovations, outsourcing costs, etc. Outsourcing costs should be taken into account when calculating the economic efficiency of innovation activities for manufacturers and buyers, if both need highly qualified professionals for the service operation of science-intensive and technically complex innovations. Especially if the innovative project is one-time, then it is worth outsourcing it to a professional team, since it is unrealistic and expensive to grow a team of professionals in a short time. In this case, it is possible to partially shift the risks of failure of the project deadlines or losses to the company providing outsourcing services, and thus, in the event of an unsuccessful project, partially compensate for their costs.

References

[1] Asaul, A.N. The phenomenon of the investment-building complex or the country's building complex is preserved in a market economy: monograph. [Electronic resource] / Anatoly Asaul. – Access mode: http://www.aup.ru/books/m65/

[2] Buzyrev, V.V. Methodology of an integrated approach to managing the development of construction enterprises in an economic downturn [text] [Electronic resource]. // Proceedings of the Irkutsk State Economic Academy. - 2019. - Issue. No. 2.

[3] Nuzhina, I.P. Regional investment and construction complex as a system and object of environmental and economic regulation [text] / I.P. Nuzhina // Bulletin of the Tomsk State University. - 2020. - No. 319. - P. 145-150.

[4] Kaverzina, L.A. Methodological approach to optimizing the functioning of the regional investment and construction complex [text] [Electronic resource] // Problems of the modern economy. Eurasian international scientific and analytical journal. - 2019. - No. 4 (24).

[5] Sahlman, K. Elements of strategic management of technology: a conceptual framework of enterprise practice / K. Sahlman, H. Haapasalo // Int. Journal of Synergy and Research. – 2020. – Vol. 1, issue 1. – P. 57-76.

[6] Innovation management course. Ed. Korennogo A.A., Karpova V.I. - K .: Research Institute of Statistics, 2020, - P. 336

[7] Grinev, V.F. Innovation management, 2020. – P. 148

[8] Azgaldov GG, Kostin AV Intellectual property, innovations and qualimetry. Economic strategies. 2018. No. 2 (60). pp. 162-164.

[9] Osborn SG, Vengosh A, Warner NR, Jackson RB (2011). Methane Contamination of Drinking Water accompanying Gas Well Drilling and Hydraulic Fracturing, vol, 108 no. 20, 2021

[10] Attallah MF, Awwad NS, Aly HF (2012). Environmental Radioactivity of TE-NORM Waste Produced from Petroleum Industry in Egypt: Review on Characterisation and Treatment. INTECH, October 2020

BIOLOGICAL DIVERSITY OF PLANT COMMUNITIES OF TECHNOGENIC LANDSCAPES OF TYRNYAUZ TUNGSTEN-MOLYBDENUM COMBINE

Svetlana Litvinskaya, Yulia Postarnak
•
Kuban State University, Russia
litvinsky@yandex.ru
ecopost@mail.ru

Abstract

The results of studying the structure of flora and plant communities of the technogenic landscape of Tyrnyauz mining and processing combine (Kabardino-Balkarya Republic), the territory of which was previously a closed facility are presented in the article. The composition of the flora, including 229 species of vascular plants, was revealed. Ecosystem diversity includes both natural and landscapes, represented by high-altitude meadows, high-altitude forests of Betula pendula, Betula litwinowii, Salix caprea, shrubby, petrophytous groupings and steppe meadows. There is a significant disturbance of ecosystems, as evidenced by the high proportion of synanthropic plant species. Rare plant species are not registered, which also indicates a high unresolved community.

Keywords: biological diversity, plant communities, technogenic landscapes, Tyrnyauz tungsten-molybdenum combine

I. Introduction

The study of the biological diversity of anthropogenic landscapes is one of the urgent problems of modern vegetation science [1]. Phytocenoses of technogenic landscapes differ from the original ones in the structure and composition of the flora. A specific synanthropic vegetation is formed here, characterized by a unified composition of its components and a significant change in the taxonomic structure [2]. The communities dominated by alien species are often found [3] in highly transformed geosystems, which are a source of biological invasions into natural ecosystems [4]. It is necessary to conduct scientific research of such territories to substantiate the proposed optimization solutions and to identify the real and expected geoecological risks of man-made territories [5].

The purpose of the research was to study the flora and vegetation of technogenic landscapes as a basis for the development of scientific solutions to optimize the environmental management of Tyrnyauz mining and processing combine. Its tasks included inventory and analysis of the flora of natural and man-made ecotopes (road, areal man-made territories); identification of the diversity of plant communities with an assessment of the general patterns of changes in altitude zones; assessment of the level of synatropization of the identified communities.

Tyrnyauz urban settlement is the largest in the Elbrus district of the Kabardino-Balkarya Republic. It is located in the mountainous part of the Republic at an altitude of 1300 m above sea level and is rich in reserves of tungsten and molybdenum (Tyrnyauzskoye deposit). Tyrnyauz appeared in 1934 as a single-industry town, when the development of a tungsten-molybdenum deposit was started here. Over time, it became the leading production of non-ferrous metal industry in the country, providing a third of the needs of the country's economy in this raw material. After the collapse of the Soviet Union, Tyrnyauz began to lose its position like other single-industry towns of the country. A new stage in the development in the history of the city began after V. Putin came to power. Today, the goal is to restore the combine.

The closed territory of the mining and processing combine for visiting interested parties caused the absence of any floristic data of this territory. To date, there is no information not only about rare species and phytocenoses, but also about the general patterns of vegetation changes in high-altitude zones. The studied area is characterized by long-term intensive economic activity (grazing, logging, road works, intensive construction on slopes, etc.), which has a negative impact on the natural vegetation cover, causing degradation and an increase in the proportion of weeds in its composition.

II. Methods

The object of the study is flora and plant communities on linear (road) and areal (landfills, pumping station territory) objects of Tyrnyauz tungsten-molybdenum deposit. The studies were carried out by traditional route and geobotanical methods in September 2020. Observations were made concerning the location of species by altitude zones, habitat types, phytocenotic role and ecological confinement of species. In total, about 200 herbarium samples were collected and 35 sample plots were made. The altitude range of studies is from 2494 m above sea level to a height of 1100 m above sea level. The names of plants are given in accordance with the latest floristic summary of S.H. Shkhagapsoev [6], Synopsis of the Flora of the Caucasus [7-9].

According to floral zoning, Tyrnyauz urban settlement is located on the border of two subdistricts: Elbrus and the Jurassic Depression subdistrict. It occupies the area of the Jurassic (Northern) depression from Baksan to Cherek with altitudes from 1200 m up to 1800-2000 m above sea level. Within this subdistrict basins are isolated, having mainly upland xerophytic and steppe vegetation surrounded by mesophilic. A total of 896 species have been recorded here [6]. The originality of the flora lies in the predominance of upland xerophytic and petrophytic vegetation.

III. Results

219 plant species belonging to 51 families have been registered in the research area. The analysis of the flora showed that boreal elements predominate in the flora, but the presence of Mediterranean features is noted. The analysis of geographical elements characterizes the flora as Boreal-Caucasian (66.58%), where the species of the Caucasian element make up 33.4%. Boreal species prevail in the flora of individual belts and habitats, and the share of ancient Mediterranean species accounts for only 12.35% [7]. Ecological analysis of the flora shows that the number of species of open grassy spaces of highlands and forest birch communities predominate. According to Raunkiær [10], hemicryptophytes numerically predominate in the spectrum of life forms of the entire flora, with a small number of chamephytes. It should be noted a significant number of therophytes (annuals-biennials), which is associated with a significant disturbance of vegetation cover along the roadsides of a linear object and especially areal territories. These are species belonging to a vagative life form that do not stay at the area of their growth but roam the area and germinate from seeds on new biotopes. One species of the parasites, *Monotropa hypopitys* L., was noted.

The following types of vegetation were observed in the research area, replacing each other when moving from top to bottom: rocky groupings of the upper mountain belt, fragments of subalpine meadows, high-altitude forests of *Betula pendula* Roth, *Betula litwinowii* Doluch., *Salix* *caprea* L., shrub thickets of *Hippophae rhamnoides* L., steppe meadows, ruderal communities of anthropogenic ecotopes and rocky vegetation of the middle mountain belt.

The linear feature (road) is dominated by forests of *Betula pendula* and *Betula litwinowii*. The sodominants are *Salix caprea* and then *Hippophae rhamnoides* with decreasing of the height and lower is *Berberis vulgaris* L. Occasionally *Pinus sylvestris* L., *Ulmus glabra* Huds. are found. *Pinus sylvestris* does not form communities in the studied zone. *Myricaria bracteata* Royle grows along the banks of watercourses.

Betula litwinowii plant communities grow on rocky substrates and are characterized by low bonitet and form low-density stands on minor soils, largely bearing traces of anthropogenic disturbances associated with the road functioning during the operation of the combine. *Betula litwinowii* is about 50 years old. The most common type of ecosystems is *Betula litwinowii* communities with *Calamagrostis epigeios* (L.) Roth participating in the grass canopy, as well as with varying degrees of grass participation. They form ecotonic biotic communities. Their uniqueness consists in a combination of two types of plant communities: forest and treeless. Plant communities of *Betula litwinowii* are in contact with steppe meadow communities, meadow steppes and rocky ecotopes.

The uppermost sections of the research area are blocky-rocky-talus ecotopes with thinned rare vegetation. Abrupt and steep slopes are characterized by extremely weakly expressed soil cover. Significant areas are outcrops with a complete absence of soil. Communities are not genetically formed. The geobotanical description was made at an altitude of 2494 m above sea level (GK 381). Vegetation is rare, Alpine type. Here grow: *Betula pendula, Betula litwinowii, Salix apoda,* undergrowth of *Pinus sylvestris*. From herbaceous plants grow *Calamagrostis pseudophragmites* (Haller f.) Koeler, *Calamagrostis epigeios, Euphrasia caucasica* Juz., *Tussilago farfara* L., *Rumex acetosella* L., *Chamaenerion colchicum* (Albov) Steinb., *Erigeron orientalis* Boiss., *Gentianella biebersteinii* (Bunge) Holub.

The slopes of the linear feature (roads) are rocky barrows. Here rarely grow the shrub forms of *Betula pendula, Salix caprea, Hippophae rhamnoides*, *Juniperus communis* subsp. *oblonga* (M. Bieb.) Galushko and herbaceous plants: *Heracleum asperum* (Hoffm.) M. Bieb., *Festuca ovina* L., *Gentianella biebersteinii* (Bunge) Holub, *Crepis pulchra* L., *Achillea millefolium* L. rarely. *Hippophae rhamnoides* forms small clusters in the lower part of the slope near the road.

Here, there is a dry stacking landfill in the alpine zone at an altitude of 2500 m above sea level (GK 382). Plant communities are not formed, thinned, without layering. The vegetation cover is a set of species whose seeds quickly germinated on the secondary rocky ecotope. *Aster amelloides* Besser, thickets of *Calamagrostis epigeios, Rumex acetoselloides* Balansa and shrubbery species of *Juniperus communis* subsp. *oblonga* grow here.

The vegetation on the areal territory "Conveyor tunnel and a section of a linear object" (GK-383) represents a range of different ecological types. There were recorded: woody species of *Pinus sylvestris* with a height of 2.5 m, thickets of *Hippophae rhamnoides, Betula pendula, Salix apoda, Salix cinerea,* herbaceous life forms: *Calamagrostis pseudophragmites, Calamagrostis epigeios, Veronica gentianoides* Vahl, *Sedum oppositifolium* Sims, petrophytic species of *Artemisia caucasica* Willd. and *Heracleum freynianum* Sommier & Levier, *Rhinanthus minor* L., *Scabiosa bipinnata* K. Koch, *Scrophularia ruprechtii* Boiss., characteristic of the mountain wastes of the Alpine belt.

The vegetation is more closed on the loose rock areas; the projective coverage is about 40%. Here grow: *Pyrethrum parthenifolium* Willd., *Calamagrostis epigeios, Artemisia absinthium* L., which grows in steppes, dry meadows and weeds, *Carlina vulgaris* L., characteristic of dry meadows from the lowlands to the middle mountain belt, *Aster amelloides* Besser, etc.

There are almost monodominant communities of *Calamagrostis epigeios* and *Chamaenerion angustifolium* (L.) Scop. that grow along the road.

The site of the surface stowing complex on the existing area of the Mukulansky quarry (GK-387). The territory is the remains of destroyed buildings, the vegetation of which is a random set of species from different altitude zones. Here grow: *Artemisia austriaca* Jacq., *Crepis rhoeadifolia* M. Bieb., *Calamagrostis pseudophragmites, Calamagrostis arundinacea, Trifolium hybridum* L., Tussilago farfara L., *Plantago major*, *Euphrasia caucasica* Juz., *Chamaenerion angustifolium* (L.) Scop., Scabiosa caucasica M. Bieb., *Cichorium intybus* L., *Melilotus officinalis* (L.) Pall., *Senecio propinquus* Schischk., *Lapsana communis* L., *Anthemis sosnovskyana* Fed., *Tanacetum vulgare* L., *Picris hieracioides* L., *Anthemis rigescens* Willd., *Erigeron orientalis* Boiss.

The linear object from the site of the surface stowing complex has an average elevation of 2410 m above sea level. Coordinates N 43 23 286 E 42 52 806. Flora and vegetation change slightly. Here are registered: *Betula litwinowii, Salix caprea, Hippophae rhamnoides,* herbaceous: *Onobrychis petraea* (M. Bieb. ex Willd.) Fisch., *Epilobium angustifolium* L., *Trifolium medium* L., *Pyrethrum parthenifolium* Willd., *Lapsana communis* L., *Calamagrostis pseudophragmites* (Haller f.) Koeler, *Phleum montanum* K. Koch, *Veronica gentianoides* Vahl, *Medicago lupulina* L., *Artemisia austriaca* Jacq., *Achillea millefolium* L., *Artemisia caucasica* Willd., *Sedum album* L., *Diplotaxis muralis* (L.) DC., *Koeleria cristata* (L.) Pers., *Leucanthemum vulgare* Lam., *Leontodon autumnalis* L., *Carduus nutans* L., *Centaurea salicifolia* M. Bieb., *Plantago media* L., *Verbascum lychnitis* L., *Echium vulgare* L., *Lotus caucasicus* Kuprian. ex Juz., *Melilotus officinalis*, *Dianthus caucaseus* Sm.. There are no formed communities. Scree groups alternate with thinned petrophytic communities.

The roadsides are covered with more closed plant groupings with a decrease in height above sea level. It is possible to distinguish a tree layer of *Betula litwinowii, Pinus sylvestris* pine, although they are short growing and have a shrubby form.

The heights at which the road is laid do not change much, because the road passes through a serpentine. There are often forks with secondary roads. Height is 2330 m. Coordinates: N 43 23 331 E 42 52 339. In this segment, communities from *Salix caprea* and *Betula litwinowii* begin to dominate in combination with herbaceous communities, which are difficult to attribute to a certain type of vegetation, because they are formed by species of different ecology and confined to high-altitude zones.

Forest communities are not yet grown at an altitude of 2300 m. The usual floral set of species is registered. In places rather closed shrub groups of *Betula pendula* and background species of the upper mountain belt are formed.

As closeness and projective coverage increase, the number of individuals of the same species increases, i.e. herbaceous plants form populations, *Salix caprea* and *Betula litwinowii* form shrubby thickets.

There is a tunnel platform at an altitude of 2300 m above sea level. The road to the tunnel is covered with rather disturbed communities, among which *Betula pendula* grow solitary. Ruderal communities are common at the tunnel. The projective coverage is 50%. Here are registered: *Tussilago farfara*, *Amoria repens* (L.) C. Presl, *Tanacetum vulgare* L., *Artemisia absinthium* L., *Heracleum asperum* (Hoffm.) M. Bieb., *Calamagrostis pseudophragmites*, *Cirsium pendulum* Fisch., *Leucanthemum vulgare* Lam., *Festuca ovina* L., *Alchemilla caucasica* Buser.

Further, the linear object goes to the zone of high-altitude forests of *Betula pendula* and *Betula litwinowii*. The crooked forests of *Betula pendula* and *Betula litwinowii* are not pronounced in this geographical point, which is explained by the arid climate of the Jurassic Basin. It is a stunted forest. The diameter of the trees is only 10 cm. *Salix caprea, Sorbus aucuparia* L. are mixed with *Betula pendula* and *Betula litwinowii*. The roadside before the beginning of the forest is covered with herbaceous vegetation, mainly vegetating grasses, *Trifolium repens* L., *Ajuga reptans* L., *Achillea millefolium* L., *Cirsium pendulum* Fisch. and bushes of *Pentaphylloides fruticosa* (L.) O. Schwarz. *Arum orientale* M. Bieb., *Alchemilla caucasica* Buser, Alpine meadow species *Rubus saxatilis* L., *Delphinium dasycarpum* Steven ex DC. are registered in the forest community.

Frequently, there are talus slopes along the sides of a linear object, where completely different species grow, ecologically more homogeneous petrophyte complexes.

A population of *Dryas caucasica* Juz. was noted on one talus (coordinates: N 43 23 523 E 42 52 181). The projective coverage is 40-50%. The community was registered once on the entire route of the study. Below the talus on the sides of the linear object grow closed herbaceous communities composed of *Cirsium obvallatum* (M. Bieb.) Fisch., *Cirsium pugnax* Sommier & Levier, *Calamagrostis pseudophragmites, Calamagrostis epigeios* including varying forbs.

Linear object (road). Herbaceous communities with decreasing altitude are replaced by thinned communities of *Salix caprea* and *Betula litwinowii* on both sides of the road. Height is from 2231 m above sea level to 1500 m above sea level.

An accumulation of construction debris is noted on the areal object – tunnel (9SHT-2165-M (07). Communities are not expressed. The composition of the flora is random, the occurrence of weed elements is high (46%). Common elements are weed species *Tussilago farfara, Artemisia absinthium, Artemisia annua* L., *Pyrethrum parthenifolium.* In places, *Calamagrostis epigeios* and *Calamagrostis pseudophragmites* form dense groupings.

There is a linear object (road) below the tunnel (height is 2231 m above sea level). Birch forests grow on both sides, alternating with herbaceous communities of *Calamagrostis pseudophragmites* and communities of *Cirsium arvense* (L.) Scop. including diverse synatropic communities of roadsides.

The main industrial site (GK 400) was surveyed. It occupies a large area where there are ruins of buildings and trampled areas where vegetation is practically absent. Communities are sparse, the set of species is random, but floral richness is noted. There were registered here: *Echinops sphaerocephalus* L., *Polygala alpicola* Rupr., *Plantago major* L., *Verbascum thapsus* L., *Tussilago farfara, Artemisia austriaca, Calamagrostis arundinacea* (L.) Roth, *Rumex confertus* Willd., *Cirsium obvallatum, Cirsium arvense, Carlina vulgaris, Achillea millefolium, Securigera varia* (L.) Lassen, *Alchemilla caucasica, Dianthus caucaseus, Pinus sylvestris, Salix caprea, Dasiphora fruticosa.* Vegetation is closed on the outskirts of the site near the rainwater and meltwater wastewater facilities.

Forest communities of *Salix caprea* and *Betula litwinowii* dominate on both sides of the road up to the final point near the village. *Heracleum asperum, Calamagrostis epigeios, Urtica urens* L., *Alchemilla caucasica, Delphinium dasycarpum* Steven ex DC., vegetative grasses, etc. are noted in herbaceous layer.

The type of communities in the loop parts of the road turns changes somewhat. The height is 2000-1800 m above sea level. There are more disturbed forests of *Betula litwinowii* growing along the sloping roadsides. There is a random collection of weedy vegetation with elements of meadow vegetation on the treeless roadsides. Here are registered: *Euphrasia caucasica* Juz., *Mentha longifolia* (L.) Huds., *Amoria repens* (L.) C. Presl, *Plantago major, Leucanthemum vulgare* Lam., *Artemisia absinthium, Echium vulgare, Achillea millefolium, Securigera varia,* among which *Ononis arvensis* L. is first noted.

Steppe communities are spread along the gas pipeline line (on the way to the pumping station), where fringe, meadow, steppe and petrophytic species grow. There is subalpine species of *Scabiosa caucasica*, petrophytic species of *Sedum caucasicum* (Grossh.) Boriss. and *Campanula alliariifolia* Willd., steppe species of *Stipa capillata* L., *Teucrium chamaedrys* L., *Salvia canescens* C.A. Mey. and meadow species of *Geranium sanguineum, Origanum vulgare, Briza elatior*. There are woody and shrubby species: *Juniperus hemisphaerica* C. Presl, *Juniperus communis* subsp. *oblonga* (M. Bieb.) Galushko, *Cotoneaster melanocarpus* Lodd., G. Lodd. & W. Lodd., *Pinus sylvestris, Betula litwinowii, Rosa canina* L., *Dasiphora fruticosa.* The projective coverage is 100%.

The linear object between the two loops is covered with birch-willow grass communities. *Betula litwinowii* dominates (diameter is 20 cm), combined with pine. The herbaceous layer is the usual set of species.

The communities change at 1650 m above sea level and there are birch-sea buckthorn shorthear communities and birch-sea buckthorn with barberry with barely-passable monodominant communities of *Hippophae rhamnoides* and *Berberis vulgris*. Both species are in a state of abundant fruiting. *Berberis vulgaris* reaches a height of 2.5 m. *Salix caprea, Juniperus hemisphaerica* (height is 2 m), *Betula litwinowii, Betula pendula, Rosa canina* are registered in the communities. *Dryopteris filix-mas* (L.) Schott, *Eryngium planum* L., *Clinopodium vulgare* L., *Mentha longifolia* (L.) Huds., etc. were recorded from herbaceous plants.

The greatest disturbance was noted in the lower sections of the linear object near Tyrnyauz urban settlement. The height is 1500 m above sea level. Wormwood disturbed communities grow along the roadsides. The water supply line starts from the village (PP-14, the lower point of the water supply). Here the conditions are wetter and weed vegetation grows with elements of meadow (*Mentha longifolia*). There are no pronounced communities.

There is a rocky and rocky-talus outcropping with petrophytic vegetation at an altitude of 1363 m above sea level (coordinates N 43 23 687 E 42 54 721) on the steep slope of the eastern exposure. The point of the gas pipeline and the linear object in the lower part near the village of Tyrnyauza. The projective coverage is from 10 to 40%. Endemic species of *Salvia canescens* C.A. Mey., *Onosma caucasica* E.G. Levin ex Popov, *Astragalus* sp. are registered here, which are not found in the rest of the surveyed sites.

IV. Discussion

Phytocenotic cover of the territory of Tyrnyauz mining and processing combine is represented by several types of natural and synanthropic communities. Natural ecosystems are represented by high-altitude meadows, high-altitude forests of *Betula pendula, Betula litwinowii, Salix caprea*, shrubby thickets of *Hippophae rhamnoides* and *Berberis vulgris*, petrophytic groupings and steppe meadows.

Synanthropic communities have been developed on the roadsides, tunnels, in the security zone of the gas pipeline. The most transformed are areal objects characterized by significant disturbance of the geological environment, reduction of tree plantations, cluttering of the territory with construction debris. During the study of areal and linear objects, a floristic list consisting of 229 species of vascular plants was registered. The species differ in different phytocenotic confinement and are allocated to high-altitude zones.

Natural communities that are not disturbed by anthropogenic activity retain their structure unchanged, with the exception of communities that are directly adjacent to synanthropic communities of roadsides and man-made wastelands. Here it is noted the presence of weeds, which poses a threat of displacement to native species. Synanthropic communities of roadsides and areal technogenic sites are a random set of weeds with elements of meadow elements, poorly expressed horizontal and vertical structure. The high proportion of weed species is explained by the long-term functioning of the road and abandonment in recent decades. Especially weed species predominate at areal objects. There are no rare species in the vegetation cover of roadsides and areal objects, which is also an indicator of ecosystem disturbance.

The results of the study of vegetation formed on disturbed landscapes will help to define the degree of their suitability for biological reclamation; to identify areas that do not require biological reclamation; to develop methods of biological reclamation taking into account specific environmental conditions.

References

[1] Mirkin B M, Naumova L G, Solomesh A I 2002 Modern science of vegetation Ufa: Logos 262 p.

[2] Shatokhina A V 2003 The structure of the flora of the technogenic landscape of the Yerkovets brown coal section (Amur region) Proceedings of the Orenburg State Agrarian

University pp 225-228.

[3] Gusev A P Anthropogenic transformation of landscapes and vegetation succession // Bulletin of the Tyumen State University. Ecology and nature management 2015 vol 2 pp 103-110.

[4] Mironova S I ,Cherosov M M 2010 Technogenic transformation of vegetation // The Far North: Plant biodiversity and ecology of Yakutia // Series Plant and Vegetation vol 3 Springer Science+Business Media BV Dordrecht pp 263-265.

[5] Myachina K V, Krasnov E V 2021 Ways of optimization of steppe landscapes in conditions of oil and gas production // South of Russia: ecology, development vol 16 No. 1 pp 76-81 DOI: 10.18470/192-1098-2021-1-76-86.

[6] Shkhagapsoev S X 2015 Vegetation cover of Kabardino-Balkaria Nalchik: Tetrafgraf LLC 352 p.

[7] Litvinskaya S.A., Murtazaliev R.A. Kavkazskii element vo flore Rossiiskogo Kavkaza: geografiya, sozologiya, ekologiya [The Caucasus Element within the Flora of the Russian Caucasus: Geography, Sozology, Ecology]. Krasnodar, Prosveshchenie Yug Publ., 2009, 439 p. (In Russian).

[8] Synopsis of the flora of the Caucasus: In 3 volumes 2003.URL: https://www.binran.ru/resursy/informatsionnyye-resursy/tekuschie-proekty/caucasian-flora/ (Accessed 15 May 2022).

[9] Shkhagapsoev S X, Guchasov ZM Geographical analysis of the flora of the Rocky Ridge and the Jurassic depression of Kabardino-Balkaria 2001// Abstracts of the participants of the III Regional Scientific and Practical Conference "Biodiversity of the Caucasus" Nalchik pp. 57-58.

[10] Raunkiær Ch Plant life forms 1937/ transl. from Danish by H. Gilbert-Carter— Oxford: Clarendon Press vi 104 p.

ASSESSMENT OF THE SUSTAINABILITY OF OBJECTS OF CULTURAL HERITAGE TO THE IMPACTS OF HAZARDOUS NATURAL PROCESSES WITH A CLIMATIC FACTOR

Elena Arefyeva[1,2], Ekaterina Alekseeva[1]

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[1]Russian National Research Institute for Civil Defense and Emergencies under the EMERCOM (Federal Center for Science and High Technologies), Moscow, Russia
elaref@mail.ru
[2]Kazan National Research Technical University named after A.N. Tupolev-KAI, Russia
kleongardt@bk.ru

Abstract

In the article, the authors propose an integrated approach to assessing the sustainability of cultural heritage objects under the influence of hazardous natural processes with a climatic factor. The approach is based on an integral indicator of the sustainability of a cultural heritage object, formed on the basis of three indicators (exposure to hazardous natural processes, physical condition and category of value of cultural heritage objects). This approach will make it possible to give a complex comprehensive assessment of a cultural heritage site and determine the weight of each factor in the formation of a common danger for such sites.

Keywords: object of cultural heritage, historical built-up areas, climate change, karst, landslide processes, flooding, sustainability of objects.

I. Introduction

Complex engineering and geological conditions of cities and modern climatic changes cause a high risk of initiation both new and activation of existing hazardous natural processes and phenomena. The consequences of data exposure have a negative impact on the state of objects of cultural heritage. Changes in the hydrogeological regime of groundwater, including those due to man-made loads and climate change, entailing the state, stability of buildings and structures [1,2]. The construction of new facilities on historical territories leads to flooding, which in turn initiates such dangerous processes as karst, landslide, and also reduce the bearing capacity of the soils of the foundations of structures [1, 2, 3]. As a result, emergency situations may occur in buildings, cracking of the walls of objects, additional wear of load-bearing structures, etc. [4,5,6].

For example, on the territory of the historical and architectural complex of the Kazan Kremlin (a UNESCO cultural heritage site), the following damage and deformations of its objects were recorded: deviation from the vertical of the curtain wall, erosion of the brickwork, cracks in the Kremlin walls, subsidence of soils of the foundations of structures, traces of wall soaking, stratification of the finishing layer (Fig. 1) [7,8].

Figure 1: *Deformations of the walls of the Kazan Kremlin (photo by the authors)*

This is due to the high intensity of natural and man-made impact on the hydrogeological environment near the Kremlin, as well as the intensification of a whole range of hydrogeological and engineering-geological processes, such as landslides, karsts, suffosions, river and ravine erosion, processing of the reservoir shore, natural and man-made flooding, subsidence phenomena in the soil [8].

The hydrogeological regime of the Kremlin Hill is determined by its geomorphology and features of the internal geological structure. Groundwater of the upper groundwater table type is almost ubiquitous at the top of the hill. Its source is atmospheric precipitation, irrigation and man-made waters. The share of the latter is especially significant in places where water utilities (water pipes, sewers) are laid and is largely associated with leaks, breakthroughs, etc. In the spring period of snowmelt and during heavy rains in the summer and autumn periods, the movement of groundwater only intensifies [7,8]. These processes of groundwater movement lead not only to flooding and liquefaction of the soils of the foundations of cultural heritage objects, but also to subsidence and uneven sedimentation of soils, a decrease in their bearing capacity and, as a result, deformation and destruction of objects occur, corrosion occurs, but also initiate other dangerous natural processes as ravine erosion, suffusion-karst and abrasion processes, landslides. In this regard, it is necessary to timely identify the negative manifestations of hazardous processes, conduct regular assessments of buildings and structures in historical territories.

Along with a number of well-known approaches to assessing sustainability [9], there is a need to develop an integrated approach by introducing an integral indicator that takes into account both the exposure of the object to hazards and the physical state of the object, the age of the object, the presence of deformation, cracks in the walls of the building.

All of the above requires the development of an integrated approach to assessing the sustainability of cultural heritage objects when exposed to hazardous natural processes with a climatic factor, aimed at preserving the architectural ensemble. Which will solve the problem of preventing the negative impact of active hazardous natural processes on historical architectural buildings and structures.

II. Development of a fuzzy model for calculating the integral indicator of sustainability of cultural heritage objects

A fuzzy controller of the Takagi-Sugeno-Kang type is a fuzzy inference system, the rule base of which contains linear analytical functions from the values of input variables in the conclusions of each rule [10,11]. The input information for the system is data on each factor of hazardous natural processes in the study area of cultural heritage objects (flat and ravine erosion, landslides, karst, reworking of the banks of reservoirs, flooding of the territory), and the result of the system is the numerical value of the integral hazard characteristic for the entire object for all factors in general. At the same time, the fuzzy nature of the degree of danger of each factor is taken into account, as well as the subjectivity of the assessment by experts in the subject area.

An integral indicator for assessing the sustainability of a cultural heritage object will be considered an indicator - G. This is a dimensionless value that can be expressed, for example, as a percentage or in fractions of a unit. The greater the G value, the greater the danger to the object and the less the sustainability of the cultural heritage object. To derive a complex integral sustainability indicator G, we define three particular indicators (Y1, Y2, Y3), on which the indicator G depends:

1. Y_1 – indicator of the object's exposure to hazardous natural processes with a climatic factor.
2. Y_2 – an indicator of the physical condition of the object (wear of structures, the presence of cracks, tifts, etc.).
3. Y_3 – indicator of the category of historical and cultural significance of a cultural heritage object.

As input variables for determining the integral indicator (Y_1), we use data from Appendix 3 of the Methodological Recommendations on Climate Adaptation [12], while taking into account those types of hazardous natural processes that are characteristic of the specific studied territory of the cultural heritage object.

To evaluate the indicator (Y_2), the initial data are indicators of the physical state of the cultural heritage object, obtained from the results of the state historical and cultural expertise (building tilt, relative difference in settlement, peeling of the lining, wear of the structure, cracks in the masonry from uneven settlement of the building (crack length)) in accordance with the category of the technical condition of the building and structure.

And when calculating the indicator (Y_3), we take into account data on the category of historical and cultural significance of a cultural heritage object.

To build a fuzzy model for evaluating the indicators (Y_1, Y_2, Y_3) of a cultural heritage object under the influence of dangerous natural processes, including with a climatic factor, it is necessary to form the left and right parts of fuzzy rules of logical inference of the form [13]. Let us consider the rules of logical inference for Y_1:

$$R_1\text{: IF } x_1 \text{ is } A_{11} \dots \text{ AND } \dots x_n \text{ is } A_{1n}\text{, THEN } y_1 \text{ is } B_1 \tag{1}$$

$$R_i\text{: IF } x_{i1} \text{ is } A_{i1} \dots \text{ AND } \dots x_{in} \text{ is } A_{in}\text{, THEN } y_i \text{ is } B_i \tag{2}$$

$$R_m\text{: IF } x_{m1} \text{ is } A_{m1} \dots \text{ AND } \dots x_n \text{ is } A_{mn}\text{, THEN } y_m \text{ is } B_m, \tag{3}$$

where x_k (k=1..n) – input variables;

y_i – output variable, i=1,m;

A_{ik} – given fuzzy sets with membership functions;

R_i – i-th inference rule.

It is necessary to build two fuzzy inference systems: Mamdani and Sugeno, to calculate the output parameters (Y_1, Y_2, Y_3) depending on the values of the input parameters for each particular indicator.

Provided that the membership functions are set for each qualitative assessment of the input and output parameters, it is possible to build the Mamdani system and calculate the value of the private indicator. However, the Mamdani system has a number of disadvantages, first of all, the impossibility of its retraining on the available initial data. These shortcomings can be avoided by a Sugeno-type system, which differs from Mamdani in the way in which the right parts of the rules are specified. In the Sugeno system, the right-hand sides are linear polynomials with respect to the input parameters with given coefficients.

To form the Sugeno system, it is necessary to use the same set of rules, however, a linear expression is written as an output parameter [13].

III. Results

As a result, a model of a three-level cascade was constructed from Neuro-Fuzzy systems of the Takagi-Sugeno-Kang type, which allows one to consistently determine all three initial partial indicators affecting the factor G (Y_1, Y_2, Y_3) (Fig. 2) [13].

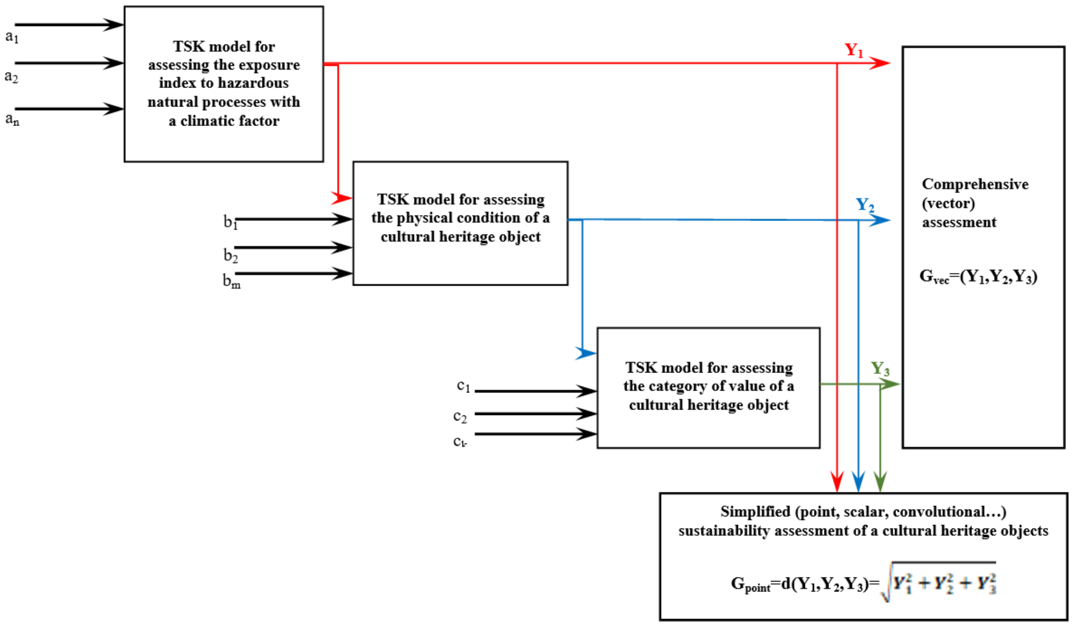

Figure 2: *Cascade Neuro-Fuzzy model of integral assessment of the sustainability index of cultural heritage objects*

The authors propose two approaches for calculating the estimate G based on the partial indicators Yi obtained at the previous stage. The first approach is to represent the quantity G as a three-dimensional vector of found Yi:

$$G = (Y_1, Y_2, Y_3) \tag{4}$$

The second approach is to calculate G as a linear convolution of the criteria Yi and obtain a scalar value of the sustainability index. Such an estimate can be obtained, in particular, as the length of the vector (Y_1, Y_2, Y_3):

$$G = \sqrt{Y_1^2 + Y_2^2 + Y_3^2} \tag{5}$$

Such a point estimate, although simplified, allows us to obtain an easily interpretable result.

To form the Sugeno system, a linear expression (function) is written: the dependence of the parameter (Y1) on the input parameters Erosion (E), Landslide (O), Karst (K), Flooding (P), Retreat (S). There should be four such functions in total - according to the number of possible qualitative estimates of the output parameter (Y1).

The function has a general form:

$$Y1=a1\ E+a2\ O+a3\ K+a4\ P+a5\ S \tag{6}$$

Thus, to determine function (6), it is necessary to calculate five unknown coefficients: a1, a2, a3, a4 and a5. In this expression, the free term a0 is omitted, since if it is present, the linear function degenerates into a singleton when calculating the coefficients according to the principle a0 = "middle of the range for a given qualitative value of the output parameter", and all other coefficients become equal to 0.

For further formation of systems of linear equations, it is necessary to have quantitative representations of the qualitative values of input and output parameters.

To determine the unknown coefficients of the linear function (4) for each qualitative value Y1* (for Y1*= "UO", "Op", "VO", "Kr"), we will develop the following procedure:

1. From Table 1, we select 5 rules so that the output value on the right side of the rule is equal to the given qualitative value Y1*, and the left side contains the maximum variety of combinations of input parameters.

2. For each selected rule, we write expression (4), replacing the parameters E, O, K, P and S with the average values of the ranges corresponding to the qualitative description from Appendix 3 of the Methodological Recommendations on Climate Adaptation [12]. As a result, 5 linear equations will be obtained with respect to five unknown coefficients ai, where i=1…5.

3. Having solved the resulting closed system of linear equations, we determine the coefficients of the linear functions of the right-hand sides of the fuzzy inference rules corresponding to the given qualitative value Y1*.

The correspondence between the data of the qualitative expression and the type of function is presented in Table 1.

Table 1: *Linear functions for the formation of the right parts of the rules of the Sugeno system*

Qualitative expression, Y_1	Type of linear function
Moderately hazardous	Y_1=0,339*Э+6,983*О+0,145*К+0,029*П+5,510*С
Dangerous	Y_1=0,067*Э+0,485*О+0,202*К+0,186*П+2,078*С
Very dangerous	Y_1= 0,031*Э+0,355*О+0,149*К+0,323*П+2,019*С
Extremely_dangerous	Y_1= 0,007*Э+0,460*О+0,784*К+0,491*П+3,886*С

Further, similarly to the Mamdani system, we will introduce into the system 5 input variables Erosion, Landslide, Karst, Flooding, Retreat, and one output variable General_Hazard_Rating (see Fig. 3). Thus, we obtain linear dependencies for a comprehensive assessment of exposure to hazardous natural processes with a climatic factor that most threaten cultural heritage sites.

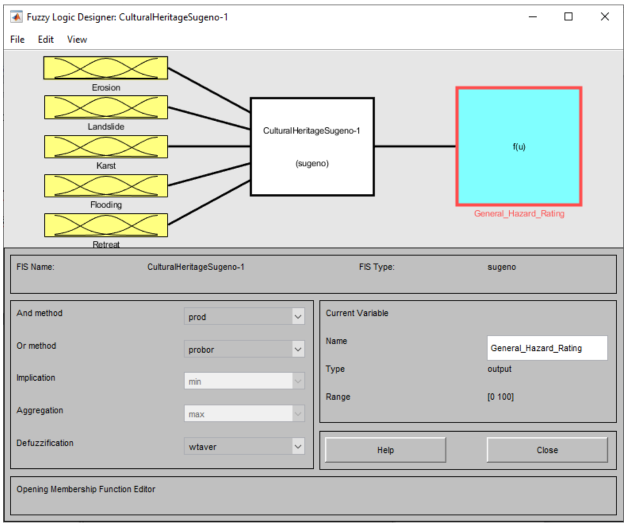

Figure 3: *View of the shell of the Sugeno system in the visualizer of the FIS package.*

IV. Conclusion

The proposed approach allows us to give a complex comprehensive assessment of the sustainability of the cultural heritage object and allows us to determine qualitatively and quantitatively the condition of the object, determine the weight of each negative factor of hazardous natural processes, including the climatic factor in the formation of the sustainability indicator in general. At the same time, the technical condition of the object and its category of significance of cultural heritage objects are taken into account. These indicators are important in determining the assessment of the sustainability of several cultural heritage objects on the territory of one municipal district or region as a whole to justify the implementation of measures to protect cultural heritage objects.

References

[1] Arefyeva E.V. Flooding of historical cities: regulation of the groundwater regime. LAP LAMBERT Academic Publishing, 6-8 66121, Saarbrücken, Germany, 2014. ISBN: 3659215473

[2] Arefyeva, E V; Muravyeva, E V; Maslennikova, N N. Environmental Risks Caused by Floods in Built-Up Areas. - IOP Conference Series. Earth and Environmental Science; Bristol Том 666, Изд. 5, (Mar 2021). DOI:10.1088/1755-1315/666/5/052032

[3] Arefyeva E.V. Forecasting emergency situations in case of flooding of cities.- LAP LAMBERT Academic Publishing, 6-8 66121, Saarbrücken, Germany, 2015. ISBN 978-3-659-42662-9, 171 p.

[4] Arefyeva E.V., Muravyeva E.V. Forecast of the impact of hazardous factors of emergency situations on the state of technosphere objects. Bulletin of the State Budgetary Institution “Scientific Center for Life Safety”, Scientific-methodical and informational journal, №2 (40),2019. – pp. 62-67

[5] Arefyeva E.V., Muravyeva E.V. Sustainability of cultural heritage objects. - International Scientific Journal "Crisis Management and Technologies", Crisis management and technology. №1(16),2020. Yerevan. Republic of Armenia.pp.73-79,

[6] Arefyeva E.V., Muravyeva E.V. and Frose T.Yu. Considering emergency hazards in construction and operation of infrastructures. - IOP Conf. Ser.: Mater. Sci. Eng. 687 066023/ International Conference on Construction, Architecture and Technosphere Safety (2019) 066023 IOP Publishing doi:10.1088/1757-899X/687/6/066023

[7] Slepak, Z. M. Geophysics for the city: on the example of the territory of Kazan / Z. M. Slepak; Z. M. Slepak. – Moscow: EAGS; 2007. – ISBN 978-5-88942-072-9. – EDN QKGZBL.

[8] Latypov, A. I. Zoning of the territory of Kazan according to the stability of soil bases to dynamic impact / A. I. Latypov, N. I. Zharkova, G. A. Cherniychuk // Geotechnics. – 2013. – № 1. – pp. 42-48. – EDN QADXGB.

[9] Arefyeva EV, E V Muravyeva, Alekseeva E. Improving the sustainability of cultural heritage sites using the INFORM Method. IOP Conference Series: Materials Science and Engineering (MSE)" , Sochi 2020 *IOP Conf. Ser.: Mater. Sci. Eng*

[10] Takagi T. Fuzzy Identification of Systems and its Applications to Modeling and Control / T. Takagi, M. Sugeno // IEEE Transactions on Systems, Man, and Cybernetics. 1985. Vol. 15. No. 1. Pp. 116-132.

[11] Novikova S.V., Kremleva E.Sh., Valitova N.L., "Soft cyclic data encoding using a quasi-fuzzy measure”, Vestnik TvGU. Seriya: Prikladnaya Matematika [Herald of Tver State University. Series: Applied Mathematics], 2019, № 3, 90–101 (in Russian), https://doi.org/10.26456/vtpmk542.

[12] Order of the Ministry of Economic Development of Russia dated May 13, 2021 N 267 "On the approval of guidelines and indicators on adaptation to climate change”.

[13] Alekseeva, E.I., Arefyeva, E.V., Novikova S.V. Assessment of the sustainability of

cultural heritage objects under the influence of hazardous natural processes based on the Takagi-Sugeno-Kanga cascade neuro-fuzzy model / // Modeling of complex processes and systems: Proceedings of section No. 10 of the XXII International Scientific and Practical Conference, Khimki, March 01, 2022. – Khimki: Academy of Civil Protection of the Ministry of the Russian Federation for Civil Defense, Emergencies and Disaster Relief, 2022. – pp. 25-30. – EDN SZVJEI.

[14] Plyuschikov, V.G., Avdotin, V.P., Arefyeva, E.V., Gurina, R.R., Bolgov M. Hydrological Risk management of Urbanized Areas n Framework of the Smart City Concept. IOP Conf. Ser:Earth Environ. Sci. 691(2021) 012019Doi: 10.1088/1755-1315/691/1//012019

[15] Oltyan, I.Yu., Arefyeva, E.V., Kotosonov A.S. Remote assessment of an integrated emergency risk index. - 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* 962 042018 https://doi.org/10.1088/1757-899X/962/4/042018

[16] Arefyeva E.V., Muravyeva E.V. On the problems of built-up areas of the Republic of Tatarstan associated with their periodic flooding. "International Research Journal, Eurasian Union of Scientists", July 2019. (ISSN: 2411-6467; DOI: 10.31618/esu.2411-6467.8.53.1

ON THE POSSIBILITY OF REDUCING HARMFUL EMISSIONS IN HIGH-PARAMETER POWER UNITS

Jamala Mammadova
•
Azerbaijan State Oil and Industry University
cemile_adna@mail.ru

Abstract

Steam-turbine units operating with above-critical parameters of water vapor have been studied. Researches show that when steam in power units moves from critical to high, supercritical and ultra-supercritical parameters, the initial parameters of the initial steam increase, the thermal efficiency of the steam energy cycle and the efficiency raise, the specific fuel consumption decreases, resulting in harmful emissions into the atmosphere (NOx, SOx and greenhouse gases CO2) are reduced, which reduces the environmental burden.

Keywords: steam turbine, temperature, pressure, ecology, fuel, harmful emissions, risk minimization, carbon dioxide.

I. Introduction

The socio-economic development of countries is directly related to the increase in electricity production. The development of traditional energy today is associated with the extraction and use of natural fuels, gas, oil and coal around the world. At present, natural fuel-operated power plants predominate, accounting for 68% of the world's electricity generation. However, the reduction of natural fuel sources, environmental pollution and other issues require the improvement of electricity generation and research in this area. Currently, steam power plants in the power system are considered more convenient to operate at a higher than critical steam (P_0 = 24 MPa, t_0 = 540^{0}C), supercritical parameters (P_0 = 28-30 MPa, t_0 = 580-600^{0}C) and ultra-supercritical (P_0 = 35-37 MPa, t_0 = 700 -720^{0}C)

Passage to supercritical and ultra-supercritical parameters by increasing the initial parameters leads to an increase in efficiency, but such equipment uses heat-resistant, precious metals, which causes to a 30% increase in capital costs, however these costs are recouped in 3-4 years. At the same time, there are a number of thermodynamic features of increasing the parameters. Thus, due to the increase in pressure, the humidity in the final stages of the turbine may increase. Therefore, double intermediate heating is used. An increase in the temperature of the feed water in the ultra-supercritical units requires an increase in the number of regenerative heaters compared to the critical high-parameter unit, the use of one- and two-lift, electric and turbine pumps. Schematic diagram of the ultrasonic supercritical block is shown in Fig.1. shown. In this scheme, double intermediate heating was used.

During a single intermittent heating, the steam pressure leading to the intermediate heating is 15-20% of the initial pressure. In the case of double intermittent heating, the pressure of the steam supplied to the first intermediate heating is equal to 25-30% of the initial pressure, the pressure of the steam supplied to the second intermediate heating is equal to 6-9% of the initial pressure. The application of intermediate heating increases the efficiency of the cycle, while reducing the humidity in the final stages of the turbine. In the final stages, the humidity is 7.42%. In general, the coefficient of performance of such blocks is 50-51%. Reports show that the transition from critical to supercritical parameters reduces the specific fuel consumption by 7%. The supercritical unit saves 14.8 g / kWh of conventional fuel compared to the base standard unit. When passing from critical to ultra-supercritical parameters, the specific fuel consumption is reduced from 300 g / kWh to 251 g / kWh.

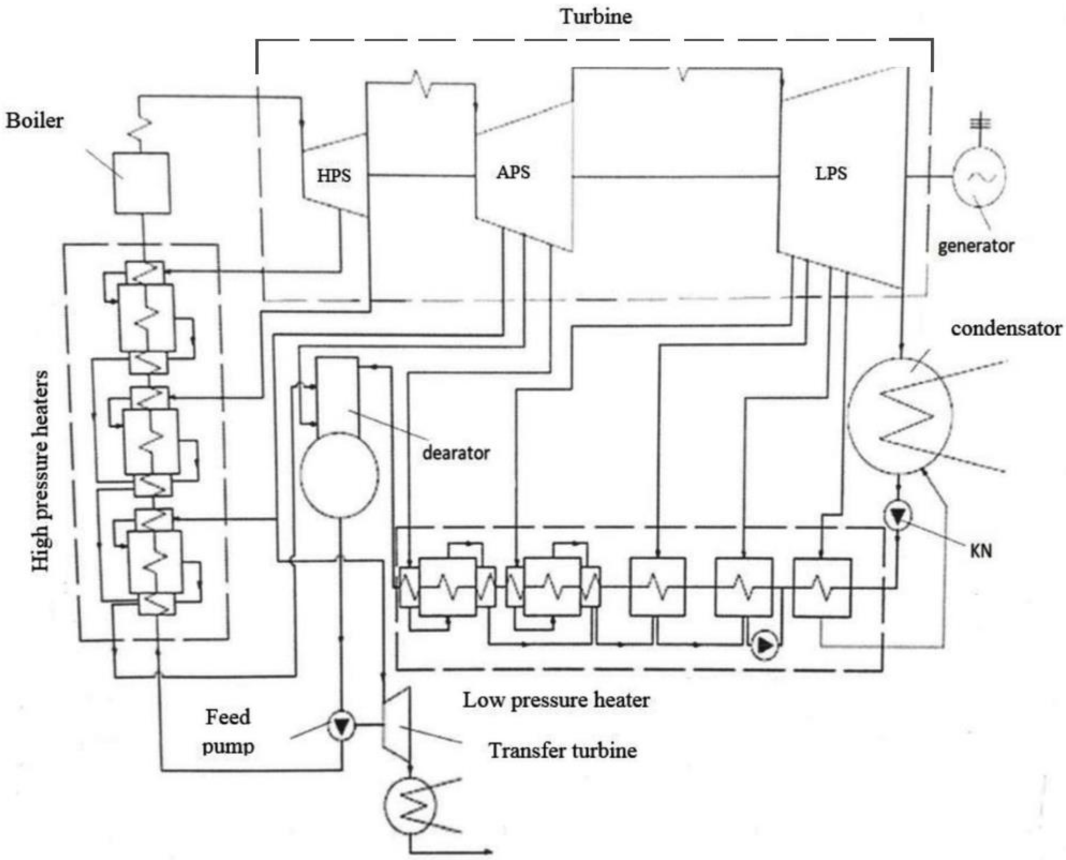

Fig. 1: *Schematic diagram of an ultra-supercritical power unit with double intermediate heating*

Fig. 2. shows the dependence of the power unit's net coefficient of performance on the initial temperature at different values of the vapor pressure in front of the turbine. An increase in the initial temperature of the steam raises the efficiency of the steam power unit. Fig. 2. shows that an increase in the initial temperature has a greater effect on the efficiency of the scheme than an increase in the initial pressure. For example, when the initial pressure is 30 MPa and the temperature rises from 600°C to 700°C, the relative increase in efficiency is 4.31%. Fig. 3. shows the dependence of the block on the initial parameters of the net coefficient of performance. The figure shows that when the pressure rises from 26 MPa to 35 MPa, the coefficient of performance increases 1.6%. Favorable temperature of the feed water also affects the technical and economic indicators. The temperature of the feed water is determined according to the water parameters in the high-pressure heaters before the boiler. Figure 4 shows the dependence of the net coefficient of performance. The on the feed water up to 30-35 MPa vapor Pressures in ultrasupercritical unit graphs show that at different steam pressures, the optimum temperature of the feed water is different. Thus, with the pressure increase, the temperature of the feed water increases. Between 30-35 MPa pressure, the optimum temperature of the feed water is 330-340°C.

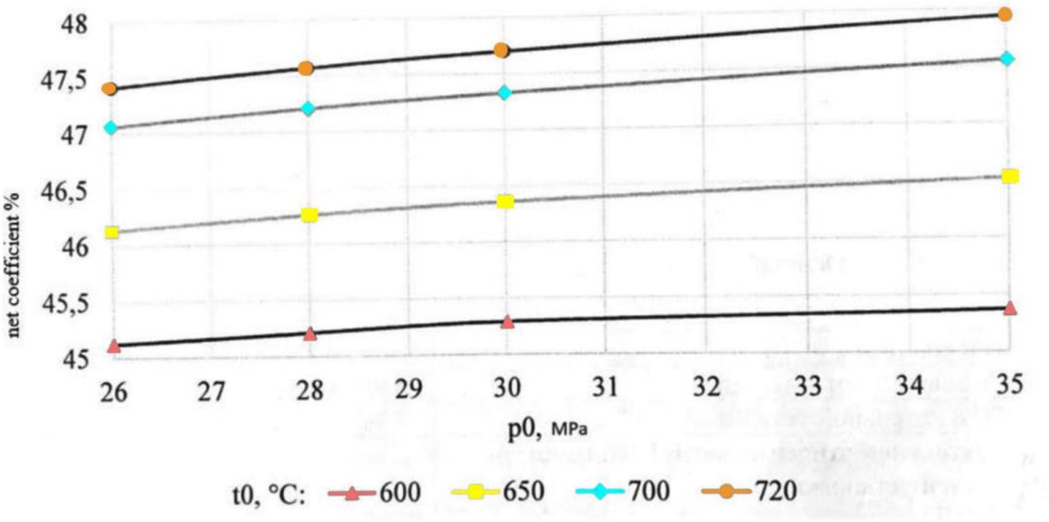

Fig. 2: *The dependence of the electrical net coefficient of performance of the power unit on the initial temperature at different pressures*

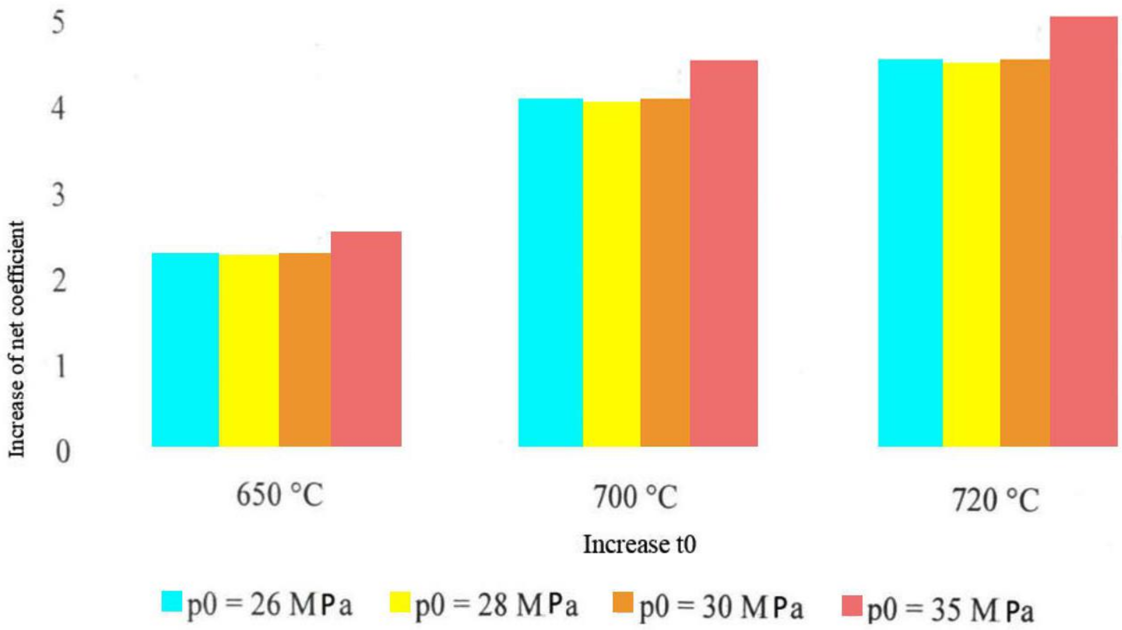

Fig. 3: *The increase in the coefficient of performance of the power block depends on the increase in the initial steam pressure*

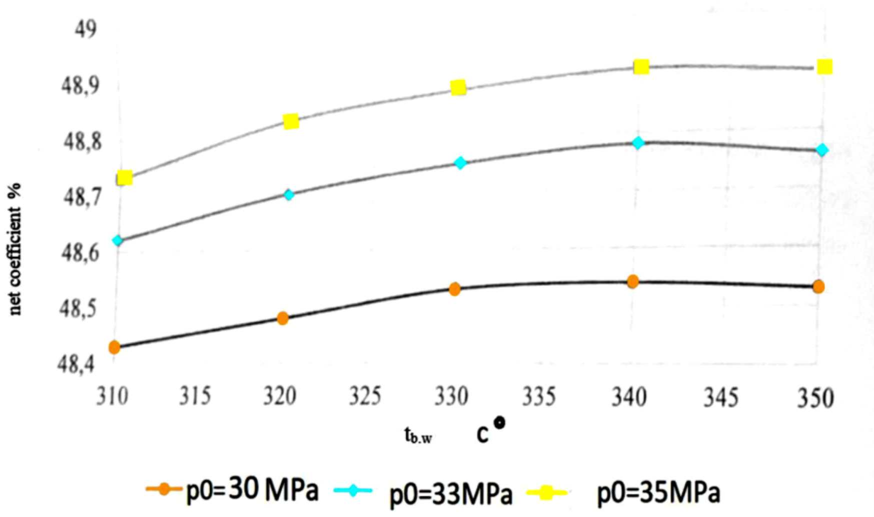

Fig. 4: *Dependence of net coefficient of performance on the temperature of the feed water*

Due to the increase in the initial parameters at these stations, as well as the use of double intermediate heating, the coefficient of performance (η_s) of the station increases, the specific fuel consumption decreases ($b_ş$) = $\frac{123}{\eta_s}$, the amount of flue gases released into the atmosphere and the amount of harmful substances also decreases. The amount of CO_2 released into the atmosphere is determined by the station's net coefficient of performance. The dependence is shown in Fig.5.

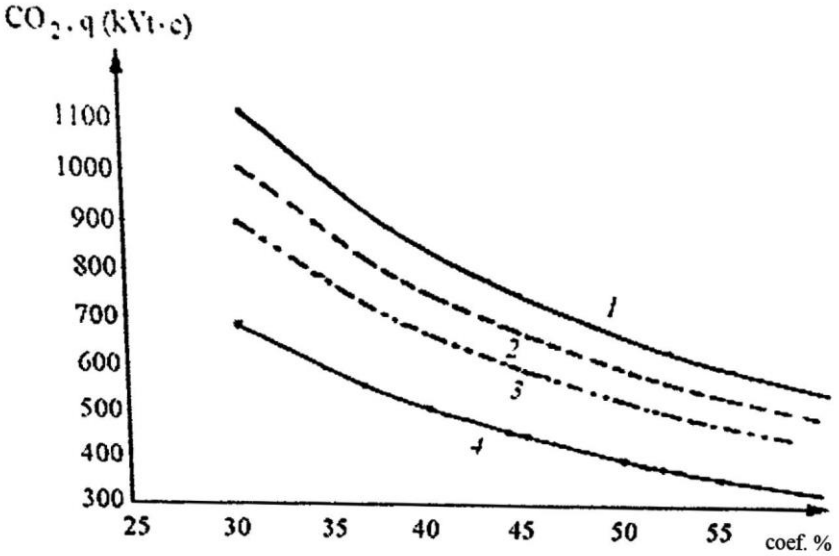

Fig. 5: *Dependence of CO_2 emitted into the atmosphere on net coefficient of performance*
1-when burning coal; 2,3- When burning biomass with coal; 4- When natural gas is burned

Fig. 5. shows that as the efficiency increases, the amount of CO_2 released into the atmosphere decreases. When burnt with coal and biomass, the amount of CO_2 emitted is the same in gas-fired power plants [1]. The greenhouse effect in the atmosphere is mainly caused by carbon dioxide CO_2, which results in climate change. Reducing carbon dioxide in the air and maintaining at least its concentration is a long process and requires a large amount of money. With stabilization of carbon dioxide in the air is shown in Fig. 6. The concentration of carbon dioxide in the atmosphere over a period of time is around 350 and 450 PPM, [2] and currently the concentration of CO_2 in the

atmosphere continues to increase. At the same time, it is predicted that if environmentally friendly technologies are used in energy production (ie from renewable energy sources, the concept of hydrogen energy, etc.), emissions of anthropogenic carbon dioxide emissions will decrease begining from 2030.

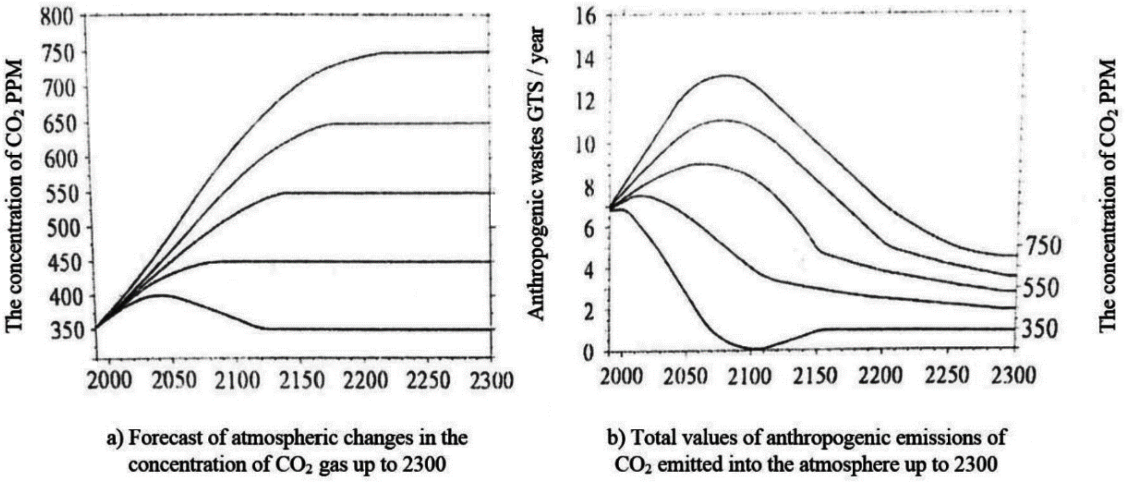

Fig. 6: *Carbon dioxide stabilization at 350-750 ppM in the air*

It should be noted that in the production of electricity, despite the use of non-traditional technologies, the use of natural fuels prevails. More than 60% of electricity [1] is generated by natural gas and solid fuel burning plants. Steam-turbine power plants, and combined steam-gas turbine thermal power plants. Maintly operate with gas fuel these stations have been upgraded to operate with special steam-gas power units and a combined Brighton-Rank cycle. In order to reduce the amount of CO_2 emitted into the atmosphere, it is necessary to increase the thermodynamic efficiency of energy complexes, and research is being conducted in this area. For this purpose, the issues of increasing the temperature of the gases entering the gas turbine, reducing the temperature of the gases emitted from the utility boiler are being studied. Currently, the temperature of the gases in front of the gas turbine is 1500º C [3,4], in this case it is possible to obtain a efficiency of 60%. Steam-power units operating with higher than critical parameters save 10-11% of fuel in steam-gas units compared to steam-gas units. However, by increasing the capital cost and service life, it is possible to deliver steam turbine blocks to steam-gas units due to thermal efficiency. It should be noted that the technological production readiness of steam turbine blocks operating at a critical higher parameter is very high.

Thus, it is expedient to create steam turbine thermal power plants with supercritical and ultra-supercritical parameters, which are an alternative to environmentally friendly steam-gas plants, and it is possible to increase the net coeffiecent of performance of such improved power units to 53-55%.

II. Conclusions

1. It is expedient to create steam turbine thermal power plants operating with supercritical and ultra-supercritical parameters, and it is possible to increase the net coeffiecent of performance of such improved power units to 53-55%.

2. It is expedient to develop and operate steam turbine units as an alternative to environmentally friendly combined steam and gas installations with an efficiency of 60% efficiency.

3. It has been found that the capacity and coeffiecent of performance of units operating with raise parameters increase, fuel is saved, the amount of harmful gases emitted into the atmosphere and the environmental load decreases.

References

[1] Kyaer S., Experience in the design and operation of power units on supercritical parameters in Denmark // Power plants 2002 №3 pp. 63-68.

[2] Liu, Ch. Global energy associations; пер. With whale. / Ch. Liu. - M Publishing House MEI, 2016 – p. 512.

[3] Trukhniy A.D., Paragas plants, power plants, textbook / A.D. Truchny. - M. Publishing house MEI, 2013 – p. 648.

[4] Tsanev S.V., Gas turbine and steam gas installations of thermal power plants: textbook for universities M. Publishing house MEI. 2013 – p. 648.

[5] Favorsky O.N., Current problems of energy security of the country with co-equipable equipment. / Bulletin of the Russian Academy of Sciences-2017-N8 pp. 679-688.

[6] Olkhovsky G.G., Thermal energy technologies for the period up to 2030. // Izvestia of the Russian Academy of Sciences. Energy - 2008 №6 pp. 79-94.

OCCUPATIONAL HEALTH RISKS IN OIL AND GAS WORKERS IN THE RUSSIAN ARCTIC

Sergei Syurin, Aleksei Kizeev
•
Northwest Public Health Research Center, Russia
kola.reslab@mail.ru
info@s-znc.ru

Abstract

To study the occupational health risks in oil and gas industry in the Russian Arctic in order to plan and guide further occupational disease prevention programs.
We studied and analyzed the data of "Working conditions and occupational morbidity" dataset with regard to the population of the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021.
Noise (38.9%), cooling microclimate (12.3%), non-ionizing electromagnetic fields and radiation (10.7%) were the most prevalent hazards in the oil and gas industry in the Russian Arctic. Combined effect of two hazards was observed in 19.0% of workers. During 15 years of follow-up, 54 new cases of occupational disease were identified in 50 employees, including sensorineural deafness (46.3%), radiculopathy (18.5%) and vibration disease (13.0%). Occupational diseases were mainly found in harmful classes 3.1 and 3.2 (85.1%) due to outdated technological processes and equipment design flaws (75.9%). In 2007-2021, occupational disease cases in the oil and gas industry made 14.8% of their overall count in the region. The mean rate of occupational morbidity was 0.426 cases / 10,000 employees, five times less than elsewhere in the industry (1,939 cases / 10,000 employees). The risk to obtain an occupational disease otherwise was higher compared to the oil and gas enterprises (RR=4.55; 95% CI 3.40-197.2; p<0.001).
The risk to gain an occupational disease in oil and gas production in the Russian Arctic was lower compared to other industries. This may be due to better working conditions, but can also result from incomplete existing diseases verification or still from some other yet unknown reasons.

Keywords: oil and gas industry, health risks, occupational diseases, Russian Arctic

I. Introduction

Hydrocarbon extraction is an important part of Russian economy. At present, up to 90% of natural gas, 14% of oil and gas condensate are produced jointly in the Yamalo-Nenets Autonomous Okrug (population 544.4 thousand people, territory 769.3 thousand km^2) and Nenets Autonomous Okrug (population 44.5 thousand people, territory 176.8 thousand km^2). Such enormous amount of material is then transported to elsewhere in Russia and other countries [1, 2]. Both regions are situated in the Russian Arctic known for harsh climate, low population density of less than 1 person/km2, underdeveloped infrastructure, and significant remoteness [3].

Human activity in the Arctic, including hydrocarbons extraction and transportation, is associated with extreme ambient conditions. These hazards include general and local cooling, geomagnetic intensity, pronounced seasonal photoperiodicity, frequent shift from cyclones to anticyclones, low oxygen content in the air and other factors [4, 5].

Those working in the oil and gas industry demonstrate an increased risk of occupational disease resulting from an exposure to a range of occupational hazards, including noise, vibration, increased labor severity and poor workplace microclimate [6-8]. Furthermore, sulfur-containing compounds of gas and oil, such as hydrogen sulfide, mercaptans, carbon disulfide, sulfur anhydride, sulfur dioxide and sulfur dust, attributed to chemicals of the second, third and fourth hazard classes are a specific occupational exposure in these workers [9-11]. The combination of occupational exposures with specific Arctic climatic conditions has been reported to increase the prevalence of ocular, respiratory, cardiovascular, musculoskeletal diseases along with malignancies [12-15], and to modify the rate and clinical manifestations of occupational diseases [16]. In addition, many oil and gas employees work shifts, usually associated with chronic stress [17].

The presented data substantiate the need for more effective health building programs for oil and gas workers in the Russian Arctic [18, 19], including the proper and timely occupational risks identification and management [20, 21].

II. Methods

We studied and analyzed the data of "Working conditions and occupational morbidity" dataset with regard to the population of the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021 (Federal Service for Supervision of Consumer Rights Protection and Human Well-Being). We assessed occupational risks in the oil and gas industry when comparing work conditions and occupational disease profile with other industries in the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021.

Data were analyzed using Microsoft Excel 2016 and IBM SPSS Statistics v. 22. We calculated Student t-values for the independent groups, followed by χ^2, relative risk (RR) and the corresponding 95% confidence interval (CI). Data are presented as absolute values with percent to the overall count in the group, as well as means with their standard errors (M ± m). P-values below 0.05 were considered significant.

This study received approval from the Committee of Bioethics of the Northwest Public Health Research Center and was conducted in accordance with the relevant guidelines and regulations.

III. Results

An analysis of hygienic studies has shown that most often oil and gas industry workers in the Nenets and Yamalo-Nenets Autonomous Okrugs are exposed to noise, a cooling microclimate, non-ionizing electromagnetic fields and radiation, whole-body vibration, increased labor severity and harmful chemicals. Individual shares of other harmful factors were much smaller and did not exceed 1.5% level. The second place in the structure of harmful factors was occupied by the combined action of two factors, which created an increased risk of developing occupational diseases [16]. Despite the similarity of working conditions in the two groups of employers, there were also significant differences. Thus, in oil and gas production, exposure to noise occurred more often, while in other sectors of the economy whole-body vibration and harmful chemicals were more prevalent factors (Table 1). In addition, the risk of contact with harmful production factors at enterprises in other industries was higher than in oil and gas production: RR=1.01; CI 1.01-1.02; $\chi2=9.69$; p=0.002.

In addition to studying the workers´ exposure to certain harmful production factors, a comprehensive assessment of working conditions at enterprises was carried out to determine their group of sanitary and epidemiological well-being (Table 2). It was found that oil and gas industry workers were more often employed at the facilities of the first (satisfactory working conditions) and the second (unsatisfactory working conditions) groups, while their number was significantly lower at the facilities of the third (extremely unsatisfactory working conditions) group. Thus, it was shown that working conditions in the oil and gas industry were more favorable compared to enterprises in other sectors of the economy.

Table 1: *The number of workers in contact with harmful production factors, (%)*

Harmful production factor	Oil and gas industry	Other industries	p
Noise	16190 (38.9)	12069 (22.7)	<0.001
Cooling microclimate	5105 (12.3)	5917 (11.1)	0.384
Non-ionizing electromagnetic fields and radiation	4431 (10.7)	6333 (11.9)	0.443
Whole-body vibration	1789 (4.3)	4948 (9.3)	0.004
Increased labor severity	1721 (4.1)	3246 (6.1)	0.184
Harmful chemicals	1199 (2.9)	5211 (9.8)	<0.001
Ionizing radiation	625 (1.5)	335 (0.6)	0.168
Fibrogenic aerosols	617 (1.5)	928 (1.7)	0.761
Insufficient lighting	590 (1.4)	1444 (2.7)	0.205
Infrasound	457 (1.1)	701 (1.3)	0.617
Biological agents	395 (0.9)	271 (0.5)	0.478
Increased labor intensity	301 (0.7)	1189 (2.2)	0.061
Hand-arm vibration	298 (0.7)	655 (1.2)	0,520
Combined impact of factors	7887 (19.0)	9946 (18.7)	0,953
Total	41605 (100.0)	53193 (100.0)	

Table 2: *Number of jobs at enterprises with different sanitary and epidemiological well-being, (%)*

Sanitary and epidemiological well-being	Oil and gas industry	Other industries	p
Satisfactory (first group)	38187 (45.0)	39520 (39.0)	<0.001
Unsatisfactory (second group)	43989 (51.8)	48811 (48.1)	<0.001
Extremely unsatisfactory (third group)	2693 (3.2)	13132 (12.9)	<0.001
Total	84869 (100.0)	101463 (100.0)	

In 2007-2021, in the Nenets and Yamalo-Nenets Autonomous Okrugs, 364 new occupational diseases were detected in 358 workers. Of these, 257 (70.6%) diseases occurred at transport enterprises, and 54 (14.8%), that is, 4.8 times less often, among people involved in the extraction and transportation of oil and gas. Occupational diseases were even less frequently diagnosed among workers in other sectors of the regional economy (Fig. 1).

One nosological form of occupational disease was diagnosed in 352 (98.3%) out of 358 workers and 6 (1.7%) workers had two diseases. Of 50 workers involved in the extraction of gas and oil, 46 (92.0%) workers were diagnosed with one occupational disease each, and four employers had two diseases. In cases of a combination of two nosological forms of occupational diseases, one of them was sensorineural hearing loss, and the second was radiculopathy. In 2007-2021, the annual number of new occupational diseases among employees of oil and gas companies varied from one to six. For other employees of the Nenets and Yamalo-Nenets Autonomous Okrug, their number ranged from 11 to 32 cases. In both groups, there was no trend towards a decrease or increase in the annual number of occupational diseases (horizontal trend lines in Fig. 2).

Occupational diseases were diagnosed in workers of 13 specialties engaged in oil and gas production and transportation. They included 16 drilling rig operators, 6 locksmiths, 4 steam generator plant operators, 3 pipelayer operators. Workers of each of the remaining 9 specialties were diagnosed with 1-2 diseases. In other sectors of the economy, occupational diseases more often developed among employers engaged in air cargo and passenger transportation: 142 pilots and 84 flight mechanics (engineers).

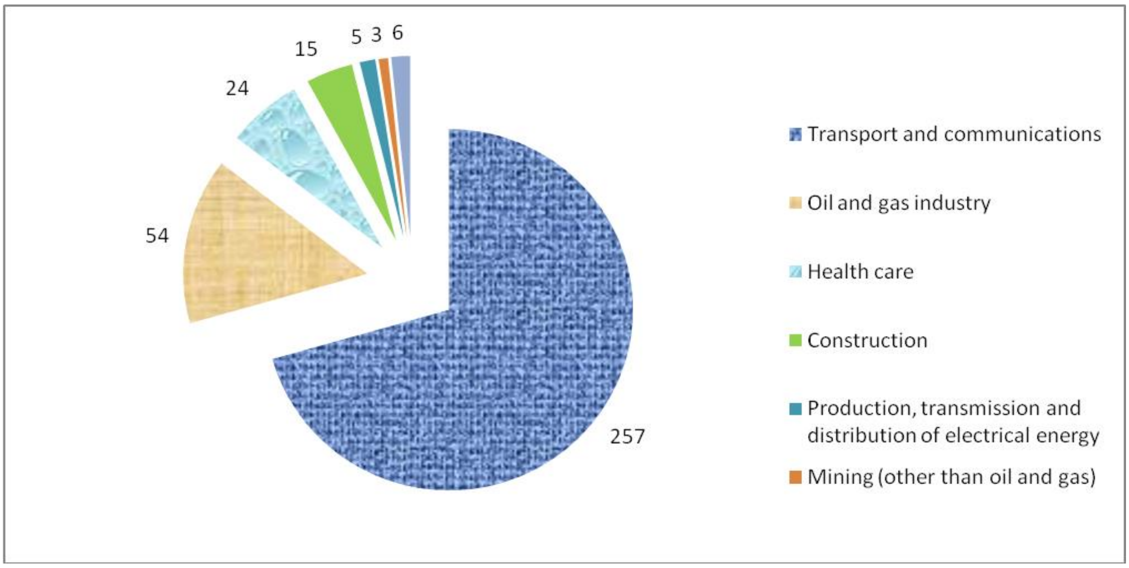

Fig. 1: *Occupational diseases in various types of economic activity in the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021 (cases)*

No significant differences were found between employees of the oil and gas industry and other sectors of the economy in age (53.9±0.7 and 55.1±0.4 years, p=0.138) and length of service (27.6±1.2 and 28.9 ±0.5 years, p=0.318) at which occupational diseases were first diagnosed. Also, there were no gender differences between the two groups, although only men were engaged in oil and gas production, while women accounted for 6.5% of 308 workers in other sectors of the economy (p = 0.064).

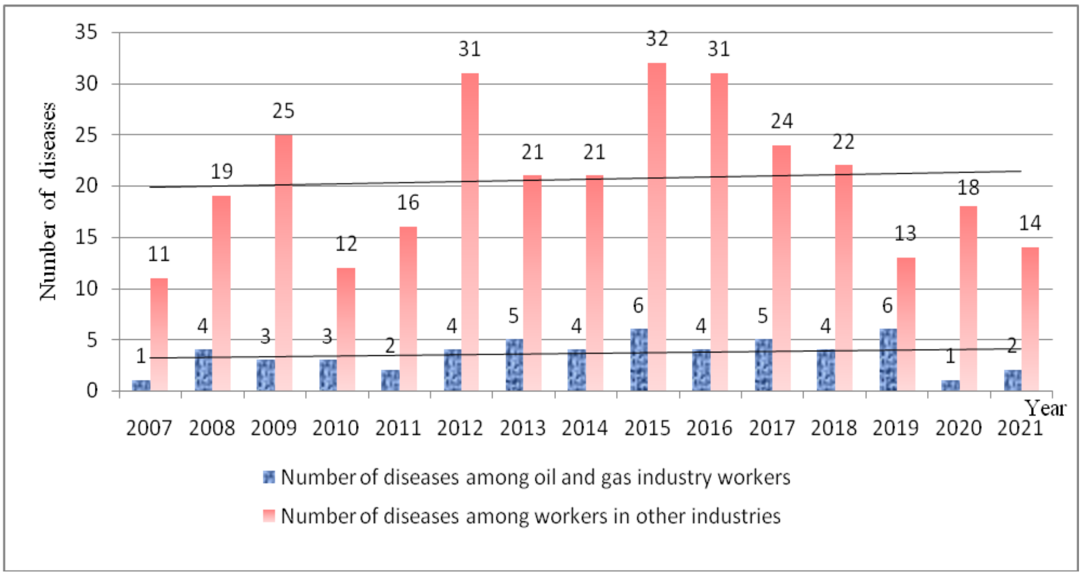

Fig. 2: *The annual number of newly diagnosed occupational diseases among employees of oil and gas industry and other industries*

Special attention in assessing the risks of developing occupational diseases is given to the study of working conditions. According to Russian legislation (Guide on Hygienic Assessment of Factors of Working Environment and Work Load. Criteria and Classification of Working Conditions. 2005), hygiene specialists establish a class of working conditions for each employee, which depends on the extent to which the actual levels of harmful production factors exceed their permissible levels (OEL). The current classification includes four classes of working conditions: 1) optimal (<OEL); 2) permissible (≤OEL); 3) harmful with the allocation of four subclasses; 4) extreme (>OEL). The degree of excess of permissible levels for the main harmful production factors and the corresponding classes of working conditions are presented in Table 3.

Table 3: *Working condition grading classification with regard to OEL exceedance*

Harmful production factor	Harmful class (3)				Extreme class (4)
	3.1	3.2	3.3	3.4	
Chemicals	1.1-3.0 OEL	3.1-10.0 OEL	10.1-15.0 OEL	15.1-20,0 OEL	>20.0 OEL
Weak fibrogenic aerosols (OEL>2 mg/m^3)*	1.1-3.0 OEL	3.1-6.0 OEL	6.1-10.0 OEL	>10.0 OEL	none
Whole-body vibration	6 dB	12 dB	18 dB	24 dB	>24 dB
Hand-arm vibration	3 dB	6 dB	9 dB	12 dB	>12 dB
Noise	5 dBA	15 dBA	25 dBA	35 dBA	>35 dBA

Note: OEL – occupational exposure limit;
** - no exposure to other types of aerosols according to the degree of fibrogenicity in this category of worker.*

The methodology to define class of working conditions with regard to labor severity, labor intensity and workplace microclimate is more complex since it is based on taking into account a set of indicators. Labor severity grading includes dynamic and static workloads, motions stereotype, lifting and moving weights and work posture. Labor intensity grading takes into account intellectual, sensor and emotional loads, as well as their monotony. Workplace microclimate assessment considers combined influence on employees of temperature, humidity, air flow velocity and physical load intensity. As for other harmful production factors, four classes of working conditions are also used to assess the labor severity, labor intensity and workplace microclimate.

As our data showed, more than 80% of all cases of occupational diseases in both groups were due to harmful production factors that corresponded to harmful classes 3.1 and 3.2. However, class 3.1 was more prevalent among employees of oil and gas enterprises, while employees in other industries were more often exposed to factors corresponding to class 3.2 (Table 4).

Noise occupied a leading place in the spectrum of harmful production factors resulting in the development of occupational diseases among employees of all industries in the Nenets and Yamalo-Nenets Autonomous Okrugs. At the same time, for workers at oil and gas enterprises, its share approached 50%, whereas noise-related diseases dominated the structure of occupational pathology of workers in other industries, exceeding 80%. A feature of occupational health disorders in oil and gas industry workers was their greater etiological relationship with the labor severity, whole-body vibration and exposure to harmful chemicals. In addition to noise, biological (infectious) factors played a greater role in the occurrence of occupational diseases among workers in other sectors of the economy. This was due to the presence of health workers in their ranks. It should be noted that only in one case an occupational disease in oil and gas workers was due to industry-specific sulfur-containing chemical compounds.

Significant differences were revealed between the structure of harmful production factors that caused occupational diseases in oil and gas industry workers and the structure of harmful production factors to which they were exposed at their workplaces. Thus, the share of labor severity among the factors causing disease development was 5.88 times greater than its share in the structure of factors with which workers were in contact at work. A similar difference for whole-body vibration was 3.89 times, for hand-arm vibration - 2.71 times, for harmful chemicals - 2.55 times. There were no differences between the shares of noise and weak fibrogenic action aerosols in the structures of disease-causing factors and the factors with which contact was noted at work. And only in the case of a cooling microclimate, the etiological significance of this factor in causing occupational diseases was 6.47 times less than its share in the structure of all existing harmful production factors. Not a single case of occupational disease in oil and gas industry workers was associated with such influences as non-ionizing fields and radiation, ionizing radiation, biological factors, infrasound, increased labor intensity and unsatisfactory lighting parameters. The main circumstances that made possible the impact of harmful production factors on employees of oil and gas enterprises were the imperfection of technological processes and design flaws in equipment. The imperfection of workplaces and the imperfection of sanitary installations created such conditions 3-4 times less often. Among employees of oil and gas enterprises, in comparison with employees of other industries, exposure to harmful factors more often arose due to imperfection of technological processes and imperfection of workplaces, and, conversely, less often the cause of exposure was the design flaws of equipment (Table 4).

Table 4: *Conditions and circumstances for development of occupational diseases in the Nenets and Yamalo-Nenets Autonomous Okrugs, cases (%)*

Indicator	Oil and gas industry	Other industries	p
Working condition class			
Class 2	2 (3.7)	3 (1.0)	0.111
Class 3.1	22 (40.7)	79 (25.5)	0.021
Class 3.2	24 (44.4)	183 (57.7)	0.046
Class 3.3	6 (11.1)	40 (12.9)	0.644
Class 3.4	0	5 (1.6)	0.348
Harmful production factors			
Noise	25 (46.3)	254 (81.9)	<0.001
Labor severity (above permissible level)	13 (24.1)	15 (4.8)	<0.001
Whole-body vibration	9 (16.7)	8 (2.6)	<0.001
Harmful chemicals	4 (7.4)	7 (2.3)	0.042
Weak fibrogenic action aerosols	1 (1.9)	1 (0.3)	0.161
Hand-arm vibration	1 (1.9)	1 (0.3)	0.161
Microclimate cooling	1 (1.9)	1 (0.3)	0.161
Ionizing radiation	0	1 (0.3)	0.676
Biological (infectious)	0	22 (7.1)	0.044
Circumstances of exposure to harmful production factors			
Imperfection of technological processes	21 (38.9)	64 (20.6)	<0.001
Design defects of machines, mechanisms and other equipment	20 (37.0)	193 (62.3)	<0.001
Imperfection of workplaces	6 (11.1)	12 (3.9)	0.024
Imperfection of sanitary installations	4 (7.4)	9 (2.9)	0.100
Contact with an infectious agent	0	16 (5.2)	0.088
Other circumstances	3 (1.9)	16 (5.2)	0.905

Ear diseases occupied the largest share in the structure of occupational diseases in oil and gas production workers. Musculoskeletal diseases were diagnosed 2.5 times less often, injuries and intoxications - 3 times less often, nervous diseases - 5 times less often. Skin and respiratory disorders were found only in isolated cases. For comparison, in the structure of diseases in other industry workers ear diseases were also the most prevalent, but to a much greater extent, since their share reached 81.9%. In this group of workers, infectious diseases ranked second, so musculoskeletal diseases, injuries and intoxications were less important than in oil and gas industry workers. The frequency of detection of the most common nosological forms of diseases corresponded to the structure of disease classes. A feature of oil and gas workers was a higher proportion of radiculopathy, vibration disease, and monopolyneropathy (Table 5).

The most prevalent nosological forms of occupational diseases belonged to the categories of ear and musculoskeletal diseases, as well as injuries and intjxications. A feature of oil and gas industry workers consisted in a higher proportion of radiculopathy, vibration disease, and monopolyneropathy (Table 5).

Table 5: *Categories and nosological forms of occupational diseases in the Nenets and Yamalo-Nenets Autonomous Okrugs, (%)*

Indicator	Oil and gas industry	Other industries	p
Occupational disease categories			
Ear and mastoid process	26 (48.1)	254 (81.9)	<0.001
Musculoskeletal system	11 (20.4)	16 (5.2)	<0.001
Injuries, poisonings and some other consequences of external causes	9 (16.7)	9 (2.9)	<0.001
Nervous system	5 (9.3)	2 (0.6)	<0.001
Skin and subcutaneous tissue	2 (3.7)	3 (1.0)	0.113
Respiratory system	1 (1.9)	3 (1.0)	0.570
Infectious and parasitic diseases	0	22 (7.1)	0.044
Malignant neoplasms	0	1 (0.3)	0.676
Prevalent nosological forms of occupational diseases			
Sensorineural hearing loss	25 (46.3)	254 (81.9)	<0.001
Radiculopathy	10 (18.5)	14 (4.5)	<0.001
Vibration disease	7 (13.0)	7 (2.3)	<0.001
Monopolyneropathy	4 (7.4)	2 (0.6)	<0.001
Allergic dermatitis	2	2 (0.6)	0.047
Tuberculosis of the respiratory organs	0	12 (3.9)	0.142
COVID-19	0	8 (2.6)	0.233

At the final stage of the study, the levels of occupational morbidity in two compared groups of workers in the Nenets and Yamalo-Nenets Autonomous Okrugs in 2007-2021 were assessed. No such information was found in the open literature, which served as the basis for the corresponding calculations. Due to the lack of official data on the average annual regional number of employees in the studied industries (necessary for calculating the incidence), we used the indicator of the average annual number of employees registered at all facilities of sanitary and hygienic well-being, that is, the number of officially employed people in the region.

According to the socio-hygienic monitoring "Working conditions and occupational morbidity" of the Nenets and Yamalo-Nenets Autonomous Okrugs´ population in 2007-2021, the average annual number of employees at sanitary and epidemiological welfare facilities in the oil and gas industry amounted to 84,869 people, and at all facilities in other sectors of the economy it reached 101463 people. Thus, the average annual level of occupational morbidity of oil and gas industry workers in the Arctic in 2007-2021 was established at 0.426 cases / 10,000 workers. For persons employed in 2007-2021 in all other sectors of the economy of the region, the same indicator was almost 5 times higher - 1,939 cases / 10,000 employees. The risk of developing occupational disease in 2007-2021 among workers in all industries in the Nenets and Yamalo-Nenets Autonomous Okrugs (except for the oil and gas industry) was higher than among workers in oil and gas enterprises: RR=4.55; CI 3.40-197.2; $\chi 2$=6.07; p<0.001.

IV. Discussion

The current study made it possible to establish a number of facts that deserve attention and discussion. First of all, we hypothesized that those employed in the oil and gas industry in the Arctic would have increased occupational health risks. This hypothesis was based on the data from other occupational groups employed in the Arctic with a known combination of occupational hazards and working shifts [12, 13, 17]. Nevertheless, other studies reported lower incidence of occupational disease in the oil and gas industry compared to that of workers of mining and coal mines [22], including occupational hearing loss [23]. Our analysis showed that in 2007-2021, occupational diseases were more often diagnosed in the transportation industry, including air transportation, and the rate of occupational disease in the oil and gas enterprises was five times lower than that of employees of other industries in the region. In addition, it was 2-5 times lower compared to the mean rate in Russia, which ranged from 1.92 cases/10,000 employees in 2011 to 0.78 cases/employees in 2020.

We offer at least six reasons of that (from most likely to least likely):

1. Better working conditions at already developed fields (this can be proven by the better state of sanitary and epidemiological well-being and the lower prevalence of certain harmful production factors) compared to other industries. Occupational hazards in this industry are likely more pronounced during mining initiation. The effect of severe climate may be most evident prior to the stage when acceptable dwelling and accommodation conditions are set. More occupational disease in drillers supports this explanation.

2. The widespread use of the shift work, making health disorders identification and registration challenging, including occupational disease. Low quality of annual screening may also contribute to that [17]. In addition, occupational diseases registration becomes impossible at a place of employment (Nenets and Yamalo-Nenets Autonomous Okrugs), if it was diagnosed at a place of permanent residence. These regions fail to set up a system of reliable information exchange regarding the cases of newly detected occupational diseases among shift workers.

3. The employees, especially those working shifts, prefer to conceal the signs of occupational disease with the purpose to keep a better paid job in the Russian Arctic. This may be even more relevant in a period of deterioration in the economy.

4. Insufficient occupational diseases detection both in Russia as a whole [24] and in the Nenets and Yamalo-Nenets Autonomous Okrugs, including that of pre-employment and periodic medical examinations. This results in an underestimation of the reported occupational disease incidence as compared to the real picture. Exposure assessment and occupational hygiene procedures quality are also of great concern. It is not clear, as an example, why work-related hearing loss is less prevalent in oil and gas industry workers with much greater exposure to noise. Conversely, vibration disease is diagnosed more often with less exposure to the whole-body vibration compared to workers in other industries.

5. In the course of performing work on a rotational basis, there is a natural division of workers into those who tolerate Arctic climatic conditions well and poorly. The first group with the initially better state of health continues to work shifts and they rarely develop occupational diseases. The second group of workers stops business trips to the Arctic due to the deterioration of

health. Possible occupational diseases either do not occur or are not registered at the place of permanent residence. Thus, the phenomenon of the so-called "healthy worker" is created, when the level of health of people working in hazardous conditions is better than the level of health of the population as a whole [25].

6. It is possible that the shift method of performing work, in addition to the well-known negative impact on health, also has positive aspects. So, after a 4-8 week shift in the Arctic, a period of rest of the same duration at the permanent place of residence follows. At this time, contact with harmful production factors is interrupted and their cumulative negative effect on the health of the worker is not created. However, this hypothesis has no scientific evidence. In the literature, we did not find studies on the effect of long alternating periods of labor activity in harmful conditions with periods of rest in favorable conditions on the development of occupational diseases.

Given the harsh climatic conditions of the Arctic, the one would expect cooling microclimate to explain a large fraction of occupational disease in the studied group, which, however, remained as low as 1.9%. However, cold is usually considered a leading stressful factor for people living and working in the Russian Arctic. Cooling, both general and local, results in a decrease in physical and mental performance, disrupts movement coordination and the ability to perform precise and complex operations, promote musculoskeletal complaints and diseases [26, 27]. Apparently, an inadequate assessment of the impact of cold on workers in the Arctic is due to the lack of hygienic standards for the microclimate of open work areas.

Study limitations. No full data on the real incidence of occupational diseases in the oil and gas industry personnel in the Russian Arctic may be a limitation of this analysis. This underestimation occurs when workers prefer to conceal their signs and medical conditions, when shift work is widely used and when the diseases verification is limited at the periodic screening.

V. Conclusion

In 2007-2021, noise was a major health risk for those working in oil and gas industry in the Russian Arctic, most often causing sensorineural deafness (46.3% of all occupational disease cases). The level of occupational morbidity (0.426 cases / 10,000 employees) in oil and gas industry workers was lower than that of workers in other sectors of the region's economy, as well as official all-Russian indicators. On the one hand, this may be due to better working conditions, on the other hand, can also result from incomplete diagnosis and registration of existing diseases or still from some other yet unknown reasons.

References

[1] Kazanin, A.G. (2019). Strategic Priorities and Challenges of the Russian Arctic Zone' Oil and Gas Industry: The Nenets Autonomous District' Case. *Prostranstvennaya Ekonomika*, 15 (2): 169-185. doi: 10.14530/se.2019.2.169-185.

[2] Safonova, T.Yu. (2020). Prospects for Russian oil and gas production in the Arctic: from collapse to development. *Kreativnaya ekonomika,* 14 *(10)*: 2569-2590. doi: 10.18334/ce.14.10.111085.

[3] Zemskov, V.V., Prasolov, V. I., Khudyakov, D. S., Kanashina, A. I., Timofeev, E. A. (2022) Assessment of the contribution of the Arctic zone to the economic development of the country. *Finance: Theory and Practice,* 26(2): 160-174. doi: 10.26794/2587-5671-2022-26-2-160-174

[4] Chashchin, V.P., Gudkov, A.B., Popova, O.N., Odland, J. Ö, Kovshov, A.A. (2014). Description of main health deterioration risk factors for population living on territories of active natural management in the Arctic. *Human ecology,* 1: 3-12

[5] Korchin, V.I., Korchina, T.Ya., Ternikova, E.M., Bikbulatova, L.N., Lapenko, V.V. (2021). Influence of climatic and geographical factors of the Yamalo-Nenets Autonomous Okrug on the

health of the population (review). *Zhurn. medical biol. research*., 9 (1): 77–88. doi: 10.37482/2687-1491-Z046.

[6] Witter, R.Z., Tenney, L., Clark, S., Newman, L.S. (2014). Occupational exposures in the oil and gas extraction industry: State of the science and research recommendations. *Am. J. Ind. Med*., 57(7): 847–856. doi: 10.1002/ajim.22316.

[7] Glass, D.C., Wood, E., Del Monaco, A., Sim, M.R. (2016). Cohort Profile: Health Watch - a 30-year prospective cohort study of Australian petroleum industry workers. *Int. J. Epidemiol*., 45(3): 700-706. doi: 10.1093/ije/dyv121.

[8] Syurin, S.A., Kovshov, A.A., Gorbanev, S.A. (2019). Working conditions in the Arctic gas and oil producing region. *Med. Tr. Prom. Ekol.,* 12: 989-994. doi: 10.31089/1026-9428-2019-59-12-989-994

[9] Holder, C., Hader, J., Avanasi, R., Hong, T., Carr, E., Mendez, B., Wignall, J., Glen, G., Guelden, B., Wei, Y. (2019). Evaluating potential human health risks from modeled inhalation exposures to volatile organic compounds emitted from oil and gas operations. Sci. *Total Environ*., 657: 187–199. doi: 10.1080/10962247.2019.1680459.

[10] Garcia-Gonzales, D.A., Shonkoff, S.B.C., Hays, J., Jerrett, M. (2019). Hazardous Air Pollutants Associated with Upstream Oil and Natural Gas Development: A Critical Synthesis of Current Peer-Reviewed Literature. *Annu. Rev. Public Health*, 40: 283-304. doi: 10.1146/annurev-publhealth-040218-043715.

[11] Field, RA, Soltis, J, Murphy, S. (2014). Air quality concerns of unconventional oil and natural gas production. Environ. *Sci. Process Impacts*, 16(5): 954-69. doi: 10.1039/c4em00081a.

[12] Gimranova, G.G., Bakirov, A.B., Shaikhlislamova, E.R., Karimova, L.K., Beigul, N.A., Mavrina, L.N. Diseases of the musculoskeletal and peripheral nervous systems in oil workers under conditions of combined exposure to vibration and the severity of the labor process. *Gig. Sanit.,* 96 (6): 552-555. doi: 10.18821/0016-9900-2017-96-6-552-555.

[13] Ikonnikova, N.V. (2017). Morbidity of gas-transport company workers, and measures to reduce it. *Med. Tr. Prom. Ekol*., 9: 83-4.

[14] Yeoman, K., Sussell, A., Retzer, K., Poplin, G. (2020). Health Risk Factors Among Miners, Oil and Gas Extraction Workers, Other Manual Labor Workers, and Nonmanual Labor Workers, BRFSS 2013-2017, 32 States. *Workplace Health Saf*., 68(8): 391-401. doi: 10.1177/2165079920909136.

[15] Onyije, F.M., Hosseini B., Togawa K., Schüz J., Olsson, A. (2021). Cancer Incidence and Mortality among Petroleum Industry Workers and Residents Living in Oil Producing Communities: A Systematic Review and Meta-Analysis. *Int. J. Environ. Res. Public Health,* 18(8): 4343. doi: 10.3390/ijerph18084343.

[16] Syurin, S.A., Kovshov, A.A. Working conditions and risk of occupational pathology at enterprises of the Arctic zone of the Russian Federation. *Human ecology,* 10: 15-23. doi: 10.33396/1728-0869-2019-10-15-23.

[17] Korneeva, Y, Simonova, N. (2020). Job stress and working capacity among fly-in-fly-out workers in the oil and gas extraction industries in the *Arctic. Int. J. Environ. Res. Public Health*, 17(21): 7759. doi: 10.3390/ijerph17217759.

[18] Ravdugina, T.G., Mosaleva, O.V. (2014). Organizational structure of medical support for employees of gas processing enterprises using the example of the enterprise "Gazprom Pererabotka". *Health care of Russian Federation,* 58 (4): 25–29.

[19] Ershov, E.V., Babenko, A.I., Ponich, E.S., Khasnulin, V.I. (2008). The system of monitoring the health of workers in the gas producing enterprise in the Far North. *Bulletin of the Siberian Branch of the Russian Academy of Medical Sciences,* 130 (2): 57–62.

[20] Lesnykh, V.V, Kashirin, A.B, Suvorova, O.S, Ivenkov, S.G. (2017). Analysis of modern approaches to the assessment of occupational risk in the gas industry. *Gas industry*, 9: 128–134.

[21] Khamidullina E.A., Chemyakin A.V. (2018). Predictive assessment of health damage risk as a result of professional activity in oil production. *XXI Century. Technosphere safety*, 3 (2): 108-116. doi: 10.21285/2500-1582-2018-2-108-116.

[22] Gorbanev S.A., Syurin S.A. (2019). Health risks and occupational pathology during extraction of fuel and energy minerals in the Arctic zone of Russia. *Russian Arctic*, 6: 42-48. doi: 10.24411/2658-4255-2019-10068.

[23] Lawson SM, Masterson EA, Azman AS. (2019). Prevalence of hearing loss among noise-exposed workers within the Mining and Oil and Gas Extraction sectors, 2006-2015. *Am. J. Ind. Med.*, 62(10): 826-837. doi: 10.1002/ajim.23031.

[24] Babanov S.A., Budash D.S., Baikova A.G., Baraeva R.A. (2018). Periodic medical examinations and professional selection in industrial medicine. *Zdorov'e naseleniya i sreda obitaniya*, 5: 48-53.

[25] Melentev A.V., Babanov S.A., Strizhakov L.A., Vinnikov D.V. (2021). Problems of professional selection and the effect of the healthy worker in occupational health. *Health care of the Russian Federation*, 65(4): 394-399. doi: 10.47470/0044-197X-2021-65-4-394-399.

[26] Anttonen H., Pekkarinen A., Niskanen J. (2009). Safety at work in cold environments and prevention of cold stress. Ind Health, 47(3): 254–261. doi: 10.2486/indhealth.47.254

[27] Farbu E.H., Höper A.C., Brenn T., Skandfer M. (2021). Is working in a cold environment associated with musculoskeletal complaints 7-8 years later? A longitudinal analysis from the Tromsø Study. *Int. Arch. Occup. Environ. Health*, 94(4): 611-619. doi: 10.1007/s00420-020-01606-6.

THE INFLUENCE OF HAUL ROAD PARAMETERS ON SAFETY

Branimir Farkaš[1], Ana Hrastov[2], Ivo Galić[1]

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[1]Mining, geology and petroleum engineering faculty, Zagreb, Croatia
branimir.farkas@rgn.hr
ivo.galic@rgn.hr
[2]RUDAR PROJEKT d.o.o., Zagreb, Croatia
ana.hrastov@rudar-projekt.hr

Abstract

Using risk assessment in a work process that can influence people, machinery, and environment enables simple and quick method of establishing potential hazards and giving those a risk rating. The big advantage is that hazards are defined for a specific case, and consequently, risk ratings are defined for each hazard. Adding risk ratings for each hazard makes it possible to assess total model risk rating and determine the average risk rating of each model. Distributional risk assessment is an additional method of analysing each model and it provides a visual overview. Additional risk control measures were applied to the least critical model to assess the hazards, and thus model risks were reduced to the least value. Risk assessment was performed on the example of "Očura II" quarry haul road based on a new risk assessment algorithm.

Keywords: risk assessment; mine safety; haul road; project parameters; distributional risk assessment; quarry; Očura II

I. INTRODUCTION

The risk signifies the probability of a potential hazard happening during work process, either as an injury or illness [1]. That is why risk assessment is a relatively simple, but very important step in ensuring the safety of work environment in different industries [2]–[4]. Risk assessment considers classification of hazards based on available information to assess the risks affecting people, property, and environment [5], [6]. The goals of risk assessment are: a) ascertaining hazards, harms, and efforts, b) risk assessment level for industrial accidents, professional illnesses, and ailments relating to profession, c) ascertaining corrective and prevention measures to keep the employees' health safety [1].

Based on the risk assessment (analysis), it is possible to recognize (detect) hazardous events which can cause unwanted consequences, and therefore also detect suitable protection measures. Very common manner of risk assessment is using the risk assessment matrix which juxtaposes the probability of (hazardous) events and the severity of the consequence [7], [8].

Some of the major causes of accidents in large coal open pits are: human error, causes due to machinery operation (loading, unloading, truck driving), and inadequately designed haul roads and parts of the open pit [9]. Considering that in mining large quantities of material are mined and transported, which often means utilization of trucks, it is therefore trucks which are linked to the large number of accidents [10]–[13]. Following this, it is necessary to constantly assess the risks to minimize the severity and number of accidents involving trucks as much as possible. The risk assessment in mining does not only include risk assessment inside the exploitation area but also the analysis and impact outside of it. For example, transporting zinc lead ore from the mine to the harbour can constitute a source of pollution impacting human health if either zinc or lead reach the food chain [14].

Some authors use multicriteria decision-making techniques after risk assessment in order to define the best way of minimizing risks, which is the result of selecting the optimum problem solution, i.e., risk minimization method [15]–[17].

The mining industry invests a lot of effort in gathering valuable data if an accident occurs, so the same or similar situation would not occur again. An example of that is the analysis of the mining landslide incident using several methods (Critical Decision Method, Rasmussen's Risk Management Framework, and Accimap method) to gather as much data as possible regarding the landslide. The safety leadership decisions and actions were analysed and safety measures for minimizing the repeated accident were implemented [18], [19]. Nevertheless, despite all efforts in administering security and protection measures, accidents still happen in the mining industry [13], [20], [21].

In order to automate the assessment of haul roads, many methods are used today that find all areas of the open pits that are suitable for transport. The Multi Dilation-LinkNeSt system [22] can be used to assess the Road network of the open pit mine which enables mapping of haul roads, which are the basis of risk assessment.

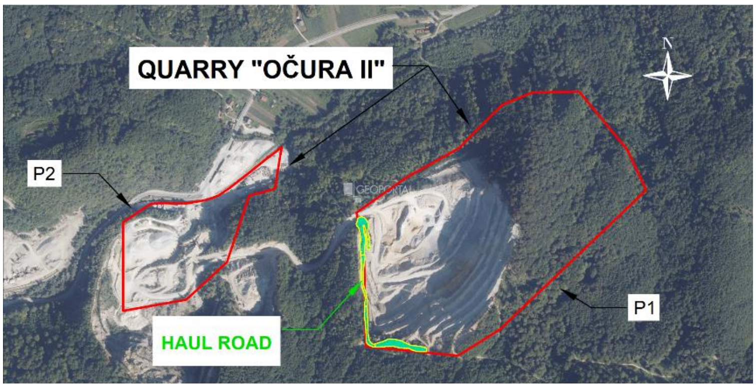
The influence of project parameters on the safety (Table 1) were analysed in the example of the haul road for the quarry "Očura II". All project parameters used must conform to the legal framework to ensure the safety of the designed road, and the safety of the workers (employees) and machinery [1], [23]–[25].

II. Site location

The surface quarry "Očura II" is located in the north-west part of Croatia (Figure 1 - a). It consists of two separate areas (polygon P1 and polygon P2) and has the total area of 29.93 ha (Figure 1 - b).

The haul road, for which the risk assessment and the influence of project parameters on safety were performed, is located at the western area of the quarry "Očura II", next to the edge of the exploitation area (Figure 1 - c).

(a)



(b)

(c)

Figure 1: *Site location of "Očura II" quarry and the haul road*

III. Risk assessment methodology

The hazard assessment of the designed haul road was performed using the process of risk assessment, which was created specifically for that purpose, in accordance with the site circumstances, legal regulations [1], [23], [26], technical specifications, and company's internal safety regulations. Three models of the haul road were observed, each with different project parameters (longitudinal and transversal inclination, length and width of the road, rotational radius) stated in Table 1. The impact of project parameters, i.e., the risks that can occur with each of the models were observed through the consequences they can have on people, machinery, and environment.

The analysis process of possible hazards that can appear in any of the three models was conducted in the manner shown in the algorithm (Figure 2). The process itself consists of three basic parts: analysis, evaluation, and control. The definition of project parameters is not considered as part of the analytical process. The analysis represents comparative analysis of the selected project parameters regarding the legal requirements and recognition, i.e., definition of potential hazards and determining their influence on the selected model of the haul road. The evaluation handles the assessment of recognized risks for the selected model of the haul road, and the evaluation of the model is performed as preliminary step for the next part. The control is where the safest model of the haul road is selected, considering the recognized hazards and administration of safety measures which minimize the hazards to acceptable level or eliminate them completely. The safest model of the haul road is one that meets regulations and safety measures.

3.1. Project parameters

The following data was used as entry data (project parameters) in order to create the models:

- Model 1 – current haul road situation [27],
- Model 2 – mining design documentation [28],
- Model 3 – the new, optimized parameters for the creation of the future haul road [29].

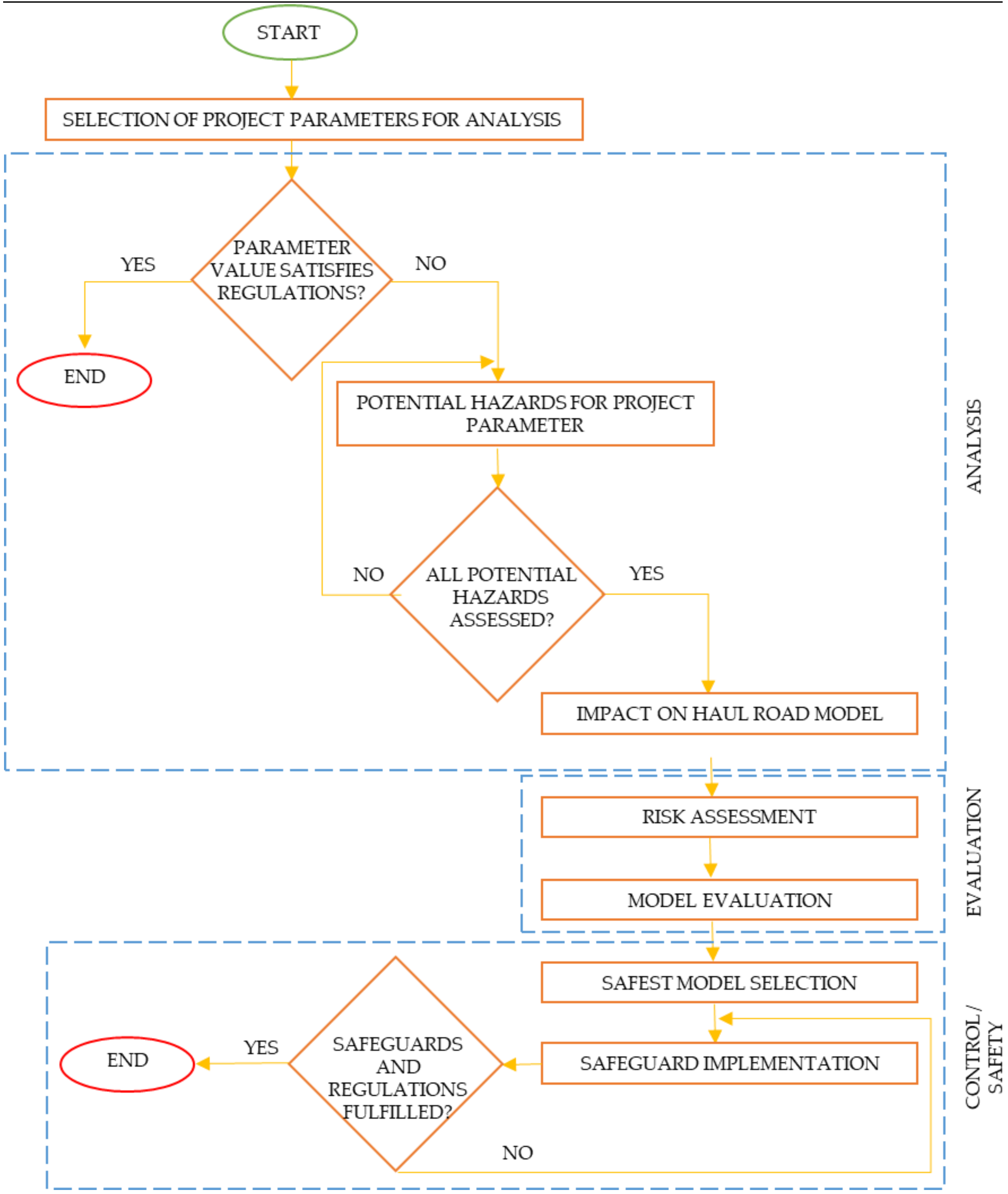


Figure 2: *Risk management process*

Model 1 represents the current state of the haul road in the field and is used in machinery transport and the people passage. The haul road is exposed to the influence of rainfall which pour down the road and erode the filled material that is regularly raised when heavy machinery and people pass.

Model 2 represents the designed haul road which needs to be constructed, and it was designed as part of the mining design intended for the transport of mining machinery and as a connection between areas of the quarry and benches. The haul road model 2 needed to be designed in consideration of the legal regulations which are absent. The decision of the inclination of the haul road was left to the experience of the design engineer.

Model 3 is the suggestion for the new haul road which was designed by taking into account the legal regulations concerning the longitudinal inclination. However, as the exploitation has reached parts of the terrain where the haul road should go, it was necessary to accept certain constraints and accommodate them while determining the project parameters for the haul road.

Based on project parameters shown in Table 1, three models of the haul road were made for the quarry "Očura II".

Table 1: *Project parameters for the quarry "Očura II" haul road*

Project parameters		Model 1	Model 2	Model 3
Longitudinal haul road inclination, % (°)	min	10.0 %	6.2 % (3.5°)	8.0 % (4.6°)
	max	37.6 %	33.1 % (18.4°)	22.5 % (12.7°)
Transversal haul road inclination, %	min	1.0	1.0	1.0
	max	6.0	2.0	2.0
Haul road width, m	min	3.0	6.0	7.0
	max	4.2	8.0	14.0
Haul road bend radius, m	min	7.8	15.0	7.0
	max	14.0	35.0	70.0
Haul road length, m	-	471.3	445.3	479.8

3.2. Determining potential hazards and their influence on models

Each of the analysed project parameters (Table 1) has a smaller or larger degree of influence on people, machinery, and environment. In order to determine the hazards that can occur during machinery and people circulation on the haul road, but also environmental impact arising from it, risk assessment matrix was created (Table 3). Based on the matrix, the probability of a certain risk and its influence is analysed.

The probability of a certain event happening is analysed from 10% (very low) to 90% (very high). The probability of the risk under 10% happening is considered a negligible value, while the probability of a risk over 90% is considered as almost certain appearance of the risk and it must be mitigated immediately. The **event probability** is distributed into five possibilities:

- Very low (10%) – hazard should not occur,
- Low (30%) – little probability of hazard occurring,
- Moderate (50%) – hazard is possible,
- High (70%) – the probability of hazard occurring is high,
- Very high (90%) – the probability of hazard occurring, and repeating, is high.

The considered risk assessment goes from the value of 1 (minor damage) to 5 (catastrophic) depending on the impact of the analysed risk, i.e., the danger it poses. The severity of consequences is also divided into five possibilities:

- Minor damage (1) – the consequences are slight, negligible health damage,
- Damage (2) – no greater consequences, temporary health damage,
- Major damage (3) – no greater consequences but can happen occasionally, significant health damage which can cause permanent diminishment of working capacity,
- Severe loss (4) – serious consequences can occur, severe permanent and/or progressive health damage,
- Catastrophic (5) – extremely severe consequences, very severe health damage with handicap or death.

The risk analysis can be done qualitatively or quantitatively. The quantitative risk analysis gives numerical assessment for the probability of events and their consequences. In qualitative risk analysis, words and/or descriptive scales are used to describe possible hazards and the impact of potential consequences. [5]. For the influence assessment of the project parameters on the safety of quarry "Očura II" quantitative assessment was selected.

The risks are separated into five levels and each level comprises of a certain value range

(Table 2). The risk range is defined considering the recognized hazards and the participants in the risk assessment. Risk levels are split into five categories, and their range is from 0.0 to 4.5. The risk level is additionally colour coded to visually emphasize the risks, from those that have negligible influence (blue colour) to those risks that are critical for the haul road (red colour).

Table 2: *Risk levels*

Risk level	Range		Note / needed actions
Insignificant	0.0	0.5	Risks that do not present immediate hazard but need to be taken into account and can be mitigated relatively simply
Sustainable	0.5	1.5	Risks that need to be followed but can be mitigated or almost eradicated through relatively simple actions
Moderate	1.5	2.5	Risks that must be minimized because there is medium probability of unwanted situations occurring
Severe	2.5	3.5	Risks that must be mitigated as soon as possible, i.e., actions need to be enacted that either mitigate the risks or eliminate them
Critical	0.0	0.5	Risks that can lead to catastrophic consequences and if they are detected, the work needs to stop immediately and actions that minimize the spotted risks must be performed urgently, work must not continue unless the risk cannot be mitigated

The risk assessment was performed on the basis of the risk assessment matrix (Table 3). The risk (cell value) is the resultant of probability of dangerous event occurrence and the impact (severity) of the consequences of that event either in the form of human injury or illness, or damage done to property and environment [8], [30].

Table 3: *Occurrence and impact risk probability matrix*

Probability	Impact	Minor damage	Damage	Major damage	Severe loss	Catastrophic
		1	2	3	4	5
Very High	90%	0.90	1.80	2.70	3.60	4.50
High	70%	0.70	1.40	2.10	2.80	3.50
Moderate	50%	0.50	1.00	1.50	2.00	2.50
Low	30%	0.30	0.60	0.90	1.20	1.50
Very Low	10%	0.10	0.20	0.30	0.40	0.50

The risk assessment was performed for the three basic risks, out of which a whole plethora of hazards during usage of the haul road arises from, and those are:

- Longitudinal inclination of the haul road,
- The width of the haul road,
- The possibility of further exploitation.

Based on the determined basic risks, specific hazards were defined which are the consequence of those risk, and based on that, the risk assessment for all three models of the haul road was performed.

IV. Results

4.1. Risk analysis and evaluation

The risk assessment based on the project parameters was performed for all three haul road models (Table 4). The hazards which can occur based on three recognized sources of risk occurrences, and as well as their influence on employees, machinery, and environment, were evaluated (13 in total). The risk evaluation of each hazard was obtained as the multiplied probability of the hazard occurring and the hazard's influence on employees, machinery, and environment.

Table 4: Model risk assessment

Risk Description (type of activity)	Hazard	Who/what is at risk?	MODEL 1			MODEL 2			MODEL 3		
			Probability of Occurrence	Impact	Risk Rating	Probability of Occurrence	Impact	Risk Rating	Probability of Occurrence	Impact	Risk Rating
Longitudinal inclination of the haul road	Mechanical damage of machinery	Machinery	0.9	4	3.60	0.7	4	2.80	0.5	4	2,00
	Machinery toppling	Workers Machinery	0.9	5	4.50	0.5	5	2.50	0.3	5	1,50
	Stone jettison from wheels turning	Workers	0.9	2	1.80	0.7	2	1.40	0.5	2	1,00
	Mechanical damage of the haul road	Environment	0.7	3	2.10	0.7	3	2.10	0.7	3	2,10
	Dust emission – inability to moisten the road	Environment	0.9	3	2.70	0.9	3	2.70	0.7	3	2,10
The width of the haul road	Machinery passage	Machinery	0.5	2	1.00	0.5	2	1.00	0.3	2	0,60
	Different types of machinery bypassing – collision	Machinery	0.7	3	2.10	0.5	3	1.50	0.3	3	0,90
	Machinery and people bypassing – collision	Workers	0.5	5	2.50	0.3	5	1.50	0.3	4	1,20
	Road width in alignment with legal regulations	Environment	0.5	4	2.00	0.5	4	2.00	0.3	4	1,20
Possibility of further exploitation development	Unstable haul road	Machinery	0.7	4	2.80	0.5	4	2.00	0.3	4	1,20
	Inability to correctly develop benches	Environment	0.5	3	1.50	0.5	3	1.50	0.5	3	1,50
	Landslides appearing in areas of the haul road	Workers Machinery Environment	0.7	4	2.80	0.5	4	2.00	0.3	4	1,20
	Landslides appearing at wrongly executed benches	Workers Machinery Environment	0.7	5	3.50	0.7	5	3.50	0.5	5	2,50
TOTAL MODEL RISK RATING					32.90			26.50			19.00

After analysing all three models, it is visible that model 1 has two critical hazards (mechanical damage of machinery and machinery toppling) which can lead to very severe consequences. The total risk rating of model 1 was obtained by adding up the individual risk ratings for each hazard, so model 1 has the total of a 32.90 risk rating. The average risk rating for model 1 is 2.53 which classifies it as severe risk model.

Model 2 has the total risk rating of 26.50, i.e., the average risk rating for model 2 is 2.04 and that classifies this model as moderate risk model. Model 2 has three severe risk ratings, while other risks are in the sustainable and moderate risk categories.

Model 3 represents the least risky model considering its total model risk rating is 19.00, i.e., on average it is 1.46 which classifies it as sustainable risk model. Model 3 has risks distributed into sustainable and moderate risk rating categories.

4.2. Distribution risk analysis of models

An additional, tabular distribution risk analysis was performed for all three models which shows in a simple, visual manner how the risks are distributed for each model. The distribution risk analysis table is split into two halves by a transversal line. The upper right half of the table represents the area where risks that can cause severe and/or catastrophic consequences of a model prevail, while in the bottom left half there are risks that will cause minor and/or negligible

RT&A, Special Issue № 4 (70)
Volume 17, November 2022

consequences.

Table 5 shows the distribution risk analysis for model 1.

Table 5: *Distribution risk analysis - model 1*

Probability \ Impact		Minor damage 1	Damage 2	Major damage 3	Severe loss 4	Catastrophic 5
Very High	90%		1	1	1	1
High	70%			2	2	1
Moderate	50%		1	1	1	1
Low	30%					
Very Low	10%					

Model 1 has the total of 4 hazards, with the probability of their occurrence higher than 90% and 5 hazards with probability higher than 70%, with total 3 Catastrophic events that can cause major damage but also the loss of human life. The detected hazards of model 1 are mostly located in the upper right corner of the table which indicates that this model requires additional risk control.

Table 6 shows the distribution risk analysis for model 2.

Table 6: *Distribution risk analysis - model 2*

Probability \ Impact		Minor damage 1	Damage 2	Major damage 3	Severe loss 4	Catastrophic 5
Very High	90%			1		
High	70%		1	1	1	1
Moderate	50%		1	2	3	1
Low	30%					1
Very Low	10%					

The risks of model 2 are distributed over the upper right part of the table but this model does not have any severe loss or catastrophic risks with the probability higher than 90%. The risk distribution gravitates toward the middle of the table which indicates that this model would need additional risk mitigation. Model 2 has a total of four risks which belong to severe loss category with the probability of 70%, and three risks in the catastrophic category, but only one of them has the probability higher than 70%.

Table 7 shows the distribution risk analysis for the model 3.

Table 7: *Distribution risk analysis - model 3*

Probability \ Impact		Minor damage 1	Damage 2	Major damage 3	Severe loss 4	Catastrophic 5
Very High	90%					
High	70%			2		
Moderate	50%		1	1	1	1
Low	30%		1	1	4	1
Very Low	10%					

The risk distribution of model 3 is relatively evenly spread in the middle of the table which indicates a model with less risks from the catastrophic category with the probability of occurrence greater than 90%, and only one risk with the probability of occurrence higher than 70%. Although there are five risks in the severe loss category, their probability of occurrence is moderate to low which indicates that this model could be made safer by applying risk control measures.

4.3. RISK CONTROL MEASURES

Model 3 is the model with the least total model risk rating of 19.00 and risk control measures were applied to the model to additionally control the hazards, i.e., to lower the total model risk rating (Table 8). For each of the 13 defined hazards of model 3, risk control was performed and measures to minimize hazards prescribed.

Table 8: *Model 3 risk control measures*

Risk Description (type of activity)	Hazard	Who/what is at risk?	Risk control measures	Residual Probability of Occurrence	Residual Impact	Residual Risk Rating
Longitudinal inclination of the haul road	Mechanical damage of machinery	Machinery	Decrease of longitudinal inclination	0.3	2	0,60
	Machinery toppling	Workers Machinery	Worker education	0.1	4	0,40
	Stone jettison from wheels turning	Workers	Worker education	0.5	1	0,50
	Mechanical damage of the haul road	Environment	Regular maintenance	0.5	2	1,00
	Dust emission – inability to moisten the road	Environment	Compacting and moistening of the haul road	0.3	1	0,30
The width of the haul road	Machinery passage	Machinery	Widening the haul road	0.1	2	0,20
	Different types of machinery bypassing – collision	Machinery	Worker education	0.3	2	0,60
	Machinery and people bypassing – collision	Workers	Enclosed areas for people	0.1	4	0,40
	Road width in alignment with legal regulations	Environment	Rehabilitating parts not in use	0.1	1	0,10

Possibility of further exploitation development	Unstable haul road	Machinery	Design of new mining works	0.3	2	0,60
	Inability to correctly develop benches	Environment	Designing of new haul roads	0.3	1	0,30
	Landslides appearing in areas of the haul road	Workers Machinery Environment	Greening the slopes	0.3	3	0,90
	Landslides appearing at wrongly executed benches	Workers Machinery Environment	Worker education	0.1	2	0,20
TOTAL MODEL RISK RATING						6.10

After applying the risk control measures, the total model risk rating of model 3 is 6.10, considering that the average risk rating is 0.47 which puts this model, i.e., the risk of the model into insignificant category.

A distribution risk analysis was performed for model 3 after risk control measures were applied (Table 9).

Table 9: *Distribution risk analysis - model 3 (after risk control measures)*

Probability \ Impact		Minor damage	Damage	Major damage	Severe loss	Catastrophic
		1	2	3	4	5
Very High	90%					
High	70%					
Moderate	50%	1	1			
Low	30%	2	3	1		
Very Low	10%	1	2		2	

V. Discussion

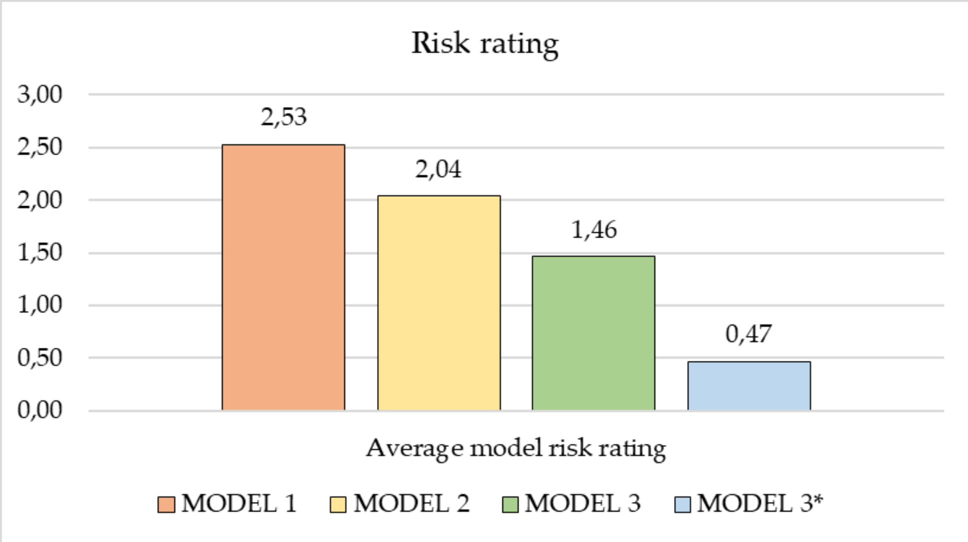
During risk assessment and selection of the safest haul road model, emphasis was given to the influence of project parameters on the safety of employees, machinery, and environment. By evaluating the potential hazards (Table 4) which can occur as the consequence of project parameters, the haul road models for quarry "Očura II" were ranked. The haul road models were ranked based on numerical risk values which were the result of the total sum of risk values of each hazard per each model (total of 13 hazards). The results of the total values of the estimated risk are shown in Table 10.

Table 10: *Haul road model risk rating*

Model	Total model risk rating	Average model risk rating
Model 1	32.90	2.53
Model 2	26.50	2.04
Model 3	26.50	1.46
Model 3*	6.10	0.47

*after risk control measures

The ranking of haul road model is additionally displayed graphically (Figure 3).



*after risk control measures

Figure 3: *Ranking of haul road models*

The model 1 with total model risk rating of 32.90 (average 2.53) represents a very risky model, i.e., represents the actual situation in the field and an urgent implementation of safety measures is necessary to prevent possible severe consequences for people and machinery. A less risky model is the model 2 (moderate category) with total model risk rating of 26.50 (average 2.04). However, implementing model 2 might cause moderate risks which could cause major damage. Model 3 accepts the current situation in the field and its total model risk rating is 19.00 (average 1.46) which classifies this model in the sustainable risk category. Regardless of the sustainable category, risk control measures were performed which in a simple manner minimized the existing hazards and thus minimized the total model risk rating. After the implementation of risk control measures the total model risk rating for model 3 is 6.10 (average 0.47) and that classifies it in the insignificant risks category.

VI. Conclusion

Considering that risk assessment is relatively easy to perform, that it is done specifically for each individual case and that it is most often performed by people with location affiliation, it represents a realistic risk assessment.

For the risk assessment procedure to be complete, it is necessary to carry out certain security measures which will mitigate the risk, and make the consequences acceptable, or will remove the risks completely. The measures that should be implemented to mitigate or eliminate the influence of project parameters are primarily visible in their compliance with official legislative (regulations, directives, laws on the basis of which project design is performed) and professional standards, prescribed measures of work safety and internal investor documents if there are any (for example guidelines for safe work in an open pit, and similar).

Lowering the risk, i.e., increasing the safety for both employees, and machinery and environment, will in this case be performed by creating a new haul road which is foreseen by model 3. The project parameters considered while designing model 3, as one of the options for risk assessment, are in compliance with legislation of the Republic of Croatia, professional standards, and experiential work information from quarry "Očura II".

By implementing Risk control measures on existing models, it is possible to reduce the possibility of risks occurring, i.e., to lower the existing risks to a negligible value. Therefore, for model 3 which is a sustainable risk model, additional risk control measures were performed to minimize the risks which resulted with model 3 being classified in insignificant category. Using distribution risk analysis, it is possible to visually ascertain, in an easy way, whether there are risks that can cause severe consequences or that model risks are, for example, insignificant.

References

[1] HZZZSR, "Procjena rizika," 2016. http://www.hzzzsr.hr/index.php/rizici-na-radu/procjena-rizika/ (accessed Aug. 06, 2022).

[2] R. F. D. S. Gomes, L. Gauss, F. S. Piran, and D. P. Lacerda, "Safety at work: A complex or an exceedingly simple matter?" Reliability: Theory & Applications, vol. 17, pp. 187–267, Aug. 2022, doi: 10.24412/1932-2321-2022-167-267-287.

[3] J. Navarro-Esbrí, A. Real, D. Ginestar, and S. Martorell, "Application of a vapour compression chiller lumped model for fault detection," in Safety, Reliability and Risk Analysis: Theory, Methods and Applications, 2009, pp. 175–181.

[4] J. C. García-Díaz, "Fault detection and diagnosis in monitoring a hot dip galvanizing line using multivariate statistical process control," in Safety, Reliability and Risk Analysis: Theory, Methods and Applications, 2009, pp. 201–204.

[5] M. Rausand and S. Haugen, Risk Assessment: Theory, Methods, and Applications, vol. Second edition. New York, 2020.

[6] Y. Yin, H. Wen, L. Sun, and W. Hou, "Study on the Influence of Road Geometry on Vehicle Lateral Instability," Journal of Advanced Transportation, vol. 2020, pp. 1–15, Oct. 2020, doi: 10.1155/2020/7943739.

[7] European Agency for Safety and Health at Work, "Risk Assessment Tool," vol. 97333, no. 541, p. 52, 2007, [Online].

[8] Ž. Rukavina, Smjernice za procjenu rizika. Zagreb: Koordinacija za sigurnost pri odobalnom istraživanju i eksploataciji ugljikovodika, 2017. Accessed: Aug. 06, 2022. [Online]. Available: https://www.azu.hr/media/1094/smjernice-za-procjenu-rizika.pdf

[9] R. Kumar and A. K. Ghosh, "The accident analysis of mobile mine machinery in Indian opencast coal mines," International Journal of Injury Control and Safety Promotion, vol. 21, no. 1, pp. 54–60, Mar. 2014, doi: 10.1080/17457300.2012.755551.

[10] V. Kecojevic and M. Radomsky, "The causes and control of loader- and truck-related fatalities in surface mining operations," Injury Control and Safety Promotion, vol. 11, no. 4, pp. 239–251, Dec. 2004, doi: 10.1080/156609704/233/289779.

[11] R. J. Thompson, G. A. Fourie, A. T. Visser, and R. A. F. Smith, "Benchmarking haulroad design standards to reduce transportation accidents," International Journal of Surface Mining, Reclamation and Environment, vol. 12, no. 4, pp. 157–162, Jan. 1998, doi: 10.1080/09208118908944039.

[12] R. Szabo, "Traffic hazards on mines – More than road safety audits help?," Australasian Mine Safety Journal, Jan. 29, 2022. https://www.amsj.com.au/traffic-hazards-on-mines-more-than-road-safety-audits-help/ (accessed Aug. 06, 2022).

[13] M. Zhang and V. Kecojevic, "Intervention strategies to eliminate truck-related fatalities in surface coal mining in West Virginia," International Journal of Injury Control and Safety Promotion, vol. 23, no. 2, pp. 115–129, Apr. 2016, doi: 10.1080/17457300.2015.1032982.

[14] M. R. Garry, S. S. Shock, and J. Salatas, "Human health risk assessment of metals exposure through subsistence foods consumption and subsistence harvest activities near a mining transport road in northwest Alaska," Human and Ecological Risk Assessment: An International

Journal, vol. 27, no. 1, pp. 227–257, Jan. 2021, doi: 10.1080/10807039.2019.1706151.

[15] B. Farkaš and A. Hrastov, "Multi-Criteria Analysis for the Selection of the Optimal Mining Design Solution—A Case Study on Quarry 'Tambura,'" Energies (Basel), vol. 14, no. 11, p. 3200, May 2021, doi: 10.3390/en14113200.

[16] M. J. Rahimdel and M. Mirzaei, "Prioritization of practical solutions for the vibrational health risk reduction of mining trucks using fuzzy decision making," Archives of Environmental & Occupational Health, vol. 75, no. 2, pp. 112–126, Feb. 2020, doi: 10.1080/19338244.2019.1584085.

[17] Y. Choi, H. Park, C. Sunwoo, and K. C. Clarke, "Multi-criteria evaluation and least-cost path analysis for optimal haulage routing of dump trucks in large scale open-pit mines," International Journal of Geographical Information Science, vol. 23, no. 12, pp. 1541–1567, Dec. 2009, doi: 10.1080/13658810802385245.

[18] S.-L. Donovan, P. M. Salmon, M. G. Lenné, and T. Horberry, "Safety leadership and systems thinking: application and evaluation of a Risk Management Framework in the mining industry," Ergonomics, vol. 60, no. 10, pp. 1336–1350, Oct. 2017, doi: 10.1080/00140139.2017.1308562.

[19] R. Szabo, "Ground control: Failure of high walls, low walls and dumps," Australasian Mine Safety Journal, 2022. https://www.amsj.com.au/ground-control-failure-of-high-walls-low-walls-and-dumps/ (accessed Aug. 06, 2022).

[20] R. Szabo, "Mine wall collapse sends truck tray into 'free fall,'" Australasian Mine Safety Journal, 2022. https://www.amsj.com.au/mine-wall-collapse-sends-truck-tray-into-free-fall/ (accessed Aug. 06, 2022).

[21] M. S. Maziah Munirah, Z. Libriati, Y. Nordin, and M. N. Norhazilan, "Prioritization of the human health and safety loss factor subject to offshore pipeline accidents," IOP Conference Series: Earth and Environmental Science, vol. 220, pp. 1–10, Feb. 2019, doi: 10.1088/1755-1315/220/1/012031.

[22] Q. Gu, B. Xue, S. Ruan, and X. Li, "A road extraction method for intelligent dispatching based on MD-LinkNeSt network in open-pit mine," International Journal of Mining, Reclamation and Environment, vol. 35, no. 9, pp. 656–669, Oct. 2021, doi: 10.1080/17480930.2021.1949800.

[23] Vlada Republike Hrvatske, Zakon o zaštiti na radu. Croatia: https://www.zakon.hr/z/167/Zakon-o-za%C5%A1titi-na-radu , 2014.

[24] SL, "Pravilnik o tehničkim normativima za površinsku eksploataciju ležišta mineralnih sirovina," Službeni list SFRJ, no. 4/1986, 62/1987, 1987.

[25] SL, "Pravilnik o tehničkim normativima za strojeve s dizelskim motorima koji se upotrebljavaju pri podzemnim rudarskim radovima u nemetanskim jamama," Službeni list SFRJ, no. 66/1978, 1978.

[26] European Parliament, Direktiva vijeća o uvođenju mjera za poticanje poboljšanja sigurnosti i zdravlja radnika na radu. European union: https://eur-lex.europa.eu/legal-content/HR/TXT/PDF/?uri CELEX:01989L0391-20081211&from=EN, 2008 .

[27] B. Farkaš and A. Hrastov, "Fotogrametrijski snimak površinskog kopa 'Očura II.'" RUDAR PROJEKT d.o.o., Zagreb, Feb. 2021.

[28] J. Pranjić, I. Zorić, M. Hatlak, F. Pranjić, and N. Gizdavec, Dopunski rudarski projekt eksploatacije tehničko-građevnog kamena na eksploatacijskom polju "Očura II" – prva dopuna. Varaždin, Hrvatska: SPP d.o.o., 2018.

[29] B. Farkaš and A. Hrastov, Elaborat niveliranja pristupnih puteva površinskog kopa „Očura II". Zagreb, Hrvatska: RUDAR PROJEKT d.o.o., 2021.

[30] Z. Vučinić, Procjena rizika. Karlovac: Veleučilište u Karlovcu, 2019.

ECOLOGICAL ASSESSMENT OF AFTER - EFFECTS OF SEISMIC VIBRATIONS

Jamila Imamaliyeva
•
Azerbaijan University of Architecture and Construction
ncamila@rambler.ru

Abstract

Assessment of direct impacts of after-effects of earthquakes on the environment, economical results of ecological damages, solutions of ecological problem. Not only communal economy and communication but also environment was damaged after earthquake. Direct impacts on the environment include real and remnant danger of industry objects especially chemical depots; damage of water stocks including water economy as well as dikes, irrigation canals; destruction of city and industry cleaning systems of filthy waters; damage of water stock may cause water flood of harmed areas. Some direct influences to the environment are expected due to disturbing of sanitation and utilization rules, burial of building wreckages and destroying of ruins. It is important to create an ecological control program, as it is impossible to appreciate all impacts on environment for the first time. Disaster recovery plan contains strategies to minimize the effects of a disaster, help an organization to quickly resume key operations or continue to operate. Disaster recovery plan, which created by an organization that contains detailed instructions on how to respond to unplanned natural hazards. The vulnerability of a country, a population, or a building is measured by how susceptible to harm or loss it is in the face of a hazard. The risk is estimated by measuring the probable occurrence of a natural hazard of certain intensity against the vulnerability of the exposed elements. For example, a building is at risk during an earthquake impacts when the earthquake (hazard) is strong enough to damage or destroy the building, also when buildings were built without seismic-resistant construction techniques (vulnerability) in the design. Risk management is important factor to creating a disaster recovery plan.

Keywords: environment, losses, infrastructure, earthquake, damage

I. Introduction

Unexpected impacts on environment includes possible changes of movement of subsurface waters and water-bearing sheets; possible changes of ecosystem, varieties of different animals and taking account the complex situation in all cases it is important to control the impacts on environment. Economical results of ecological damages are:

a) financial damage; b) industrial losses; c) financial costs – that direct, straight and remote losses. Dwelling fund, social infrastructure and national economy was damaged due to calamity. For the first calculation total damage consists 5 billion dollar. But for reconstruction with higher standards is needed 6 billion. Health and education, industry, tourism, municipality infrastructure, social building, cultural monuments, water and electricity providing systems, transport, telecommunication and ecology was damaged in the result of earthquake. Earthquakes cause destructive effects to buildings, transportation networks, infrastructure systems, critical facilities and produces a range of social and economic impacts. Earthquake hazard elimination must be based on an analysis of system-level consequences to be effective. Linking physical damage to social and economic impacts is difficult for several reasons. First, and fortunately, there are relatively few damaging earthquakes to provide actual data that can be used for understanding and modeling social and economic impacts. Second, there is not a simple deterministic relationship between physical damage and resultant impacts, and a number of contributing and confounding factors mediate this relationship. There is considerable uncertainty in the incidence of impacts across populations. There are also complex social interactions that can amplify or reduce the impacts. And finally, social and economic impacts develop and change over time. Some impacts do not manifest themselves immediately and many are not resolved in the short term. This extended temporal dimension adds complexity to linking social and economic impacts to physical damage, which occurs within a very short time period.

Under natural disasters are understood destructive natural phenomena, a result which may arise or there is a threat to life and health of people, there is a disruption or destruction of property and elements of the natural disasters. In some cases, they are caused by man, as a result of industrial or other activities without ecological balance in nature. To natural disasters typically include: earthquakes, floods, mudslides, landslides, snow drifts, volcanoes, durability to the drought. Such disasters in some cases, may be classified as fires, especially the massive forest and peat.

Natural disasters can be found in different ways. Bewilderment, as for centuries people meet various disasters, or quietly with faith in our own strength. Sure, we take the challenge of disasters can only those who are armed with knowledge on how to act in any circumstances would only correct decision: save yourself, help others, how can prevent the destructive action of natural forces. Natural disasters which are the tragedy for all state, and, especially for those regions of the country where they arise are investigated. The correct behavior of the population at natural disasters relying on knowledge of bases of civil defense is a basis of decrease in human losses and material damage.

II. Methods

Social results of ecological damages.

In the social plan earthquake caused a lot of human losses and destructions. Besides of direct suffering many people lost their relatives and seriously injured. The tragedy continues its influence in the health of widows, orphans, alone and the olds. Another social damage was that losing their shares especially farmer economy, work and property people were bankrupted. Death of people, damage to dwellings, lost of dwelling s, industrial force, work places disturbed the stability of condition, financial loan system, markets and distributing channels of resources became insolvent.

Earthquake-specific phenomenon occurring in certain parts of the crust. They can occur both on land and under water. It's very important for someone to know when and where will be earthquakes. Modern science has information about where it can be a disaster of a force, but to accurately predict the day and hour is not yet. Earthquake precursors, as is already installed can appear number of indirect signs. In the period of the preceding the earthquake, for example, changes the parameters of physical and chemical composition of groundwater, which is recorded by special devices geophysical stations [1]. By the harbinger of possible earthquakes include the following symptoms that are especially need to know the population of seismically dangerous areas and it was this odor of gas in areas where before the air was clean and previously a similar phenomenon was reported, concerns the birds and animals, the outbreak in the form of scattered light of lightning, sparking closely spaced, but not touching electrical wires, a bluish glow the inner surface of the walls of houses, self-tan fluorescent tubes shortly before the tremors. All these symptoms may be the reason for alerting the public about a possible earthquake.

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III. Results

Health.

Earthquake caused a lot of death and suffering of people. People injured in serious moral, orthopedic, craniocerebral, abdominal and pectoral cavity, disabled physically and mentally.

People who rescued after earthquake lost their work ability for a long time. Health infrastructure was damaged seriously. Additional risk is that people had to use dirty water. For overcoming the situation is needed urgent medical care, and the hopeless people needed psychological support. To help to some of the regions still was very difficult. Gathering the people in one place and insanitary conditions in temporary dwellings were under the threat of cholera. Health authority already announced about skin disasters.

Education.

Primary and secondary, high education institutions was seriously damaged. Thousands of building damaged or fully destroyed. More than thousand student and schoolchildren, many professors lost their lives.

Dikes, water storehouses and irrigation systems.

As the result of earthquake, water supply and water channels infrastructure were seriously damaged. Small soil dikes and water storehouses were destroyed.

Water supply.

Water supply systems other places were damaged. Dikes for water supply, pump stations, pipelines of these regions were damaged, subsoil water sources filled with soil.

Electricity supply, transport and communication.

Although electricity lines were damaged it was possible to restore the electricity supply in natural calamity regions. The changing of dilapidated electricity equipment is not expected but the issue of modernization of electricity net in damaged regions was urgent problem. Damage to infrastructure systems produce economic losses. The studies shown that disruptions to these services produce facility repair costs, revenue loss to the service provider, direct economic loss to consumers and indirect economic loss. Moreover it is not possible to join new equipment to previous damaged parts. Road cover around villages and small towns were seriously damaged so to go to some dwellings it is possible only with helicopter. Telecommunication also was destroyed. Phone lines were damaged in the result of destruction of Automatic Phone Network. Damage to transportation systems produce significant repair costs, disrupt the movement of people and goods. Damaging of the transportation network have significant economic impacts, contribute to economic losses following an earthquake. Destructive causes of earthquake makes long-term disruption, taking years to fully restore.

Industry, agriculture and cattle-breeding.

Agriculture as the main industry was fully destroyed. Such losses also affected to domestic industry, market and factory. The loss of agriculture founds and small business shares made the local populations' life more incredible. Main losses were cattle-breeding and irrigation systems.

IV. Discussion

Solutions of ecological problem.

Serious problems of population replacing and building crumbs occur during restoration process. It requires immediate and correct decision for gathering building crumbs and additional transport. It is advisable to reuse concrete and stone pieces. The situation must always be under control. The decisions must aim to less damage to ecology. It is important to be attentive in abolishment of dangerous industry substances.

It is important to work out a plan for ecological issues and it is necessary to set up temporary camps for injured people. Other urgent measures include:

a) to control the systems of water supply and dikes (till rain season)

b) operative controls for reducing of ecological remaining risk from destroying or deterioration of industrial infrastructure

c) technical assistance in restoration of ecological entities

For reducing ecological risk and carrying out a useful restoration process may be advised followings:

A) overall estimation of ecological damages of earthquake.

B) examination and analyzing of industrial risk about transportation, keeping and processing of dangerous things

C)to maintain the infrastructure of environmental control

D) to apply ecological clean technology

E) acceptance of serious ecological normative by public and social bodies for restoration of industrial entities and ecological stability.

Restoration strategy.

The restoration strategy of damaged regions must be aimed to social sphere and maximum participation of public. Total damage seems small in global scale but earthquake caused enormous loss to local population. Providing with temporary settlements - urgent measure during winter. Moreover, restoration is necessary for operating of dwellings communal economy, water and energy systems, communications, municipal and ecology structure and local managements bodies. Measures on providing the most vulnerable groups of population with vital means are also necessary. Only on – time aid can be effective.

Restoration concept under local management body – must be basis of state program. Key to success lays on creating efficient mechanism of decentralization of management. Taking into consideration of opinion of population, costs and advantages they must decide where to restore the villages, on old or another places.

Connection with society, publicity and information supply – carrying out the plan of restoration of damaged regions is basis of success. Political initiative, financing and technical knowledge can not be effective in places where does not exists exchange of information. So including ecological issues for providing more effective mutual relations with organizations and support for restoration program government must carry out urgent strategy of communication with people.

An earthquake may last from several seconds to several hours (periodically repeated tremors). By applying the frequency of shocks and the time of their occurrence may be communicated by radio and other means available. It is their actions to conform with these messages.

Firstly, such work will be done by individuals, consisting in the formation of civil defense. But the rest of the population at the call local authorities and governments DPP should participate in urgent search and rescue and recovery operation workers in the areas of destruction [2]. In carrying out such works primarily extracted from the rubble of wrecked and burning buildings of people who have a first aid; suit in the rubble of air travel; localize and eliminate the accident on engineering networks that threaten human life or prevent the carrying out rescue operations; precipitates or strengthen the construction of buildings and structures located in a dangerous condition; Tools collection points for the victims and medical centers, and organize water. The sequence and timing of works sets the head of civil defense object caught in the earthquake zone.

Great support from the population can be provided medical facilities and medical office of civil defense in maintaining normal health and living conditions in temporary settlements (Antiseismic buildings) affected by the earthquake population. We must help to prevent outbreaks in places such infectious diseases that are typically satellite disaster. In order to prevent the emergence and spread of epidemics should be strictly adhered to epidemic measures not shy away from vaccinations and taking drugs that prevent disease. We must carefully observe the rules of personal hygiene and ensure that they comply with all family members, need to be reminded about the neighbors, coworkers.

Rules of the population in the earthquake and actions to eliminate their effects.

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Rules of the population, with debris flows and landslides, and actions to mitigate their effects.

Mudslides, it flows from the mountains, a mixture of water, sand, clay, gravel, fragments of stones and even boulders. Landslides are the result of violations of the conditions of equilibrium slopes, often along rivers and reservoirs, the main cause of their occurrence is the saturation of groundwater argillaceous rocks to plastic and flowable state, resulting in and is slipping down the slope of huge masses of soil with all buildings and structures.

Of great importance to the conduct and actions of people in mudslides and landslides organization provides early detection and recording features of these natural disasters and the organization alert (warning) about the disaster.

In flood dangerous areas of possible signs of debris flows are excessive (heavy) precipitation (mud flows as a result of torrential rainfall are usually formed after a drought), rapid melting of snow, mountain lakes and reservoirs, in violation of the natural runoff of mountain rivers and streams Change channels and the formation of dykes.

In most cases, the population about the danger of debris flow can be prevented in just ten minutes or less for one to two hours or more. The approximation of such a flow can be heard by the characteristic sound of the pealing and colliding with each other boulders and fragments of stone, resembling thunder approaching at high speed train.

The most effective way to deal with a mudslide early implementation of a complex of organizational-economic, agricultural, agroforestry and waterside activities.

Population in flood dangerous areas must strictly comply with the recommendations of felling forests, farming, grazing by livestock. In mudflow in the way of its movement to settlements strengthening the dam, built embankments and temporary retaining walls, arranged mud traps, ditch, etc.

Landslides, like debris flows, often caused by heavy rains and soil erosion. Well thought-out human activity, which resulted in altered conditions for the stability of the soil (the destruction of forests even individual trees, mining and excavation Works where the geological structure of the earth, etc.).

Initial indications that landslide movements are the appearance of cracks on buildings, breaks on the roads, embankments buckling of the earth, the displacement of the base of various high-rise structures and trees at the bottom on the top.

Antilandslide events that must be involved people are challenged surface water arbor, the device supports various engineering structures, Thrush passage for drainage of soil landslide, unloading and planning landslide slope. In addition, people living in landslide areas should not allow the diversion of water from the taps, damaged water pipes and hydrants, shall promptly arrange drainage effluents in the cluster of surface water (with the formation of puddles).

With the threat of debris flow or landslide and availability of time the population was evacuated from dangerous areas to safe zones, evacuation is both on foot and with using transport. Mudslides and landslides are a serious danger in their sudden appearance. In this case, the most terrible panic. In the case of capture anyone want to stream mudflow affected by all available means. These funds may be poles or ropes, served saves. Show rescued from the stream to flow direction, with a gradual approach to its edge. When landslides may be heaping people ground, causing them to blows and injuries, falling objects, cave building structures trees. In these cases, it is necessary quickly to provide assistance to victims, if necessary, and to do artificial respiration. Consequences of landslide eliminate the formation of engineering services with the participation of the population. After stopping the landslide formation of road and bridge building organizations begin to work to rebuild roads, bridges, power lines and communications, construction of drainage ditches, cleaning roads and streets of the drifts and debris.

Rules of the population during floods and actions to mitigate their effects.

Severe natural disasters are floods. The main causes of most floods are heavy rains, intense snowmelt and river flooding as a result of the tidal wave or the wind changes in the river mouth. Especially dangerous is flooding arising from landslides and avalanches of rock, a sudden eruption of dams or moraine lake waters, and they are usually accompanied by the transfer not only water, but almost all debris and loose material, and therefore often take disastrous. Actions carried out during floods because of the time of pre-emption floods, as well as the experience of observing the past years the manifestations of this element. The extent of flooding, for example, caused by the spring, summer or autumn floods, may be anticipated for a month or more, surges flooding - for several hours (up to days).

When the time of pre-emption flood efforts are being made for the erection of the waterworks on the rivers and in other places alleged flooding. To prepare and conduct the evacuation in advance of population and agricultural animals, the removal of property from areas of possible flooding. On the evacuation in case of floods, as a rule, was declared special order of the commission to combat flooding. The population of the evacuation order early and be notified by local radio broadcasting networks and local television, working in addition be notified through the administration of enterprises, institutions and educational institutions. Evacuation in the nearest towns, outside of flood zones. The resettlement of the population is carried out in public buildings or residential area inhabitants. At local enterprises and institutions under the threat of flooding changes the mode of operation and settings it where the work stops. Protecting some of the wealth is sometimes provided on the site, which are sealed sumps, entrances and window openings basements and ground floors buildings.

In the area of possible flooding temporarily quit school and preschool, children are transferred to schools and institutions that are in safe places. In the case of flash floods warning the population is made all the available technical means of notification, including through loud speaking mobile installations.

Sudden onset of flooding is the need for special behavior and actions of people. If people are living on the ground floor or other lower floors and on the street there is the rise of the water must leave the apartment, ascend to the upper floors, if the single-storey house- take the attic. Search for people in the flooded area is organized and implemented immediately, for it brought the crews of floating funds of civil defense units and all other available forces and means.

Rules of the population, with snow drifts and actions to mitigate their effects.

Winter manifestation of the elemental forces of nature are often expressed in snowdrifts as a result of snowfalls and blizzards. Snowfalls, the duration of which may be from 16 to 24 hours greatly affect the economic activity of the population, especially in rural areas [12]. The negative impact of this phenomenon is aggravated by storms (blizzards, snowstorm) in which the rapidly deteriorating visibility, suspended transport links, as well as long-distance.

With the announcement of curtain warning-warning of possible snow drifts - to restrict movement, especially in rural areas, to create a home needed supply of food, water and fuel. In some areas with the onset of winter on the streets, between houses, you must pull the ropes to help in severe snowstorm oriented to pedestrians and to overcome the strong wind.

Especially dangerous snow drifts are for people caught in the path, away from human habitation. When proceeding by road should not attempt to overcome the snow drifts, you must stop completely close the blinds machine shield the engine from the radiator. If it is possible to install a car engine in the windward side. From time to leave the car, shovel snow, to avoid being buried under it. In addition, not snowbound car - a good benchmark for the search team. Motor vehicle and must be warming up to avoid it "freezing".

When heating the car is important to prevent wicking into the cab (body, interior) of exhaust gases, to this end it is important to make sure that the exhaust pipe is not piled snow.

If the path together will be a few people (several cars) it is best to gather all together and use one car as cover, the engines other cars must be emptied. Do not leave the cover-car: in the heavy snow (blizzard) guidelines at first glance seems to be reliable, a few tens of meters may be lost.

In rural areas receiving storm warnings to procure the required quantity of fodder and water for animals kept on farms. Scot contained on remote pastures in a matter of urgency is distilled in the nearest shelter, pre-equipped in the terrain or fixed camps.

With the formation of icy magnitude of the disaster increases [8]. Hoar-frost education on the roads made it difficult, and the rugged terrain and completely stop the operation of road transport. Pedestrians find it difficult, and the collapse of various structures and objects under load become a real danger. In these circumstances it is necessary to avoid being in dilapidated buildings, under power lines and communications and near their poles, under the trees.

In mountain areas after heavy snowfall increases the risk of avalanches. About this risk population is advised various warning signals installed in the field of possible avalanches and possible avalanches. We should not disregard these warnings; we must strictly implement their recommendations.

To fight with snowdrifts and ice formation and involved civil defense services, as well as all able-bodied population of the area and, if necessary, and neighboring areas.

Snow work in the cities primarily conducted on the main roads, restored the work of life-sustaining water supply facilities. Snow is removed from the roadway to leeward. Widely used engineering technique that is at equipping units, as well as snow plow equipment installations. For the work involved all the available transport, handling equipment and people.

References

[1] "Assets, Threats and Vulnerabilities: Discovery and Analysis. A comprehensive approach to Enterprise Risk Management". (2001). Symantec Corporation.

[2] Imamaliyeva J.N. Events of devastating nature and liquidation of their results. (2008). National Academy of Sciences of Azerbaijan Republic Centre of seismic service. The catalogue of the seismic-prognosis observations in Azerbaijan territory in 2007, Baku, p.132-136.

[3] Imamaliyeva J.N. Environmental impacts of earthquakes. (2008). Science and science technical and industrial Academy of Sciences of Azerbaijan Republic Centre of seismic service. The catalogue of the seismic-prognosis magazine, ecology and water management №3, Baku, p. 7-13.

[4] Guha-Sapir, D., Hoyois, Ph., Below, R. Annual Disaster Statistical Review 2013: The Numbers and Trends. (2014). Brussels: Centre for Research on the Epidemiology of Disasters (CRED).

[5] Global Assessment Report on Disaster Risk Reduction: Making Development Sustainable: The Future of Disaster Risk Management. (2015). The United Nations Office for Disaster Risk Reduction (UNISDR).

[6] Disasters, planning, and development: managing natural hazards to reduce damage. (1991). Washington, D.C.: OAS. Organization of American States.

[7] Imamaliyeva J.N. Some of the environmental consequences of natural disasters. National Academy of Sciences of Azerbaijan Republic Centre of seismic service. The catalogue of the seismic-prognosis observations in Azerbaijan territory in 2009, Baku-2010, p.80-85.

[8] Imamaliyeva J.N. Natural disasters and acts of the population to eliminate their consequences. (2008). Azerbaijan Architecture and Construction University. Scientific works №2 Baku, p. 76-79.

[9] Bobok S.A., Yurtushkin V.I. Emergencies. Protection of the population and territories. (2000). –M.:. -288 p.

[10] Bykov A.A., Murzin N.V. The problem of analyzing the security of man, society and nature. (1997), St. Petersburg: Nauka, - 247 p.

[11] Ivanov B.S., Cutters E.A. Life safety. (2005). 3rd ed. – M.: MGIU, -225 p.

[12] Atamanyuk V.G., Shirshov L.G., Akimov N.I. Civil Defence, M: Vysshaya shkola, 1986.

[13] Cutter, S. L., Boruff, B. J., and Shirley, W. L. (2003). Social vulnerability to environmental hazards. Social Science Quarterly, 84(2), pp. 242-261.

[14] French S. P. and Xudong J. (1997). Estimating Social and Economic Impacts of Infrastructure Damage with GIS. Journal of the Urban and Regional System Association.

[15] Rose, A., Benavides, J., Chang, S., Szczesniak, P., and Lim, D. (1997). The regional economic impact of an earthquake: Direct and indirect effects of electricity lifeline disruptions. Journal of Regional Science, 37, pp. 437- 458.

THE STRENGTH OF WALLS MADE OF CELLULAR CONCRETE BLOCKS REINFORCED WITH COMPOSITE MESH UNDER THE ACTION OF STATIC AND DYNAMIC LOADS

Arkadiy Granovskiy, Bulat Dzhamuev, Vadim Mukminov

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Moscow State University of Civil Engineering, Russia
arcgran@list.ru

Abstract

The results of experimental studies of the strength of masonry walls made of cellular concrete blocks under various force influences are presented. It is noted that the use of walls made of cellular concrete blocks with a density of D400-D600 in seismic areas can significantly reduce the magnitude of the seismic load on the structure. According to the results of the research, the behavior of the masonry under the action of loads modeling seismic impacts, considering its reinforcement with composite materials based on carbon fiber reinforced polymer (CFRP) and bazalt fiber reinforced polymer (BFRP). Data on tests on the vibration platform of full-size wall samples, considering external reinforcement with CFRP tapes, are presented. An increase in the seismic resistance of reinforced structures due to the use of composite materials has been revealed. The nature of the destruction of wall panels reinforced and non-reinforced with composite canvases is shown. According to the results of tests of fragments of walls made of cellular concrete blocks using reinforcement composite mesh based on basalt fiber, the effect of its use in axial stretching of masonry was noted. The use of a composite mesh with a 25×25 mm cell based on basalt fiber made it possible to increase the tensile strength of the masonry across the cross section by 28%.

Keywords: cellular concrete blocks, composite materials, seismic resistance, tests for skewing and stretching of masonry.

I. Introduction

The problem of ensuring a comfortable level of work and human habitation in industrial and residential premises of buildings is associated with a significant expenditure of energy resources, the consumption of which does not directly depend on their extraction and reproduction.

According to the EU, if appropriate measures are not taken, Europe's dependence on external energy supplies, and Russia's dependence on energy production, will increase by 65-70% by 2030 relative to the beginning of the XXI century. In this regard, the EU – Klimatschutzpaket 20-20-20 document was adopted for the possibility of reducing energy costs in the EU, which set a goal of reducing energy consumption by 20% compared to 1990. According to Russian and European sources, 40% of the total primary energy consumption goes to the maintenance of buildings, of which 75-80% is for heating in winter and cooling in summer of residential and administrative buildings.

To improve the energy efficiency of buildings in Europe, a document was developed – the European Directive on Building Energy Efficiency "EPBD" (Energy Performance of Buildings

Directive). In the period from 06.07.2010 to 31.12.2020, the EU member states must ensure that all new buildings under construction must generate as much energy as they consume. The purpose of this step is to develop houses with zero energy consumption. A similar task is facing the Russian construction industry.

One of the main ways to reduce heat loss through enclosing structures is the use of modern cellular concrete and taumalite wall materials with reduced thermal conductivity characteristics. According to the company "YTONG" for the period from 1950 to 2015, the coefficient of thermal conductivity of autoclaved aerated concrete blocks decreased from 0.21 W/m ×°C to 0.07 W/m × °C.

Despite the advantages of cellular concrete block walls over brick walls, the disadvantage of this type of material is their low compressive strength and the effect of shear forces. This factor hinders the use of cellular concrete blocks in earthquake-prone regions. In this regard, the University's Research Center conducted comprehensive studies of the strength of masonry walls made of cellular concrete blocks under the action of seismic loads using special adhesive solutions and composite materials. This should have made it possible to increase the adhesion of the blocks to each other and the strength of the masonry under the action of compressive and tensile loads on the walls during an earthquake.

As foreign studies have shown, when meeting the requirements of Standards for masonry walls of buildings erected in earthquake-prone regions and performing special seismic protection measures, the seismic resistance of walls made of cellular concrete blocks may be quite sufficient for different earthquake intensities. According to [1,2], more than 15,300 low-rise residential buildings made of cellular concrete blocks were built in Japan from 1970 to 1979. Surveys of these buildings carried out in 1980 confirmed their higher reliability in case of earthquakes compared to houses made of other stone materials.

Surveys of buildings made of small–piece brick and stone materials [3-7] have shown that typical damages of brick buildings during earthquakes are:

- diagonal and cross cracks in piers, lintels, as well as on solid sections of walls;
- separation of longitudinal and transverse walls and the occurrence of vertical cracks in the places where they adjoin;
- horizontal cracks in the piers at the level of the lintels and window sills.

II. Experimental setup and realization of the test

The experimental studies consisted of three stages. At the first stage, the fragments of the walls were examined for deformations (Fig. 1) with various reinforcement options using carbon fiber fabrics of the brand MBrace FIB 230/4900.200 g / 5,100m, glued to the masonry fragments of the walls with special adhesives. At the second stage, seismic tests of life-size cellular aerated concrete block wall panels were carried out. The tests were carried out on a seismic platform. At the second stage, seismic studies of life-size cellular aerated concrete block wall panels were carried out. The tests were carried out on a seismic platform.

At the first stage, 4 series of wall samples were tested with CFRP reinforcement and without reinforcement (concrete class – B3.5 and density – D500):

- **I series** – reference samples of masonry wall fragments without CFRP sticker (Figure 2);
- **II series** – fragments of walls made of cellular concrete blocks with one-sided reinforcement with three CFRP canvases (Figure 3a);
- **III series** – fragments of walls made of cellular concrete blocks with double-sided reinforcement with three CFRP canvases (Figure 3b);
- **IV series** – fragments of walls made of cellular concrete blocks with double-sided

reinforcement with one CFRP canvas (Figure 4).

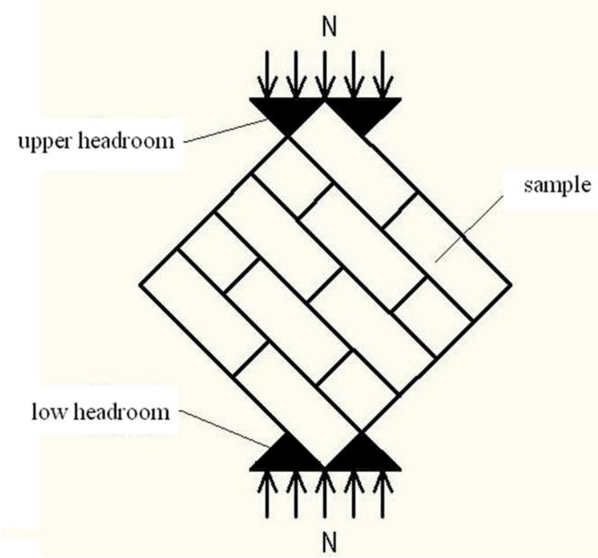

Fig. 1: *Test diagram*

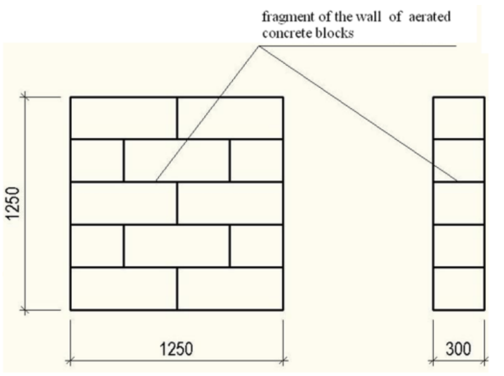

Fig. 2: *Reference samples*

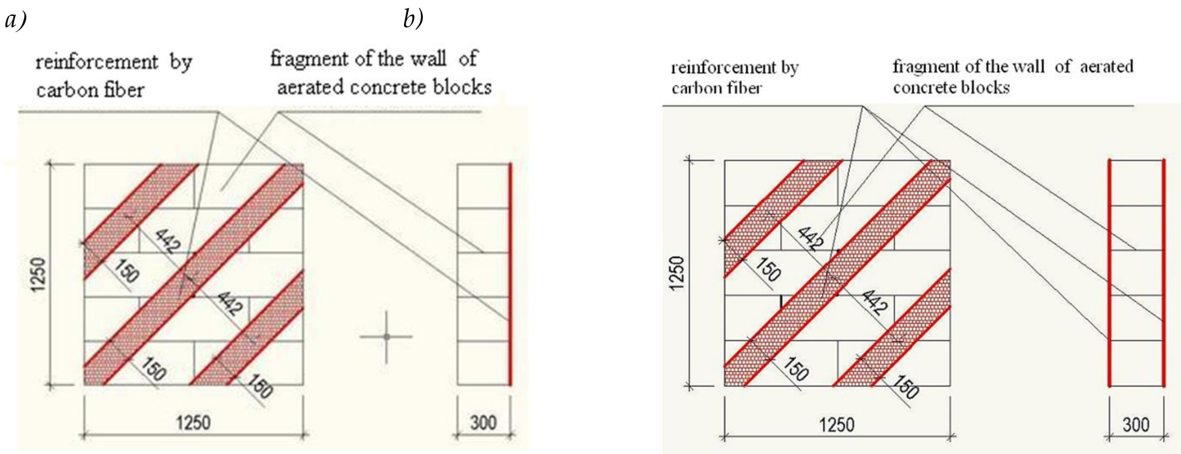

Fig. 3: *Samples of the II (a) and III (b) series*

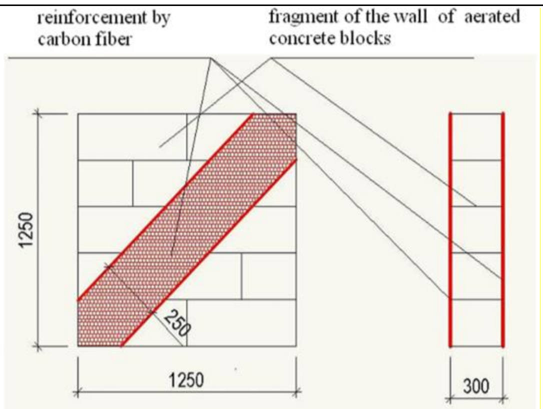

Fig. 4: *Samples of fourth series*

At the second stage, two series of life-size aerated concrete block panels were tested for the effect of seismic loading. The sample of the I series is a panel made of aerated concrete blocks without CFRP reinforcement (Figure 5a). The sample of the II series is a panel made of aerated concrete blocks with double–sided reinforcement with CFRP tapes (Figure 5b). The width of the tapes was 300 mm.

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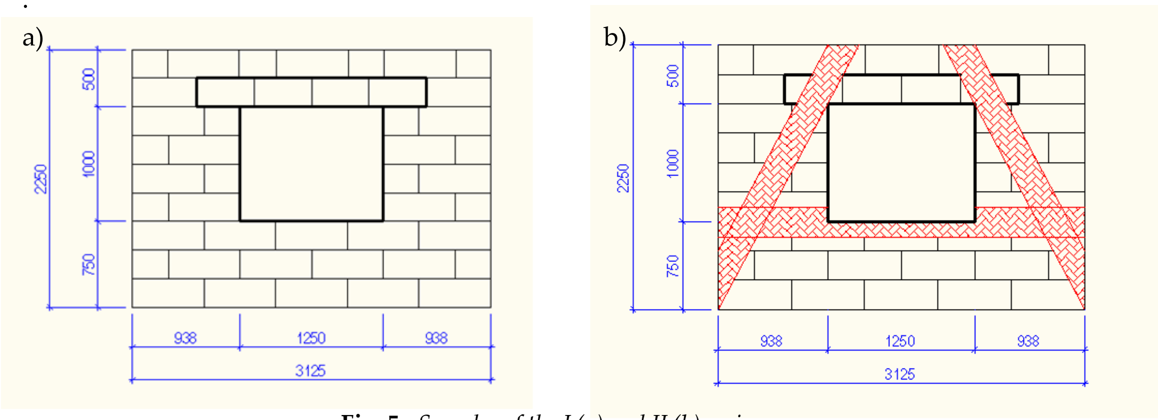

Fig. 5: *Samples of the I (a) and II (b) series*

With the help of special jacks with a capacity of 100 kN and vertical strands, the compression load of the sample was created at all stages of the tests (Figure 6). At the initial stage of dynamic tests, the static vertical load on the sample was q = 1.2 MPa. Due to the inertial force developed by the vibrating machine (Figure 7), a given frequency spectrum of impacts and a certain level of the amplitude of the platform vibrations were provided. The maximum amplitude of the platform oscillation was 43.8 mm. Figure 8 shows a vibration platform with an installed sample of the I series.

In the process of dynamic tests, after passing the loading cycle corresponding to accelerations of 1, 2 and 4 m/s^2, samples were unloaded by an amount of qi = 0.4 MPa. During the tests, 3 loading modes of the prototypes were performed.

The loading mode under dynamic action was selected based on the following basic conditions:

- the period of vibrations of the ground base, depending on the distance to the epicenter of the earthquake, varies from 0,1 to 1.5 s [8], with the duration of the oscillatory process – 10-50 s. During the tests, the duration of the dynamic impact on the structure at each stage of loading was 40-50 s;
- the frequency range of vibrations most dangerous for existing buildings is in the

range from 3 to 10 Hz. The frequency range of the platform oscillation varied from 1 to 9.9 Hz, the number of oscillation cycles was 200-500 cycles.

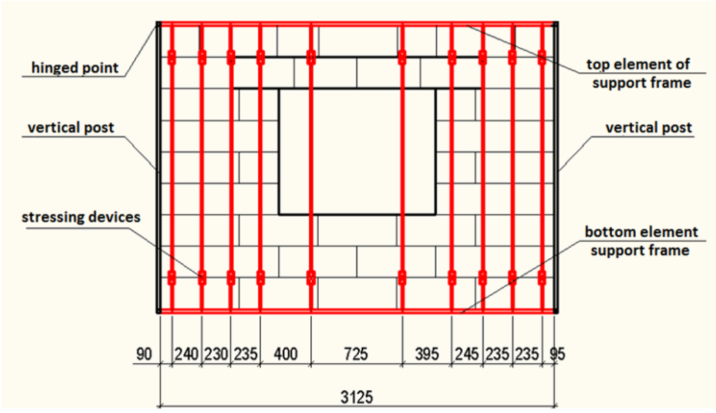

Fig. 6: *Device for creating a vertical load*

Fig. 7: *Pendulum platform*

Fig. 8: *Samples I series on the vibration platform*

At the third stage of the research, tests were carried out on the effect of a load simulating temperature effects. The experimental sample of cellular concrete blocks with and without reinforcement with a composite mesh based on basalt fiber had dimensions of 1815×1220×250 mm. Figure 9 shows the test scheme and the general view of the sample during the tests. The thickness of the mortar seam of the masonry was 3 mm.

a) b)

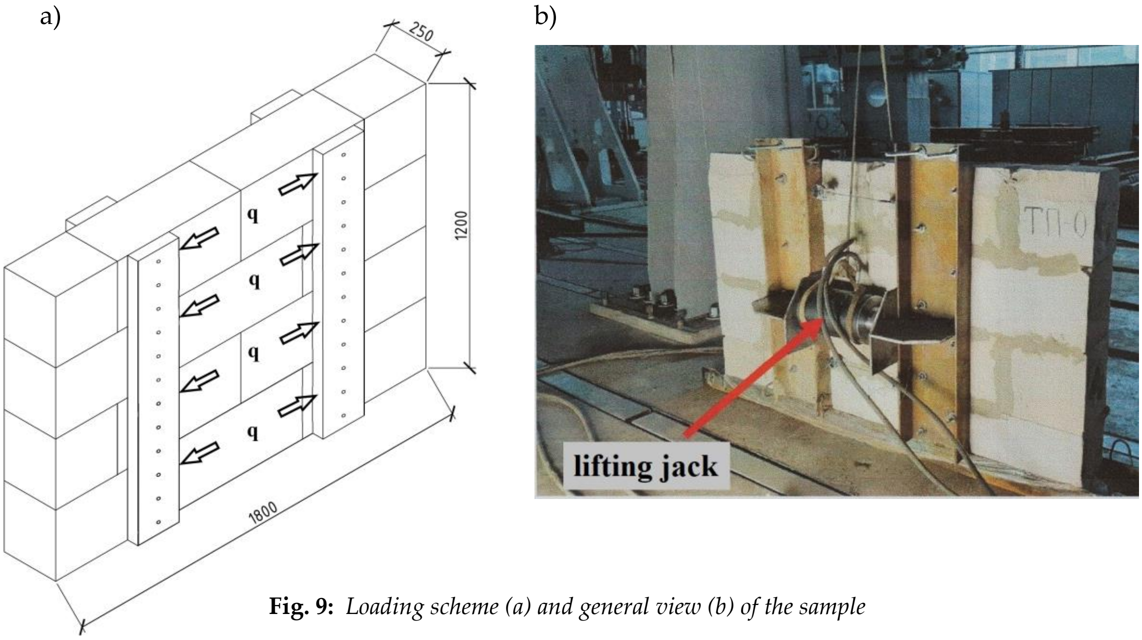

Fig. 9: *Loading scheme (a) and general view (b) of the sample*

Two samples were tested:

- reference sample without reinforcement with composite mesh;
- a sample reinforced with a basalt mesh with a 25×25 mm cell in each row.

The wall fragments were tested using a power plant that includes two jacks with a capacity of 1000 KN each. The load from the lifting jacks was transferred to the distribution beams from two channels No. 27 (Figure 9b). Masonry deformations were measured using electronic clock-type indicators with an accuracy of 0.001 mm.

III. Analysis of test results

1st stage. Analysis of the results of tests for skewing of samples of fragments of masonry walls made of cellular concrete blocks reinforced with CFRP tapes (Table 1) allows us to note the following.

1. The values of transverse tensile deformations in the samples of the II series are 1.3-1.5 times less than in the non-reinforced samples of the I series.
2. In the samples reinforced on both sides (III series), the transverse deformations are 1.6-1.7 times less than in the samples of the I series.
3. When the samples were reinforced with CFRP tapes on one side of the sample, the transverse tensile deformations decreased by 1.3 times compared to non-reinforced samples.
4. The destruction of the test sample (Figure 10) was of a fragile nature. The moment of appearance of the 1st crack corresponded to a load equal to $0.9 \times N_{des}$.
5. The use of reinforcement with CFRP allowed to increase the load-bearing capacity of samples when skewed compared to non-reinforced samples by:

- 11% - when reinforced with three CFRP tapes on one side of the sample;
- 85% - when reinforced with three CFRP tapes on both sides of the sample;
- 34% - when reinforced with one CFRP tape on both sides of the sample.

Table 1: *Results of tests of samples for skew*

Series No.	Sample No.	Sample amplification scheme	N_{des}, (KN)	R_{sl}, (MПa)	R_{sl}, (MПa)	Relative strength (%)
I	1	Not reinforced	200	0.76	0.59	100%
	2		132	0.50		
	3		157.1	0.60		
	4		133	0.51		
II	1	Reinforced with 3 canvases on one side	171.4	0.65	0.66	111%
	2		173.0	0.66		
	3		174.0	0.66		
III	1	Reinforced with 3 canvases on both sides	285.7	1.09	1.09	185%
	2		285.7	1.09		
	3		283.4	1.08		
	2		143.8	0.55		
	3		152.6	0.58		
IV	1	Reinforced with 1 canvas on both sides	200	0.76	0.79	134%
	2		214.3	0.82		
	3		204.7	0.78		
	2		242.8	0.77		
	3		230.1	0.73		

a)

b)

Fig. 10: *General view of the III series samples before (a) and after (b) tests*

2nd stage. In the process of dynamic testing of a non-reinforced sample of a wall panel with an opening, the frequency spectrum of dynamic effects varied in the range from 1.4 to 6.2 Hz. The amplitude of the platform vibrations in the horizontal plane varied from 1.0 to 13.8 mm, in the vertical plane – from 0.1 to 9.5 mm. The magnitude of horizontal acceleration varied from 0.08 to 6.5 m/s^2, in the vertical plane – from 0.04 to 3.19 m/s^2. The resulting acceleration spectrum corresponded to earthquakes from 4 to 9.8 points on the MSK-64 scale. With the compression load of the sample equal to 0.8 × R_b, no damage was found in the masonry. After reducing the compression level of the sample to 0.4×Rb, vertical cracks appeared with the opening of horizontal seams (Figure 11).

Fig. 11: *The nature of the destruction of a non-reinforced panel made of cellular concrete blocks during dynamic tests*

During dynamic tests of the CFRP-reinforced sample, no cracks were found in the blocks and seams at compression stresses of 0.4×R_b. After reducing the compression load to 0.2×Rb, the appearance of cracks in the blocks above the bridge was recorded. After reducing the compression load to 0.2×Rb, the appearance of cracks in the blocks above the bridge was recorded. Some of the CFRP tapes peeled off from the concrete, but the wall did not collapse. The magnitude of the horizontal acceleration of the vibration platform varied from 1.0 to 15.5 m/s^2, in the vertical plane – from 0.2 to 4.1 m/s^2. At a frequency of 7.6 Hz and an amplitude of 2.1 mm, a resonance occurred. However, no cracks or damage were found in the masonry (Figure 12).

Fig. 12: *General view reinforced with CFRP tapes after testing*

Stage 3. Comparison of the test results of non-reinforced and reinforced polymer reinforced with basalt fiber (BFRP) tensile samples along the cross-section of the wall (the tests simulated temperature effects) allows us to note the following.

1. The destruction of the non-reinforced sample during stretching occurred at a load from the jacks equal to 35 kN. The reinforced sample collapsed at a load of 45 kN.
2. During the destruction, a vertical crack was formed along the entire height of the prototype (Figure 13a). During tests in a reinforced sample, the composite mesh ruptured along the entire height of the sample (Figure 13b).
3. Compare of the tensile test results of the non-reinforced and reinforced samples showed that the destruction of the reinforced sample occurred at a load 28% higher than that of the non-reinforced sample.

a) b)

Fig. 13: *The nature of the destruction of the reinforced sample during stretching*

Conclusions

1. The use of composite materials (CFRP) to strengthen load-bearing wall structures made of cellular concrete blocks allows them to be used in earthquake-prone regions with earthquakes from 7 to 9 points on the MSK-64 scale.
2. The strength of masonry reinforced with CFRP composite tapes under the action of shifting seismic loads allows to increase its strength, depending on the structural solution of reinforcement by 10-85% compared with non-reinforced samples.
3. The use of CFRP composite mesh for reinforcing masonry walls made of cellular concrete blocks increases its strength under the action of tensile forces (modeling of temperature effects) by more than 25% compared to non-reinforced masonry.

References

[1] Trambovetsky V.P. On the use of cellular concrete in seismic construction // Concrete and reinforced concrete. – Moscow, 1980. – No. 9. – P.46.

[2] Trambovetskiy V.P. Cellular concrete abroad // Concrete and reinforced concrete. – Moscow, 1988. – No. 7. – P.20-21.

[3] Denis M. and etc. Lessons from the 1985 Mexican earthquake // Canadian Journal of Civil Engineering. – 1986. – Vol.13. – №5. – P.535-557.

[4] Polyakov S.V., Safargaliev S.M. Earthquake resistance of buildings with load-bearing brick walls. – Alma-Ata, 1988. – 188p.

[5] Steinbrugge K, Moran D. Engineering analysis of the consequences of the 1952 earthquakes in Southern California // Translated from English – Moscow, 1957.

[6] Polyakov S.V. Consequences of strong earthquakes. – Moscow, 1978. – 311p.

[7] Williams D., Scribener J.C. Response of reinforced masonry shear walls to static and dynamic cyclic loading // Proceedings of the 5 WCEE. – Rome, 1973.

[8] Korchinsky I.L. and etc. Earthquake–resistant construction of buildings. - Moscow, 1971.

APPLICATION OF DIGITAL TECHNOLOGIES FOR PLANNING MEASURES TO PREVENT HAZARDOUS PRODUCTION FACILITIES ACCIDENTS

Sayali Alekperova

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EDC Expert, LLC, Moscow, Russia
kaplansayali@gmail.com

Abstract

Hazardous production facilities operational safety is ensured by risk of emergency situations effective management, such as planning and implementing technical measures, namely safety and reliability measures. These measures are planned according to project specific hazards to prevent accidents and incidents on technological processes. The focus of such decisions should take into account the facilities life cycle stages and phases of beginning and amplification of probable emergency situations. This article discusses basics and results of application of artificial intelligence and machine learning technologies for planning measures to improve the reliability and ensure the safety of oil and gas production and transportation facilities during their full life cycle.

Keywords: technological processes, productions safety, risk management, artificial intelligence, platform solutions

I. Introduction

Automation today is typical for most of the processes that accompany the stages of design, construction and operation of hazardous production facilities.

Such significant stages as engineering surveys, identification of key design solutions, actual up-to-date process data collection, processing and transmission are undergoing significant modernization through the introduction of digital systems. In these processes, machine learning is of particular importance.

The fourth industrial revolution opens up new options for improving each stage envisaged in the implementation of significant investment projects for the hazardous production facilities design, construction and operation. At the same time, it defines new requirements for justifying the sufficiency of hazardous production facilities design solutions, such solutions implementation control and also effective structural condition monitoring throughout facilities complete life cycle.

II. Methods

The safety of facilities is ensured by the planning and timely implementation of technical and organizational measures, the main task of which is to ensure effective management of the risk of emergency situations occurrence and development at each stage of the life cycle of buildings and structures that are part of fuel and energy facilities, namely, at the stages of hazardous production facilities design, construction, commissioning operation and operation.

To evaluate design decisions, assessment of the need for introduce additional technical and organizational measures, improve the efficiency of the measures planning stage, and enhancement the efficiency of decisions made in terms of their priority, the use of machine learning and the introduction of decision support systems based on artificial intelligence are proposed.

Application of artificial intelligence for these purposes provides:

1) using the full data potential;

2) reliable forecasting;

3) automation of complex tasks.

In particular, the use of artificial intelligence at the stages of sampling, systematization and classification of key data, that are used for risk analysis, significantly increases the efficiency of identifying, predicting and evaluating probable accidents.

Accident risk management effectiveness is ensured by objectively assess the risk and identify factors that affect the occurrence and development of emergency situations. This factors called “influence factors” ore “factors” [1].

In this case not only to the prevention of probable emergencies should be provided: timely forecasting and detection of emergencies and, in some cases, localization and liquidation of emergencies consequences must be applied.

For identification and analysis of all probable accidents, and then planning effective reliability and safety measures a large amount of data is used.

For the purpose of orderly storage of such data and their further use, the following indicators are proposed to classified:

1) Buildings and structures designed and operated as part of hazardous production facilities, on the basis of the danger of such buildings and structures in the context of the likelihood of beginning and development of probable accidents and incidents;

2) Influence factors;

3) Probable emergencies;

4) Measures that ensure the prevention, timely detection, localization and elimination of the consequences of accidents.

III. Results

As a result of the buildings and structures classification (1) the following hazard signs of buildings/structures were identified:

1.1) The building/structure is vulnerable to external influences. For example, underground tanks and pipelines are more secure than above and below ground structures.

1.2) Explosive and flammable substances are handled in the building/structure. The amounts of a hazardous substance, as well as physical processes of its release and distribution are analyzed.

1.3) Probable escalation of the accident to neighboring buildings/structures: the actual distance between buildings/structures, the presence of hazardous substances in neighboring buildings/structures are analyzed.

1.4) An accident in a building/structure will lead to a long-term disruption of the facility functioning: it is analyzed to what extent the building/structure is involved in the process cycle at the facility.

1.5) The consequences of an emergency situation in a building/structure can lead to human casualties, cause damage to the environment.

The above sings are taken into account in the decision-making process on planning measures to predict probable emergencies.

The occurrence of an accident is not always due to a combination of influence factors. At the same time, the degree of a single factor influence may turn out to be more critical than their combination. For this reason it is especially important to classify the influence factors (2) according to the following criteria:

2.1) The possibility of preventing/reducing the negative impact of the influence factor at the stages preceding operation.

2.2) Features of defects, caused by the influence factor.

2.3) The possibility of timely identification of the factor causing the emergencies.

2.4) The influence of a defective hole, formed as a result of the influence of a factor: the volume of probable leaks and a forecast for the further development of a defective hole, taking into account the building/structure construction materials.

2.5) The scope of work to restore the building/structure after the influence of the factor.

It is most preferable to prevent the influence of the factor at the stage of development of design documentation by including appropriate measures in the design decisions. But the nature of the influence factors is such that they appear in the process of operation of buildings and structures. Moreover, most influence factors often occurs imperceptibly, but can lead to sudden emergency situations.

For this reason, it is necessary to provide building/structure high-quality structural condition monitoring during their operation, and also prompt transmission of monitoring results in order to process them and make decisions on the implementation of additional measures.

Probable emergencies (3) were classified according to the following criteria:

3.1) Accompanied by the release and controlled distribution of a hazardous substance.

3.2) Accompanied by the release and uncontrolled distribution of a hazardous substance.

3.3) Leading to complete or partial shutdown of the technological process.

3.4) Leading to complete or partial destruction of the building/structure.

3.5) Affecting neighboring buildings/structures.

3.6) Leading to workplace injuries and fatalities.

Not every accident will lead to a shutdown of the technological process. For example, a traffic accident on inter-site or on-site roads of oil and gas fields. But, in some cases, for example, accidents on quarry roads can lead to significant delays in the implementation of facility logistics.

For effective risk management, measures provided for the prevention, timely detection, localization and elimination of the consequences of accidents are implemented. It is necessary to systematize, classify and store these measure in an orderly manner for the purpose of further use.

Measure classification (4) based on the Classifier [3] developed for main gas pipelines.

The following classification criteria have been adopted:

– multiplicity of options for compensation of one influence factor;

– the possibility of using one measure to compensate for various factors;

– possibility of interchangeability of measures taking into account the specifics of the project;

– the multiplicative effect of two or more influence factors and the need to revise the set of measures in the presence of this effect.

In addition to taking into account the specifics of events in the classification, the following additional requirements were imposed:

– measure classification depending on the stage of implementation of the investment project;

– taking into account many aspects in the measure classification;

– ensuring the possibility of updating the classifier;

– flexibility of the classifier structure and the possibility of updating it with new measures;

– classifier clarity.

The following facets are accepted as unifying classification features:

4.1) Focus of the proposed measures. For determining the sufficiency of a set of measures relevant to specific conditions, it is necessary to take into account the focus of measures to prevent an emergencies, as well as at all stages of minimizing damage from an emergencies.

4.2) Type of compensatory measure: technical, average and non-technical.

4.3) Stage of the building/structures life cycle at which the measure is implemented.

4.4) Scope of implementation of compensatory measures.

The facet method was used to classify measures (Table 1)

Table 1: *Facets for measure classifier*

Facets			
№ of Facet	Facet name	Subcategory	Subcategory name
I	Focus of the proposed measures	IA	Emergencies prevention
		IB	Timely detection of accidents
		IC	Incident consequences localization
		ID	Accidents consequences elimination
II	Type of compensatory measure	IIA	Technical
		IIB	Average
		IIC	Non-technical
III	Stage of the building/structures life cycle	IIIA	Engineering survey
		IIIB	Design
		IIIC	Construction
		IIID	Operation
		IIIE	Reconstruction
		IIIF	Preservation
		IIIIG	liquidation
IV	Scope of implementation of compensatory measures	IVA	Applied elements of building structures
		IVB	Design features, accessories
		IVC	Devises and methods of diagnostics, testing, control
		IVD	Site preparation
		IVE	Devises of localization and liquidation of the accident consequences

Classifier is a part of developed Safety and reliability measures planning and implementation (SARM PI) system, using artificial intelligence for generate effective solutions.

SARM PI System stages shown in Figure 1.

Artificial intelligence and digital technologies application ensures the impartiality of risk assessment results: generated reports contain analytics, based on key indicators of probable hazards, caused by influence factors, and recommended measures planned according to approved criteria, such as:

– the advantage of technical measures over organizational ones;
– the advantage of preventing an accident over its localization;

– the advantage of focusing measures directly on the buildings/structures of the hazardous production facilities.

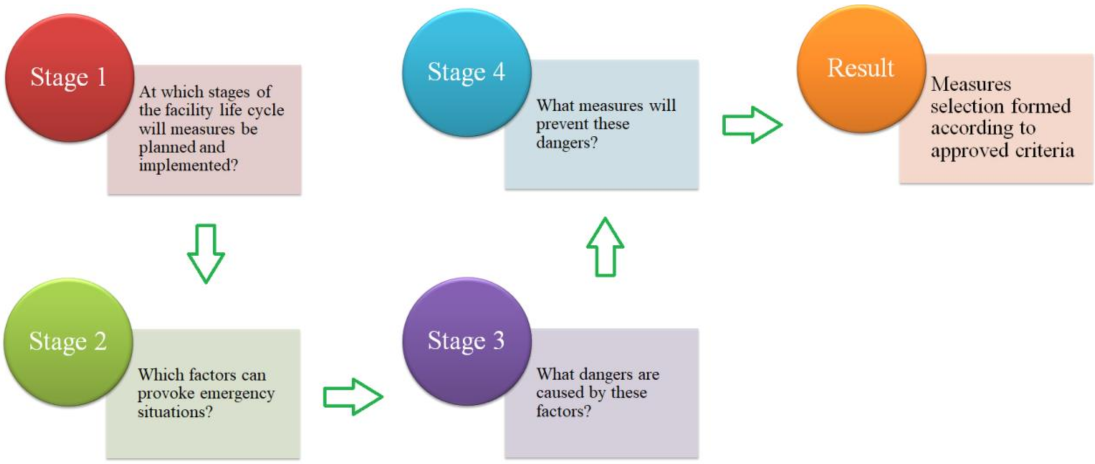

Figure 1: *Safety and reliability measures planning and implementation (SARM PI) System stages*

Formed selection is not final: artificial intelligence offers priority measures, but the final decision is made by a person. Decisions quality and validity significantly improved by using artificial intelligence, machine-learning systems and integrated databases.

Effective risk management is guaranteed by using comprehensive information about influence factors, which provoking emergency situations, and parameters (preconditions) of such factors.

SARM PI System was applied to plan and implement measures to ensure the ensure safety and reliability at all stages of the facilities life cycle.

IV. Discussion

I. Examples of developed databases used in SARM PI System

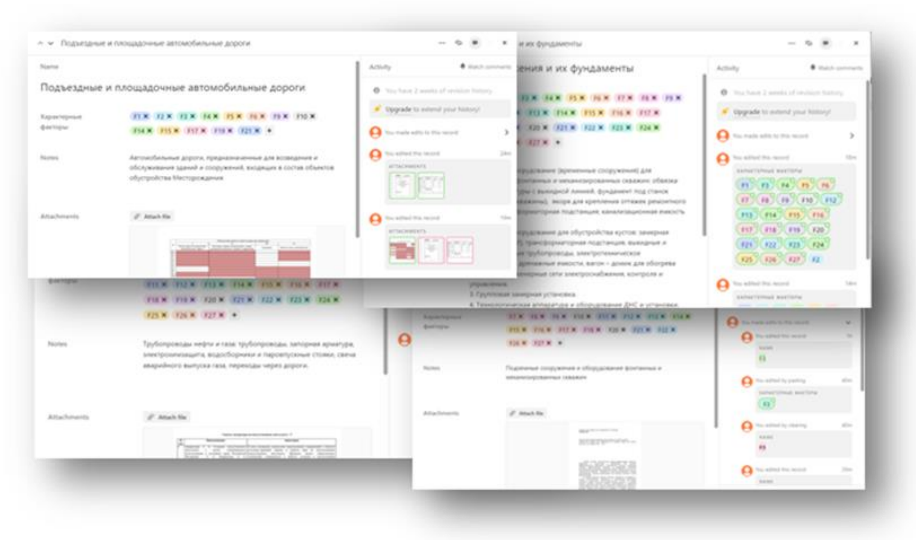

Figure 2: *Influence factors database*

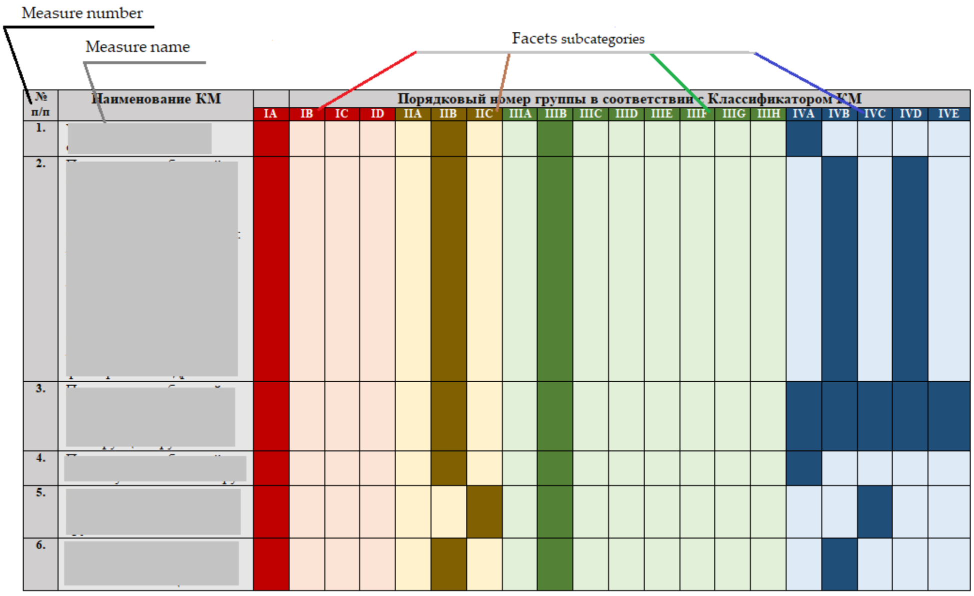

Figure 3: *Measure Classifier Structure*

I. Benefits of using the SARM PI System

Application of SARM PI System provided:

1. Expansion accounting and assessment of probable hazards that can lead to emergency situations.
2. Detailed analysis of predicted emergencies.
3. Improvement of priority measures decision-making.
4. Formation of a step-by-step description of the decision-making algorithm in order to make adjustments, comments and clarifications.
5. Improvement the impartiality of the decisions made. Measures (combinations of measures) hade only be approved if the actual reduction in risk indicators is confirmed. At the same time, the risk analysis itself was also objective and impartial.
6. Improvement of acceptable risk criteria.
7. Formation of variations of combinations of measures, taking into account the investment feasibility of their implementation for the actual conditions of construction and operation of fuel and energy facilities.
8. Security and reliability of reports generation and provision.

References

[1] Alekperova S.T., Revazov A.M. Development and Implementation of the Staged Safety System of Trunk Gas Pipelines. *Environmental Protection in the Oil and Gas Complex*, 2018, No. 3, P. 12–15.

[2] Revazov A.M., Alekperova S.T. Planning of Measures to Ensure the Trunk Pipelines Safety. *Gas Industry*, 2018, No. 12, P. 20–26.

[3] Alekperova S.T. "Systematization of the results of the classification of measures aimed at ensuring the safety of main pipelines". Certificate of state registration of the database No. 2017621123 dated September 29, 2017. Federal Service for Intellectual Property of Russian Federation.

[4] Alekperova S.T. "Program to assess the need to establish additional technical requirements in the field safety of the capital construction object". Certificate of state registration of the Computer Program No. № 2022611927 dated February 4, 2022. Federal Service for Intellectual Property of Russian Federation.

[5] Alekperova S.T. "Program for planning measures for ensuring integrated security of fuel and energy complex facilities of the Russian Federations". Certificate of state registration of the Computer Program No. № 2022665167 dated August 11, 2022. Federal Service for Intellectual Property of Russian Federation.

GLOBAL CLIMATE POLICY TRENDS AND CHALLENGES FOR RUSSIA

Rustam Gakaev, Magomed-Sadyk Bakhaev, Salah Edisultanov
•
Chechen State University named after A.A. Kadyrov, Russia
rustam.geofak@yandex.ru
salamova_chgu@mail.ru

Abstract

Regulators would do well to develop a climate strategy with more ambitious climate targets and a comprehensive strategy to reduce GHG emissions in the oil and gas sector (including a strategy to reduce methane emissions). It may include a variety of regulatory mechanisms - standards, targets, requirements for monitoring, reporting and pricing of GHG emissions, rules for certification and verification of projects to reduce emissions, etc. It is also important to approve public funding for R&D and pilot projects to reduce GHG emissions, especially in areas of deep decarbonization. It is necessary to further analyze the competitive advantages of Russia in the field of decarbonization, and then promote them both domestically and on the world market. Corporations should include decarbonization in their overall business strategy and investment plans, rather than limiting it to health, safety, environment and investor relations departments. To implement an effective decarbonization strategy for any company, it is necessary to review the strategy and corporate governance as a whole.

Keywords: decarbonization, climate strategy, GHG emissions, world market, climate targets, carbon dioxide

I. Introduction

The current goals and commitments of countries, primarily the largest emitters of greenhouse gases (GHGs), characterize the insufficient “ambitiousness” of climate policy in the world. According to preliminary WMO data, 2020 will be one of the three warmest years on record, and according to the Climate Action Tracker2, the efforts announced by the countries of the world as of November 2020 will not allow achieving climate goals, and global warming by the end of XXI century can reach about 3 °C [1]. Russia is one of the world's largest GHG emitters (about 5% of total GHG emissions), which leads to increased attention in the international arena to its climate goals and policies. According to the national inventory data [3], Russia has significantly reduced GHG emissions in the long term: in 2018, GHG emissions in Russia amounted to 2.2 billion tons of CO2-eq. (excluding land use, land use change and forestry (LULUCF)), which is 30.3% less than their value in 1990 (3.2 billion tons of CO2-eq) [1-2]. If LULUCF is taken into account, the decline will be even more pronounced - by 47.6% in 2018 compared to 1990. However, in recent years, the country's GHG emissions have been rising, and Russia's target, for example, in the Climate Action Tracker, is described as "critically insufficient" - corresponding to a warming of more than 4 ° C (assuming that all countries would make similar efforts). This poses a challenge to Russia's image as a climate-responsible country. The current accounting of GHG emissions and removals in the world does not fully reflect the objective picture, which is especially typical for developing countries and for individual GHGs, which creates a challenge for the need to improve the quality of data for international comparisons - in the context of the formation of climate positions as a factor in the competitiveness of producers from different countries. There is a growing number of countries, regions and companies around the world supporting climate change away from fossil fuels. There is a refusal of coal generation in the electric power industry as the most carbon-intensive direction of electricity production. There are initiatives to move away from the use of internal combustion engines in transport and from the exploration and production of hydrocarbons. Such initiatives pose the challenge of reducing demand for traditional energy resources already in the medium term relative to previous expectations. Plans to abandon the consumption of fossil fuels in different countries of the world for Russia, as for the largest exporter of traditional energy resources, lead to a narrowing of their sales markets. The effect of plans to phase out fossil fuel production is less obvious, and such plans are more of a symbolic nature. According to the International Energy Agency, the projected volumes of world oil consumption in 2040 in a hypothetical sustainable development scenario that assumes the achievement of climate goals are 32% lower than in the business-as-usual scenario, gas - 36% lower and coal - 61% lower [4]. The International Civil Aviation Organization and the International Maritime Organization are making efforts to minimize the adverse climate impacts of international traffic. For aviation, the introduction of a charge from 2027 for exceeding CO2 emissions from the baseline (2019) is already planned, and when discussing maritime transport, proposals arise, for example, to improve the operational energy efficiency of existing ships and to reduce emissions of methane and volatile organic compounds. This means the challenge of strengthening the requirements for Russian carriers in international markets.

Russia takes part in the formation of international climate policy, being a party to the UN Framework Convention on Climate Change, its Kyoto Protocol, the Paris Agreement and international treaties for the protection of the ozone layer. At the national level, strategic documents in the field of combating and adapting to climate change have been adopted and are being developed, measures are being taken to reduce GHG emissions, and a goal has been set to reduce them by 2030. Russian climate policy focuses on measures to adapt to climate change, unleashing the potential of energy efficiency (a draft of a new comprehensive plan for improving energy efficiency has been prepared), protecting and restoring forests, as well as implementing environmental and environmental initiatives. Separately, to stimulate alternative renewable energy sources in the electric power industry, the regulatory framework for their support in the wholesale and retail markets, in isolated energy regions, and for microgeneration has been formed and is being specified. With regard to carbon regulation in Russia, the Concept for the Formation of a System for Monitoring, Reporting and Verification of GHG Emissions in the Russian Federation (2015) was adopted [5]. As of January 2021, consideration of the rules for the introduction of mandatory carbon reporting (draft of the Federal Law "On the Limitation of GHG Emissions"), as well as the creation of conditions for the implementation of voluntary initiatives to reduce emissions and increase GHG absorption (draft Concept of the accounting system, registration, release into circulation, transfer and offset of the results of climate projects implemented on the territory of the Russian Federation). In January 2021, a roadmap was approved for the implementation of an experiment in the Sakhalin Oblast to establish special regulation of GHG emissions. In addition, the introduction of public non-financial reporting is being considered (draft Federal Law “On Public Non-Financial Reporting”) [5-6]. Interest in green finance is growing in Russia: the development of a national taxonomy of sustainable finance and the launch of a system of low-carbon certificates are being considered.

II. Methods

It seems important to move to proactive actions in terms of climate policy measures and focus on supporting the competitiveness of the Russian economy [4]. In the light of the planned introduction of a transboundary carbon mechanism in the EU, it can be expected that the problem of carbon regulation will reach the level of international relations. Russia is one of the major trading partners of the EU, which currently does not have any system of carbon regulation (carbon taxes or emissions trading), which deprives the country of flexibility in terms of the ability to offset payments for GHG emissions on its territory [6]. As a result, in order to maintain (full or partial) payments for GHG emissions in Russia, as well as for a symmetrical response, it is advisable to take the following steps: Explore the possibilities for developing carbon regulation measures in Russia (in the form of a national GHG emissions trading system (NTS)), which in the general case and at the initial stage will work on a voluntary basis. However, if there are relevant requirements from the EU for certain groups of goods (which are covered by the TUR), a transition to a mandatory regime may be required. It is proposed to hold timely consultations with the EU on issues of compliance with the EU decarbonization practice, as well as to study the experience of implementing the JTC in China. Explore the possibility of introducing symmetrical measures for imports from the EU (to equalize conditions with the EU and other countries that may introduce regulation in response to EU measures) with simultaneous compensation for consumers in Russia. Work out support (compensation) measures in Russia for enterprises and industries most affected by the introduction of TUR and carbon regulation measures, including benefits within the national trading system, as well as tax incentives [7]. In addition, along with those being implemented (improving energy efficiency, supporting RES, etc.), it is possible to identify measures for the further development of climate policy, on the introduction of which there is a relative consensus in Russia: Improving the accounting and protection of the forest fund: identifying preferred approaches to accounting for the absorptive capacity of forests , soils and water bodies; implementation of carbon farm projects; development of a methodology for accounting for GHG emissions by product range; improving the quality of data on Russian forests; expansion and protection of the forest fund of Russia. Implementation of a national system for reporting and monitoring GHG emissions: Development of a reporting system that will allow obtaining up-to-date information on GHG emissions at the level of regions, municipalities and sectors of the economy, as well as modeling and predicting the consequences of climate policy and climate risks. Development of a reporting system at the corporate level, which will allow Russian companies to comply with external "climatic" requirements in terms of information disclosure [8].

Study of methods and methods for assessing the carbon footprint and methods for verifying the data obtained (including the entire production chain). Formation of a system of low-carbon (including "green") certificates recognized at the international level (for a wide range of projects that contribute to the reduction of GHG emissions - renewable energy sources, "green" and "blue" hydrogen, projects to improve energy efficiency, increase GHG absorption). Conducting consultations with the European Commission for the recognition of local certification systems. Formation of the image of Russia as a climate-responsible country: coverage of the efforts undertaken by the country (with the indication of restrictions and intentions); looking for opportunities to promote climate initiatives that are in the national interest (eg international cooperation on climate change adaptation or support for carbon capture and storage (CCS) projects); creating alliances with countries with similar interests to strengthen the negotiating position during international climate negotiations; development of an index that evaluates the efforts of countries to combat climate change in Russia or within a regional association with Russian participation (for example, the EAEU or BRICS) [9]. Expanding opportunities for promoting Russian low-carbon technologies for export in order to diversify Russian exports: diversifying Russian exports of energy resources (in particular, hydrogen), energy efficiency and renewable energy technologies, and other low-carbon technologies; exploring the possibilities of the Sustainable Development Mechanism (SDM) under the Paris Agreement; using mechanisms to provide sustainable (including green) financing; creation of conditions and support for the implementation of voluntary initiatives to reduce GHG emissions by Russian exporters. Equally important, but much more difficult in an economy dominated by traditional energy resources, is to agree on medium and long-term guidelines for national climate policy, which should indicate the direction of the transition to a low-carbon development path - in line with international trends [6]. This is the aim of the draft Strategy for the socio-economic development of the Russian Federation with low GHG emissions until 2050, prepared by the Ministry of Economic Development of Russia. It should determine: priorities for the development of the domestic market, including the balance of traditional and new low-carbon areas; assessment of the prospects for export diversification (by directions and types of supplied goods and technologies); conditions for strengthening Russia's climate policy - they may be the most difficult to agree on, but, nevertheless, it is advisable to work them out as risk scenarios in order to prevent a slowdown in economic growth rates and a lag in the long term (in the event of a deterioration in the situation with adaptation and acceleration development of climate policy in the world)[5]. The draft Strategy for Social and Economic Development with Low GHG Emissions provides for the development of an action plan for its implementation, which proposes to take into account the identified challenges and measures. In addition, we can consider the organization of monitoring the challenges of the development of climate regulation in the world for the Russian economy and a comprehensive assessment of their impact.

III. Results

Climate change is one of the key global challenges. There is a conventional position, fixed at the UN level, that this problem is of an anthropogenic nature. The increase in the concentration of greenhouse gases in the atmosphere, caused by human activity, puts the dynamics and accounting of GHG emissions at the center of attention of international climate policy [4]. The international climate policy framework is shaped by the UN and is characterized by a truly global scope. The common basis for interaction and coordination was laid by the UNFCCC, and issues related to GHG emissions from international aviation and maritime transport are dealt with by such UN specialized agencies as the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) [5]. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) to prepare independent, science-based climate change assessments. The IPCC and former US Vice President Al Gore were awarded the 2007 Nobel Peace Prize “for their efforts to build and disseminate broader knowledge of anthropogenic climate change and lay the foundations for the actions needed to counter such change [6].

According to the UNFCCC, Parties develop, periodically update, publish and provide to the Conference of the Parties national inventories of anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protoco [7]: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorine-containing gases (perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3)), using comparable methodologies agreed by the Conference of the Parties [8]. The main greenhouse gas of the planet - water vapor - is not directly taken into account by the UNFCCC, but the IPCC reports noted that with warming, the content of water vapor in the atmosphere increases: with a temperature rise of 1 ° C, the atmosphere can contain approximately 7% more water vapor [9]. The obligation to annually provide information in the form of a national inventory according to the reporting format of the UNFCCC is only for the countries of Annex I of the UNFCCC, including Russia. As a result, the UNFCCC database on GHG emissions is characterized by incomplete information on developing countries. As part of the specification of the rules for the implementation of the Paris Agreement, it was decided that national inventories of GHG emissions and removals should be submitted by all countries - developed countries starting from 2022, and developing countries - from 2024 [10]. For least developed countries and small island developing countries, there is more flexibility in reporting. The IPCC develops and updates for the UNFCCC the Guidelines for National GHG Inventories aimed at harmonizing the approaches of different countries (the last update was in 2019). Accounting does not involve measurement, but calculation of GHG emissions and removals (using emission and removal factors), but a decision on measurement can be made at the national level. Countries may use their own methodologies if they are scientifically validated and approved by the UNFCCC. The GHG inventory includes data related to LULUCF [9]: forest management, planting of forests, deforestation, more advanced agriculture and land use, etc. Accounting under the UNFCCC is subject to increase or decrease in carbon stocks as a result of human activities (in managed forests or on managed lands) over a certain period. In 2003, the IPCC introduced the Good Practice Guidance for Land Use, Land-Use Change and Forestry. Since LULUCF calculations and projections are subject to uncertainty, the UNFCCC records GHG emissions including and excluding LULUCF [9-10]. According to the IEA, the uncertainty in estimating global emissions of carbon dioxide is 10%, methane - 25%, nitrous oxide - 30%, fluorine-containing gases - 20%. At the country level, the uncertainty in estimating carbon dioxide emissions is in the range of 5–10%, and for other GHGs in some cases it can exceed 100% (for example, nitrous oxide emissions from agriculture or methane emissions from fossil fuel extraction), so that existing national estimates should be considered as estimates of the order of magnitude. Traditionally, GHG emissions are calculated from production activities, but there are a growing number of studies that estimate GHG emissions from consumption, taking into account export and import flows. Such calculations are more complex and involve greater uncertainty.

Since the beginning of the industrial revolution, anthropogenic GHG emissions have begun to rise and their sinks to fall due to intensive land use, which has changed the absorption properties of the earth's surface. The increase in anthropogenic GHG emissions resulted in an increase in global GHG concentrations in the atmosphere and air temperature. According to WMO data, the global molar fraction of GHGs in the atmosphere in 2019 reached record levels: carbon dioxide reached 410.5 (±0.2) parts per million, methane - 1877 (±2) parts per billion, nitrous oxide - 332, 0 (±1) parts per billion, which is 148%, 260% and 123% higher than pre-industrial levels, respectively[10]. The average global temperature in January–October 2020 was about 1.2 (±0.1)°C above pre-industrial levels (1850–1900). According to WMO preliminary data, 2020 will be one of the three warmest years on record. This finds expression in changing climatic conditions, the spread of adverse weather events and the increasing frequency of natural and man-made disasters. The growth of anthropogenic GHG emissions in the world is on an upward trend, despite the expected decline of 7% in 2020 as a result of the spread of coronavirus [10]. According to the Netherlands Environment Agency (PBL) [8], global GHG emissions reached 52.4 billion tonnes of CO2-eq in 2019. Taking into account LULUCF, GHG emissions in 2019 are estimated at 57.4 billion tons of CO2-eq [10]. Although the PBL data are not reference data and may differ from national inventories (in particular, for Russia they exceed the national estimate), they offer the most complete temporal and country coverage of GHG emissions. The largest GHG emitters in the world in absolute terms are China, the US, the EU-27, India, Russia and Japan. They accounted for 61.1% of total GHG emissions in 2019 (excluding LULUCF). Their combined share, according to PBL, has remained virtually unchanged since 1990 (62.4%), although GHG emissions in China and

India increased by 3.5 and 2.6 times, respectively, while in Russia and the EU-27 they decreased by 16.4% and 22.3% [8]. At the same time, according to the data of the national cadastre of Russia, in 2018 the decrease compared to 1990 was 30.3%. Other major GHG emitters include Brazil, Indonesia, Iran [8-9].

Along with absolute indicators of GHG emissions, relative estimates are common. Russia's values for both indicators are higher than the global average: according to PBL, in 2019 they were 640 kg CO2-eq/USD. (in constant 2017 GDP PPP prices) (with a world average of 400 kg CO2eq/US$) and 17.4 tCO2eq/person [8]. (with the global average of 6.8 tCO2-eq/person). An analysis of the structure of GHG emissions shows that the energy sector is the largest contributor to GHG emissions in all countries. This is due not only to the intensive consumption of fossil fuels, but also to the peculiarities of the interpretation of the "energy" sector by the IPCC: it includes GHG emissions from the combustion of all types of fossil fuels, including for the purpose of generating heat and energy and in transport, as well as atmospheric losses of gaseous fuels. products that occur in the form of technological emissions, leaks and flaring, regardless of the economic sectors in which they occur [5]. The energy sector, as interpreted by the IPCC, accounts for an average of about 70% of total GHG emissions. The structure of greenhouse gas emissions is dominated by carbon dioxide (72.5% in 2019 excluding LULUCF), methane accounts for 18.7%, nitrous oxide - 5.4%, the remaining 3.3% is provided by fluorine-containing gases.da, Mexico, the Republic of Korea, Australia, Saudi Arabia, Turkey and South Africa [8-9].

IV. Discussion

Most of the world's countries have now outlined their climate goals and commitments to reduce GHG emissions at the international level (in Nationally Determined Contributions under the Paris Agreement). Some countries go further by declaring a commitment to carbon neutrality, that is, achieving zero net carbon emissions [8-9]. The Paris Agreement is comprehensive, but countries shape their goals and commitments on their own - based on the principle of common but differentiated responsibilities (according to national circumstances) - and regularly review them towards increasing "ambition". The Paris Agreement affirmed that developed countries "should continue to take the lead by setting economy-wide absolute emission reduction targets", but the commitments of developing countries are very diverse. Of the 190 parties to the Paris Agreement, the majority (74 countries) have formulated their commitments to reduce GHG emissions relative to the business-as-usual scenario (scenario targets); 61 parties, including Russia and the EU, have fixed absolute targets (as a percentage of the base year) and 8 more have indicated the target level of GHG emissions they are striving for; 25 countries declared only actions aimed at reducing GHG emissions, and another 13 - indirect goals that are not directly linked to GHG emissions; 9 countries focus on relative GHG emission reductions, typically per unit of GDP (relative targets). In addition, many countries, along with unconditional, have conditional goals that can be achieved by providing them with financial assistance. The question of the wording of goals causes a lot of controversy in international climate negotiations - so far only an agreement has been reached19 that from 2031 a single time frame for the provision of NDCs will be in force for all countries. There are opinions that large developing countries are not interested in a clear system of comparison, as it will focus on the dependence of global GHG emissions on their national actions.

The strengthening of the climate agenda is leading to an increase in the demand for disclosure of carbon reporting by businesses, which is broadcast through investor sentiment, the development of voluntary initiatives, and changes in relevant regulation. There is a constant increase in the requirements for the volume and quality of the requested information, which is reflected in the change in methodologies. International standards for carbon reporting emerged in the early 2000s. In 2003, the World Resources Institute, together with the World Business Council for Sustainable Development, created the GHG Protocol, the global standard for accounting for GHG emissions in carbon reporting. This Protocol distinguishes GHG emissions depending on the scope: "Scope 1" includes direct GHG emissions that are emitted from sources owned or controlled by the reporting entity; 'scope 2' shows the indirect GHG emissions associated with the production of electricity, heat or steam purchased by the reporting entity; 'scope 3' shows all other indirect emissions, including transportation in vehicles not owned or controlled by the reporting entity, outsourced activities, waste disposal, etc [9]. In 2015, at the initiative of G20 finance ministers and central bankers, the FSB Task Force on Climate-related Financial Disclosure was established under the Financial Stability Board. In 2017, the TFCD developed recommendations for voluntary disclosure of information about the financial risks of companies arising from global climate change. The recommendations have become the de facto new standard for carbon reporting disclosure, which has found wide support among regulators and companies. In the context of increasing demand for carbon reporting, voluntary initiatives in this area are developing. A striking example is the international project on voluntary disclosure of carbon reporting (Carbon Disclosure Project), which arose in the early 2000s. The development of voluntary initiatives is accompanied by an increase in the number of cases of introduction of mandatory requirements [10]. In 2018, the EU adopted obligations to disclose non-financial reporting, including environmental issues (Directive 2014/95/EU44) for 6,000 large European companies. We can expect further expansion of the practice of legislative consolidation of mandatory requirements for the disclosure of carbon reporting, including due to the growing interest in introducing trade restrictions based on the carbon footprint of manufactured products. In this case, the company's carbon reporting will be the main source of information for regulators who will make appropriate decisions. Stock exchanges are also actively introducing carbon reporting into their own activities as one of the components of sustainability reporting and issuer reporting.

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References

[1] Environmental Protection Agency (EPA). National Green-House Emission Data; 2018

[2] Khan Z, Dotty S. Endophyte-assisted phytoremediation. Curr Topics in Plant Biology. 2020, 12:97–105.

[3] USEPA, United States Environmental Protection Agency. Inventory of U.S. Greenhouse Gas emissions and Sinks (1990–2005). Washington DC EPA 430-R07-002, 2020.

[4] Gakaev R.A., Bayrakov I.A., Bagasheva M.I. Ecological foundations of the optimal structure of forest landscapes in the Chechen Republic. In the collection: Environmental problems. A look into the future. Proceedings of the III scientific-practical conference. Executive editor Yu.A. Fedorov. 2006.S. 50-52.

[5] Hallding, K.; G. Han and M. Olsson, China's Climate- and Energy-security Dilemma: Shaping a NewPath of Economic Growth. Journal of Current Chinese Affairs, 2020, 83(3), pp. 119-134.

[6] Hansen, J.; M. Sato; R. Ruedy; K. Lo; D. W. Lea and M. M. Elizade, Global Temperature Change, PNAS, 2020, 103(39), pp. 14288–14293.

[7] Leggett, J. A.; J. Logan and A. Mockey, China's Greenhouse Gas Emissions and Mitigation Policies, CRS Report for Congress 2008.

[8] Verfaillie, H., and R. Bidwell, Measuring Eco-efficiency: A Guide to Reporting Company Performance, World Business Council for Sustainable Development, Geneva, 2020.

[9] Kantyukov R R., Kolybanov K. Yu, Ravikovich V I Information technologies for preparing control decisions in automated systems of environmental monitoring, 2019.

[10] Ni BJ, Yuan Z. Recent advances in mathematical modeling of nitrous oxides emissions from wastewater treatment processes, 2020, pp. 336–346.

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MAGNETIC NANOPARTICLES FOR MONITORING MICROPLASTICS POLLUTION IN THE SURFACE WATERS

Iuliia Bakhteeva[1*], Irina Medvedeva[1,2], Marina Filinkova[1],
Ilia Byzov[1], Mikhail Uimin[1,3], Evgeny Tseitlin[2]

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[1]M.N. Miheev Institute of Metal Physics, Ural Branch, RAS, Russia
[2]Ural State Mining University, Yekaterinburg, Russia
[3]Ural Federal University, Yekaterinburg, Russia
julformal@gmail.com
ivmedko@gmail.com
filinkova-ms@yandex.ru
ivbyzov@gmail.com
uimin@imp.uran.ru
tseitlin.e.m@gmail.com

Abstract

The accumulation of plastic waste in the world's oceans is a growing public concern, under the action of water and solar radiation, the macroscopic plastic objects break down into micro- and nano-sized particles. The amount of microplastics in natural waters is currently unknown because of the difficulties of their quantification in water. It is proposed to use the method of the preconcentration of micro- and nano- plastic particles in water using two main approaches, such as the addition of composite magnetic nanoseeds that form aggregates with detectable plastic particles, and the subsequent separation of these hertetoaggregates from water by magnetic separation. In order to concentrate polyethylene (PE, 20-100 μm) and polyethylene terephthalate (PET, 10-20μm) particles from water, the magnetic Fe-C-NH_2 nanoseeds (10 nm) were added to the water, afterward, the magnetic sedimentation of the formed heteroaggregates in a gradient magnetic field was conducted. The effect of magnetic nanoparticles concentration in suspension, the time expose for the heteroaggregation on the efficiency magnetic preconcentration have been investigated.

Keywords: nanoparticles, microplastics, preconcentration, aqueous suspensions, magnetic sedimentation.

I. Introduction

The production and consumption of huge amounts of the products from artificial polymeric materials lead to the release of the plastics into the surface water bodies. Plastic bottles and packaging, fishing nets, etc. are collected in large agglomerates floating along the banks of rivers, lakes, and on the surface of the oceans [1, 2, 3]. Under the action of water and solar radiation, the macroscopic plastic objects break down into micro- and nano-sized particles. Such particles are the most dangerous for ecosystems, as they enter the food chains of aquatic organisms and may eventually end up in the human body [4]. At high dilution, the concentration of microplastics in the seas and large rivers waters is small but can be significant in the small lakes and rivers with slow water exchange.

The amount of microplastics in natural waters is currently unknown because of the difficulties of their quantification in water [5], especially for the small particles. It is proposed to use the method of the preconcentration of micro- and nano- plastic particles in water using two main approaches, such as the addition of composite magnetic nanoseeds that form aggregates with detectable plastic particles, and the subsequent separation of these hetertoaggregates from water by using magnetic field [6, 7, 8]. The preconcentration will allow quantitative determining of the microplastics in water by the instrumental methods (for example, by an optical method using a standard spectrophotometer). Controlling the formation of the heteroaggregates from the magnetic and plastic particles is a non-trivial task and it requires detailed studies [9, 10]. The added nanoseeds should have a surface capable of binding small plastic particles due to electrostatic interactions and contain a magnetic material that allows them to be manipulated in an external magnetic field. The aggregate formation is influenced by a number of conditions, among them the chemical composition and pH of the aqueous medium, the value of the particle surface charges (zeta potential), and the magnetic nanoseeds concentration.

In this work, the magnetic preconcentration of the microparticles from the most common plastics such as polyethylene (MPE) and polyethylene terephthalate (MPET) [11, 12] in aqueous solutions by using composite nanoparticles as magnetic seeds was studied. The nanoseeds have a magnetic core of iron with high specific magnetization and a carbon shell with attached amino groups, Fe@C-NH_2 (FNP). The carbon shell with attached amino groups provides the formation of aggregates with the plastic particles in the water due to the electrostatic attraction. The resulting heteroaggregatesare separated (concentrated) by magnetic sedimentation. To determine the concentration of the plastic particles, the resulting sediment was analyzed by the spectrophotometry method together with the PLS spectrum processing algorithm [13, 14]. An important advantage of this method is a possibility to determine the concentration of the plastic particles in heteroaggregates, avoiding the stage of the magnetic nanoseeds separation, which simplifies the analysis.

II. Methods

Aqueous suspensions of PE and PET microparticles with a solid phase concentration of 0.1 g / l were used. The average hydrodynamic diameter of the plastic particles in PE suspensions was 20-100 μm, in PET suspensions it was 10-20 μm.

Magnetic carbon coated Fe@C nanoparticles were prepared by the gas condensation method [15]. For a surface modification of the composite Fe-C particles, the method suggested in [16] was applied. The synthesis of Fe@C-NH_2 composite nanoparticles with a core-shell structure was performed as described earlier [17, 18]. The average size of the synthesized composite nanoparticles was about 10 nm. The saturation magnetization of the Fe@C-NH_2 nanopowders was 60 $A{\cdot}m^2/kg$.

The zeta potential of the particles in the water was detected by Dynamic Light Scattering method (DLS, NanoZS, Malvern, UK). For that, a He-Ne laser beam of λ=633 nm was used, operating in the back-scattering mode at the angle of 173°.

Particle images were obtained by scanning electron microscopy (SEM) using an Inspect F (FEI) instrument.

The absorption spectra of the mixed suspension samples were monitored and were processed mathematically using the PLS algorithm [13]. This procedure allowed to determine the partial concentrations of the MPE and FNP or MPET and FNP components in water. The UV–visible absorbance spectra were collected at the interval of wavelengths of 190 – 1100 nm using the SF-102 spectrophotometer (Fig. 1), for that, an aqueous suspension sample was placed in a quartz cell ($12.5\times 12.5\times 45$ mm^3). The calculations were performed using the R-language [19] and the PLS package [20]. The suspension samples of different compositions were prepared in the range of 0–0.1 g / l. The concentration values as detected from the absorption spectra for 32 PE and for 46 PET samples were used as a calibration set, and the other 15 concentration values were used for a test set. The relative standard error for single components is 7% both for PE and for PET. It was shown that the minimum detectable concentration for MPE and MPET was 0.002 g / l.

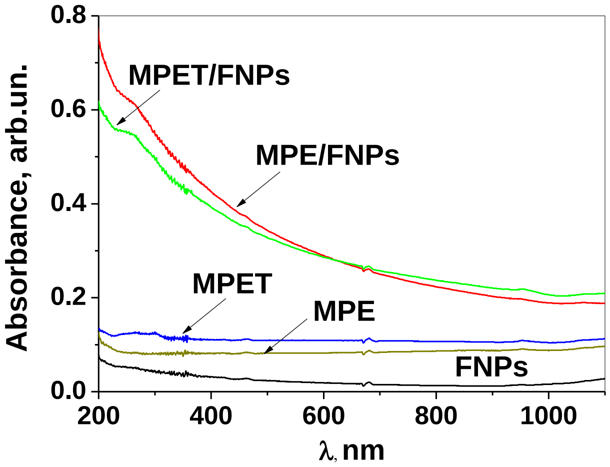

Figure 1: *Absorption spectra of aqueous suspensions of FNPs (0.01 g / l), MPE and MPET (0.1 g / l) and their mixture for the mass concentration ratio 1 : 10.*

The Magnetic Preconcentration Efficiency (MPCE) was determined from the change in the residual concentration of MPE, and MPET particles in water:

$$\mathrm{MPCE} = \frac{c_0 - c}{c_0} \cdot 100\% \qquad (1)$$

where c_0 is the initial concentration, c is the residual concentration of particles in water, g / l.

III. Results and discussion

At the first step, the magnetic FNPs were added to suspensions of MPE or MPET. At the second step, magnetic sedimentation of the MPE/FNP and MPET/FNP aggregates was carried out in the aqueous suspension. Finally, the resulting precipitate, consisting of the mixture of the plastic and magnetic particles, was analyzed by the UV–Visible Spectrophotometry method together with the PLS spectrum processing algorithm. Preliminarily, the precipitate was redispersed in the water.

Since the heteroaggregation of the plastic and the composite magnetic particles is caused by their electrostatic attraction, the necessary condition is that the initial particles have high values of the electric surface charges of opposite signs. The magnitude and the sign of the surface charge of the particles in water suspensions are characterized by the zeta potential [21]. In order to evaluate the possibility of the interaction of the plastic particles with magnetic seeds and the formation of heteroaggregates, as well as to estimate the amount of the needed added magnetic particles, the zeta potential of the particles in aqueous suspensions was monitored.

It was measured at all pH values, MPE and MPET are negatively charged (-17±2 and -29±2 mV, respectively), which is consistent with the data of the other researchers [22]. In aqueous suspensions, FNPs have a high positive zeta potential (30±2 mV) in the region of pH < 7 opposite to the plastic particle's charge. Thus, the pH range of 6-7 was chosen for the heteroaggregation process. When the plastic particles interact with added magnetic particles (seeds) of opposite charge, MPET/FNP and MPE/FNP heteroaggregates were formed (Fig. 3).

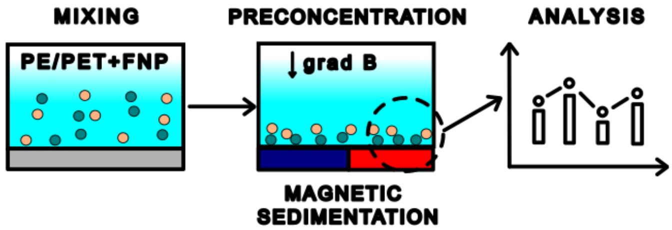

Figure 2: *Scheme of the determination of concentrations of MPE and MPET in water using the preconcentration by magnetic sedimentation.*

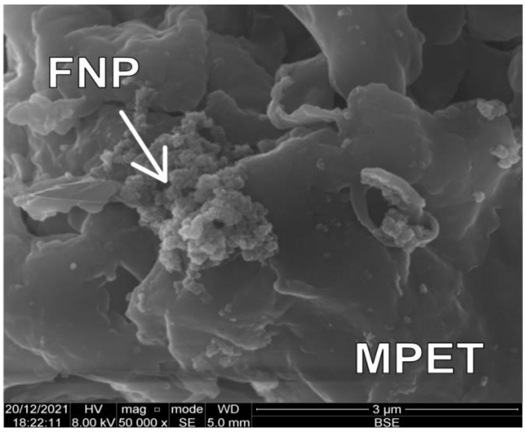

Figure 3: *SEM images of MPET/FNP heteroaggregates from aqueous suspensions (c_0(MPET) = 0.1 g / l, c_0(FNP) = 0.005 g / l).*

In order to carry out the magnetic separation of the plastic particles from the water suspensions, it is necessary that the zeta potential of heteroaggregate in the suspension is close to zero. Under this condition, the suspension becomes unstable and the magnetic sedimentation of heteroaggregates occurs very quickly. Therefore, the conditions for the compensation of the surface charge for various particles compositions ratios were studied. For the MPET/FNP mixed suspensions (with c_0(MPET) = 0.1 g / l), heteroaggregation should proceed most efficiently in the range of c(FNP) = 0.001–0.005 g / l. For the MPE/FNP mixed suspensions (with c_0(MPE) = 0.1 g / l), the zeta potential values close to zero are achieved at the concentration range of c(FNP) = 0.005–0.05 g / l. Thus, it is possible to control the required amount of magnetic particles that must be added to fully interact with the plastic particles.

Figure 4 shows the Magnetic Preconcentration Efficiency of MPE for various contents of the added magnetic particles in water and for various heteroaggregation exposure times. For c_0(FNP) = 0.005 g / l, it is about 85%, and it is not changed significantly by the increase in the time exposure from 15 to 30 minutes. Raising the concentration of magnetic seeds up to 0.05 g/l improves the MPE extraction even with the aggregation time of 15 minutes. The longer exposure (up to 30 minutes) allowed to reach the MCE value of about 100%.

It had been determined that the separation of MPE and MPET from water was close to 100% with the addition of optimal concentrations of the added magnetic nanoparticles and the heteroaggregation time of 30 minutes.

Using the plastic particles preconcentration followed by the magnetic separation lets to achieve a range of measurable concentrations of plastics in the water. Thus, for example, at a preconcentration of 100 times, the plastic concentrations up to 0.00002 g / l can be determined by this technique.

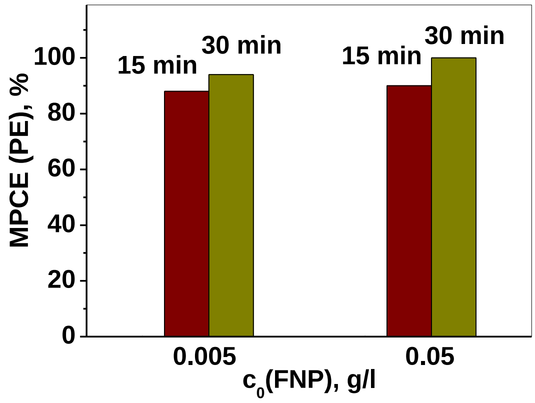

Figure 4: *MPCE (PE) for two concentrations of FNPs (c_0 = 0.005 and 0.05 g / l) and for heteroaggregation exposure times 15 and 30 minutes*

IV. Conclusion

This study provides a scientific basis for the use of composite magnetic nanoparticles for the preconcentration of plastic microparticles in water, and the subsequent determination of its concentration in the process of monitoring pollution of natural waters. The range of problems that need to be solved for the wide application of this method is determined. Among them is the search for composite magnetic nanoseeds with the maximum ability to selective capture microplastics in water, and the creation of portable magnetic systems for the magnetic separation of the concentrate from water. The next step is to apply portable, easy-to-handle devices that allow obtaining quantitative information on the plastics pollution of water bodies, processing it, and transmitting it to database centers.

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References

[1] Besseling, E. Quik, J. T. K. Sun, M. Koelmans, A. A. (2017) Fate of nano- and microplastic in fresh water systems: a modeling study. *Environ. Pollut.* 220:540-548.

[2] Carr, S. A. Liu, J. Tesoro, A.G. (2016) Transport and fate of microplastic particles in wastewater treatment plants. *Water Res.* 91 174-182.

[3] Da Costa, J. P. Santos, P. S. M. Duarte, A. C. Rocha-Santos, T. (2016) (Nano)plastics in the environment -Sources, fates and effects.*Sci. TotalEnviron.* 566-567 15-26.

[4] Enfrin, M. Dumée, L.F. Lee, J. (2019) Nano/microplastics in water and waste water treatment processes -Origin, impact and potential solutions. *Water Research* 161: 621-638.

[5] Novotna, K. Cermakova, L. Pivokonska, L. Cajthaml, T. Pivokonsky, M. (2019) Microplastics in drinking water treatment – Current knowledge and research needs. *Sci. Total Environ.* 667: 730–740.

[6] Chin, C.-J. M. Chen, P.-W. Wang, L.-J. (2006) Removal of nanoparticles from CMP waste water by magnetic seeding aggregation. *Chemosphere* 63: 1809–1813.

[7] Medvedeva, I. Bakhteeva, Yu. Zhakov, S. Revvo, A. Byzov, I. Uimin, M. Yermakov, A. Mysik, A. (2013) Sedimentation and aggregation of magnetite nanoparticles in water by a gradient magnetic field. *J. Nanopart. Res.* 15: 2054.

[8] Lv, M. Zhang, Z. Zeng, J. Liu, J. Sun, M. Yadav, R. S. Feng, Y. (2018) Roles of magnetic particles in magnetic seeding coagulation-flocculation process for surface water treatment. *Sep. Purif. Technol.* 212: 337-343.

[9] Bakhteeva, Iu. A. Medvedeva, I. V. Filinkova, M. S. Byzov, I. V. Zhakov, S. V. Uimin, M. A. Yermakov, A.E. (2019) Magnetic sedimentation of nonmagnetic TiO_2 nanoparticles in water by heteroaggregation with Fe-based nanoparticles. *Sep. Purif. Technol.* 218: 156.

[10] Bakhteeva, Iu. A. Medvedeva, I. V. Zhakov, S. V. Byzov, I. V. Filinkova, M. S. Uimin, M. A. Murzakaev, A. M. (2021) Magnetic separation of water suspensions containing TiO_2 photocatalytic nanoparticles. *Sep. Purif. Technol.* 269: 118716.

[11] Awaja, F. Pavel, D. (2005) Recycling of PET. *Eur. Polym. J.* 41: 1453–1477.

[12] Pivokonsky, M. Cermakova, L. Novotna, K. Peer, P. Cajtham, T. Janda, V. (2018) Occurrence of microplastics in raw and treated drinking water. *Sci. Total Environ.* 643: 1644–1651.

[13] Wold, S. Sjöström, M. Eriksson, L. (2001) PLS-regression: a basic tool of chemometrics. *Chemom. Intell. Lab.* 58109: 130

[14] Bakhteeva, Iu. Byzov, I. Filinkova, M. Medvedeva, I. Zhakov, S. Uimin, M. (2019) Simultaneous spectrophotometric determination of titanium oxide and iron oxide nanoparticles in water by using PLS algorithm. *SN Appl. Sci.* 1: 307.

[15] Tsurin, V. A. Yermakov, A. Ye. Uimin, M. A. Mysik, A. A. Shchegoleva, N. N. Maikov, V. S. Gaviko, V. V. (2014) Synthesis, structure, and magnetic properties of iron and nickel nanoparticles encapsulated into carbon. *Phys. Solid State*. 56: 287–300.

[16] Si, Y. Samulski, E. T. (2008) Synthesis of Water Soluble Graphene. *Nano Lett.* 8:1679–1682.

[17] Bakhteeva, Iu. A. Medvedeva, I. V. Byzov, I. V. Zhakov, S. V. Uimin, M. A. Yermakov, A. E. (2017) Speeding up the magnetic sedimentation of surface-modified iron-based Nanoparticles. *Sep. Purif. Technol.* 188: 341–347.

[18] Bakhteeva, Iu. A. Medvedeva, I. V. Byzov, I. V. Demin, A. M. Konev, A. S. Zhakov, S. V. Uimin, M. A. Murzakaev, A.M. Medvedeva, O. M. (2021) Synthesis of Fe@C nanoparticles containing sulfo groups on their surfaces and study of their aggregation behavior in aqueous media. *Russ. Chem. Bull.* 70:722–731.

[19] R Development core team R: A Language and environment for statistical computing. (2021) Vienna, Austria: the R foundation for statistical computing. http://www.R-project.org/

[20] Mevik, B.-H. Wehrens, R. Hovde Liland, K. (2021) PLS: Partial least squares and principal component regression. http://CRAN.R-project.org/package=pls.

[21] Lim, J. Yeap, S.P. Che, H. X. Low, S. Ch. (2013). Characterization of magnetic nanoparticle by dynamic light scattering. *Nanoscale Res Lett* 8: 381.

[22] Li, Y. Wang, X. Fu, W. Xia, X. Liu, C. Min, J. Zhang, W. Charles, J. (2019) Crittenden interactions between nano/microplastics and suspended sediment in water: Implications on aggregation and settling. *Water Res.* 161: 486-495.

EARLY WARNING AND ENVIRONMENTAL MONITORING SYSTEMS IN THE CONTEXT OF ECONOMIC DIGITALIZATION

Nasrudin Alkhanov[1], Aslan Inalkaev[2], Larisa Khatsieva[3]

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[1]Chechen State University named after A.A. Kadyrov, Russia
[2]Chechen State Pedagogical University, Russia
[3]Grozny State Oil Technical University named after Acad. M.D. Millionshchikov, Russia
n.alkhanov@mail.ru
Luhz@mail.ru
salamova_chgu@mail.ru

Abstract

Digital technologies have completely changed the way of life of billions of people in just a couple of decades. Computers, smartphones, consumer electronics, information systems have become an integral part of work and life. The rapid development of digital technologies opens up a huge range of opportunities in various areas, including for solving environmental problems - from the creation of services for efficient waste management, monitoring and data collection systems, climate change observations, the search for charging stations for electric vehicles to the creation of systems that help prevent environmental disturbances and predict natural disasters. The development of society, the complication of its infrastructure require careful thoughtful resource management, mastering new means and methods of information processing, ways to quickly solve management problems, evaluate and control changing processes. In modern economic science, deep research is being carried out on smart city design methods: system dynamics, agent-based modeling, cluster analysis, and others. The conceptual models of the "smart city" are proposed to be based on the assessment of satisfaction with the conditions of the urban environment, taking into account the influence of multiple characteristics: the development of retail trade; food supply; housing construction; crowd behavior in emergency situations; distribution of harmful emissions into the city.

Keywords: Digital technologies, environmental problems, natural resources, environmental protection

I. Introduction

In various types of its activities, a person has long used a system of observations of objects or phenomena [1]. Already in ancient times, people could foresee the time of the flood, make an approximate weather forecast, etc. For example, the famous Greek philosopher Thales of Miletus (7th–6th centuries BC) became famous for predicting a solar eclipse (585 BC), and before him, Babylonian astronomers could quite successfully predict the eclipse of the moon. It is also reported that Thales once, foreseeing a rich harvest of olives on the basis of astronomical data, distributed a small amount of money as a deposit to the owners of all the oil mills in Miletus and Chios. When it was time to harvest olives, there was a sudden demand for oil mills. Then he began to give at the mercy of the oil mills contracted by him and, thus, greatly enriched himself. Or, for example, Anaximander, a student of Feles, predicted earthquakes, which is still a difficult task today [1].

Also, brilliant examples of the organization of observations of the natural environment are described in 37 volumes of "Historia naturalis" ("Natural History") by the Roman encyclopedist Pliny the Elder (1st century AD), which contained information on astronomy, physics, geography, zoology, botany , medicine, history, agriculture, and until the Middle Ages served as the most complete encyclopedia of knowledge [2]. As examples, one can also cite the well-known folk signs of the weather forecast, which have developed according to centuries-old observations, have been passed down from generation to generation and form part of the culture of most peoples [2].

By the end of the 60s. In the 20th century, as a result of observations and their analysis, almost all highly developed countries came to the conclusion that it is necessary to take urgent measures to prevent the deterioration and degradation of the natural environment. Later (in the 1970s) it became clear that a scientific approach to assessing the state of the natural environment and the development of models of interaction between society and nature were needed [3]. In connection with the powerful anthropogenic pressure on the natural environment and the rapid development of the technosphere, the main task of mankind at present is to find ways out of the current critical ecological situation. But in order to make the right decisions, it is necessary to have complete and reliable information about the state of the environment.

During the existence of mankind, especially in the 20th century, a large amount of factual material has been accumulated on changing nature, as well as natural-anthropogenic systems. However, in order to assess, predict and timely prevent possible adverse effects, special observations are needed, which would be carried out taking into account the links (direct and reverse) between human activities and the state of the environment. The term "monitoring" appeared before the Stockholm UN Conference on the Environment in 1972. Under the term monitoring (from the English monitoring - control, meaning - from the Latin monitor - the one who reminds, warns, overseer) it was decided to understand the system of continuous monitoring, measurement and assessment of the state of the environment [4].

At the same time (1972), the first proposals appeared on the need to create a Global Environmental Monitoring System, which has not yet been created due to disagreements in the volumes, forms and objects of monitoring, the distribution of responsibilities between existing observing systems and other problems. political nature. But in the future, such a system should take shape, becoming part of a single integrating process taking place in the world, called globalization. From the very beginning, two points of view appeared in the interpretation of the monitoring. Many foreign researchers proposed to carry out a system of continuous observations of one or more components of the environment with a given goal and according to a specially developed program. Another point of view (Yu.A. Izrael, 1977) proposed to understand by monitoring only such a system of observations that makes it possible to identify changes in the state of the biosphere under the influence of anthropogenic activity, i.e. monitoring only anthropogenic changes in the natural environment [4]. According to another Russian researcher I.P. Gerasimov (1975), it was proposed to consider a multicomponent set of natural phenomena subject to diverse natural dynamic changes and experiencing various impacts and human transformations as an object of general monitoring [5]. In recent decades, society has increasingly used information about the state of the natural environment in its activities. This information is needed in the daily life of people, in housekeeping, in construction, in emergency situations - to alert about impending natural hazards. But changes in the state of the environment also occur under the influence of biospheric processes associated with human activity. Determining the contribution of anthropogenic changes is a specific task.

By now, for more than a century, many developed countries of the world have been conducting regular meteorological, seismological, phenological and other observations that help to predict the future state of the environment with greater accuracy.

In 2015, the Department of Nature Management and Environmental Protection of Moscow and the state environmental budgetary institution Mosecomonitoring introduced an automated system for monitoring the environmental situation in the region, the main tasks of which are to collect, store, and analyze up-to-date data on the environmental situation in the region for government agencies. authorities and population.

II. Methods

The penetration of digitalization into all spheres of daily human activity on a global scale allows us to talk about the digital transformation of all sectors of production, the life of society and the formation of a digital society. It is noteworthy that the concept of "digitalization" is found in regulatory legal acts only from the point of view of reflecting its technical component and is understood as a transition from an analog form of information transmission to a digital one. Currently, the term "digitalization" is used in a narrow and broad sense. Digitization in the narrow sense refers to the transformation of information into digital form, which in most cases leads to lower costs, the emergence of new opportunities, etc. A large number of specific transformations of information into digital form leads to such significant positive consequences that determine the use of the term digitalization in broad sense. As a transition to digital information of all aspects of economic and social life, digitalization is turning from a simple method of improving various private aspects of life into a driver of global social development, ensuring an increase in the efficiency of the economy and an improvement in the quality of life. Therefore, digitalization in a broad sense is understood as a modern global trend in the development of the economy and society, which is based on the transformation of information into digital form and leads to an increase in the efficiency of the economy and an improvement in the quality of life [6].

In the broadest sense, the process of "digitalization" can be understood as a socio-economic transformation initiated by the massive introduction and assimilation of digital technologies, i.e. technologies for creating, processing, exchanging and transmitting information. The concept of digitalization for the social sciences is not unambiguous, does not have a generally accepted definition, a lot of work by various researchers does not contribute to the formation of a unified approach to the definition of digitalization [7]. Regulatory legal acts consider the process of digitalization mainly from the technical side, despite the widespread use of the concept. The uncertainty of the distinguished features of digitalization, the lack of consensus in the scientific community in its definition leads to the impossibility of using the concept to regulate the digitalization process. Digitalization in Russia is acquiring specific features, the main prerequisites for the formation of a digital economy in Russia are:

- development of physical infrastructure for Internet access,
- growth in the number of Internet users,
- development of e-commerce,
- development of the IT industry,
- development of the national e-government system.

Indeed, according to a report by the International Telecommunication Union, almost the entire population of the world now lives within the range of a mobile cellular network signal.

However, it seems that the use of neural networks as a control element, to improve environmental and economic efficiency or to predict pollutant concentrations in the atmosphere of industrial cities19 or for other purposes of implementing a smart city, does not introduce fundamental changes in its legal nature that would allow the formation and wide dissemination of a new term - neurocity. To scale the content of the Smart City Institute without its deep theoretical study and the formation of a consistent regulatory framework for implementation seems premature. Of the general questions regarding the development of the Smart City concept, it is important to point out the existence of two main approaches to determining its features, characteristics and components [8]:

- technological (narrow), which takes into account only specific technical solutions, smart technologies and the degree of involvement of the information and telecommunications network "Internet" in the implementation of projects;

- comprehensive (broad), taking into account development indicators through the digitalization of all spheres of public relations, the presence of feedback and the degree of social activity in the electronic environment. The main indicators of project implementation from the point of view of a narrow approach are: involvement of residents in solving issues of local importance; digital traffic control systems; "intelligent" street lighting; public Wi-Fi network; the use of solar panels; SMS-alert of emergencies: refusal of cash payment for services and goods. According to representatives of this position, "Smart City" combines engineering, IT, business and social infrastructure to use the collective intelligence of the city [9].

Economic theory considers the city as a system of production and consumption of goods and services. The city is the center of economic activity, concentrating the functions of production of goods and services, their consumption, exchange, distribution. Thus, from the standpoint of the economy, the city is primarily the location of business and the totality of markets for factors of production. Summarizing, it can be noted that a city is a complex structure, including, on the one hand, an existing geographical object, on the other hand, an activity space (economic, social, cultural, etc.).17 Based on the foregoing, a city can be defined as a populated a point that is an industrial, economic and cultural center, has a developed infrastructure (social, industrial, engineering and transport), a certain number of inhabitants, most of whom are engaged in non-agricultural production and services, has an important (industrial, socio-economic, socio-cultural, historical) meaning.

The digitalization of the urban environment involves the creation of a modern city - a city open to the perception of everything new, with a developed infrastructure, which is managed using the most modern technologies (digital communications, computerization, automated control systems, in the future, the transition to the introduction of elements of artificial intelligence), a city with a developed structure of municipal government, involving a significant number of city residents in the process, a city with openness of city authorities to the needs of citizens, and the ability to respond flexibly to the needs of the population. Around the world, the urgency of numerous problems of cities has led to the search for ways to structure them and various models of solutions. Such cities are increasingly being labeled "smart". One way to conceptualize the concept of a smart city is to model it as a sustainable and livable city.

III. Results

The subject of regional monitoring, as follows from its very name, is the state of the environment within a given region [8].

Background monitoring, carried out within the framework of the international program "Man and the Biosphere", aims to fix the background state of the environment, which is necessary for further assessments of the levels of anthropogenic impact. Observation programs are formed according to the principle of choosing priority (subject to priority determination) pollutants and integral (reflecting a group of phenomena, processes or substances) characteristics. Pollutant priority classes established by experts and adopted in the GEMS system [9].

Determination of priorities in the organization of monitoring systems depends on the purpose and objectives of specific programs: for example, in regional monitoring, priority is given to cities, water bodies - sources of drinking water supply and spawning grounds for fish, therefore, in relation to observation environments, first of all, atmospheric air and fresh water are studied. reservoirs. The priority of ingredients is determined taking into account criteria that reflect the toxic, radioactive or pathogenic properties of pollutants, the volume of their entry into the environment, the characteristics of transformation, the likelihood and magnitude of impact on humans and biota, and other factors. On the territory of the USSR in the 70s [5-6]. On the basis of hydrometeorological service stations, the National Service for Observation and Control of the State of the Environment (OGSNK) was organized, built on a hierarchical principle.

In a processed and systematized form, the information obtained is presented in cadastral publications, such as “Annual data on the composition and quality of surface waters on land” (according to hydrochemical and hydrobiological indicators), “Annual of the state of the atmosphere in cities and industrial centers”, etc. To date, massive collections like "Annual data..." practically do not come to libraries. Some materials can be obtained (purchased) from the regional divisions of Roshydromet [10].

It must be said that the Unified System of Environmental Monitoring of Moscow began to be created in 1995. For 25 years, the system has undergone more than one modernization and today it works in accordance with the requirements of the World Health Organization (WHO) according to the directives of the European Union. At present, the Moscow Environmental Monitoring System is the largest and most modern in the Russian Federation and includes: 60 automatic air pollution control stations (18 million measurements per year); automatic systems for monitoring industrial emissions on chimneys (35 million measurements per year); 5 automatic noise control stations (276 thousand measurements per year); 1,300 sites for constant monitoring of soil conditions (7,000 measurements per year); 66 observation sites for the state of surface water bodies (32 thousand measurements per year); 1 automatic water pollution control station (259 thousand measurements per year); an observation system for dangerous geoecological processes (543,000 measurements per year); 130 sites for constant monitoring of the state of green spaces (200,000 measurements per year). The system is divided into 10 environmental monitoring subsystems by types of pollution. Air. Collection of data on the content of pollutants in the atmospheric air of the city. Analysis of the environmental situation of the city according to international standards (AQI). The soil. Collection of data on the state of soils in the city. Automation of reporting on the results of the study; Geological processes. Collection, analysis and storage of data on weather conditions. Cartographic link. Formation of analytical reporting. Weather conditions. Collection, analysis and storage of data on weather conditions. Formation of analytical reporting. Noise impact. Collection of data on the sound pollution of the city. Analysis of city noise pollution in conjunction with weather conditions. Ground water. Collection of data on the level, chemical composition and temperature of water in wells and wells of the city. Construction of statistical models based on the received data. The groundwater. Collection of data on the chemical composition of waters in open reservoirs of the city. Keeping statistics of excesses. Condition of green spaces. Maintenance of directories of green spaces of the city. Monitoring of the state of objects of observation. Automated reporting on research results. Industrial emissions. Monitoring the composition and volumes of industrial emissions from enterprises through automated data collection devices. Monitoring of environmental pollution. Automation of the process of obtaining results from mobile stations. Processing and storage of received data.

IV. Discussion

In terms of technology, the digital transformation of cities is based on several areas of information technology development - social communications, big data and predictive analytics, cloud technologies, artificial intelligence, mobility, "Internet of things", cybersecurity technologies, digital platforms - these technologies are key to the whole range of technological solutions for smart cities. The digital transformation unfolding in the world affects key industries and areas that, on the one hand, are concentrated in cities, and, on the other hand, are integral parts of its life support: modern production, transport and mobility, energy, communications, housing and communal economy, trade and services, healthcare, education, municipal government systems. It is known that digital technologies provide the cheapest ways to solve many problems in the field of logistics, management, communications, allow regions to compensate for resource insufficiency, and increase the attractiveness of the living environment [8]. The Government's understanding of the need for widespread urban digitalization and concrete steps to introduce elements of a "smart" city are becoming important reasons that encourage the subjects of digitalization of urban spaces to work on projects in various cities of Russia. Challenges facing cities when carrying out the digitalization of their territory, they are complicated by territorial differences and digital inequality of territories. The digitalization of urban space will benefit not only large cities with developed infrastructure, whose residents have a large number of digital competencies, but also small towns, which are the majority in Russia. Large cities traditionally have not only great economic potential, but also experience large-scale projects in the field of digitalization, more opportunities to attract investors, and the absence of a staffing problem is also important [9]. At the same time, the administrations of small towns and rural settlements not only have less financial resources, but are also forced to solve infrastructure problems, independently train or attract personnel capable of servicing high-tech equipment, and also instill in local residents a set of necessary digital competencies. As one of the most important objects of management activity for the creation of a "smart city", one can single out the development of civil society and local government, the creation of a "smart society". The main objectives of this area will be: the creation of new mechanisms for interaction between government institutions and the local community, the formation (by analogy with electronic government) of a platform for interaction with citizens through information and telecommunication technologies, the inclusion of information resources of local governments in a single urban digital space.

"Electronic space" cannot function in isolation from the physical one, and the existing institutions of the public legal system, forms and mechanisms for solving state problems and issues of local importance are undergoing IT transformations, which are becoming the main trend of their further development. The digitalization of municipalities has a high potential for improving the quality of life on the ground, being also a necessary feedback mechanism and a means of involving the population in solving local issues. In addition, in the process of improving legal regulation and the implementation of certain digital technologies, local governments in the development of interaction with the population will move from information presence to interactive interaction. The development of practice-generated, conditionally spontaneous IT tools for solving local issues in the vast majority of large cities already contributes to an increase in the level of communication and information exchange, the formation of the possibility of electronically exercising public and municipal control, as well as solving local issues [10]. In many Russian municipalities, there are the necessary technological platforms and information resources for the parallel remote electronic implementation of direct democracy on places. Universal digital technologies have been tested that have a high potential for application regardless of the type of municipality, which in the most general form are referred to as "Smart City". The digitalization of municipalities has acquired particular importance in the fight against the coronavirus infection Covid-19 5: the work of state authorities and local governments for different periods, but in most cases was transferred to a remote mode. The legal regime of the pandemic mediated the mass acquisition of "digital skills" by the population, the use of IT forms of participation of residents in solving local issues (public hearings, discussions, polls, gatherings) and taking into account the results of socially significant events online in the decisions of the authorities. It is generally accepted that the forced restrictions mediated the "digital leap" in every municipality [8]. Thus, despite the cross-border nature mediated by digitalization, with the help of new IT forms and methods, it is possible to resolve issues of local importance with real consideration of historical and local traditions, features and needs of each municipality, and to prevent a universal approach to the implementation of local self-government in Russian Federation. For the effectiveness of digitalization and maintaining the independence of local self-government, a certain basis of the constitutional system, the development of a unified concept and systematic legal regulation of the formation of innovative resources of municipalities of various types is of fundamental importance.

References

[1] Jebunnahar, Kolybanov K Y Water Quality Modelling of the Bunganga-Lakhya River System, Calibration Report // River Research Institute, Ministry of Water Resources, Government of Bangladesh, 2018, 105-135.

[2] Kolybanov KYu, Panova S A Data warehouse as the basis of a corporate information system. Software products and systems, M , No. 1, 2019

[3] Andrea, J.J., Burns, C., Touza, J. Renewable Energy as a Luxury? A Qualitative Comparative Analysis of the Role of the Economy in the EU's Renewable Energy Transitions During the 'Double Crisis'. Ecological Economics, Vol. 142, 2020,81–90

[4] Yang, J., Zhang, F., Jiang, X., Sun, W. Strategic Flexibility, Green Management, and Firm Competitiveness in an Emerging Economy. Technological Forecasting and Social Change, Vol. 101, 2018, 347–356

[5] Dulal, H.B., Dulal, R., Yadav, P.K. Delivering Green Economy in Asia: The Role of Fiscal Instruments. Futures, Vol. 73, 2019, 61–77

[6] Mauritzen, J. Cost, Contractors and Scale: An Empirical Analysis of the California Solar Market, 2018, 105-214

[7] Meckling, J., Hughes, L. Protecting Solar: Global Supply Chains and Business Power. New Political Economy, Vol. 23, No. 1, 88–104

[8] Monasterolo, I., Raberto, M.The EIRIN Flow-of-Funds Behavioural Model of Green Fiscal Policies and Green Sovereign Bonds. Ecological Economics, Vol. 144, 2018, 228–243

[9] Kantyukov R R., Kolybanov K. Yu, Ravikovich V I Information technologies for preparing control decisions in automated systems of environmental monitoring. «System Analysis. Theory and practice" No. 2, 2006

[10] Braverman A., Saulin A. 2019. Integral assessment of the performance of enterprises Economic issues, 6 (1), 108

DEVELOPMENT OF INNOVATIVE DRAINAGE PIPE DESIGNS THAT REDUCE THE RISKS OF LOSS OF STABILITY IN DIFFICULT CONDITIONS

Fakhreddin Gabibov, Khadija Salaeva

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Azerbaijan Scientific Research Institute of Construction and Architecture
farchad@yandex.ru
Azerbaijan University of Architecture and Civil Engineering
salaeva_x@mail.ru

Abstract

The article shows natural and architectural analogies in which triangular and arched arches are the most stable. A new design of a drainage pipe with a cross section in the form of a Reulot triangle with an angular arch, related to cycloidal structures and increased stability, has been developed. Based on model studies, it was revealed that the arches in the form of half an astroid are the most stable, in this regard, a new design of a drainage pipe with a vault in the form of intersecting hyperbolas has been developed, which practically corresponds to half an astroid.

Keywords: drainage pipe, structure, stability, arch, Reulot triangle, arch.

I. Introduction

Application in the practice of industrial, urban, transport and hydraulic engineering horizontal tubular drains are a combination of drainage pipes with loose filter sprinkles. The structural forms of tubular drains and their main elements are determined by the hydrogeological and hydrochemical features of the drained area, and also depend on the layout of the protected structures, their purpose and conditions of work.Ceramic, asbestos cement, polymer, concrete and reinforced concrete pipes are used as drainage pipes. The studies of A.Y.Tulaev [1], S.K.Abramov, B.M.Degtyarev and I.V.Korinchenko [2], S.I.Storozhuk [3], G.A.Razumov [4], F.G.Gabibov and H.B.Salaeva [5, 6] and others are devoted to the constructions of horizontal tubular drainage. The monographs of R.Prevo [7], L.A.Babin, L.I.Bykov and V.Ya.Volokhov [8], S.V.Vinogradov [9], P.P.Borodavkin and A.M.Sinyukov [10], L.A.Dimov and E.M.Bogushevskaya [11] are devoted to the calculation of horizontal pipeline (including closed drainage).] and others. Many computer programs have been developed to calculate horizontal pipelines [12, 13, 14, 15]. Currently, a very urgent task for engineers is to identify the most stable cross-sections of horizontal drainage pipes, which are often laid in difficult ground conditions.

II. Investigation of natural and architectural analogies to identify the most stable drainage pipe sections

To identify the most rational and stable vaults for drainage and collector pipes, it is undoubtedly useful to use natural analogies found in mining and underground construction, as well as analogies from the experience of designing and constructing vaults, domes and arches of famous architectural structures.In mining and underground construction, one of the costly items is fixing the arch of the workings to prevent its collapse. In order to reduce the material costs associated with carrying out this kind of work, various forms of workings were proposed at different times, ensuring the formation of a "natural balance" vault.

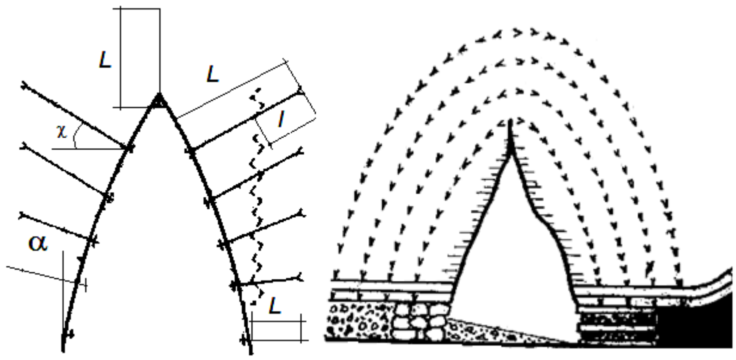
Thus, in the work of S.B.Stajevsky [16], the results of field and experimental studies of the stability of underground workings, depending on the shape of their cross-section, are presented. It has been established that workings with a cross-section close in shape to a triangle and with walls deviated from the vertical by an angle $\alpha \leq 15 \div 30^{\circ}$ have their own high load-bearing capacity, and if necessary, they require insignificant costs to strengthen them.

A significant increase in the strength of soils and rocks in the vicinity of the triangular section is due to the fact that in the zones adjacent to the apex of the triangle, the vertical and horizontal stress components reach significant values that have very close numerical values (the effect of all-round compression).

M.M. Protodyakonov [17] notes: "Based on observations of old abandoned drifts, the fastening of which has long rotted and has not been renewed, and over which, with the appropriate lateral rocks, a natural vault is formed, which holds for years and decades without further fixing, it was decided to achieve directly obtaining the same vault." Further in the work [17] it is noted: "... the drifts have the form of a very high arch ..." and "... can stand for many years without repair."

S. K. Kilesso [18] cites the fact that there are triangular drifts, which are without any repairs from the IV century BC

To the conclusion that the production cross section close to the triangular are the most optimal for large depths, based on field data and results of calculations, came and the authors [19]. Figure 1 shows the arches of natural equilibrium.



a) *b)*

Figure 1: *Vaults of natural equilibrium: a) – a vault obtained experimentally; b) – a vault in an abandoned tunnel*

The history of the development of arched structures in the general history of construction reflects the process of changing the relationship between the growing material and cultural needs of people and the growing possibilities of meeting these needs.

The arch as a load-bearing structure, simultaneously perceiving and transmitting the load, has brought its unique charm to our days through millennia. As O. Buettner and E. Hampe [20] note: "It was already known to the architects of antiquity that if a stone beam was given an arched shape, then it acquires new bearing properties that can significantly increase the overlapped span with the same building material."

E.Torroja [21] gives the following characteristic of the arch as a bearing element of a building structure: "From the point of view of stress distribution, the arch is the biggest find in the history of classical architecture. Even today, it has not lost its significance, although humanity has been getting used to the idea for quite a long time that it is the arch that is the element that increases the strength of the structure."

In the era of ancient Greek civilization, "false arches" were mostly erected. The most famous and oldest arched structures are the gateway arch and the arched vault, preserved from the Mycenaean culture. We find these curved systems with a continuous arched line of protruding cantilever elements in almost all ancient cultures.

In numerous works on the history of construction equipment by scientists of the past and modern specialists, the evolution of arched structures is described in detail. L. Adler [22] points out that "even before the appearance of arched structures in ancient Greece, they were already known to the Etruscans living in the territory later conquered by Ancient Rome. Therefore, it is the Etruscan arches that can be considered the forerunners of Roman arches and vaults."

The desire of the masters of Gothic cathedrals to reduce the mass of structures and preserve the load-bearing capacity of arched structures led to the creation of giant lattice arched loops (figure 2). In the arched loops obtained by medieval architects, who at that time solved not only artistic but also design problems, empirically, in vertically interacting paired arches, elements of modern reloid structures are viewed.

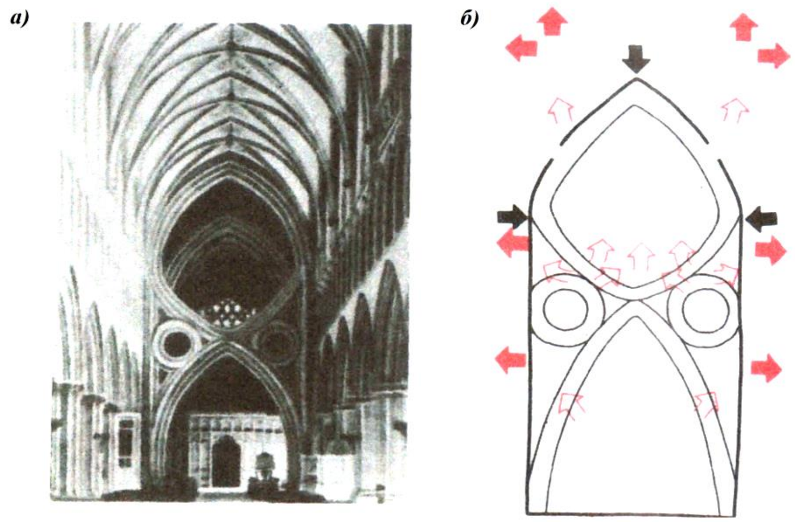


Figure 2: *Reinforced arched hinges of the Cathedral in Wales (Great Britain), the end of the XII century: a) – type of arched hinges of the cathedral; b) – the scheme of the arched loop*

III. Development of drainage pipes with arches of increased stability

The design of the drainage pipe (figure 3) in cross-section in the form of a Reulot triangle, which has a bottom part 1 and side parts 2, has been developed. There is a perforation 3 along the entire surface of the drainage pipe. One of the corners 4 of the cross-section of the pipe is located in its upper consolidated part. Ground water passing through the protective drainage sprinkling, through the perforation of the bottom 1 and side parts 2 of the drainage pipe, enters its inner cavity and flows to the collector along a given slope. Compared to pipes with a circular cross-section, the considered design has higher indicators of stability, strength and water absorption capacity [23].

Model studies [24] show that the greatest stability is observed in the development with a vault in the form of half an astroid. A new design has been developed (figure 4) of the drainage pipe, in which the arch 1 with intersecting hyperbolas 2 practically corresponds to half of the astroid. At the same time, in the lower semicircular part 3 of the pipe section, due to perforation 4, during the period of elevated groundwater level, pressure micro-streams will occur, which will erode the formed silty deposits.

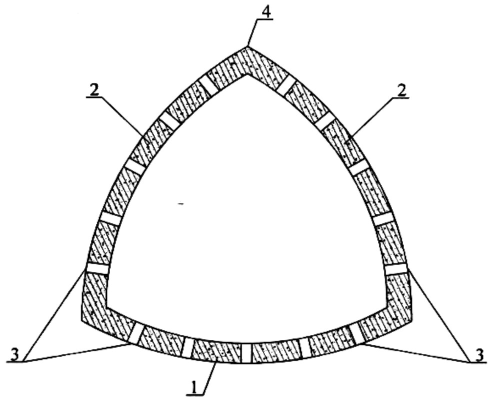


Figure 3: *Drainage pipe with a peppered cross section in the form of a Reulo triangle with an angular arch: 1 – bottom part of the pipe; 2 – side parts of the pipe; 3 – perforation; 4 – upper arch corner of the pipe*

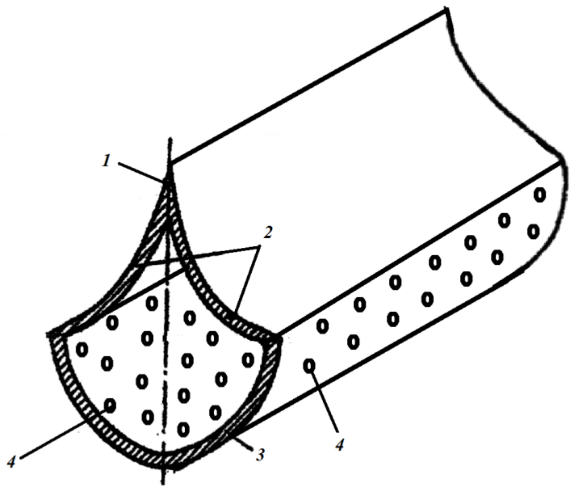


Figure 4: *Drainage pipe with a vault formed by the intersection of hyperbolas: 1 - vault; 2 - hyperbolas; 3- semicircular lower part of the pipe; 4- perforation*

IV. Conclusions

1. Natural and architectural analogies have shown that triangular and arched arches are the most stable;

2. A new design of a drainage pipe with a cross-section in the form of a Reulot triangle with an angular arch has been developed, relating to cycloidal structures and increased stability;

3. Based on model studies, it was revealed that the arches in the form of half of the astroid are the most stable, in this regard, a new design of a drainage pipe with a vault in the form of intersecting hyperbolas has been developed, which practically corresponds to half of the astroid.

References

[1] Tulaev,A.Ya. Drainage of the roadbed of urban roads. Moscow: Stroyizdat, 1983, 132 p.

[2] Abramov, S.K., Degtyarev B.M., Korinchenko I.V. Horizontal drains with porous concrete pipe filters. Moscow: Stroyizdat, 1976, 80 p.

[3] Storozhuk, S.I. Porous drainage in the arid zone. Moscow: VO "Agropromizdat", 1987, 103 p.

[4] Razumov, G.A. Design and construction of horizontal water intakes. Moscow: Stroyizdat, 1988, 240 p.

[5] Gabibov, F.G., Salaeva, H.B. Research, analysis and refinement of round drainage pipe designs with structural additions for the development of their individual functions. Collection of articles of the XXII International Scientific and Technical Conference "Effective building structures: theory and practice", Penza: Privolzhsky House of Knowledge, 2022, pp.38-48.

[6] Gabibov, F.G., Salaeva, H.B. Engineering analysis of round drainage pipes and their complementary technical elements in horizontal drainage structures. Materials of the XII National Scientific and Practical Conference "The bowels of Kalmykia are unique and interesting", Elista: Kalmyk University Publishing House, 2022, pp.173-182.

[7] Prevo, R. Calculation of the strength of pipelines laid in the ground. M.: Stroyizdat, 1964, 123 p.

[8] Babin, L.A., Bykov, L.I. Volokhov,V.Ya. Typical calculations for the construction of pipelines. M.: Nedra, 1979, 176 p.

[9] Vinogradov, S.V. Calculation of underground pipelines for external loads. Moscow: Stroyizshchdat, 1980, 135 p.

[10] Borodavkin, P.P., Sinyukov, A.M. The strength of trunk pipelines. M.: Nedra, 1984. 245 p.

[11] Dimov, L.A., Bogushevskaya, E.M. Main pipelines in swamps and flooded areas. Moscow: Publishing House "Mountain Book", Publishing House "Moscow State Mining University", 2010, 392 p.

[12] Awoshika, K., Tokano, M. Analysis of pipelines subjected to differential ground settlement. Nippon kokanTechn.Rept., №14, 1972.

[13] Muleski, G.E., Ariman, T. A shell model for buried pipes in earthquakes. Soil Dyn. and Earthquake Eng., Vol. 4, №1.

[14] Trautman, C.H., O'Rourke, T.O. Lateral force-displacement of buried pipe. Geotechn.Eng. J. 111, №9, 1985, p.1077-1092.

[15] Trautman, C.H., O'Rourke, T.O. Uplift force-displacement response of buried pipe. Geotechn.Eng. J. 111, No.9, 1985, p.1061-1076.

[16] Stajevsky, S.B. To the choice of form and fixing of workings. FTPRPI, No.5, 1986, pp. 27-32.

[17] Protodyanov, M.M. Rock pressure and various fastening. M.-L: OGIZ, 1931, 186 p.

[18] Kilesso, S.K. Architecture of the Crimea. Kiev: Budivelnik, 1983, 96 p.

[19] Baryshnikov, V.D., Mashukov, V.I., Pirlya, K.V. Analysis of the stress state of rocks in the vicinity of preparatory workings. FTPRPI, No. 4, 1982, pp. 114-116.

[20] Buettner, O., Hampe, E. Structure – Bearing structure – Bearing structure. Moscow: Stroyizdat, 1983, 340 p.

[21] Torroja, E. Logik der Form. München.Verlag G. D. W. Callwey, 1961.

[22] Adler, L. VomWese n der Baukunst. Leipzig ImYerlag der Asia Major, 1926.

[23] Gabibov, F.G., Habibova, L.F., Hasanov, S.T. Drainage pipe. Patent of the Russian Federation for invention No. 2611803, 2017.

[24] Gabibov, F.G., Bogomolov, A.N., Salaeva, H.B. Determination of the most stable arches of drainage and collector pipes by analog and model studies. "Architecture and Construction in Azerbaijan", No. 1, Baku, 2022, pp.2-9.

SUSTAINABLE DEVELOPMENT OF THE GLOBAL LABOR MARKET IN THE CONTEXT OF THE TRANSFORMATION OF THE INDUSTRIAL COMPLEX OF THE DIGITAL ECONOMY

Madina Barzaeva[1], Ruslan Ilyasov[2]

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[1]Grozny State Oil Technical University named after Acad. M.D. Millionshchikov, Russia
[2]Chechen State University named after A.A. Kadyrov, Russia
madinaborz@mail.ru
ilyasov_95@mail.ru

Abstract

The relevance of the study is due to the fact that the current global labor market is under the influence of the IV industrial revolution (Industry 4.0). The purposes of the study are to assess the risk and impact of cyclical and sudden trends affecting the labor market and, as a result, the forms of labor organization and labor functions of employees. In this regard, authors considers academic theories in the context of conceptualizing the impact of Industry 4.0 on the labor market and labor functions, and identifies long-term trends in the transformation of the professions market. The empirical basis of the study is information prepared on the basis of open statistical data of Rosstat and the Ministry of Science and Higher Education of the Russian Federation, as well as resources of analytical publications and scientific publications, including materials from international organizations, leading consulting companies, global associations, leading educational institutions and other active participants in the global educational environment and labor market experts. The study examined a list of trends affecting organizations, their strategies and business models; describes the impact of trends on the transformation of current professions and the emergence of new ones; the need for skill sets necessary to match these professions has been identified. The scientific novelty of the study lies in the substantiation of the concept shifted in favor of a highly skilled workforce (skills-biased technical change, SBTC) and the theory of displacement of routine labor (routine-biased technological change, RBTC).

Keywords: global labor market, business models, industrial complex, transformation, digital economy.

I. Introduction

The development of a digital economy based on the production, dissemination and consumption of information causes major socio-economic shifts, including in the field of labor relations, while changing the type of professional activity and the nature of labor itself. In the digital economy, the accumulation of material wealth ceases to be the main goal of society, intangible values and interests come to the fore [1]. The new nature of labor is associated with the improvement of the qualifications of workers, their constant training and creative communication. The development of the labor market based on digital technologies leads to the modernization of labor relations: in communication between employers and contractors, there is an active use of information and communication technologies (hereinafter referred to as ICT) and the formation of new norms of behavior. Until now, the domestic labor market has remained virtually unchanged under the influence of digital technologies, but the accelerating digitalization of the economy poses new challenges for industries and the state that they have not faced before. The problems of employment in the digital economy acquire a new meaning. Human and social capital are considered as key sources of wealth, which requires a conceptual shift in people's consciousness from the position of "profit maximization" to the position of "utility maximization". Thus, the period of the emergence of the digital economy requires a quick response to changes in the labor market, investments in human capital and new ways of its qualitative improvement, adaptation to new conditions, and program measures from the state. The current global labor market is under the influence of the IV industrial revolution (Industry 4.0). The labor market does not exist in a vacuum: it is influenced by many trends, changing strategies and business models, the image of employees, their set of competencies and responsibilities. Trends, in turn, are formed under the influence of social and technological factors. Industrial revolutions are one of the most important technological trends affecting the job market. The concept of the IV industrial revolution was proposed by the President of the World Economic Forum Klaus Schwab at the Hannover Industrial Exhibition in 2011 [3,5]. Initially, the term denoted a project of the German government to digitalize production. However, the term was successfully borrowed by other countries and is now used everywhere. Unlike the III industrial revolution, which implies the automation of only certain processes, Industry 4.0 is to digitalize the entire production and create a single ecosystem in which enterprises, products and consumers are connected and interact with each other using new digital and social technologies [1,8]. Trends like these are causing massive change: certain segments of the workforce become obsolete and abolished, and emerging professions that the labor market is in need of are instantly in short supply. For many workers, this means either the loss of a job or a major change in career trajectory. At the level of organizations and the state, there is a need to overcome emerging personnel and skills gaps through the creation of mass retraining programs. Let us consider the impact of cyclical and sudden trends affecting the labor market and, as a result, the forms of labor organization and labor functions of workers. We live in a challenging era: the situation of the coronavirus pandemic has been superimposed on the ever-increasing pace of technological change. According to the 2021 BCG report, 36% of employees worldwide have lost their jobs or experienced a reduction in working hours [1,2]. This is especially true for areas related to tourism, media, art and creativity. Anxiety and excitement in the face of uncertainty are not only experienced by those whose activities have been affected by the pandemic: more than 66% of employees have the desire or need to change jobs, regardless of their profession, income or geographic location. Anxiety is also rising due to the growing level of automation and digitalization: 41% of employees are more concerned about technological changes and their impact on the workplace than before the pandemic [3,4] . In Russia, half of the working-age population - more than 35 million people - is at risk of replacing labor with digital and automated solutions. 80% of able-bodied Russians are not ready to work in modern markets. Some areas of work become obsolete and abolished, and emerging new professions in which the labor market is in need are instantly in short supply. Therefore, the majority of employees are ready to retrain to ensure their peace of mind in the future, and are already putting considerable effort into this: last year, more than 66% of employees devoted at least two weeks to their own training. Today, many companies are in unique circumstances: employees have a strong internal demand for their own development, which is also synchronized with the need of organizations for constantly learning proactive employees. The most successful companies have been testing retraining programs for several years that preserve internal human resources by providing employees with a smooth transition from one role to another or the opportunity to improve their skills in their current position. The situation of the coronavirus pandemic was superimposed on the ever-increasing pace of technological change, and also spurred the acceleration of the consequences of long-term trends: the disappearance of a number of obsolete professions, the emergence of previously unknown specialties, an increase in the duration of an active career, and much more. In order to contain the spread of the virus since 2020, numerous measures have been taken around the world in accordance with the recommendations of the World Health Organization, from physical distancing, restrictions on freedom of movement and the closure of non-essential businesses and organizations, to the isolation of entire cities in various regions. In response to the crisis and the restrictions associated with it, organizations began to actively introduce new technologies and business models into work processes, which led to the formation of new trends in the labor market. The purpose of the study is to assess the impact of cyclical and sudden trends affecting the labor market and, as a result, the forms of labor organization and labor functions of employees. In this regard, the author considers academic theories in the context of conceptualizing the impact of Industry 4.0 on the labor market and labor functions, and identifies long-term trends in the transformation of the professions market. The scientific novelty of the study lies in the substantiation of the concept, biased in favor of a highly skilled workforce (skills-biased technical change, SBTC) and the theory of displacement of routine labor (routine-biased technological change, RBTC) [5].

II. Methods

We can assume two vectors for the development of the labor market in the context of the digitalization of the economy. The first scenario, an optimistic one, is based on the fact that the labor market in the digital economy is in need of creative people who are able to think creatively. Manufacturing will generally not need people, but they will be needed for the "human-centric" services, as robots in the near future will not be able to replace creativity, invention, design, programming and maintenance of themselves, the organization and adjustment of production. Technologies for online control of robotic equipment will be developed, which will require a large number of online operators [6]. Thus, the introduction of AI and robots in the manufacturing sector should be seen as an expansion of technical capabilities. In addition, digital technologies will enable older workers and workers with disabilities to better integrate into the market, while machines perform dangerous and routine work. People will be able to more actively use their freed time for other work or leisure, for creativity and the provision of innovative services. With the timely development of educational programs and their implementation with the help of the state, the transition from old professions to new ones will become less painful. Personnel of the "digital era" will ensure the production, storage, processing and implementation of information, create unique knowledge, and manage it [7]. New digital technologies have a number of features that positively affect the labor market. First, the use of modern digital job search portals allows candidates to improve their career opportunities by accessing an extensive database of current vacancies. Thanks to the Internet and special web services, the transparency of information about both employing companies and potential job seekers has increased significantly. In the United States, more than 130 million people are registered on the LinkedIn platform, which is a significant proportion of the US working population. In turn, various social networks play a significant role, from which you can get a lot of useful information about employers and employees. Second, digital platforms increase productivity as they more closely match the applicant's profile to the job offer. In addition, they reduce unemployment, as well as reduce shadow employment and job search time. Examples include digital platforms such as Uber and YouDo, whose business models are based on the efficient matching of supply and demand levels in the labor market. Thirdly, the introduction of modern digital tools in all spheres of life contributes to the emergence of new professions and jobs. In the past, a significant proportion of the population initially worked in the primary sector (production of raw materials, such as agriculture and mining). During the first industrial revolution, this trend changed: a significant part of the working population moved into the secondary sector (manufacturing industry). However, from the beginning of the world wars to the present day, there has been a trend towards the development of the tertiary sector (service), which today employs 70% of workers. According to some authors, the fourth and fifth sectors will soon appear, which include information services and services that require high intellectual standards [7]. In preparing the study, the data obtained in the course of our own quantitative study conducted in September 2021 in the format of an online questionnaire were used. The survey involved 211 specialists from Russian organizations from 26 fields of activity responsible for personnel training and development, among which: - 38% - HR directors; - 30% - specialists of training and development departments; - 16% - training directors; - 16% - respondents who are responsible for personnel development, but their positions have a different name (vice president for employee experience management and organizational development, director of internal development, head of HR, etc.). Participants of the survey were asked seven closed-ended questions that dealt with the following topics: skills gaps among employees of organizations; the skills that their retraining programs focus on; forms and technologies used in the organization of retraining programs (the effect obtained through the introduction of such initiatives). In recent decades, the influence of the following long-term trends on the professions market has been noted [2]: - IV industrial revolution and digitalization; - changes in the content of labor functions and a decrease in the share of non-routine operations; - demographic changes, including the increase in life expectancy and the aging of the population; - orientation of business to specialists with a wide range of developed skills and their requirements for organizations; - development of a culture of continuous education. Other trends are developing as a result of sudden crises, including the coronavirus pandemic: - the development of new systems for the division of labor and work formats; - accelerating the pace of automation; increasing the pace of development of electronic commerce; - the need to adapt human resources (HR) and educational processes to the conditions of uncertainty and turbulence. The following trends related to Industry 4.0 [7] affect the work processes of organizations:

- network integration, which allows all elements of the ecosystem to interact with each other;
- intelligent technologies that automatically collect and process information for decision -making;
- flexible automation, which provides remote control of production processes.

Thus, the global technological trends affecting industrial production are: 1. Intelligent technologies. Automatically track the occurrence of events and provide information for decision making. 2. Network integration. Provides communication between individual network nodes and improves access to information. 3. Flexible automation. Includes response mechanisms, actual automation and remote control. Advances in technology and automation have a direct impact on the job market. According to OECD estimates published before the coronavirus pandemic, in the next 15–20 years, about 15% of current jobs will disappear due to automation, and another 32% will require retraining due to new business demands [6]. A study by the World Economic Forum points to the elimination of 85 million positions by 2025, while robotization will create 97 million new jobs. The greatest demand is expected for specialists in the field of data and artificial intelligence, content creation and cloud computing [9]. In such conditions, the organization of advanced professional retraining and advanced training programs for current employees becomes a competitive advantage for companies. A number of academic theories conceptualize the impact of Industry 4.0 and indicate long-term trends in the transformation of the professions market. Among such concepts, one can single out the theory of technological progress biased in favor of a highly skilled workforce (skills-biased technical change, SBTC) and the theory of displacement of routine labor (routine-biased technological change, RBTC). The SBTC theory emphasizes the increase in demand for highly skilled labor and highlights the demand for skills related to digitalization and information technology [10]. The RBTC theory points to the serious impact of digitalization on the labor market. The demand for positions associated with non-routine intellectual tasks is increasing; at the same time, the demand for positions based on easily automated routine (cognitive and physical) actions is decreasing.

With the development of automation, a significant decrease in the share of routine tasks in the duties of employees is expected. In addition, the need to produce highly competitive products and services requires staff to be able to effectively interact with each other and with a potential consumer of an innovative product. As a result, there will be an increase in the number of professions associated with non-routine operations based on high expertise, as well as with such universal competencies as cooperation, communication, critical thinking, creativity and other socio-emotional skills. Therefore, retraining in the field of developing soft skills is becoming an inevitable and important element in adapting organizations to new conditions and preparing employees for a different type of task. Thus, according to a study by WeWork and Workplace Intelligence, 53% of company employees want to work from the office less than three days a week after the end of the pandemic [2,3]. Managers need to think about retraining programs for such specialists now, as new work formats will require them to have more advanced communication and digital skills.

III. Results

The digital economy requires completely new skills and competencies. To leverage digital technologies effectively and scale up business nationally and internationally, organizations need employees with the right mix of technical, business, interpersonal and creative skills. In the current conditions, basic skills (the ability to write correctly, count, etc.) [8] are clearly not enough anymore - you must also have business and interpersonal qualities. Critical to any manufacturing process or service delivery are state-of-the-art technical skills, complemented by leadership-level skills (C-suite level, entrepreneurial) specifically tailored for digital management. For employers, the so-called “soft skills” of potential candidates have recently become a priority: personal qualities and social skills, for example, the ability to work in a team, curiosity, initiative, critical thinking, self-management, the ability to solve complex problems, interact with different people to prioritize. At the same time, as noted by some leaders of large organizations, the role of formal diplomas and certificates of education has significantly decreased. Top companies such as Google, Apple, and IBM, as well as international consulting giant Ernst & Young, do not require college degrees for employment—relevant experience is sufficient. But this is not always mandatory. The main thing that a candidate must do is to show that he really suits the vacancy for which he is applying. New working conditions require new skills – digital [9]. “Digital skills” is generally understood as a set of skills in the use of digital devices, communication applications and networks to search for and manage information, create and distribute digital content, interact and collaborate, and solve problems in the context of effective and creative self-realization, learning, work and social activity in general. The trend towards the formation of new work formats also affects the mobility of employees. More and more specialists prefer to work remotely in organizations whose offices are located abroad or in smaller cities within the country [5,6] . So, in the United States, a large outflow of population in 2020 was observed from New York, San Francisco and Boston. At the same time, small regional cities, such as Madison, Jacksonville or Salt Lake City, have shown large population growth over the past year. With the active introduction of new formats of work, retraining of specialists plays a first role, as organizations need to quickly train employees in remote team management, skills in working with digital tools, leadership and decision-making in times of crisis. The pandemic crisis has accelerated the process of automation and significantly affected the willingness of companies to adopt new technologies. Before the pandemic, the level of adoption of cloud computing, big data analytics and e-commerce technologies had already taken shape and is holding a high bar. However, companies are now seeing an increase in interest in implementing encryption and cybersecurity technologies, artificial intelligence and robotics.

Artificial intelligence has a higher potential for implementation in the field of information and communication technologies, financial services, healthcare and transport. Big data analytics, the internet of things, and robotics will have wider applications in the mining and metallurgical industries. At the same time, it is planned to actively introduce encryption and cybersecurity technologies in the public sector. An additional factor stimulating the need for retraining is the redistribution of current tasks between humans and robots. Data from the World Economic Forum indicates that by 2025 even more tasks will be automated using robots. Thus, the introduction of new technologies accelerated by the pandemic will help significantly stimulate the economic growth of almost all industries and will create an increased demand for new professions and a set of skills. Early launch of retraining and skills upgrading programs in the company will help to avoid a decrease in the level of efficiency of work processes [10].

In the context of the pandemic, the automation of industries based on repetitive operations has significantly accelerated [7-8] . The manufacturing and trade industries have 30% more operations that can be automated compared to sectors where business processes are not based on repetitive operations (education or healthcare). In industries with high operational productivity, the automation potential is 1.3 times higher than in other industries. If earlier organizations planned the phased introduction of certain technologies, then as a result of the pandemic, most companies have an urgent need for specialists working with information security, cloud technology security, etc. This need has increased the need for retraining of personnel and determined the priority content of these programs. The market for professions is undergoing significant changes today. According to the World Economic Forum, by 2025 the global labor market will see an overabundance of data entry specialists, secretaries, payroll specialists, auditors and accountants, as well as production workers and administrators [8]. The trend towards a decrease in demand for these professions is generally typical for Russia, where the coronavirus pandemic has significantly accelerated the pace of automation and digitalization of business processes. Therefore, the data on changes in the demand for professions in Russia do not differ much from those in the world. Positions that involve the performance of a large number of routine operations will be automated and forced out of the labor market. At the same time, there is a demand for new technological professions. For example, there is a growing need for IT professionals and professionals in digitalization and automation (for example, operators of equipment with digital program control), artificial intelligence and machine learning, as well as analysts and data scientists. In addition, there is a growing need for managerial personnel, specialists in business conduct and in the field of sustainable development. Cyclical trends and sudden crises not only change the demand for professions, but also affect the skills requirements of existing professions. Technologically more advanced economies require more sophisticated and knowledge-intensive skills [6]. A good example is the evolution of agricultural professions. Initially, the requirements for the heads of agricultural enterprises included mainly an understanding of the peculiarities of growing certain crops. However, the current skill requirements have changed due to the growing demand for skills in data analysis in the field of agro-industrial complex, the development of biopharmaceuticals and innovative technologies, food safety and e-commerce. This is also why the employment of workers and specialists from countries with less developed economies for similar positions in more developed countries, as a rule, occurs with preliminary retraining. An increase in the number of tasks and an increase in the knowledge intensity of the technologies used are characteristic of all industries, including manufacturing, IT, medicine and education. Now more and more companies require knowledge of programming languages from future engineers, from medical workers - the details of modern pharmaceuticals, and from teachers - an understanding of the principles of operation of digital educational platforms. In such conditions, the demanded specialists of the future need to have a certain set of knowledge and professional skills [7]. The business of a high-tech industrial company can be improved by digital technologies, but not replaced. Not a single production function has disappeared yet - only transactional ones are leaving. Therefore, it is worth talking not about the disappearance of professions, but about their transformation and/or unification. Due to intensive digitalization, automation and robotization, the ability to use artificial intelligence technologies, one person can have skills from 2-5 professions. This does not mean that the concept of a profession is gone. She remained and was enriched with functions that were previously adjacent to her. At the same time, the view on the intensity of labor and the requirements for people with a higher level of knowledge have changed. One of the reasons for the emergence of conditionally new, but in fact a significant change in existing professions, is technological progress. For example, if earlier the diagnosis of malfunctions of locomotives was carried out manually, in fact by tapping and ringing, visual diagnostics, now this requires the skills to read safety devices. Today, a locksmith should not only be able to wield a wrench, but also read instrument indicators, work with equipment [9]. 3D technologies and prototyping technologies will definitely be actively used in our production, so we need the appropriate specialists. In their companies, employees are not faced with disappearing or disappeared professions, however, there is a serious change in the functionality of existing ones. For example, robotization leads to significant changes. All sorts of remotely controlled robots are already actively used in production: drones flying, moving along walls and penetrating hard-to-reach areas, so there is a high need for such specialists. In this regard, there is an urgent need to train both current employees and university students in these skills. Nevertheless, the functional content of some positions will change. For example, the driver of a load-and-dump machine will remain so, but the machine itself will change. The board will become more robotic and automated, and the participation of the driver-operator will be minimal, observant and controlling. A similar situation will be with a number of other professions and specialties. There is a request for cross-disciplinary positions requiring a combination of financial and business analysis, business planning and advanced technical skills. In the context of a pandemic and automation, for almost all changing professions, understanding the remote economy will be important. The report of the Hamburg School of Applied Sciences, supported by the European Commission, focuses on digital and soft skills.

IV. Discussion

In the coming decade, entirely new professions will emerge that will require a different set of unique skills. Under the influence of radical technological breakthroughs in the 21st century, a significant number of new professions have already emerged. For example, the invention of the airplane became the basis for the emergence of such professions as a pilot or flight attendant. The emergence of genetic engineering has led to the emergence of geneticists, reproductive physicians [3]. Thus, innovative scientific and technological changes can create demand for previously unknown professions. New professions are professions that have emerged as a result of a radical change in technology in the production of goods and the provision of services and require special knowledge, skills and abilities to perform new types of labor operations. The formation of new professions is influenced not only by technological innovations, but also by social ones. The introduction of payment systems using plastic cards has given rise to an entire industry of workers associated with this activity. The development of insurance medicine led to the emergence of the profession of a health insurance agent [4]. The emergence of network forms of interaction between people has served as a source of such highly paid professions today as a blogger or a broker on an electronic exchange. Special foresights can be used to predict new professions. Foresight (from the English foresight - "foresight") is a social technology that allows you to create a forecast for the development of an industry, region or country. There are various skills foresight technologies. The Skills Technology Foresight methodology includes three special foresight sessions: - technology foresight aimed at building a vision for the future of the industry and professionals working in it, or revising an existing vision; - forecasting skills based on technological foresight; - recommendations to the education system, policy makers and labor market stakeholders aimed at closing the gap between future demand and supply of skills. The work of each session takes place in groups, where, with the help of a moderator, experts representing an industry or foresight subject collectively create an integrated map of the future using special cards. Since 2014, under the auspices of the Agency for Strategic Initiatives, using the Skills Technology Foresight methodology for the purposes of vocational guidance and the choice of educational trajectories, the Atlas of New Professions has been developed and updated. Using this technology, Russian specialists and experts predicted the emergence of 300 unique professions in 27 industries [8]. Forecasts about the professions of the future can additionally be made on the basis of an analysis of existing scientific and technological trends and directions for the development of the labor market. An analysis of existing materials on the topic of new professions suggests the emergence of the following popular areas in the coming decades.

One of the most common types of employment in the digital economy is working from home instead of moving to the office during the working day. In addition, the following types of work have appeared: during vacations (on a train, on an airplane, in a hotel), for a foreign employer without going abroad (for example, the work of offshore programmers), etc. The development of labor relations in the digital economy leads to the replacement permanent staff by temporary workers, and many jobs can be performed thousands of miles from the office and even across national borders. A notable trend in recent years has been the very rapid growth in the number of freelance freelancers. Thus, in the United States alone in 2017, there were 57.3 million people working in freelance mode (including part-time jobs), which is 36% of the working population of the country [9-10]. As a result, the new labor relations contribute to: - a significant reduction in transaction costs (rental of office space, recruitment, transportation costs); – introduction of flexible labor organization and flexible staff; – increase in labor productivity (due to the elimination of obstacles to work that exist in the office); - increasing motivation (increasing trust between the employer and the employee); – Improved customer service (24/7, no overtime pay). In the digital economy, not only the nature of labor is changing, but the entire system of labor relations. If in the traditional economy there are vertical economic relations of management / subordination between the employee and the employer, then in the digital sector the manager is no longer so much a boss as a person coordinating the work of people, sometimes located at a great distance from each other. Accordingly, vertical connections are replaced by horizontal ones, while the employee's dependence on the head of the company is significantly weakened [8]. An increase in the independence of an employee forms a special kind of partnership between him and the manager, requiring a corresponding increase in trust. The specialist himself forms a portfolio of orders, agrees on the scope and timing of the work, as well as the amount of his own remuneration. The qualification and authority of the performer provide him with a constant replenishment of the portfolio of orders. Therefore, there inevitably arises a rejection of the "one job for a lifetime" philosophy and a desire to independently form and manage a portfolio of works. It is also important that digital employment provides new opportunities for both residents of cities and residents of the "outback": workers who were previously forced to move from the provinces to the capital in order to be present at the central office, today can live in any locality that has access to the Internet.

References

[1] Gishkaeva L.L., Kataev A.A., Khekhaeva Z.V. New Challenges for the Labor Market. Economics and Business: Theory and Practice. 2021. No. 8 (78). pp. 40-43

[2] Pinyavina E.A. Creation of forest carbon (carbon) landfills: economic component. Actual directions of scientific research of the XXI century: theory and practice. 2021. No. 1. p.26-34.

[3] Kergrouch S. Industry 4.0: new challenges and opportunities for the labor market Foresight. 2017, 11(4), pp. 6-8

[4] Serebrennikov S.S., Kharitonov S.S. Technological transition from Industry 2.0. and 3.0. in the industrial sector, 2020, 4 (24), pp. 67-79.

[5] Ilyasov R.Kh. Spline modeling and analysis of relationships in the economy with the possible presence of regression switching points, 2018, 11(4), pp.165-175

[6] Hansen, J.; M. Sato; R. Ruedy; K. Lo; D. W. Lea and M. M. Elizade, Global Temperature Change, PNAS, 2020, 103(39), pp. 14288–14293.

[7] Grace, K. When Will AI Exceed Human Performance? Evidence from AI Experts / K. Grace, J. Salvatier, A. Dafoe, B. Zhang, O. Evans, 2018

[8] Frey, C.B. The Future of Employment: How Susceptible Are Jobs To Computerisation? University of Oxford, 2019, pp. 123-152

[9] Wisskirchen, G. Artificial Intelligence and Robotics and Their Impact on the Workplace. IBA Global Employment Institute,2020, pp.635-698

[10] Economics of Transition. Educational upgrading, structural change and the task composition of jobs in Europe, 2018.

THE PROBABILITY-STATISTICAL STUDY OF THE AMELIORATIVE CONDITION OF LANDS

Anar Hummatov
•
Azerbaijan University of Architecture and Construction
Azerbaijan Hydrotechnic and Melioration Scientific Production Union
hummatovanar@rambler.ru

Abstract

Article devoted is comparative study of satellite imegary and collected field-research data on the research area with different natural and economic conditions. Probability - statistically evaluations were performed for the purpose of land reclamation research which of based on indicators of salinity, humus and values of NDVI, which is around the point of the where the soil sample was taken. The study was carried out to know the land reclamation condition by using GIS technology and Regression analysis. We discuss how data can be organized so that important features can be grasped quickly and effectively. During carrying out of reclamative researches and processing of the collected data necessary to solve various problems, which are applied information technology and a geographic information system (GIS), accoding to directions on the study.

Keywords: probablity-statistical, vegetasion index, amelaration candition of lands, dry residue, humus

I. Introduction

Development of innovative technologies and use of geographic information systems accoding to wide perspectives are opening up and increasing the efficiency of scientific research; effective solution of many practical problems in a short period of time during monitoring; in the assessment of natural resources, in environmental protection, in the study of land reclamation, with using aerospace data. The basic problems in the land reclamination for saline land which can be solved using aerospace data are systematizing. Application of such progressive methods to more prompt and accurate, as well as from economic view is considered more efficient research.

Soil salinity is an increasing problem on Earth that affects the development of plants, with negative effects for agriculture. Identification of salinized soils, monitoring and mapping is a very difficult; because salinization is a dynamic process, drawing up maps characterizing land reclamation conditions based on the processing of satellite images it has special importance for the evaluation and clarification of the current situation.

The analysis of multi-temporal multi-spectral satellite images that illustrate the seasonal dynamics of land surfaces is very reliable.

II. Research area and Methods

Research works were carried out for the purpose of comparative study of actual and satellite images; for analysis of information capability of aerospace Earth monitoring data; for digital image processing; for more accurate processing of resolutions of space images, in Shirvan Experimental Amelioration Station (SEAS) and Zardob Experimental Plot (Zardob EP), which are considered as key objects (Fig 1). For this purpose, used various open internet (earthexplorer.usgs.gov etc.) databases. Used a GPS (global positioning system) receiver to record locations and reserch points [3].

The study site SEAS is located in Shirvan plane in the center of Azerbaijan, between latitudes 40°30′45″ N and longitudes 47°39′08″ E (40.5033^{0}N47.6985^{0}E) and it covers an area of 206.5 ha (Fig. 1). The area has an arid climate with an average annual precipitation of 320 mm and annual evaporation from the water surface 162.95 mm yr−1[1].

The study site Zardob Experimental Plot is located in Shirvan plane the center the of Azerbaiyan, between latitudes 40° 13′ 6″ North and longitudes 47° 42′ 30″ East (40.1936^{0}N 47.6180^{0}E) and it covers an area of 638.3 ha (Fig. 1). The area has an arid climate with an average annual precipitation of 350 mm and annual evaporation from the water surface 150 mm yr−1 . July is the hottest month in SEAS and Zardob Experimental Plot, averaging 26°-27°[1].

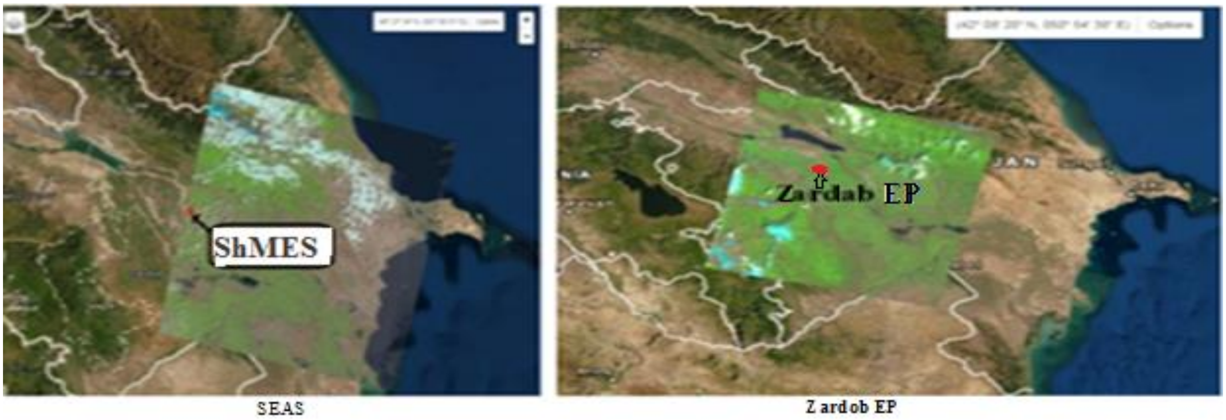

Figure 1: *Location map of the study area*

Depending on the salinity of soils such plants as garasoran, shahsevdi gishotu, are widely spread in these regions.

Various research points were identified and research was carried out, for perform a comparative study of the results of chemical laboratory analysis of soil samples and the results of the satellite images in the territory of SEAS and Zardob EP.

Both datas of laboratory analysis and collected as a result of visual inspection, using the appropriate formula of the Vegetation Index, systematized by using information from literature and internet resources for the purpose of organizing monitoring of lands . There are two types of Earth remote sensing techniques: aerial survey and space survey. Medium spatial resolution satellite images from the LandViewer resource have gained most popularities . Carrying out research in the research area based on the database of Landsat 8 and Sentinel-2 satellites image. In addition to the Landsat-8 RT satellite image, Sentinel-2 L2A satellite data was also used in this study to identify and compare the research areas [2,3,7].

Various multispectral images of satellite imagery data of different dates were studied for in order to study the monitoring of reclamation processes in the research area. Use Ecxel for statistical analysis for data, including the analysis of descriptive statistics characteristics of soil salinity at different soil layer and humus, NDVI and their correlation, Descriptive Statistics analysis and Correlation analysis tool, respectively [4,5,8,12].

SEAS Zardob EP

Figure 2: *Research area in LandViewer Software*

Most commonly used vegetation index is Normalized Vegetation Difference Index (NDVI). NDVI indices were evaluated taking into account the salinity level of the soil cover in the area involved in the study, wild vegetation, the presence of garden and forest area in the fields under various cultivated crops (barley, wheat, cotton, corn, clover). Taken a photo that shows soil surface conditions and vegetation, for investiqation. Vegetation indices play an important role in evaluating the state of vegetation which of based on spectral reflectance properties. A Vegetation Index is a single value calculated by transforming the observations from multiple spectral bands.

Vegetation index means, especially during the growing season of the plant accoding to depending on other factors (land cover, meteorological conditions) the relationship between spectral reflection coefficients at different wavelengths is understood. These indices enhance the contrast between soil and vegetation but minimize the effects of illumination conditions. However, they are sensitive to optical properties of soil background. The Normalized Difference Vegetation Index is an indicator of the greenness of the biomes.

As a result, how much topsoil to the salinization process allows to determine whether it has been exposed. By using the NDVI index, type of plant, density and height of plant are important, for decoding setallite images is considered one of the main indicators in investigation of the reclamation situation. [9,10,11].

The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which allows us to generate an image showing the relative biomass. The Normalized Difference Vegetation Index (NDVI) is a quantitative index of greenness ranging from 0-1, where 0 represents minimal or no greenness and 1 represents maximum greenness. NDVI values range from +1.0 to -1.0. High NDVI values (approximately 0.6 to 0.9) correspond to dense vegetation such as that found in temperate and tropical forests or crops at their peak growth stage. A zero means no vegetation and close to +1 (0.8 – 0.9) indicates the highest possible density of green leaves. If the NDVI is lower than 0.15, most probably all the plants died in this part of the field. Typically, these figures correspond to plowed soil without any vegetation. NDVI varies between 0.2 to 0.5, in the grasslands with sparse vegetation and the shrubby place. Various soil types reflect solar radiation differently [5,6,8,12].

It was estimated using the Normalized Difference Vegetation Index (NDVI) which is computed by the Equation

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \tag{1}$$

Where: ρ_{NIR} is the near infrared spectral wavelength, and ρ_{RED} is the red spectral wavelength.

$$For\ Landsat\ 8\ \ NDVI = \frac{B5 - B4}{B5 + B4}\ \ and\ \ For\ Sentenental\ \ NDVI = \frac{B8A - B04}{B8A + B04}$$

Satellite sensors like Landsat and Sentinel both have the necessary bands with NIR and red.

We discuss how data can be organized so that important features can be grasped quickly and effectively. The next step was to summarize the data (dry residue, humus) for evaluate soil salinity based on samples taken from different soil layers in order to study reclamation process in SEAS and Zardob Experimental Plot by mathematically and statistically methods. Statistic estimation are animportant part of research which search for better for safer and more allows to effective control the meliorative situation. Statistical measures which can be used to describe the characteristics of a set of data. In a single value that serves as a representative value of the overall data. Such measures are the mean, the mode, the median, standard error and etc. The most commonly used measure of central tendency is the mean— the arithmetic average of a group of scores. The median is the middle value. Another measure of central tendency, the median, is used in situations in which the mean might not be representative of a distribution. For example, the mode of a set of data is the value which occurs with the greatest frequency. How a set of data can be summarized by a single representative value which describes the central value of the data. The median is the middle score in a distribution after the scores have been arranged from highest to lowest or lowest to highest. The most important measures of variability are the sample variance and the sample standard deviation. The simplest measure of variation is the range—the difference between the lowest and the highest scores in a distribution. Confidence Level: The percentage of all possible samples that are expected to include the true population parameter. They are most often constructed using confidence levels of 9 5% or 99 %. Statisticians use confidence intervals to measure uncertainty in a sample variable[8,12,13].

Regression is a statistical term wherein a statistical tool is used to find relationships within a given data. The correlation coefficient (‘R’) is represented by a value that varies from +1 through 0 to −1. Correlation is used to denote the association betweentwo quantitative variables [13]. Positive correlation, one in which a direct relationship exists between the two variables. This means that an increase in one variable is related to an increase in the other, and a decrease in one is related to a decrease in the other, as well as the strength of that relationship (weak, moderate, strong). Negative correlation indicates that an increase in one variable is accompanied by a decrease in the other variable. 0 indicates no linear correlation between two variables.

III. Results

From 9 different points in soil samples were taken at a depth of 1 m, the coordinates of each well were determined using ArcGIS Earth software in the SEAS area. In total 45 soil samples: between 0 and 20 cm depths, between 20 and 40 cm depths, between 40 and 60 cm depths, between 60 and 80 cm depths, between 80 and 100 cm depths, were collected for used in this study. The soil samples were taken in the field at different soil types (i.e., during the dry season) and in weather conditions with no rainfall, but sunny [1,4].

In addition, Zardob Experimental Plot from 8 different points in soil samples were taken at a depth of 1 m, were collected for used in this investigation. Accordingly, the condition of the plant and soil in the around of the each well was recorded, for the purpose data of satellite images for mutual comparison with field and laboratory measurements (Table 1).

Initially, the georeferencing of the soil sampling points was carried out, converted and defined according to UTM (Universal Transfer Mercator), which is considered as the international coordinate system. The latitude and longitude of SEAS and Zardob EP have been calculated based on the geodetic datum WGS84.

İn additional, the collected soil samples were chemical analyzed, according to the degree of salinity and humus indicators. Salinity is a measure of the concentration of soluble salts in the soil. Soil salinity is the salt content in the soil. The soil salinity is estimated as measured in the laboratory. It is known that humus is one of the main indicators of soil fertility and assumes an important role as a fertility component of all soils.

Table 1: *Coordinates of soil sampling points and general situation around wells in the study area*

Well number	Universal Transfer Mercator		The condition of the plant and soil around the point	
	SEAS	Zardob PS	SEAS	Zardob PS
1	38 N 729399 4486411	38 N 722115 4450924	Phytomelioration area, Pomegranate garden (1-2 m), field overgrown with liquorice	Grass-plot
2	38 N 729400 4486992	38 N 722166 4450544	a field of barley 10 ha	Grass-plot, prickly place, tamariks grove and etc.
3	38 N 729061 4486501	38 N 722593 4451232	Former paddy field, salinity and broom plant	1 ha field of wheat
4	38 N 729018 4486360	38 N 722735 4451432	Sweet Flag , area under water, reedy place	salt-ridden lands, no plants
5	38 N 728515 4486656	38 N 723248 4452841	saline soil	First the grain was cultivated, after cultivated corn field
6	38 N 728597 4487060	38 N 723280 4452589	Grassy, weeds	Alfalfa, Clover and Natural grass
7	38 N 728117 4486953	38 N 722808 4455249	Saline soil, tamariks, salt grass	First the grain was cultivated, area currently under weeds, natural grass
8	38 N 728169 4487201	38 N 722892 4454671	field of wheat	Field under cotton plant
9	38 N 727583 4486319		Pomegranate garden, pine and the other trees	

Satellite data of the Normalized Difference Vegetation Index can be used to quantify changing patterns in ecosystem productivity [9,10,11]. According to NDVI indicator analyzed on the basis of various multispectral images taken by Landsat 8 and Sentinental-2 L2A in the territory of SEAS and Zardob PS (Table 2).

Table 2: *Conducting generalization on both research areas showed that the vegetation is distributed on the NDVI index based on research materials in the following*

Candition of plants according to NDVI index	Dense vegetation	Moderate vegetation	Sparse vegetation	Open soil
Range of the NDVI index	1.00– 0.60	0.60–0.40	0.40 – 0.20	0.20 – -1.00
Area in SEAS , with hectares	84,76	62,88	38,11	20,64
Area in Zardob PS with hectares	111,56	252,27	220,59	53,88

During carrying out of reclamative researches and processing of the collected data necessary to solve various problems, which of Excel has been used [8]. Excel software was used for generalzlation and statistikal evaluation of the parameters and NDVİ. According to, observation data and result of the chemical analiyse on the soil profile are described in Table 3,4. Based on the results, the analysis is made to determine the relationship between reflectance values and indices of soil salinity to estimate the soil salinity from the setillate image.

In the SEAS area summary statistics of soil salinity in different soil layers and NDVI was performed, and the results, present in Table 3.

Table 3: *Statistics of research material at soil sampling point in the SEAS area*

Statistics of research materials	Dry residu,% S						Humus, % N			NDVI
	Soil layer (cm)						Soil layer (cm)			
	0-20	*20-40*	*40-60*	*60-80*	*80-100*	*0-100*	*0-20*	*20-40*	*0-40*	
Mean	1,826	1,739	1,709	1,690	1,629	1,718	1,750	0,539	1,144	0,350
Standard Error	0,710	0,490	0,487	0,511	0,516	0,535	0,306	0,139	0,155	0,061
Median	0,684	1,312	1,274	0,984	1,13	1,1172	1,55	0,450	1,200	0,35
Standard Deviation	2,130	1,471	1,460	1,532	1,547	1,605	0,917	0,417	0,464	0,182
Sample Variance	4,537	2,165	2,131	2,347	2,394	2,575	0,840	0,174	0,215	0,033
Kurtosis	-1,664	-1,530	-1,365	-0,485	-0,897	-1,317	-0,204	2,185	-1,347	0,589
Skewness	0,770	0,517	0,612	0,892	0,713	0,736	0,450	1,555	0,175	0,580
Range	4,858	3,712	3,714	4,326	4,234	4,152	2,95	1,3	1,275	0,6
Minimum	0,102	0,126	0,158	0,138	0,104	0,142	0,45	0,15	0,5	0,1
Maximum	4,96	3,838	3,872	4,464	4,338	4,294	3,4	1,45	1,775	0,7
Count	9	9	9	9	9	9	9	9	9	9
Confidence Level (95,0%)	1,637	1,131	1,122	1,178	1,189	1,233	0,704	0,15	0,5	0,140

Table 3 shows statistics characteristics of soil salinity of different vegetation types.

Summary statistics of soil salinity was performed in different soil layers, and the results, present in Table 3, indicated that the average soil salinity value was comparatively high with regard to the generally accepted limit for most agricultural crops. Soil salinity is multi-factorial phenomenon, i.e., caused by various factors or combinations of factors.

In the Zardob EP area summary statistics of soil salinity in different soil layers and NDVI was performed, and the results, present in Table 4. Table 4 shows statistics characteristics of soil salinity of different vegetation types.

IV. Discussion

The minimum and maximum values of soil salinity were 1,629 % in 80 - 100 cm soil layer and 1,826 % in 0 - 20 cm soil layer, respectively in the SEAS area . Descriptive statistics showed, the average soil salinity value was comparatively high in 0-20 cm (the maximum value was 4,96 %). The results showed that Standard Error of dry residu (%) for 0 - 20, 20 - 40, 40 – 60, 60 - 80 and 80 - 100 cm was 0.710, 0.490, 0.487, 0,516 and 0.516. There are degree of salinization within the upper 1 m of soil and aeration zone according to, average by between from 0,142 to 4,294%, weakly, moderately and strongly saline soils, respectively.

And by the amount of humus, these soils are considered poorly secured. If in the 0–20 cm layer the humus content was 1,75 % , then in the 20–40 cm layer its amount was only 0.54% in the SEAS area. These soils according to the graduation, adopted in our republic, are considered low humus by the content of humus.

Table 4: *Statistics of research material at soil sampling point in the Zardob EP area.*

Statistics of research materials	Dry residue, %						Humus, %			NDVI
	Soil layer (cm)						Soil layer (cm)			
	0-20	20-40	40-60	60-80	80-100	0-100	0-20	20-40	40-60	
Mean	0,675	0,592	0,798	0,762	1,179	0,801	1,375	1,356	1,200	0,544
Standard Error	0,239	0,181	0,333	0,297	0,613	0,315	0,343	0,388	0,372	0,078
Median	0,502	0,457	0,474	0,566	0,577	0,515	1,025	1,025	0,700	0,600
Standard Deviation	0,675	0,513	0,942	0,841	1,735	0,890	0,971	1,097	1,053	0,219
Sample Variance	0,456	0,263	0,888	0,707	3,010	0,792	0,942	1,203	1,109	0,048
Kurtosis	1,783	0,639	5,950	5,693	7,228	7,040	-1,892	-1,520	-1,701	2,193
Skewness	1,512	1,276	2,362	2,259	2,649	2,596	0,435	0,543	0,661	-1,037
Range	1,942	1,46	2,892	2,616	5,246	2,787	2,45	2,85	2,6	0,75
Minimum	0,118	0,106	0,132	0,116	0,156	0,17	0,25	0,2	0,2	0,1
Maximum	2,06	1,566	3,024	2,732	5,402	2,957	2,7	3,05	2,8	0,85
Sum	5,402	4,736	6,382	6,092	9,432	6,409	11	10,85	9,6	4,35
Count	8	8	8	8	8	8	8	8	8	8
Confidence Level(95,0%)	0,564	0,429	0,788	0,703	1,450	0,744	0,811	0,917	0,881	0,183

In addition, study to condition of plants and humus index (from Table1,2) was found accodingly 3,4% in well 9 (under the pomegranate orchard) where the humus index is the highest, the lowest value 0,4% in well 4 (under swamp and salinity), respectively, around of the points where the soil samples were taken.

The Descriptive statistics of the NDVI index, around of the soil sampling points, accordingly to the Mean for the study area was 0,350, the Standard Deviation was 0.182, and minimum and maximum values were 0.1 and 0.7, respektivly. A low standard deviation indicates that the values are close to the mean, while a high standard deviation indicates that the values are dispersed over a wider range.

The minimum and maximum values of soil salinity were 0,592 % in 20 - 40 cm soil layer and 1,179 % in 80 - 100 cm soil layer, respectivel in the Zardob EP area

Descriptive statistics showed, the average soil salinity value was comparatively high in 80-100 cm (the maximum value was 5,402 %). The results showed that Standard Error of dry residu (%) for 0 - 20, 20 - 40, 40 – 60, 60 - 80 and 80 - 100 cm was 0,239, 0,181 , 0,333 , 0,297 and 0,613. There are degree of salinization within the upper 1 m of soil and aeration zone according to, average by between from 0,17 to 2,957%, weakly, moderately and strongly saline soils, respectively.

In the 0–20 cm layer the humus content was 1,375% , then in the 20–40 cm layer its amount was only 1,356% in the Zardob EP area. These soils according to the graduation, adopted in our republic, are considered moderately humus by the content of humus.

In addition, study to condition of plants and humus index (from Table1,2) was found accodingly 2,57 % in well 2 (on the bank of the Kura) where the humus index is the highest, the lowest value 0,22% in well 4 (completely unplanted, uncultivated land), respectively, around the points where the soil samples were taken.

The Descriptive statistics of the NDVI index, around of the soil sampling points, accordingly to the Mean for the study area was 0,544, the Standard Deviation was 0.219, and minimum and maximum values were 0.1 and 0.85, respektivly.

Statistical analysis between the soil salinity (dry residue, S,%), Humus(%) and the environmental indices derived from satellite images (NDVI) was performed. Pearson's correlation coefficient (R), calculated were in the soil layer, 0 - 20, 20 - 40, 40 - 60 and 60 - 80 cm, respectively. Pearson's correlation coefficient measures the strength and direction of the relationship between: soil salinity and NDVI, Humus and NDVI, respectively.

The statistical analysis of soil sampling of the soil salinity (with dry residue), humus and NDVI level indicated carryed out and obtained following results in area of SEAS.

For every land use plots, soil samples were taken at two depths: 0–20 cm (topsoil layer) and 20–40 cm (subsoil layer) using soil auger. Results indicated that NDVI values (database of Landsat 8 and Sentinel-2 satellites image) and humus were better correlated with Humus ($R_{0-20} = 0{,}68, R_{0-40} = 0{,}90$, respectively) which indicates a strong relationship than the other paramert. Comparative resalts show that direction of the relationship between, humus and NDVI, respectively, as NDVI increases, humus also trend to increase. Humus have been decrease from topsoil layer ($R_{0-20} = 0{,}69$) to subsoil layer ($R_{20-40} = 0{,}55$), respectively.

The correlation coefficient of soil salinity between NDVI of 0 - 20, 20 - 40, 40 – 60, 60 - 80 and 80 - 100 cm were $R_{0-20} = -0{,}51, R_{20-40} = -0{,}50, R_{40-60} = -0{,}42, R_{60-80} = -0{,}41, R_{80-100} = -0{,}50$, respectively.

The statistical analysis of soil sampling of the soil salinity (with dry residue), humus and NDVI level indicated carryed out and obtained following results in area of Zardob PS.

For every land use plots, soil samples were taken at two depths: 0–20 cm (topsoil layer) and 20–40 cm (subsoil layer) using soil auger. Results indicated that NDVI values (database of Landsat 8 and Sentinel-2 satellites image) and humus were better correlated with Humus ($R_{0-20} = 0{,}68, R_{0-40} = 0{,}90$, respectively) which indicates a strong relationship than the other paramert. Comparative resalts show that direction of the relationship between, humus and NDVI, respectively, as NDVI increases, humus also trend to increase. Humus have been decrease from topsoil layer ($R_{0-20} = 0{,}31$) to subsoil layer ($R_{20-40} = 0{,}27, R_{40-60} = 0{,}25$), respectively.

The correlation coefficient of soil salinity between NDVI of 0 - 20, 20 - 40, 40 – 60, 60 - 80 and 80 - 100 cm were $R_{0-20} = -0{,}89, R_{20-40} = -0{,}83, R_{40-60} = -0{,}81, R_{60-80} = -0{,}77, R_{80-100} = -0{,}75, R_{0-100} = -0{,}85$, respectively.

Research of satellite images based on vegetation index, visual images of different wells (general condition of plants, height, etc.) and with laboratory analysis results (dry residue, humus) has shown that it is completely identical. Relationships between soil salinity and spectral indices differ for bare and vegetated soil surfaces.

References

[1] Shyhlinskij E.M. "Climate of Azerbaijan". Baku (2000).

[2] https://eos.com/landviewer

[3] https://earthexplorer.usgs.gov/

[4] Hummatov A.H., Osmanov Sh.H. , Hummatova V.N. Investiqation of land reclamination situation based on aerocosmic image. The collection of sciences works of Azerbaijan Hydrotechnic and Melioration Scientific Production Union on 2022, volume XLIII – Baku, " ELM", 2019, page 90-101(In Azerbaijani.)

[5] Mushtaq Ahmad Ganie, Asima NusrathDetermining the Vegetation Indices (NDVI) from Landsat 8 Satellite Data. DOI URL: http://dx.doi.org/10.21474/IJAR01/1348

[6] Amal Allbed, Lalit Kumar. Soil Salinity Mapping and Monitoring in Arid and Semi-Arid Regions Using Remote Sensing Technology: A Review. http://www.scirp.org/journal/ars

[7] https://sentinels.copernicus.eu

[8] Excel® Data Analysis For Dummies®, 2nd Edition Published by: John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030-5774, www.wiley.com

[9] Mapping soil salinity in irrigated land using optical remote sensing data. Rachid Lhissou , Abderrazak El Harti , Karem Chokmani. Eurasian Journal of Soil Science 3 (2014) p.82 – 88

[10] Mohamed Elhag, "Evaluation of Different Soil Salinity Mapping Using Remote Sensing Techniques in Arid Ecosystems, Saudi Arabia", *Journal of Sensors*, vol. 2016, Article ID 7596175, 8 pages, 2016

[11] Satellite monitoring systems in forestry. Journal of Physics: Conference Series 1515 (2020) 032043 IOP Publishing doi:10.1088/1742-6596/1515/3/032043

[12] Dr. Seema Amit Agarwal. Use of Statistics in Research. International Journal for Modern Trends in Science and Technology 2021, 7, pp. 98-103

[13] Experimental Statistics for Agriculture and Horticulture . Ireland, Clive Ireland, CABI Publishing, 2010, p.360

ASSESSMENT OF INHALATION NON-CARCINOGENIC RISKS BASED ON EVOLUTIONARY MODELS ON THE EXAMPLE OF KRASNOYARSK

Liubov Kalimanova[1], Olga Taseiko[1,2]

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[1]Reshetnev Siberian State University of Science and Technology, Russia
[2]Federal Research Centre for Information and Computational Technologies, Krasnoyarsk, Russia
kalimanova.l@mail.ru
taseiko@gmail.com

Abstract

The essence of the problem of the methodology for assessing non-carcinogenic risk is to assess the potential consequences for human health in different variants of previous and existing exposures in the future harmful factors. The article considers how atmospheric air pollution in Krasnoyarsk city affects human health.

Keywords: non-carcinogenic risk, chemicals, evolutionary models, atmosphere

I. Introduction

The city of Krasnoyarsk is a modern large industrial city, which is a complex multicomponent urbanized ecological system. The consequences of industrialization have led to the fact that the population of the city has been living in a crisis environmental situation for decades, that cannot but affect the health of residents. The main sources of air pollution by suspended substances are metallurgy, heat power engineering, building materials, municipal and industrial boilers, as well as secondary pollution. Sulfur dioxide pollution — companies of non-ferrous metallurgy, heat power engineering. Carbon monoxide pollution — municipal and industrial boilers, metallurgy, vehicles and forest fires. Nitrogen dioxide pollution — companies of heat power engineering, metallurgy, motor transport.

The essence of the problem of risk analysis methodology is to assess the potential consequences for human health in different variants of previous, existing or possible in the future exposures of harmful factors, as well as from the comparative characteristics of various factors, sources of their education, medical, social and economic efficiency of various options for management decisions.

The aim of the study is to build a paired mathematical model that reflects the effect of exposure to the chemical substance sulfur dioxide on the risk of circulation system disorders.

II. Methods

The construction of a paired mathematical model that reflects the effect of chemical exposure on the probability of a response includes the sequential implementation of the following steps.

- Formation of a data table of agreed values "exposure marker — response marker"

- Calculate the probability of the response marker deviation from the norm for each observation in the data table.
- Evaluation of the parameters of a mathematical model reflecting the dependence of the probability of deviation of the response marker from the norm of the exposure marker

The data table is formed according to the data of paired models construction (Table 1).

Table 1: *Pair Model Building Data*

Observation number	Exposure value (x)	Answer value (y)
1	2013	17399
2	2014	17035
3	2015	36222
4	2016	35845
5	2017	35098
6	2018	35290
7	2019	35300

Evolutionary equations are constructed in the form of recurrence relations that allow organizing an iterative calculation procedure in time steps. These models make it possible to calculate the non-carcinogenic risk at any given point in time by predicting the accumulation of the risk of effects, taking into account the duration of exposure and age. This makes it possible to predict life expectancy (projected life expectancy) and reduce it under the influence of risk factors. The risk evolution model is a system of recurrent relationships for individual body systems, which include terms that reflect the influence of individual environmental factors on evolution risk of functional disorders of critical systems [1].

To assess the accumulation of risks, existing and developed epidemiological models were used in accordance with MR 2.1.10.0062-12 "Quantitative assessment of non-carcinogenic risk when exposed to chemicals based on the construction of evolutionary models".

When constructing an evolutionary model, the processes of accumulation of functional disorders in the body due to natural causes are taken into account. The prediction of the risk of health disorders in the model is made through the calculated risk value at the current time. At the initial point in time, the risk value is assumed to be 0.01. Based on paired exposition-effect models, which are elements of the evolutionary model, it is possible to assess the temporal dynamics of the risk of disorders of organs and systems.

To solve this problem, data on monthly concentrations of pollutants in the city of Krasnoyarsk, provided by the Regional State Budgetary Institution "Implementation Center Measures for Nature Management and Environmental Protection of Krasnoyarsk Territory".

The study also used the primary database of deaths and life expectancy of the population of the city of Krasnoyarsk from 2013 to 2019, including data on deaths from diseases of the circulation system [2].

III. Results

For a more complete description of the issue under consideration, a result was obtained that leads to the following conclusion that the mortality rate of the population of the city of

Krasnoyarsk from diseases of the circulation system during the from 2013 to 2014 is inferior to the period from 2015 to 2019, as shown in Figure 1. This is confirmed by the fact that the severity of the disease is characterized by coronary heart disease, cerebrovascular diseases, myocardial infarction and oncological diseases [3].

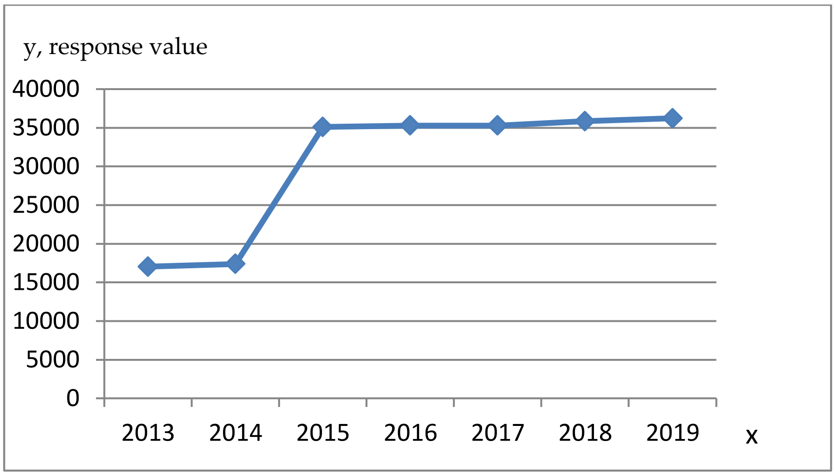

Figure 1: *Mortality of the population of the city of Krasnoyarsk from diseases of the circulatory system*

The probability of deviation of the response marker from the norm for each observation in the data table is calculated using the "sliding window" technology. To do this, each observation in the data table (each value of the exposure marker (x i) is assigned an estimate of the probability of deviation of the response marker from the norm (p i) calculated for the range ("sliding window") [4]:

$$x_i - \delta < x \leq x_i + \delta \qquad (1)$$

Here δ is the width of the "sliding window", which is determined from the relationship:

$$2\delta = \frac{10x_{max} - x_{min}}{N} \qquad (2)$$

N is the total number of studies for the entire population.

The probability of deviation of the response marker from the norm is estimated using the classical probability formula:

$$p_i = \frac{m_i}{n_i} \qquad (3)$$

m_i is the number of studies that deviate from the norm for the range $x_i - \delta < x \leq x_i + \delta$; n_i is the total number of studies for range $x_i - \delta < x \leq x_i + \delta$.

As a result, an estimate of the probability of the response marker deviation from the norm was obtained using a "sliding window" (Figure 2.).

When modeling "exposure–response" relationships, when assessing non-carcinogenic risk, the principle of action threshold is laid, according to which negative effects or responses from health are manifested starting from the reference level. The probability of developing negative effects is determined using regional models that are adequate for a specific set of chemical factors [4].

Paired models reflecting the "exposure–response" relationship make it possible to assess the probability of developing specific reactions (diseases and death) from exposure to a chemical.

The parameters of the pair model reflecting the relationship "exposure — response probability" are estimated by constructing a logistic regression model [4]:

$$p = \frac{1}{1+e^{-(b_0+b_1 x)}} \tag{4}$$

where, p is the probability of deviation from the norm;
x — exposure level;
b_0 , b_1 — mathematical model parameters.

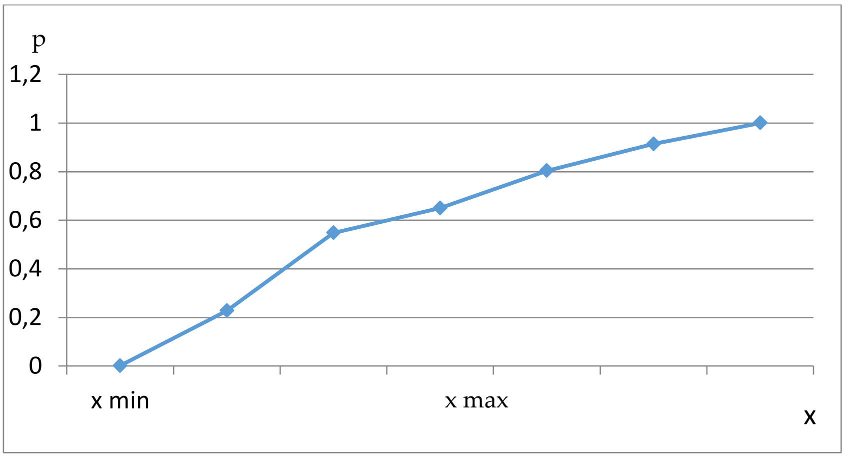

Figure 2: *Estimating the probability of a marker deviation from the norm*

To build the model, the values of data exposure markers (Table 1) and the corresponding probability values are used.

Based on the results obtained, an exposure of the probability of a response was identified in order to justify an examination of the dependencies obtained to assess their biological adequacy.

When modeling the risk of non-carcinogenic effects from chemical factors using evolutionary models of risk accumulation, the concept of an increase in the risk of disorders of the body's system is used, due to the action of a chemical substance during the time determined by the research objectives [4]:

$$\Delta R = g \langle p(x) - p(x_0) \rangle \tag{5}$$

where,
ΔR is an increase in the risk of disorders of the critical system of the body due to the action of the chemical substance during the time determined by the research objectives
g is a coefficient characterizing the severity of violations of the critical system in relation to the performance of body functions. The g coefficient is estimated based on the ratio of mortality and morbidity due to the same cause of dysfunction of an individual org/system; x 0 is the reference level for the marker expositions;
$< x >$, Kelly brackets that take values$<x> = 0$ at $x < 0$ and $<x> = x$ at $x \geq 0$.

The algorithm for calculating x_0 is based on the construction of regression models that reflect the influence of the exposure level on the "odds ratio" (OR) indicator, which characterizes the strength of the relationship between the values of the exposure level and the response. The OR ≥ 1 [4] condition is taken as a criterion for the presence of a connection.

Based on the above algorithms for calculating calculations, the study showed that for each observation, the odds ratio is calculated, which is carried out by conditional division of the sample into two parts: below and above the current level of the exposure marker ([xmin, xi] and [xi, xmax] (figure 3). Accordingly, here xi is the current level of the exposure marker. For both intervals, a value is calculated that characterizes the probability of deviation of the response marker from the norm pi- and i+ respectively, as the ratio of the number of observations that differ from the norm to the total number of observations.

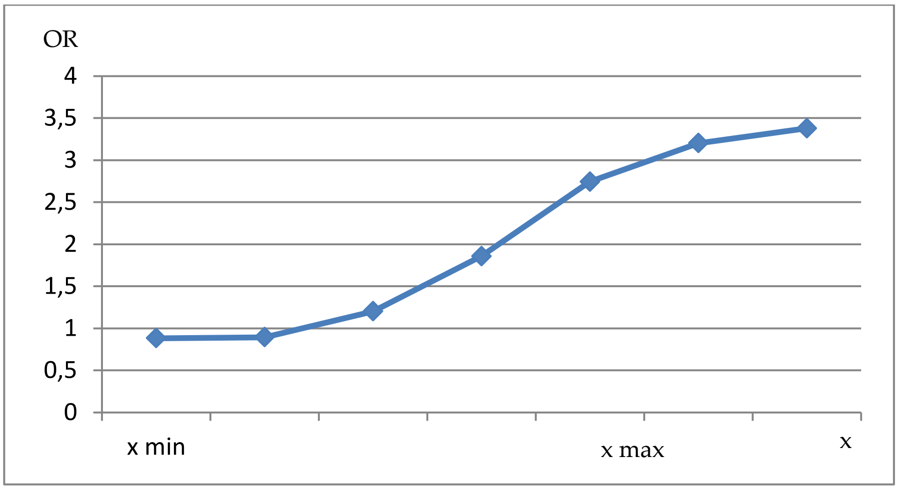

Figure 3: *Increase in the risk of violations of the critical system of the body*

The parameters of the dependence of the odds ratio on the exposure value are estimated by constructing a regression model in the form of an exponential function [4]:

$$OR = e^{a_0 + e^{a_1 x}} \tag{6}$$

where, a_0, a_1 are model parameters determined by regression analysis.

The calculation of the reference level of the exposure factor (x_0) in relation to the type of response is carried out based on the condition $OR = 1$, using the formula:

$$x_0 = \frac{a_0}{a_1} \tag{7}$$

The proposed approach makes it possible to calculate the risk at any given point in time by predicting the accumulation of risk of effects, taking into account the duration of exposure and age. On this basis, it is possible to predict life expectancy and reduce it under the influence of risk factors. To describe the dependencies of the occurrence of adverse effects on human health due to malnutrition, the threshold logistic relationship between the increase in the risk of disease was used and the value of the indicator [5]:

$$\Delta R_{t\,ij} = b_{ij}\left[\frac{1}{1+e^{-b_{ij_0} x_i^j}} - \frac{1}{1+e^{-b_{ij_0}}}\right] \tag{8}$$

where, x_t^j is the normalized value of the j-th indicator in the time period t; b_{ij}, b_0^{ij}, b_1^{ij} are the parameters of the threshold logistic dependence.

The integral risk of developing health disorders for all systems associated with exposure to adverse factors is calculated by the formula [6]:

$$R_{t\,int} = 1 - \prod_i^n = 1\,(1 - R_t^i) \tag{9}$$

Based on the data obtained (Table 2), paired models have been compiled, which use the following assessment scale of the given risk index:

— the value $\widetilde{R_t}$ is less than 0.05, which can be assessed as a risk that is negligible (acceptable, allowable), not different from the usual, daily risks;

— the value $\widetilde{R_t}$ is in the range of more than 0.05-0.35, which can be assessed as a moderate risk. Measures are recommended for the organization of continuous monitoring of the structure of nutrition;

— the value $\widetilde{R_t}$ is in the range of more than 0.35-0.6, which is assessed as a high risk. Measures to reduce the impact of the negative factor are recommended;

— the value $\widetilde{R_t}$ exceeds 0.6, which is assessed as a very high risk. Measures are recommended to immediately stop non-normative consumption of nutrients and trace elements.

Table 2: *Paired Exposure-Effect Models*

Target organs	Pollutants															
	Carbon monoxide				Sulphur dioxide				Nitrogen dioxide				Suspended solids			
	R_t^i	α_i	ΔR_t^i	ΔR_t^j	R_t^i	α_i	ΔR_t^i	ΔR_t^j	R_t^i	α_i	ΔR_t^i	ΔR_t^j	R_t^i	α_i	ΔR_t^i	ΔR_t^j
DS	10^{-2}	10^{-4}	10^{-4}	10^{-4}	10^{-2}	10^{-4}	10^{-6}	10^{-5}	-	-	-	-	10^{-2}	10^{-4}	10^{-6}	10^{-5}
CCC	10^{-2}	10^{-2}	10^{-2}	10^{-3}	-	-	-	-	-	-	-	-	10^{-2}	10^{-2}	10^{-6}	10^{-6}
SC	-	-	-	-	10^{-2}	10^{-3}	10^{-2}	10^{-2}	-	-	-	-	-	-	-	-

Notes: *DS-respiratory system; CCC-cardiovascular system, SC-circulatory system.*

Coefficients that take into account the evolution of risk due to natural causes (α_i) are determined based on background morbidity and mortality rates for classes of diseases that reflect functional disorders of critical organs and systems. Health indicators characteristic of the most prosperous regions in terms of pollution of environmental objects are chosen as background levels.

The empirical values of the coefficients take into account both the severity of the clinical course and outcomes of diseases, and the degree of disruption of the activity of the functional systems of the body.

The values of risk evolution coefficients due to natural causes for critical body systems are given in (Table 3).

The evolutionary model allows you to calculate risk at any given point in time. The prediction of the risk of health disorder in the model is carried out through the calculated risk value at the current time. At the initial point in time, the risk value is assumed to be 0.01. Based on the known change in chemical exposure over time, it is possible to determine a long-term outlook for the period of life expectancy.

Initial risk levels can be estimated from the frequency and severity of morbidity and mortality at the start of the calculation.

As a result of the study, a model of recurrence ratios for individual body systems was obtained, reflecting the influence of individual environmental factors on the evolution of the risk of functional disorders critical systems.

The risk of developing circulation system disorders of varying severity from exposure to sulfur dioxide at time t:

$$R_{t+1}^{CK} = R_t^{CK} + (0{,}051 \cdot R_t^{CK} + 0{,}72 \cdot \langle e^{-0{,}000189} - e^{-0{,}000166 \cdot x} \rangle \cdot C \qquad (10)$$

where, R_{t+1}^{CK} is the risk of disorders of the body system at time t+1;
R_t^{CK} is the risk of disorders of the body's system at time t;
C is the time empirical coefficient taken in accordance with Table 3.

IV. Discussion

In the structure of morbidity the leading place in Krasnoyarsk is taken by respiratory diseases - 376.1 (the region - 334.7 cases per thousand population, the Siberian Federal District - 392.5 per 1000 population, in the Russian Federation - 403.2), in the second disease of the circulation system - 326.5. The incidence of cancer is 35.4 per thousand of the population. This trend can be seen in most territories. Based on the calculations carried out, it can be concluded that the risk of developing the respiratory system exceeds the risk of the circulation system from sulfur dioxide.It is appropriate to pay attention that in 2017, respiratory diseases are in the first place in terms of prevalence from sulfur dioxide. In 2017, in the Krasnoyarsk Territory, compared to 2016, the incidence of respiratory diseases in cases per 100 employees increased by 4.1%. In the period 2018-2019, as in previous years, acute respiratory infections of the upper respiratory tract accounted for the main share of cases in the structure of respiratory diseases — 70.1... 73.7%; bronchitis and emphysema — 4.9... 6.0%; acute pharyngitis and tonsillitis — 4.0... 5.9%; pneumonia — 2.5... 3.7% and others.

The study made it possible to determine that, in general, the effect on the respiratory system of the population Krasnoyarsk from pollution is more significant than the effect on the circulation system. This is confirmed by the fact that the increase in mortality from respiratory diseases is especially clearly associated with an increase in suspended particles in the atmospheric air with a diameter of less than 10 microns, which can cause many adverse health effects depending on their chemical composition and dispersion [7]. Further calculations can serve as the basis for organizing in-depth studies of the influence of environmental factors on the health of medical and preventive measures. Based on the results of studies, it is possible to identify an additional risk of morbidity and mortality due to diseases of almost all classes and ages.

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References

[1] Bunyatov A. The most common respiratory diseases and evaluation of the effectiveness of the implementation of hospital treatment protocols for the relevant patient populations, 2019. 13 p.

[2] Kiryanov D., Kamaltdinov M. Methodology for calculating additional morbidity and mortality based on evolutionary modeling of population health risk. Health risk analysis, 2014. 39p.

[3] State report on the state and protection of the environment in the Krasnoyarsk Territory in 2018, 2019. 302 p.

[4] Zaitseva N.V., Shur I.V., May P.Z., Kiryanov D.A., Atiskova N.G., V.M. Chigvintsev, M. Yu. Tsinker, E. V. Khrushcheva // Moscow: Federal Center for Hygiene and Epidemiology of Rospotrebnadzor, 2012. 36 p.

[5] Goryaev D., Tikhonova I. Hygienic assessment of atmospheric air quality and risks for the health of the population of the Krasnoyarsk Territory, 2018. 77 p.

[6] Rakhmanin Yu., Sinitsyna O., Novikov S. Guidelines for the comprehensive prevention of environmentally conditioned diseases based on risk assessment. M. : Federal Center for Hygiene and Epidemiology of Rospotrebnadzor, 2017. 68 p.

[7] Krasnoyarsk Regional Fund for Support of Scientific and Scientific and Technical Activities [Electronic resource] / URL: http://www.sf-kras.ru/2022/04/08/.

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RISK MANAGEMENT IN THE PRODUCTION AND TRANSPORTATION OF NATURAL GAS UNDER THE CONDITIONS OF THE ECONOMIC CRISIS IN THE ENERGY MARKET

Eldar Gasumov[1], Ramiz Gasumov[2], Gazanfar Suleymanov[1], Khalig Gurbanov[1]

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[1]Azerbaijan State University of Oil and Industry (Azerbaijan)
[2]JSC "North Caucasus Research Design Institute of Natural Gas" (Russia)
e.gasumov@gmail.com
R.Gasumov@yandex.ru
e.hasanova@asoiu.edu.az

Abstract

The article considers possible specific risks in the production and transportation of natural gas from Azerbaijan to the European continent in the context of the economic crisis in the world energy market. It is stated that the effective management of strategic, as well as specific risks, should be based on a comprehensive identification and description of the risks that determine the key indicators of the gas industry. The necessity of ways to minimize political and economic risks to ensure uninterrupted and reliable export of natural gas from the AR to the countries of the continent, including alternative routes for the transportation of natural gas, taking into account the risk of the transit country, is substantiated.

Keywords: natural gas, risks, exporter, gas pipeline, market, energy carriers.

I. Introduction

In the context of the growing demand for energy resources in the world, the Republic of Azerbaijan (AR) expressed its readiness to expand the volume of natural gas exports to the countries of the European continent. The geopolitical realities in the world and the rising cost of natural gas open up new export opportunities for the gas producing countries of the Caspian region. However, the risks associated with the extraction and transportation of natural gas are also increasing in the context of the economic crisis on energy carriers and the instability of the geopolitical situation in the world. Here, the specific features of the gas business, which differs from other types of energy carriers, are of great importance.

And also, the economic foundations for the development of the gas business also take into account the risks, taking into account the peculiarities of the current stage: the coronovirus pandemic in the world, the risk of a global recession, the energy transition (“green energy”, the development of energy from renewable energy sources (RES), low-carbon energy, hydrogen production), the introduction of elements of the fourth industrial revolution (a predicted event, the mass introduction of cyber-physical systems into production), the digitalization of gas technologies, the quality of the mineral gas resource base (SMB), etc. and a systematic approach is used in a timely manner in managing the risks of companies in the gas industry, how quickly they can provide appropriate answers to the full list of risks that have a negative impact on the production, environmental and financial and economic results of their activities, contribute to the quality preparation of measures and monitoring to prevent and prevent negative consequences that will affect not only the effective performance of their activities, but also the prospects for the gas business as a whole [1]. The gas industry has specific features, as it depends on many internal and external factors related to geopolitical, socio-economic, technical and technological, mining and geological, environmental and technological, natural and other components. In this regard, when managing risks in the gas business, one should take into account the whole range of technological risks, which allows making informed decisions on the balanced development of the production and technological process in conditions of high uncertainty, a long duration of the innovation cycle and active global competition [2]. It is necessary to consider this in the context of the entire "life cycle", from the natural gas production process to the delivery to the consumer (preparation, storage, transportation, processing) of the final product.

II. Material and research methods

The study used the analytical method, the method of comparison. Methods for collecting, processing and analyzing information were determined by the specific objectives of the study based on a systematic approach.

III. Results of the study and their discussions

Problems that reflect the specifics of the gas industry affect the implementation of the strategic goals of oil and gas companies, and this type of risk remains significant for the fuel and energy complex (FEC) of the country [2]. Azerbaijan has significant reserves of natural gas. Over the past 10 years, there has been an increase in gas production in the country by more than 2 times. Only, in 2021, 43.9 billion cubic meters of natural gas were produced in Azerbaijan, which increased by 19.5% compared to 2020. 35.1 billion cubic meters of gas were transported through the main gas pipelines, which is 18.6% more than a year earlier, and the volume of exports amounted to 65.9 million tons of liquefied hydrocarbon gas, which is 2.1 times more than 2020 [1, 3].

Azerbaijan is gradually increasing gas exports to Europe and continues to grow every year, since it has not yet brought exports to Europe to design capacity - within the second stage of the development of the gas condensate field (GCF) "Şahdəniz" (Shahdeniz), this is slightly more than 10.0 billion cubic meters per year. Accordingly, gas supplies to European markets will increase within three years, which will generally serve to saturate the markets of the continent, demonstrating, in addition, the republic's active participation in solving the problems of ensuring the energy security of Europe. The volume of Azerbaijani natural gas supplies to Europe in 2021 amounted to 8 billion cubic meters, and in subsequent years - 9.0 billion cubic meters in 2022 and more than 11.0 billion cubic meters in 2023. A gradual increase in exports is provided for by the adopted schedule in 2013, when the "Şahdəniz" consortium officially announced the construction project of the Trans-Adriatic Gas Pipeline (TAP) for the export of Azerbaijani natural gas from the second stage of the development of the "Şahdəniz" gas condensate field to Europe [1, 3, 4].

Azerbaijan reliably fulfills the concluded gas contracts, there were no interruptions in supplies, the terms of the contract were not violated, there was no political agenda behind the energy policy. Azerbaijan's energy policy is very open, transparent, business and results oriented and has led to cooperation and mutual support. The shares of Azerbaijani gas in the markets of European countries and Turkey are dynamically growing, which is why there is a need to increase production through the development of new oil and gas deposits, primarily in the waters of the Caspian shelf, including jointly with other countries in the region. And for this, there are sufficient reserves of natural gas in the fields of the countries of the Caspian region. Only proven gas reserves in Azerbaijan amount to more than 2.6 trillion cubic meters. cubic meters. The largest of them is the

"Şahdəniz" gas condensate field with reserves of more than 1.2 trillion. cubic meters, where it is planned to expand the third stage of work on the development of a field in the Caspian Sea [1, 3, 4].

This is the minimum expected reserves, since the experience of the AR associated with the development of oil and gas fields shows that the always discovered resources in volume exceed the predicted ones. This became possible due to the introduction of new technologies in the exploration of new deposits. For example, the state company SOCAR, together with the Japanese oil and gas and metallurgical corporation JOGMEC, will conduct 2D seismic surveys on the promising block Utalgi (Utalgi) in the Shamakhi-Gobustan oil and gas region on the shelf of the Caspian Sea. Such a study will make it possible to assess hydrocarbon reserves and minimize economic risks (due to the non-discovery of a productive deposit) and optimize investment investments (to ensure industrial gas production) [5].

Soon, production will begin at one of the largest GCF "Abşeron" (Absheron), where it is planned to produce 1.5 billion cubic meters of gas at the first stage. The estimated reserves of the Babek field are 400.0 billion cubic meters, the Umid field is at least 200.0 billion cubic meters. There are large reserves of natural gas in the deep-water part, where the Azəri-Çıraq-Günəşli oil and gas complex (Azeri-Chirag-Guneshli) has been operating for a long time. The commissioning of the main export route, the Southern Gas Corridor (SGC), with a diversified gas transmission network connecting Azerbaijan with Turkey and Europe, opens up new export opportunities for the gas business [4].

According to the International Energy Agency, Europe's natural gas import requirements will increase by almost 2% compared to 2021, despite a more than 4% year-on-year decline in gas demand. The AR is expanding the geography of its natural gas exports to European countries, as gas plays a key role in moving away from coal and moving towards a carbon-free economy, as well as in the current geopolitical situation in the world. The SGC gas export route is of great importance for Europe's energy security, including its potential to enter new markets such as the Western Balkans [6, 7].

Currently, SGC is considered as one of the promising priorities in the energy supply of an increasing number of countries and there is great interest in its development. European consumers are supplied with about 27.0 million cubic meters of Azerbaijani gas per day. Since the commissioning of SGC, 14.8 billion cubic meters of gas has been exported to Turkey via the Trans-Anatolian Natural Gas Pipeline (TANAP) and 9.4 billion cubic meters to Europe via TAP. Azerbaijani natural gas exports are directly connected to the Turkish gas transmission system. Considering that two gas hubs are already being formed in Europe - German and Turkish-Azerbaijani, and taking into account the length of the transport arm, logistics costs and other things, it is expedient for Turkey to create its own underground gas storages (UGS). This will further strengthen the key functions of the gas hub - this is the possibility of geo-referencing storage facilities, diversifying gas portfolios and playing a role in the market pricing of natural gas. In the near future we should expect the creation of gas hubs in Turkey and Azerbaijan. To do this, it is necessary to have not only the possibility of transit, but also the storage of natural “blue fuel”, since without this it is impossible to fully perform the functions of a gas hub [4, 8, 9].

Azerbaijan has sufficient reserves to increase the supply of natural gas to the European continent, however, unlike the oil market, the export of this energy carrier increases in the presence of specific requests from buyers and in the presence of signed export contracts. This is due to the specifics of the gas business, and primarily from the technical and technological (geological) features of the development of gas condensate fields and the production of “blue fuel”. Without a strategic vision and risk management, it is very difficult to balance the supply and demand for natural gas, since it takes more than 5 years to start gas production at a new field. Therefore, it is important to forecast options for the development of the gas business and manage risks in the production and transportation of natural gas in the context of the economic crisis in the energy market. And also, it is necessary to take into account other aspects taking place in the world energy market. Despite the fact that natural gas is considered the most environmentally friendly fossil, against the backdrop of global climate change, even on this issue there are discrepancies. All this is reflected in the decision of banking structures to provide loans, as well as the provision of prerogatives in strategic projects, which ultimately affects the cost of production [9, 10].

The export-raw material development model of the Azerbaijan Republic is characterized by its stability, however, the current economic crisis in the global energy market, as well as for managing risks in the production and export of natural gas, requires reformatting this development model, significantly strengthening the role of the state in the development of the national economy.

The geopolitical and energy crisis has become a catalyst for the transformation of international cooperation, disrupting the global technological chains of natural gas exports. Determination of the correct strategic policy of the gas industry, maintaining a stable, sustainable financial condition, in order to invest in further improving the material and resource base for the long term - this is the algorithm for the success of oil and gas companies in the fuel and energy complex (FEC). In this regard, the implementation of promising projects and mechanisms to ensure proper quality and optimal choice of company strategies should be focused on the risks associated with key trends and problems in the development of the gas industry [2].

Azerbaijan is studying the possibility of expanding gas supplies to Europe. In accordance with EU legislation, Trans Adriatic Pipeline AG (TAP AG) regularly conducts market testing to determine the commercial feasibility of increasing the capacity of the main gas pipeline. The next market test is currently underway, and based on its results during this year, TAP AG will determine whether the capacity of the pipeline will be expanded and, if so, by how much. The test results will help improve the quality of making feasibility-based managerial and strategic decisions with minimal risks [6, 9, 10].

The EU favors secure natural gas supply routes and reliable energy exporters. On this issue, the positions of the Azerbaijan Republic and the EU fully coincide, since the energy policy of the Republic of Azerbaijan is very open, transparent, designed for business and results, and has led to cooperation and mutual support. Azerbaijan has been proving in practice and real deeds for more than ten years that it is a reliable partner and a conscientious exporter of the fulfillment of agreements on the supply of oil and gas. Despite the fact that the Azerbaijani energy carrier remains inexpensive for European consumers, it is necessary to improve and strengthen risk management in the gas business.

An important stage in the process of risk management is the systematization of specific risks, which makes it possible to improve the mechanisms of economic management of the gas industry, taking into account risk minimization. Specific risks of the gas industry at different stages of the production cycle [2]:

- at the exploration stage (GEW): exploration errors and undiscovered deposits; discovery of an unprofitable deposit; irrational development of the deposit and its earlier development; losses due to inaccurate determination of the volume of reserves and the hydrocarbon recovery factor (HC);

- in the development of hydrocarbon fields: the wrong choice of drilling technology, hydrocarbon production and reserves assessment; technical failures of equipment and force majeure situations; pollution during the discharge of formation waters, liquid and solid wastes; impact on the ecosystem during geological exploration and geophysical research; delays, failures, stoppages of hydrocarbon production; lack of qualified personnel in the context of the digitalization of the industry;

- in the development of hydrocarbon fields: the wrong choice of drilling technology, hydrocarbon production and reserves assessment; technical failures of equipment and force majeure situations; pollution during the discharge of formation waters, liquid and solid wastes; impact on the ecosystem during geological exploration and geophysical research; delays, failures, stoppages of hydrocarbon production; lack of qualified personnel in the context of industry digitalization;

- when storing natural gas: an unsuccessful choice of an underground reservoir (geological section) for creating an underground gas storage; wrong choice of drilling technology; non-compliance with the technological regime of gas extraction and injection into the reservoir; incorrect assessment of the thickness of the deposit; incorrect choice of the grid (location) for the placement of observation and production wells; the presence of interlayer flows and the formation of technogenic deposits;
- in the processing of gas and condensate: installation of equipment for the processing of raw materials with poor quality characteristics; logistics of the production cycle of gas and condensate processing; delays, failures, stops in the processing of raw materials; ineffective recruitment;
- when transporting gas: related to the conditions of the gas and condensate sales market, the return of products; transport risk; transit country risk;
- when selling gas and gas condensate in the domestic and foreign markets: the imposition of sanctions by foreign countries; changes in the course of the government and legislation on the use of raw materials, environmental protection, tax and customs regimes; in case of non-receipt, suspension of licenses and permits; investment opportunities for field development, development participants [2, 11, 12].

The most important thing in the system of specific risks is to distribute them according to the stages of production. The most difficult to quantify and qualitatively assess the specific risks arising at the exploration stage, resulting from geological exploration and geophysical developments. In addition, with the help of the proposed system of specific risks, a more complete range of accounting for geological risks is achieved, which in the future will provide information on possible deviations in production and financial indicators, thereby minimizing the losses of oil and gas enterprises associated with investing in field development. oil and gas [2, 12, 13].

Transport risk and the risk of a transit country is the most important factor in foreign economic activity and the implementation of export deliveries. Since the transport system for the export of hydrocarbons has a number of problems, characterized by economic feasibility, political influence and the presence of a certain kind of risk (including the geopolitical influence of different countries). In addition, in the political aspect, oil and gas companies seek to reduce the risk of an environmental catastrophe by implementing a kind of policy (the implementation of which is controlled by the relevant authorities and international organizations) aimed at enhancing the safety of energy facilities, including pipelines [12-15].

Azerbaijani natural gas supplies for export to Europe (including Turkey) are directly dependent on transit countries. Natural gas is supplied from the AR to Europe (including Turkey) through the main gas pipeline (MGP): the South Caucasus pipeline (South Caucasus pipeline - "SCPx") with a capacity of 7.5 billion cubic meters and "TANAP" with a capacity of 16.0 billion cubic meters, a section of which which passes through the territory of Georgia [7, 10, 11].

The geopolitical and geological position of the Republic of Azerbaijan allows us to assert a high transit potential of the country for the transportation of energy carriers, including natural gas from the Caspian region and East Asia, and large volumes of hydrocarbon reserves in the countries of these regions form the prerequisites for the export of natural gas to the markets of the European continent [9, 16].

The issue of natural gas transit through the territory of another country is always associated with a number of political and economic risks. Therefore, ensuring uninterrupted and reliable export of "blue fuel" by the EU consumer requires a review of the policy of gas transit through transit countries and the creation of alternative routes to manage possible risks. Azerbaijan and the gas-producing countries of the Caspian region can expand cooperation in the development of joint oil and gas fields, transportation of hydrocarbons and swap gas supplies, there are new proposals to increase the volume of supplies. New initiatives are being implemented to strengthen bilateral and multilateral cooperation in the field of gas supplies and transport logistics. As President of the Republic of Azerbaijan Ilham Aliyev noted, "We must expand our activities related to export, enter new markets. ...We have established energy ties with all four neighboring countries. We are currently working on a new project. At present, our plans already include laying a new line along the Zangezur corridor from Azerbaijan to the Nakhchivan Autonomous Republic, and from there to Turkey and Iran. I said that the Zangezur corridor was redesignated not only for railways, roads, and air transport. The Zangezur corridor will simultaneously play its role in the export of energy types" [17].

In this regard, there are good prospects for laying a new line from Absheron to Nakhchivan, entering the gas transmission network of Turkey and Iran, including an alternative route for the gas pipeline through the Zangezur corridor.

According to international experts, natural gas from Turkmenistan coming to Nakhchivan, through Iran, then in Turkey, in the future, can expand the capacity of SGC [11, 18]. And also the implementation of the Trans-Caspian Gas Pipeline (TCGP) project will allow the countries of Central Asia to supply gas to the countries of the continent in the amount of an additional 10-12 billion cubic meters per year through the territory of the Republic of Azerbaijan and Turkey. According to many experts, Caspian gas supplies can pass through the TANAP and TAP gas pipelines, and the countries of the region can increase their importance in the global economy and receive additional profit [6, 10, 18, 19]. The production and supply of liquefied natural gas (LNG) also has good prospects and is a politically and economically beneficial direction.

IV. Conclusion

Under the conditions of the economic crisis in the world's energy market, the management of the specific risks of the gas industry should be carried out at different stages of the production cycle from exploration to the delivery of "blue fuel" to the consumer.

Effective management of strategic as well as specific risks should be based on a comprehensive identification and description of risks, as well as the determination of key indicators of the gas industry, which will allow in practice to comprehensively take into account both the negative consequences of the event and the positive ones.

To minimize political and economic risks, to ensure uninterrupted and reliable export of natural gas from the AR to the countries of the continent, it is advisable to have alternative routes for the transportation of natural gas, taking into account the risk of the transit country. It is necessary to improve the production and export of LNG, as well as to develop transport logistics for the supply of LNG from the countries of the Caspian region to European markets.

References

[1] Gasumov, E.R. (2022). Analysis of the current state and development trend of the gas industry in Azerbaijan. *Bulletin of the Altai Academy of Economics and Law,* 3-2: 159-166.

[2] Lomachenko T.I. (2020). Risk management strategy for oil and gas companies. *Bulletin of the Altai Academy of Economics and Law,* 12-1: 133-137.

[3] Gasumov, E.R., Gasumov, R.A. (2022). Influence of innovation and investment activity on the development of the oil and gas industry in Azerbaijan. *Questions of Economic Sciences,* 2 (114): 15-22.

[4] Gasumov, E.R. (2021). Azerbaijan is becoming a gas research country and an exporter of gas to Europe. *Natural and Technical Sciences,* 3: 104-111.

[5] Nasibov, G.D., Mukhtarov, Kh.Z. (2021). Prospects for the oil and gas bearing Shamakhi-Gobustan depression in connection with its structural and tectonic features. *Bulletin of the Tomsk Polytechnic University. Georesources Engineering*, 4-332: 7-16.

[6] Gasumov, E.R. (2021). Azerbaijan's participation in the diversification of the continent's gas transport infrastructure. UNEC scientific news, 9-9: 60-71.

[7] Gasumov, E.R. (2021).Efficiency of expert supplies of Azerbaijan natural gas. *Polish journal of science,* 42-1. R.28-30.

[8] Gasumov, E.R. (2021). Azerbaijan becomes a regional energy hub. *Deutsche Internationale Zeitschrift fur Zeitgenossissche Wissenschaft,* 6-2: 17-20.

[9] Gasumov, E.R., Gasumov, R.A. (2021).Caspian region may become one of the main gas suppliers to Europe. *Science. Education. Practice: proceedings of the International University Science Forum (Can-ada, Toronto),* 1: 16-23.

[10] Gasumov, E.R. (2020). Principles of state innovation policy in relation to the gas industry of Azerbaijan. *Eurasian Union of Scientists,* 11(80)-5: 29-33.

[11] Karataev, A.S., Shumilova, V.M. (2012). Specific risks are generators of financial risks that are typical for oil and gas companies. *Bulletin of the Yugra State University,* 4(27): 41-44.

[12] Gasumov, E.R., Gasumov, R.A. (2020). Innovative Risk Management for Geological and Technical (Technological). *SOCAR Proceedings,* 2: 8-16.

[13] Timofeeva, S.S., Mironova, S.A. (2017). Occupational risks in conducting exploration work for oil and gas. *News of the Siberian Branch of the Earth Sciences Section of the Academy of Natural Sciences. Geology, exploration and development of mineral deposits.* 1(58): 114-126.

[14] Kidyamkin, A.A. (2014). Trends in regulating the transit of Russian gas exports to the EU. *Bulletin of the University*, 4: 66-69.

[15] Akimochkin, I.V. (2012). Problems and risk factors in the field of oil and gas transportation. Territory oil and gas, 6: 136-139.

[16] Gasumov E.R. (2021). Prospects for cooperation between the Caspian countries in the development of oil and gas fields. *Eurasian Union of Scientists,* 2(83)-5: 15-19.

[17] The President of Azerbaijan spoke at a meeting of the Advisory Council for the SGC. (2021). *URL: https://report.az/ru/energetika/prezident-azerbajdzhana-prinimaet-uchastie-v-zasedanii-konsultativnogo-soveta-po-yugk.*

[18] Gasumov, E.R. (2021).Current state and development trends of the gas industry in Azerbaijan. *International independent scientific journal,* 26-2: 3-7.

[19] Benashvili, K.A. (2020). The role of the project "Southern Gas Corridor" in the implementation of the energy strategy of the European Union. *Creative Economy,* 9-14: 2181-2193.

CONTROLLING OF THE BEGINNING OF THE LATENT PERIOD OF ACCIDENTS AT PUMPING STATIONS

Telman Aliev[1,2], Naila Musayeva[1,2], Narmin Rzayeva[1,2], Rauf Gadimov[2], Tahir Alizada[2], Ana Mammadova[1,2]

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[1]Azerbaijan University of Architecture and Construction
[2]Institute of Control Systems of the Azerbaijan National Academy of Sciences
director@cyber.az musanaila@gmail.com nikanel1@gmail.com rauf_qadimov@mail.ru
tahiralizada@gmail.com anahaciyeva@gmail.com

Abstract

It is shown that the control system of pumping stations does not ensure signaling of the beginning of the latent period of accidents. Because of this, their state of emergency is detected at the point when it becomes apparent. At the same time, elimination of a malfunction at the moment of its initiation requires much less resources and time than after-accident repairs of the pump. We propose algorithms and technologies for calculating the estimates of the noise variance and cross-correlation functions between the useful signal and the noise of the vibration signals, which allow forming informative attributes for signaling and control of the beginning of the latent period of malfunctions. These technologies can also be used to improve fault-free operation at reservoir pressure maintenance stations during oil production at compressor stations, at drilling rigs, at artesian wells, etc.

Keywords: water supply, pump stations, control malfunction, vibration signal, oil production accidents

I. Introduction

Nowadays in the pumping stations in any systems of technological water supply and water removal, as well as in urban systems of cold and hot water supply, sewage pumping stations of wastewater pumping and treatment facilities for monitoring and control, automatic control systems are used, which ensures exceptional reliability of stations and allows them to operate for a long time without repair. They process analog and discrete information according to a specified algorithm and form necessary signals to control technological equipment, display information on parameters and state of the technological process, prepare transmission of information on current state of equipment, on parameters and state of the technological process, detect emergency situations or malfunctions of technological equipment, automatically connect additional pumping units in case of insufficient capacity. Thanks to this, the population's vital problem related to water supply, water supply, wastewater pumping, irrigation of agricultural crops, etc., is addressed reliably and successfully. However, for the many advantages of the mentioned control systems, they do not provide signaling of the beginning of the latent period of accidents. The importance of this problem is due to the fact that any accident is always preceded by the initiation of certain defects, after which the latent period of accidents begins. After some time, it develops and only after that it is reflected in the readings of measuring instruments of control and monitoring systems. The duration of the latent period depends on the dynamics of defect development. Because of the above mentioned, control systems of pumping stations detect the beginning of their emergency state at the moment when it takes on explicit form. Therefore, in practice there are cases when it turns out to be late and the accident cannot be prevented. Naturally, to eliminate this drawback it is necessary to create new technologies for the monitoring and signaling of the beginning of the latent period of the emergency state of the equipment of pumping stations.

II. Problem statement

Currently, in pumping stations, the control of technological processes is carried out by means of control systems, which allow obtaining all kinds of information in time and promptly managing the process of operation of pumping stations. However, these systems do not provide the operating personnel with adequate information about the initial latent period of the emergency state. Because of this, the probability of an accident depends to a certain extent on the attentiveness and qualification of the operating personnel.

Studies have shown that a vibration process inevitably forms in pumping units as a result of continuous rotational motion under high pressure. Therefore, it is advisable to use vibration sensors to monitor the beginning of the latent period of malfunctions during the operation of pumping stations, because the beginning of the malfunction is largely reflected on the vibration signals.

At the same time, determining the moment of emergence of correlation between the useful signal and the noise of vibration signals makes it possible to adequately monitor the beginning of changes in the technical condition of the pumping station. Consequently, there is a possibility to create a tool to determine the moments of emergence of correlation between the useful signal and the noise, which allows to signal the beginning of a latent period of the emergence of an accident situation.

Thus, at the beginning of the latent period of the emergency state in the pumping unit on the vibration signals $\boldsymbol{g(t)}$ along with the noise $\boldsymbol{\varepsilon_1(t)}$ caused by external factor, the noise $\boldsymbol{\varepsilon_2(t)}$ emerges, correlated with the useful signal $\boldsymbol{X(t)}$, which is a carrier of information about the beginning of the latent accident period [1,2]. In this case, due to the presence of correlation between the useful signal $\boldsymbol{X(t)}$ and total noise $\boldsymbol{\varepsilon(t) = \varepsilon_1(t) + \varepsilon_2(t)}$, the following equality takes place:

$$\boldsymbol{D_g = M\big[(X(t)+\varepsilon(t))(X(t)+\varepsilon(t))\big] = M[X(t)X(t)] + M[X(t)\varepsilon(t)] + M[\varepsilon(t)X(t)] + M[\varepsilon(t)\varepsilon(t)]}.$$

Taking into account that for stationary vibration signals $\boldsymbol{g(i\Delta t)}$ with normal distribution law in the presence of correlation between $\boldsymbol{X(t)}$ and $\boldsymbol{\varepsilon(t)}$, the following conditions and equalities hold:

$$\boldsymbol{M[X(t)X(t)] = D_X,\ M[X(t)\varepsilon(t)] = R_{X\varepsilon}(0) \neq 0,\ M[\varepsilon(t)\varepsilon(t)] = D_\varepsilon \neq 0.}$$

We have

$$\boldsymbol{D_g \approx M[X(t)X(t)] + 2M[X(t)\varepsilon(t)] + M[\varepsilon(t)\varepsilon(t)]}.$$

Consequently, the variance $\boldsymbol{D_g}$ of the total vibration signal $\boldsymbol{g(i\Delta t)}$ is determined from the formula

$$\boldsymbol{D_g \approx D_X + 2M[X(t)\varepsilon(t)] + D_\varepsilon}. \tag{1}$$

From formula (1) it is obvious that at the beginning of the malfunction as a result of the emergence of the noise $\boldsymbol{\varepsilon_2(t)}$, due to the correlation between the useful signal $\boldsymbol{X(t)}$ and the total noise $\boldsymbol{\varepsilon(t)}$, the variance of the total noise $\boldsymbol{D_{\varepsilon\varepsilon}}$ has the following form:

$$\boldsymbol{D_{\varepsilon\varepsilon} = 2R_{X\varepsilon}(0) + D_\varepsilon}$$

Obviously, the estimates $\boldsymbol{D_\varepsilon}$ and $\boldsymbol{R_{X\varepsilon}(0)}$ of the vibration signal $\boldsymbol{g(t)}$ practically can be used as an informative attribute of the beginning of the latent malfunction period on the pumping unit. Consequently, to control the beginning of the latent period of malfunctions in the control system of pumping stations it is required to determine the estimates $\boldsymbol{R_{X\varepsilon}(0)}$ and $\boldsymbol{D_\varepsilon}$ vibration signal $\boldsymbol{g(i\Delta t)}$.

III. Difficulties of controlling the onset of malfunctions by estimates of the correlation characteristics of vibration signals

As stated above, pumping units in the process of operation tend to go into the latent period of an emergency state as a result of various defects [1-4]. Usually, this process is reflected on the vibration signals in the form of noise $\varepsilon(i\Delta t)$, which has correlation with the useful signals $X(i\Delta t)$ when a malfunction occurs [1, 5, 6]. Consequently, during this period the total noise $\varepsilon(i\Delta t)$ forms from the noise $\varepsilon_1(i\Delta t)$, which arises from the influence of external factors and from the noise $\varepsilon_2(i\Delta t)$, which arises from the emergence of various malfunctions. In this case, the variance of the vibration signal has the form:

$$D_g \approx R_{gg}(0) \approx \frac{1}{N}\sum_{i=1}^{N} g^2(i\Delta t) \approx \frac{1}{N}\sum_{i=1}^{N} X^2(i\Delta t) + 2\frac{1}{N}\sum_{i=1}^{N} X(i\Delta t)\varepsilon(i\Delta t) + \frac{1}{N}\sum_{i=1}^{N} \varepsilon^2(i\Delta t) \approx$$
$$\approx R_{XX}(0) + 2R_{X\varepsilon}(0) + R_{\varepsilon\varepsilon}(0). \qquad (2)$$

It is also known from the literature [1-4] that in this case the formula for determining the estimate $R_{gg}(\mu)$ can be represented in the form:

$$R_{gg}(\mu) \approx \frac{1}{N}\sum_{i=1}^{N} g(i\Delta t)\, g((i+\mu)\Delta t) \approx \frac{1}{N}\sum_{k=1}^{N} (X(i\Delta t) + \varepsilon(i\Delta t))(X((i+\mu)\Delta t) + \varepsilon((i+\mu)\Delta t)) \approx$$
$$\approx \frac{1}{N}\sum [X\,(i\Delta t)X((i+\mu)\Delta t) + \varepsilon(i\Delta t)X((i+\mu)\Delta t) + X(i\Delta t)\varepsilon((i+\mu)\Delta t) + \varepsilon(i\Delta t)\varepsilon((i+\mu)\Delta t) \approx$$
$$\approx R_{XX}(\mu) + R_{\varepsilon X}(\mu) + R_{X\varepsilon}(\mu) + R_{\varepsilon\varepsilon}(\mu) \approx \begin{cases} R_{XX}(0) + 2R_{X\varepsilon}(0) + R_{\varepsilon\varepsilon}(0)\ when\ \mu = 0 \\ R_{XX}(\mu) + 2R_{X\varepsilon}(\mu)\ when\ \mu \neq 0 \end{cases}. \qquad (3)$$

Experimental studies have shown [1-4] that during the operation of pumping station equipment, during the latent period of accidents $R_{X\varepsilon}(\mu)$, $R_{\varepsilon\varepsilon}(\mu)$ are tangible quantities, i.e., the following inequality takes place:

$$\begin{cases} R_{X\varepsilon}(\mu) \gg 0 \\ R_{\varepsilon\varepsilon}(\mu) \gg 0 \end{cases}$$

and therefore, there is a significant error in the estimate of $R_{gg}(\mu)$.

Because of this, it becomes difficult to ensure the adequacy of the results of monitoring the operation of equipment by traditional technologies. This is one of the factors preventing the use of traditional technologies of correlation analysis of noisy signals to control the specified equipment. In this regard, it is obviously necessary to create new effective technologies of vibration signal analysis, allowing to reduce errors from the influence of the noise $\varepsilon(i\Delta t)$ improve the adequacy of the obtained results.

From expressions (2) and (3) it is obvious that in the presence of correlation between the useful signal and the noise, the estimate of the correlation function $R_{XX}(\mu)$ of the useful signal $X(i\Delta t)$ can be determined from the expression:

$$R_{XX}(\mu) = \begin{cases} R_{gg}(0) - 2R_{X\varepsilon}(0) - R_{\varepsilon\varepsilon}(0) & \text{when } \mu = 0 \\ R_{gg}(\mu) - 2R_{X\varepsilon}(\mu) & \text{when } \mu \neq 0 \end{cases}.$$

It was shown in [1, 2] that the estimates of the variance $D_{\varepsilon\varepsilon}$ of the total noise $\varepsilon(i\Delta t)$ can be determined from the expression:

$$D_{\varepsilon\varepsilon} \approx R_{\varepsilon\varepsilon}(0) \approx \frac{1}{N}\sum_{i=1}^{N}\left[g^2(i\Delta t) + g(i\Delta t)g\big((i+2)\Delta t\big) - 2g(i\Delta t)g\big((i+1)\Delta t\big)\right].$$

Due to this it is possible to determine the estimates of the variance of the useful signal $\mathrm{X}(i\Delta t)$ according to the formula

$$D_{\mathrm{X}} = D_g - D_{\varepsilon\varepsilon}.$$

However, despite the availability of the estimates of $D_{\varepsilon\varepsilon}$ and D_{X}, to solve the problem under consideration, it is obviously necessary to create a technology for determining the estimate of the cross-correlation function $R_{X\varepsilon}(\mu)$ between the useful signal and the noise.

IV. Technology for determining the estimate of the mutual-correlation function between the useful signal and the noise of the vibration signals

Studies have shown [1, 2] that the nature of the relationship between the noise and the useful signal is clearly reflected on the estimate of the cross-correlation function $R_{gg'}(\mu)$ between the centered $g(i\Delta t)$ and non-centered $g'(i\Delta t)$ noisy signals, which can be determined from the expression:

$$R_{gg'}(\mu) = \frac{1}{N}\sum_{i=1}^{N} g(i\Delta t)g'((i+\mu)\Delta t), \tag{4}$$

$$\begin{cases} g(i\Delta t) = X(i\Delta t) + \varepsilon(i\Delta t) \\ g'(i\Delta t) = X'(i\Delta t) + \varepsilon'(i\Delta t)' \end{cases} \tag{5}$$

where $g(i\Delta t)$, $g'(i\Delta t)$, $X(i\Delta t)$, $X'(i\Delta t)$, $\varepsilon(i\Delta t)$, $\varepsilon'(i\Delta t)$ are centered and non-centered samples of the noisy signal $g(i\Delta t)$, the useful signal $X(i\Delta t)$ and the noise $\varepsilon(i\Delta t)$ respectively.

The analysis of equalities (4), (5) has shown that by means of the formula for calculating the estimate of the cross-correlation function between centered and non-centered noisy signals it is possible to estimate the cross-correlation function $R_{X\varepsilon}(\mu)$ between the useful signal $X(i\Delta t)$ and the noisy signal $\varepsilon(i\Delta t)$. In this regard, consider one possible way to analyze the relationship between the useful signal $X(i\Delta t)$ and noise $\varepsilon(i\Delta t)$. From the literature it is known that [1-4], [6-10] under the condition of stationarity, the normal distribution law and the absence of correlation between $X(i\Delta t)$ and $\varepsilon(i\Delta t)$, the following equality takes place:

$$\frac{1}{N}\sum_{i=1}^{N} X(i\Delta t)\varepsilon(i\Delta t) = 0, \tag{6}$$

$$\frac{1}{N}\sum_{i=1}^{N} X'(i\Delta t)\varepsilon'(i\Delta t) = 0 \tag{7}$$

and when calculating the estimates of $R_{gg'}(\mu)$ from formula (6), the following equalities hold between the number N^{++} of positive products of samples $g^{+}(i\Delta t)$, $g'(i\Delta t)$ and the number N^{-+} of negative products of samples $g^{-}(i\Delta t)$, $g'(i\Delta t)$

$$\begin{cases} N^{++} = N^{-+} \\ N^{++} + N^{-+} = N^{\cdot} \end{cases} \tag{8}$$

At the beginning, for the time shift $\mu = 0\Delta t, 1\Delta t, 2\Delta t, \ldots$ the following inequality takes place between the absolute values of samples $g(i\Delta t)$, $g'(i\Delta t)$ and between the sums of positive and negative products

$$R_{g^+g'}(\mu) = \frac{1}{N}\sum_{i=1}^{N^{++}} g^{+}(i\Delta t)g'((i+\mu)\Delta t) > \frac{1}{N}\sum_{i=1}^{N^{-+}} g^{-}(i\Delta t)g'((i+\mu)\Delta t) = R_{g^-g'}(\mu). \tag{9}$$

Computational experiments and analysis of expressions (4), (8) showed that when multiplying the samples of the non-centered signal $g'(i\Delta t)$ by their centered samples $g(i\Delta t)$, despite the fulfillment of equality (7), (8), the following inequality takes place

$$\frac{1}{N}\sum_{i=1}^{N^{++}} \left|g^{+}(i\Delta t)g'\left((i+\mu)\Delta t\right)\right| \neq \frac{1}{N}\sum_{i=1}^{N^{-+}} \left|g^{-}(i\Delta t)g'\left((i+\mu)\Delta t\right)\right|.$$

In formula (4), (9) the difference of the sum of positive and negative products for $\mu = 0$ is much greater than zero, i.e.,

$$\sum_{i=1}^{N^{++}} g^{+}(i\Delta t)g'((i+\mu)\Delta t) - \sum_{i=1}^{N^{-+}} g^{-}(i\Delta t)g'((i+\mu)\Delta t) \gg 0, \tag{10}$$

which shows that the correlation between $X(i\Delta t)$ and $\varepsilon(i\Delta t)$ is explicitly reflected on the estimate of $R_{g^+g'}(0)$, because the following inequality always takes place for $\mu = 0$:

$$\frac{1}{N}\sum_{i=1}^{N^{++}} g^{+}(i\Delta t)g'((i+\mu)\Delta t) \gg \frac{1}{N}\sum_{i=1}^{N^{-+}} g^{-}(i\Delta t)g'((i+\mu)\Delta t). \tag{11}$$

In most real cases, however, the quantity

$$R_{g^+g'}(0) \approx \frac{1}{N}\sum_{i=1}^{N^{++}} g^{+}(i\Delta t)g'(i\Delta t)$$

is practically a rough estimate of $R_{gg'}(\mu)$ for $\mu = 0$, i.e.,

$$R_{gg'}(0) \approx R_{g^+g'}(0).$$

Because of this, in these cases, an estimate of the correlation coefficient $R_{X\varepsilon}$ between the useful signal and the noise can be determined by the magnitude of the difference $R_{g^+g'}(0)$ and $R_{gg}(0)$ according to the formula

$$R_{X\varepsilon}(0) \approx R_{g^+g'}(0) - R_{gg}(0) = \frac{1}{N}\sum_{i=1}^{N^{++}} g^+(i\Delta t)g'(i\Delta t) - \frac{1}{N}\sum_{i=1}^{N} g(i\Delta t)g(i\Delta t).$$

Naturally, the error in the estimate of the cross-correlation function depends on the difference $R_{g^+g'}(0) - R_{g^-g'}(0)$. But practically always condition (11) is fulfilled and the difference of the obtained difference from zero can be taken as the information about the presence of correlation between the useful signal and the noise, i.e,

$$R_{X\varepsilon}(0) \approx R_{g^+g'}(0) - R_{gg}(0).$$

In practice, taking into account expression (10), an approximate estimate of $R_{X\varepsilon}(0)$ can be determined from the formula

$$R_{X\varepsilon}(0) = \left[R_{g^+g'}(0) - R_{g^-g'}(0)\right] - R_{gg}(0) = \left[\frac{1}{N}\sum_{i=1}^{N^{++}} g^+(i\Delta t)g'(i\Delta t) - \frac{1}{N}\sum_{i=1}^{N^{-+}} g^-(i\Delta t)g'(i\Delta t)\right] - \frac{1}{N}\sum_{i=1}^{N} g(i\Delta t)g(i\Delta t). \quad (12)$$

Thus, when the noise $\varepsilon_2(i\Delta t)$, which is correlated with the useful signal $X(i\Delta t)$ emerges, the estimate $R_{X\varepsilon}(0)$, which can be determined from formula (12), will be different from zero. However, if there is no correlation between them, then the estimate of $R_{X\varepsilon}(0)$ will be zero. Due to this feature of formula (12) it is evident that it is reasonable to use the estimate of $R_{X\varepsilon}(0)$ to control the onset of malfunctions of pumping stations.

V. Possibility of practical control of the beginning of accidents at pumping stations with the use of noise as a carrier of diagnostic information

Pumping units under the influence of pressure between the inlet and outlet during operation function in a continuous oscillatory mode, and it is vibration signals that contain the most information about the beginning of a latent period of emergency state of this object. However, the control system of the station registers the moment of time, when the object goes into the emergency mode, but the above-mentioned informative attribute is not used. This leads to unreasonable costs, because elimination of malfunction at the moment of its origin requires much less costs and time than after-accident repairs. Therefore, using the estimate of the correlation coefficient $\boldsymbol{R_{X\varepsilon}(0)}$ between the useful vibration signal $\boldsymbol{X(i\Delta t)}$ and the noise $\boldsymbol{\varepsilon(i\Delta t)}$ to control the beginning of the latent period of accidents is the most advisable option.

The importance of this problem is also due to the fact that in real life, most pumping stations are designed for small facilities that cannot purchase and operate expensive equipment with very advanced and expensive control and monitoring systems. In these cases, pumps with inexpensive and simple control systems are used. Here, in order to ensure fault-free operation, first of all, signaling of the beginning of the latent period of accidents is required.

It is generally known that [11, 12] during vibration control, as a rule, vibration displacement, vibration velocity and vibration acceleration sensors are used. Vibration displacement sensors characterize the position of the controlled object, vibration acceleration sensors — the rate of change in its position in time, vibration acceleration sensors — the rate of change of velocity. These three parameters characterizing vibration are interrelated and by controlling, for instance, vibration acceleration by single or double integration it is easy to calculate the other two parameters. In the low-frequency domain, vibration displacement sensors have proved themselves. For medium-frequency objects, vibration velocity sensors are usually used, and for high-frequency objects, vibration acceleration sensors are used. Based on the analysis of possible applications of various vibration sensors to monitor the beginning of changes in the technical condition of pumping units, Bean Device AX-3D type sensors, which can be easily installed on the pump structure, turned out to be one of the possible options. This sensor is preferred because it makes it possible to collect the measurement information from the sensors using Wi-Fi, via a Bean CetanWay Contoller type controller. The range of Wi-Fi signals from the BeanDevice AX-3D sensor is up to 650 meters, which is quite sufficient for the operation of pumping stations. Technical parameters of the BeanDevice AX-3D sensor are described in [1]. Thus, in this version, the signal from the vibration sensor BeanDevice AX-3D, mounted on the pump housing, is picked up at the control panel, where it is analyzed by the Bean CetanWay Contoller according to formula (12). When the estimate of $\boldsymbol{R_{X\varepsilon}(0)}$ is non-zero, an alarm is triggered.

VI. Conclusion

Nowadays, in pumping stations in any systems of technological water supply and wastewater disposal, as well as in urban systems of cold and hot water supply, sewage pumping stations of wastewater pumping and treatment facilities, automatic control system is used for monitoring and control. Thanks to this, the population's vital problem related to water supply and water supply, wastewater pumping, irrigation of agricultural crops, etc., addressed is reliably and successfully. However, for the many advantages of the mentioned control systems, they do not provide signaling of the beginning of the latent period of accidents. The importance of this issue is due to the fact that any accident is always preceded by the initiation of certain defects, after which the latent period of accidents begins and it develops after some time. Only then it begins to be reflected in the readings of measuring instruments of monitoring and control systems. The duration of the latent period depends on the dynamics of defect development. Because of the above in the control systems of pumping stations the beginning of their emergency state is registered when it takes the explicit form.

The existing technologies for analyzing noisy signals do not allow solving this problem. The algorithms and technologies proposed here for calculating the estimates of the noise variance and the cross-correlation functions between the useful signal and the noise, allow forming informative attributes for the signaling and control of the beginning of the latent period of malfunctions. Application of the proposed technology in any systems of process water supply and water disposal, in urban systems of cold and hot water supply, in sewage pumping stations of wastewater pumping and treatment facilities can increase the degree of fault-free operation of pumping stations. It should be noted that the proposed technologies can also be used to improve fault-free operation of electric centrifugal pump units in oil production, modular cluster pump stations for water injection into the reservoir to maintain reservoir pressure, as well as to improve fault-free operation of compressor stations of main oil and gas pipelines, drilling units, at artesian wells, transport facilities, etc.

References

[1] Aliev T. A. Noise Control of the Beginning and Development Dynamics of Accidents, Springer, 2019. 201 p. DOI: 10.1007/978-3-030-12512-7

[2] Aliev, T. A., A Rzayev, A. H., Guluyev, G. A. and other. (2018). Robust technology and system for management of sucker rod pumping units in oil wells, *Mechanical Systems and Signal Processing,* 99:47-56. DOI: 10.1016/j.ymssp.2017.06.010

[3] Bendat J. S. and Piersol A. G. Random Data, Analysis & Measurement Procedures, Wiley, New York, 2000.

[4] Collacott R. A. Mechanical Fault Diagnosis and condition monitoring, 1977. 506 p.

[5] Popkovich G. S. and Kuzmin A. A. Automation of water supply and sewerage systems,

Moscow, Stroyizdat, 1983. 151 p. (in Russian)

[6] Yakovlev S. V., Karelin Ya. A., Laskov Yu. M. and Kalitsun V. I. Water disposal and wastewater treatment. Moscow, Stroyizdat, 1996. 591 p. (in Russian)

[7] Thompson D. Railway Noise and Vibration: Mechanisms, Modelling and Means of Control, 1st Edition, Kindle Edition, 2008. 845 p.

[8] Metin, M and Guclu, R. (2014). Rail Vehicle Vibrations Control Using Parameters Adaptive PID Controller, *Mathematical Problems in Engineering*, Hindawi, 1-10. DOI: 10.1155/2014/728946

[9] Lin, C. C., Wang, J. F. and Chen, B. L. (2005). Train-Induced Vibration Control of High-Speed Railway Bridges Equipped with Multiple Tuned Mass Dampers. *Journal of Bridge Engineering*, 10(4):398-414. DOI: 10.1061/(ASCE)1084-0702(2005)10:4(398)

[10] Sun, C. and Gao, L. (2017). Medium-to-low-speed freight rail transport induced environmental vibration and analysis of the vibration isolation effect of building slope protection piles, *Journal of Vibroengineering*, 19(6):4531-4549. DOI: 10.21595/jve.2017.18168

[11] Anderson, D., Gautier, P., Iida, M. and other. (2016). Noise and Vibration Mitigation for Rail Transportation Systems. *Proceedings of the 12th International Workshop on Railway Noise*, *12-16 September*, Terrigal, Australia. DOI: 10.1007/978-3-319-73411-8

[12] Dudkin, E.P., Andreeva, L.A. and Sultanov, N.N. (2017). Methods of Noise and Vibration Protection on Urban Rail Transport, *Procedia Engineering*, 189:829-835. DOI: 10.1016/j.proeng.2017.05.129

CONTROL OF A TUBE FURNACE IN CONDITIONS OF RISK AND INCREASED EXPLOSION HAZARD

Aygun Safarova, Elchin Melikov, Tamella Magerramova
•
Azerbaijan State Oil and Industry University
aygsafa@rambler.ru
elchin03@mail.ru
tamellatm@gmail.com

Abstract

In the condition of rapid production intensification based on an increasingly complete and rational use of technical, material and labor resources, improvement of the production organization and labor, improvement of the system and management and planning methods, there is a need for an operational analysis of the current situation, improvement of methods for regulating, managing and reducing the anthropogenic, man-made and natural character risks. In the oil and gas sector, the distinctive features of which are the multi-connectedness and multidimensionality of their constituent technological apparatuses, industrial, environmental and economic risks are especially high. Considering that the technological processes basis is thermal processes occurring in apparatuses, in connection with this, the abstracts pay attention to topical automation issues, regulation and control of increased fire and explosion hazard processes occurring in a tube furnace, ensuring a reduction in the risk of the aforementioned emergencies.

Keywords: tube furnace, thermal processes, control object, gas-air ratio, production risk, explosive mixture, risk management

I. Introduction

Risk management is the most important element of successful activity for any production and industry associated with increased production and investment risks. All these factors are present in the oil and gas industry, and the successful operation of this industry is largely the result of proper and effective risk management, and above all, technological and industrial safety - a measures system designed to eliminate or minimize the accidents risk, environmental damage or damage to process equipment [1-4].

It is known that fires and explosions bring the greatest property damage to oil and gas enterprises, which account for almost half of all cases.

Industrial and technological safety, that is, the creation of such conditions at an enterprise or facility when the risk of accidents is minimal, and in the event of an emergency or an accident, an action plan is established to prevent it with minimal losses (damages) - an already established segment of the risk management system. Technologies for detecting and preventing the accidents development, fires and explosions are built into technological production systems [5, 6].

It should be noted that the increased danger processes of (fire and explosion hazard) also include thermal processes that play an important role in the chemical, petrochemical and oil and gas sectors.

As you know, the chemical reactions of substances, as well as their physical transformations, are accompanied by thermal phenomena. It is thermal effects that often form the basis of technological processes. In this regard, the automation issues, regulation and control of the heat exchangers functioning o, tube furnaces, evaporators and other chemical technology objects associated with heat transfer are relevant.

II. Methods

The main technological apparatuses of the refinery at the electric desalination plant-atmospheric-vacuum tube include tube various types furnaces (tube block furnaces, double tent-type furnaces, furnaces with radiant walls and vertical-torch type). Among them, tubular block furnaces are the most common, since the most perfect way to heat oil is to heat it in these furnaces [7].

In addition, when regulating the fuel gas-air ratio in similar tubular block furnaces, it is necessary to ensure safety measures, since with a lack of air in the furnace, an explosive mixture can form, which, under favorable conditions, can lead to accidents, explosions and fires [8, 9].

As is known, a tubular block furnace is a complex multidimensional and multiply connected automation and control object. When considering it as a control object, the analysis of the processes occurring in the furnace makes it possible to identify the main input and output parameters, as well as disturbing influences (Figure 1).

Disturbing influences: air temperature (controlled parameter), gas temperature (controlled parameter), rotational speed of electric motors (controlled parameter), oil consumption (controlled parameter), gas flow (controlled parameter) and oil quality (uncontrolled parameter).

The output parameter of the considered object is the oil temperature at the outlet.

The regulating purpose a tube furnace is to maintain the outlet product temperature in the presence of a large disturbances number, many of which are uncontrollable, which increases the risk of the aforementioned emergencies.

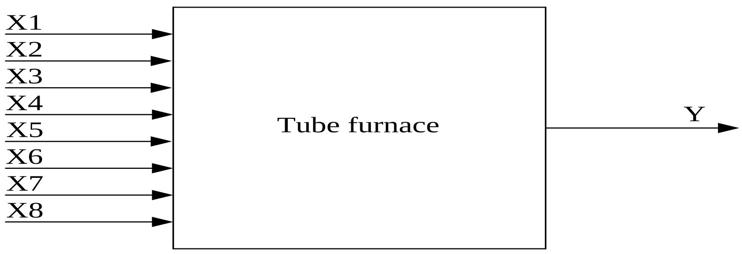

Figure 1: *Tube furnace as a control object*

X_1 - raw material consumption, X_2 - gas flow, X_3 - air flow, X_4 - temperature at the tube furnace inlet, X_5 - air temperature, X_6 - gas temperature, X_7 – rotational speed of electric motors, X_8 - oil density

In addition, a tube furnace is an inertial object with a delay in the main control channels, so the choosing task a control information parameter that quickly responds to changes in the furnace operation mode and developing an automatic control system that would compensate for the main disturbances is relevant.

The study of methods for constructing an automatic control system for the temperature at the outlet of a tube furnace is carried out on the heating an oil emulsion example that flows through the coil of a tube furnace and is heated by the heat generated during the combustion of fuel gas and air. From a large factors number affecting the exit temperature of the oil emulsion, the fuel gas supply and oil emulsion can be distinguished. The oil emulsion supply, as well as its temperature, are the main disturbances sources, and the fuel gas supply and air are control actions.

Namely, when regulating the fuel gas-air ratio, it is necessary to ensure safety measures, since an explosive mixture can form in the furnace if there is a lack of air. In this regard, it is necessary to provide for limiting the fuel flow so that this flow never exceeds the maximum allowable value corresponding to the current air flow value. When the air consumption decreases relative to a certain value, it is necessary to automatically reduce the fuel supply to the furnace. The solution to this problem can be found from the dependence of the temperature in the furnace on the ratio of fuel gas-air, which is extreme.

On Figure 2, the extreme controller finds the maximum flue gas temperatures above the pass wall by acting on the fuel gas-air ratio controller, which controls the primary air supply.

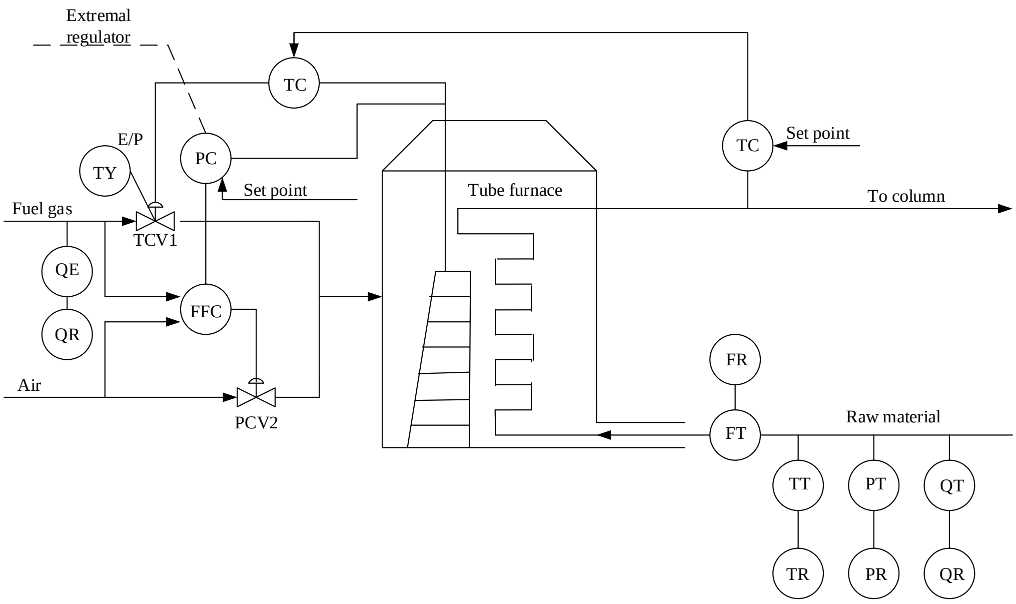

Figure 2: *Functional cascade scheme for controlling the product temperature in the furnace with an extreme controller that corrects the fuel gas-air ratio*

The circuit for stabilizing the fuel gas-air ratio is shown here. It regulates the fuel gas flow F_{fg} in a certain ratio with the air flow F_{air} (the so-called flow ratio regulator), so that the restriction on the fuel gas flow determines the temperature above the bridge wall T_{bw}:

$$F_{fg} = f(T_{bw}) \cdot F_{air}.$$

As a rule, the transfer functions for the channel fuel gas consumption - temperature above the bridge wall, as well as for the channel temperature above the bridge wall - temperature at the furnace outlet are the same type and can be described by first-order inertial dynamic links with delay:

$$W(p) = \frac{k}{T \cdot p + 1} e^{-\tau p}$$

According to the technology, the requirements with the indicator of the automatic temperature control system at the furnace outlet are as follows:

1) aperiodic nature of the transient process with an allowable overshoot of 0÷15%;

2) establishment (regulation) time no more than 3e4 s;

3) the temperature must be between 5°C and 90°C.

As a method for adjusting the controllers parameters, the method of automatic tuning for the PID-Control block using the MATLAB modeling package was chosen.

The automatic tuning results provided the specified requirements for the quality of the oil emulsion temperature transient process (Figure 3): aperiodic nature of the transient process with an 7% overshoot; regulation time T_{reg}= 2.5e4 s; the range of temperature change satisfies the technological regulations for the heating the oil emulsion process: from 5°C to no more than 90°C.

To maintain an appropriate temperature at the furnace outlet, it is also necessary to control such an important parameter of the considered technological process as the temperature in the preheater.

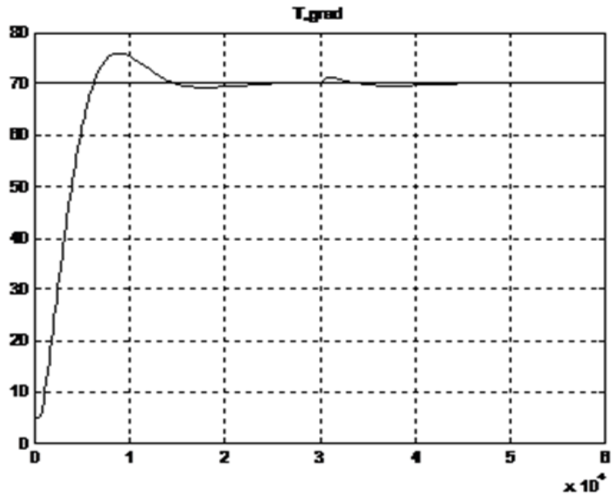

Figure 3: *Graph for the transient response of the oil emulsion temperature at the tube furnace outlet*

As a control algorithm, we will use the PID-control algorithm, which allows us to provide good control quality, a fairly short time to reach the regime and low sensitivity to external disturbing factors.

Below in Figure 4 shows a functional diagram of the oven temperature maintenance system.

The operator panel sets the temperature to be maintained in the preheater. This temperature is then fed to the PLC. The PLC also receives the value from the temperature sensor, compares the values, and finally generates a current output signal. This signal is sent to the electric drive, which opens or closes the gate valve. The electric drive converts electrical energy into the gate valve stem translational movement, resulting in a change in temperature in the tube furnace

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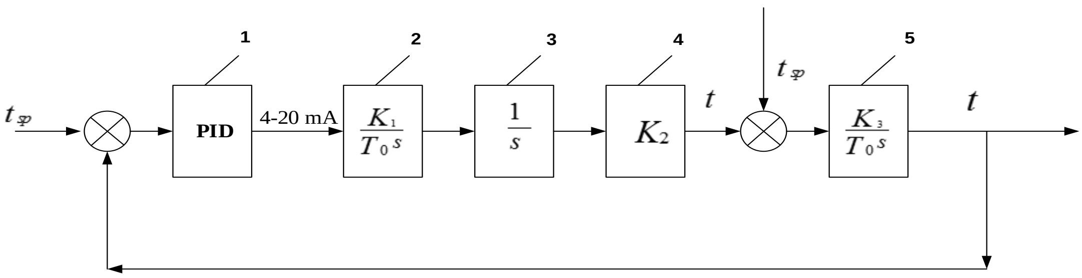

Figure 4: *Functional diagram of the temperature maintenance system in the furnace*
1 - PLC, 2 - Electric drive, 3 - Gate drive, 4 – Converting combustion gas into heat, 5 – Preheater

III. Results

The PLC also receives the value from the temperature sensor, compares the values, and finally generates a current output signal. This signal is sent to the electric drive, which opens or closes the gate valve. The electric drive converts electrical energy into the gate valve stem translational movement, resulting in a change in temperature in the tube furnace.

In this case, the linearized model of the control system is described by the following equations below set:

- discrepancy signal:

$$\theta = t_{sp} - t$$

- gate valve with electric drive:

$$T\frac{d\omega}{dt} + \omega = kI$$

$$\frac{d\varphi}{dt} = \omega$$

- preheater and gas conversion into heat:

$$v = k\varphi$$

$$T_{\text{под}}\frac{d\theta}{dt} + \theta = k_{\text{под}}v,$$

where I is the current control signal, ω is the engine angular speed, φ is the damper movement, v is the heat released when burning gas, θ is the temperature in the preheater.

In the controlling process the object under study, it is necessary to maintain the outlet temperature equal to 120 °C, therefore, a step action acts as the transfer function of the assignment, which changes its value from 0 to 120 °C at the time the program starts.

The model with selected blocks is shown in Figure 5.

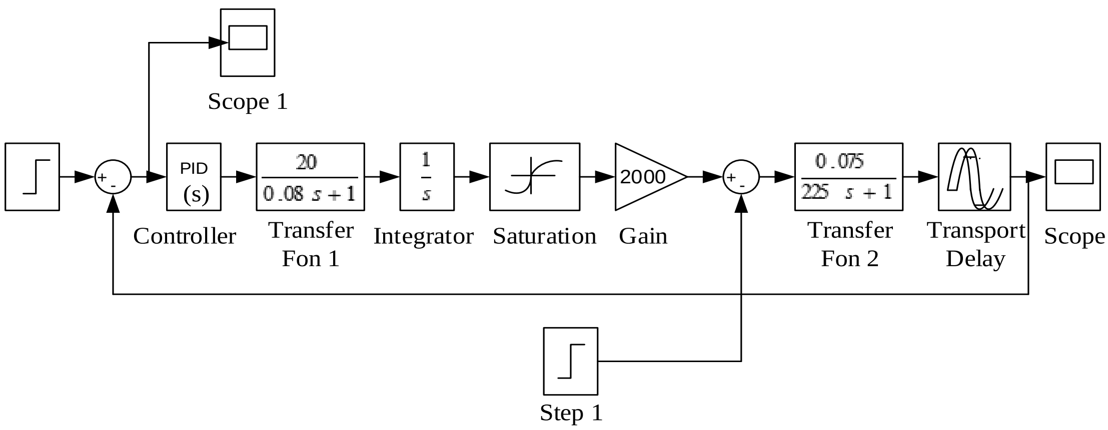

Figure 5: *Model in Simulink*

IV. Discussion

As a research result, a cascade-type control system is presented for the effective a tube furnace control, which is an object operating in risky and explosive conditions. This control system type provides more efficient and optimal control of the technological object under study, operating both under information deficiency conditions and under the various disturbances influence. In addition, in order to improve the quality of object under consideration control, the problem of synthesizing an automatic control system was solved, and the results obtained make it possible to improve the quality of the technological object under study transient process and ensure the stability of the automatic regulation system. This, in turn, minimizes the technological and technical risks that may arise at the facility, as well as the explosion likelihood of the technological apparatus.

References

[1] Khafizov A. M. Informaczionno-upravlyayushhaya sistema obespecheniya bezopasnosti trubchatykh pechej s ispolzovaniem geneticheskikh algoritmov: Dissertacziya na soiskanie uchenoj stepeni kandidata tekhnicheskikh nauk: 05.26.03/Khafizov A. M.;FGBOU VO "Ufimskij gosudarstvennyj neftyanoj tekhnicheskij universitet", 2019, 161 s.

[2] Fedorov Yu.N. Osnovy postroeniya ASUTP vzryvoopasnykh proizvodstv. V 2-kh t., M.: SINTEG, 2006, T.1, 720 s., T.2, 632 s

[3] Verevkin A.P., Matveev D.S., Khusniyarov M.K. Obespechenie bezopasnosti trubchatykh pechej na osnove operativnoj diagnostiki avarijnykh sostoyanij. Zhurnal "TERRITORIYa NEFTEGAZ" - otraslevoe nauchno-prakticheskoe izdanie, g. Moskva, #4, 2010, s. 20-23.

[4] Lebedeva M.I. Modeli i algoritmy avtomatizaczii sistemy` vzryvo-pozharozashhity tekhnologicheskogo proczessa pervichnoj pererabotki nefti. Dissertacziya na soiskanie uchenoj stepeni kandidata tekhnicheskikh nauk, g. Moskva, 2015, Akademiya Gosudarstvennoj Protivopozharnoj Sluzhby MChS Rossii, 182 s.

[5] Lebedeva, M.I. Povyshenie nadezhnosti avtomatizirovannoj sistemy upravleniya protivopozharnoj zashhitoj ob`ekta neftepererabotki/A.B. Fedorov, M.I. Lebedeva, A.B. Bogdanov//Materialy XXI nauchno-tekhnicheskoj konferenczii "Sistemy bezopasnosti – 2012", c. 216-219.

[6] Iskhakova L.A. Obespechenie nadezhnosti avtomatizirovannykh tekhnologicheskikh kompleksov/L.A. Iskhakova, D.S. Matveev//Aktualnye problemy nauki i tekhniki: Cbornik trudov I Mezhdunarodnoj konferenczii molodykh uchenykh/UGNTU, Ufa, 2009, s. 49-51.

[7] Khusniyarov M.Kh. Obespechenie bezopasnoj ekspluataczii trubchatykh pechej neftekhimii i neftepererabotki na osnove primeneniya sovremennykh sredstv i sistem avtomatizaczii/M.Kh. Khusniyarov, D.S. Matveev//Promyshlennaya bezopasnost na vzryvopozharoogneopasnykh i khimicheski opasnykh proizvodstvennykh ob`ektakh: Materialy III Mezhdunarodnoj nauchno-prakticheskoj konferenczii/redkollegiya: N.Kh. Abdrakhmanov i dr./UGNTU, Ufa, 2009, s. 69-72.

[8] Matveev D.S., Chikurov A.B., Khusniyarov M.Kh. i dr. Sistema operativnogo diagnostirovaniya avtomatizirovannogo tekhnologicheskogo kompleksa trubchatoj pechi na osnove produkczionnykh pravil//Neftegazovoe delo, Elektronnyj zhurnal-2011, #4, s. 4-13.

[9] Khafizov A.M., Koshelev N.A., Gumerov D.A., Kryshko K.A., Sidorov D.A. Razrabotka virtualnogo trenazhera - imitatora vozniknoveniya avarijnoj situaczii - snizheniya raskhoda nagrevaemogo produkta v trubchatoj nagrevatelnoj pechi//Fundamentalnye issledovaniya, 2016, # 10, s. 576-580.

METHODS OF INCREASING RELIABILITY TO REDUCE THE CONSTRUCTION RISKS OF HIGH-RISE MONOLITHIC REINFORCED CONCRETE BUILDINGS

Sahib Farzaliyev, Shaig Guluzadeh

•

Azerbaijan University of Architecture and Construction
sferzeli@gmail.com
shaiq-quluzade@mail.ru

Abstract

Since the construction of high-rise monolithic reinforced concrete buildings is a complex and dynamic system and it is influenced by a large number of factors, the quantitative indicator of organizational and technological reliability is probabilistic in nature, their assessment can be solved by mathematical statistics by interviewing experts. In our republic, the volume of construction of high-rise monolithic reinforced concrete buildings has reached a record level. Statistics show that the construction of monolithic reinforced concrete buildings in the republic is 86.0% in housing construction. This makes it relevant to study and develop methods for improving the organizational and technological reliability of high-rise monolithic reinforced concrete buildings.

The assessment of the organizational and technological reliability of the construction of monolithic reinforced concrete buildings includes such issues as the probability of completion of construction, that is, the implementation of a construction project on time and within budget, with the necessary quality. Thus, it is necessary to analyze in more detail the factors determining the reliability of the construction of monolithic reinforced concrete buildings using the methods of probability theory and mathematical statistics.

Keywords: reliability, expert assessment, high-rise, monolithic reinforced concrete, construction production, organizational-technological problems, quality control

I. Introduction

To improve the quality and competitiveness of manufactured construction products, it is required to perform work in the shortest possible time, with minimal costs and high quality, which is one of the main directions of effective production organization. Ensuring that the work is carried out according to the planned schedule depends on the overall reliability and durability of the construction complex. Both in our country and in the world, monolithic reinforced concrete construction retains its dominance in the construction of buildings and structures. Statistics on the construction of monolithic reinforced concrete buildings in our country show that the construction of monolithic reinforced concrete buildings in our republic accounts for 86.0% in housing construction. This makes it relevant to increase the organizational and technological reliability of high-rise monolithic reinforced concrete buildings.

To manage the process of business organization, it is proposed to use such a criterion as organizational and technological reliability (OTR). Quality is understood as the ability of technological, organizational, managerial decisions to provide a certain result of construction production in conditions of random violations inherent in construction as a complex stochastic system.

During the construction of monolithic reinforced concrete buildings, issues of organizational and technological reliability should be addressed in order to make rational decisions that reduce the time required to perform more labor-intensive work, reduce costs and improve the quality of construction products. Since construction production is a complex and dynamic system and it is influenced by a large number of factors, the quantitative characteristics of organizational and technological reliability are probabilistic in nature, their assessment can be solved on the basis of mathematical statistics by means of a questionnaire.

Thus, construction is the most important stage in the development of an effective means of preventing the occurrence of factors that negatively affect the timing, estimated cost and quality of the object, ensuring the reduction of construction risks and increasing its organizational and technological reliability.

Since construction is a complex production system, there is a noticeable increase in the number of factors that can negatively affect the timing, cost and quality of the construction of an object, acting as the main criteria for its organizational and technological reliability[1]. Therefore, the risk of making probabilistic decisions has a high degree, which makes it important to study and develop methods to ensure the reliability of construction.

II. Methods

The methodological basis of the research is a systematic approach aimed at studying and solving the works of domestic and foreign scientists dealing with the problems of reducing the risks of construction of high-rise monolithic reinforced concrete buildings and increasing its organizational and technological reliability.

During the research, methodological guidelines of leading scientific institutions dealing with the problem of improving the organizational and technological reliability of the construction of monolithic reinforced concrete buildings, statistical data obtained during quality monitoring, regulatory legal acts, as well as actual materials of a number of contractor construction organizations performing large volumes of monolithic reinforced concrete works were used.

The method of expert assessments, probability theory and mathematical statistics, reliability theory, graph-analytical method and mathematical modeling methods were used as the research methodology.

III. Results

3.1. Research of the indicator of organizational and technological reliability of quality improvement.

The object of the study on the basis of analytical research and scientific approach was chosen the construction of high-rise monolithic reinforced concrete buildings and structures representing a more complex construction technology. The analysis showed that currently the weakest point of the existing organization of the production of monolithic reinforced concrete buildings is the efficiency of the construction organizations and all project participants. Failure to complete the construction stage on time, a decrease in the quality of work, high labor intensity of technological operations-all this affects the reliability of the construction object as a whole. Accordingly, the most important direction of improving the technology of construction of monolithic reinforced concrete buildings is the development and implementation of organizational and technological solutions that reduce the time required to perform technological operations with greater labor intensity in the construction of monolithic buildings and structures, improve the use of machinery, mechanisms and equipment, increase labor productivity, improve the quality of construction and installation work.

Currently, the issues of increasing OTR, determined by taking into account organizational and technological factors, have a great impact on the efficiency of construction production, and management methods of these factors are becoming especially relevant. In this regard, the optimization of organizational structural and production processes in the construction of monolithic reinforced concrete buildings, which reduces the risks of construction and increases its organizational and technological reliability, is the most important stage.

Based on the analysis of regulatory documents and technical literature in the field of organization of construction production and technology, the main indicators of organizational and technological reliability of the construction of monolithic reinforced concrete buildings affecting safety and quality were identified, unresolved problems affecting the efficiency of construction processes were identified. These data allow us to conclude that it is necessary to develop new methods to improve the organizational and technological reliability of the construction of monolithic reinforced concrete buildings.

The research work under consideration is devoted to the development and formation of organizational and technological solutions, thanks to which it is possible to avoid an increase in construction time due to certain violations and to increase the OTR of the construction of monolithic reinforced concrete buildings.

The scientific hypothesis of the research work is the possibility of improving the quality of the organization and efficiency of the functioning of production processes in construction on the basis of increasing the organizational and technological reliability of the construction of monolithic reinforced concrete buildings.

Table 1: *The distribution of demand violations in percentages identified by representatives of construction organizations during construction expertise.*

Detection (non-compliance) of a demand violation	**The value of the discrepancy as a percentage**	**Accumulated percentage**
When performing concrete works	30%	30%
When performing reinforcement work	27%	57%
When performing earthworks	22%	79%
When performing mold work	11%	89%
When performing pile work	7%	96%
When performing preparatory work	3%	99%
When performing other work	1%	100%
Total:	**100%**	

As can be seen from Table 1., about 80 percent of discrepancies occur with 20 percent of the reasons that significantly improve the quality and efficiency of construction using monolithic reinforced concrete technologies.

In this case, the 80/20 rule shows that the result is mainly affected by :

- violations when performing concrete work, including when performing monolithic concrete work in winter;
- violations during the performance of reinforcement work;
- violations when performing earthworks.

The largest number of deviations identified in the construction control was revealed during the organization and production of concrete works. As a rule, the concreting stage, which includes control of access of materials to the process of pouring concrete mixture and preparation of equipment, has the longest duration of all other related work. Violations detected at the concreting stage can significantly increase the overall construction period. Thus, the elimination of the causes of violations and inconsistencies identified during the performance of concrete works will improve the quality and organization of construction work from monolithic reinforced concrete as a whole [3].

The material for constructing the Pareto diagram (Fig.1) is systematized by the nature of violations by groups within the framework of the main technological stages of work. The following groups of violations should be taken into account:

-inconsistencies in the control of primary permits;

- inconsistencies during access control to working documentation;

- inconsistencies in the quality control of the maintenance of executive documentation;

- inconsistencies in the input control of materials, structures and equipment entering the facility;

- non-compliance with the requirements of the organization of construction production;

- non-compliance with the requirements of the project documentation;

-inconsistency of organizational and legal norms, occupational safety and health, fire safety requirements, sanitary and epidemiological requirements and environmental protection requirements;

- inconsistencies during laboratory tests.

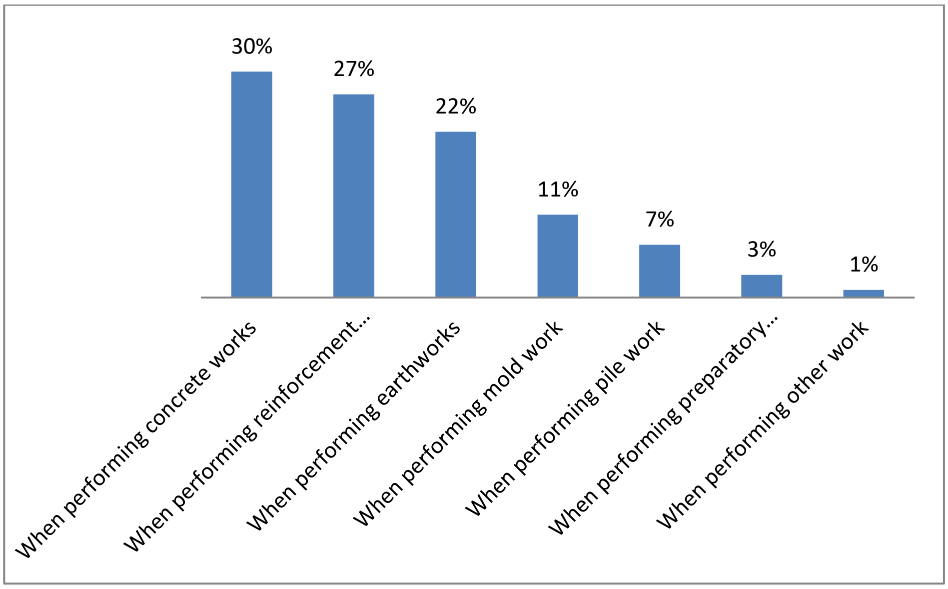

Figure 1: *Pareto diagram*

But the combination of various reasons for the formation of deviations can lead to a complete or partial failure of the production system. Therefore, in order to identify the root causes of failures in the production system, it is necessary to quantify the degree of their impact on the organizational and technological reliability of monolithic construction. According to the assessment of construction reliability indicators, we classify the main types of inconsistencies and failures of the production system according to the degree of their impact on the operational condition of the facility.

3.2. Methods for determining the reliability of the construction of high-rise monolithic reinforced concrete buildings.

The reliability of construction production can be considered as the reliability of the results of activity, the ability of an object to keep all parameters within specified limits in terms of time. Thus, reliability in construction is a complex characteristic that depends on the quantity and quality of the components of the construction process and production units, their relationship, the tendency to failures and the ability to correct them. The reliability of construction production combines the following indicators: continuity, durability, maintainability and storage capability.

Continuity is the property of an object to maintain its operability continuously for a certain period of time and throughout the entire period of operation. The probability of continuous operation is the probability that there will not be a break in the operation of the system in a given period of time.

Durability is the property of an object to maintain a state of operability until the final state is reached in the installed maintenance and repair system. Durability is laid down during design, provided during production and maintained during operation.

Maintainability is the property of an object to remain in a state of operability through maintenance and repair and suitability for restoration of operability.

Storage capacity is the property of an object to keep within specified limits the values of parameters characterizing its ability to perform the necessary functions during and after storage or transportation

The construction of high-rise monolithic reinforced concrete buildings is a complex production system consisting of numerous interconnections and elements. In accordance with this, the determination of the reliability of the construction of monolithic reinforced concrete buildings comes from a comprehensive assessment of the reliability indicators of all elements of the construction process. The process of erecting buildings or structures using monolithic reinforced concrete technology is characterized by the life cycle of the object and consists of several stages: design, manufacture, operation. Figure 2 schematically shows the organizational and technological reliability of monolithic reinforced concrete construction, taking into account its forming factors.

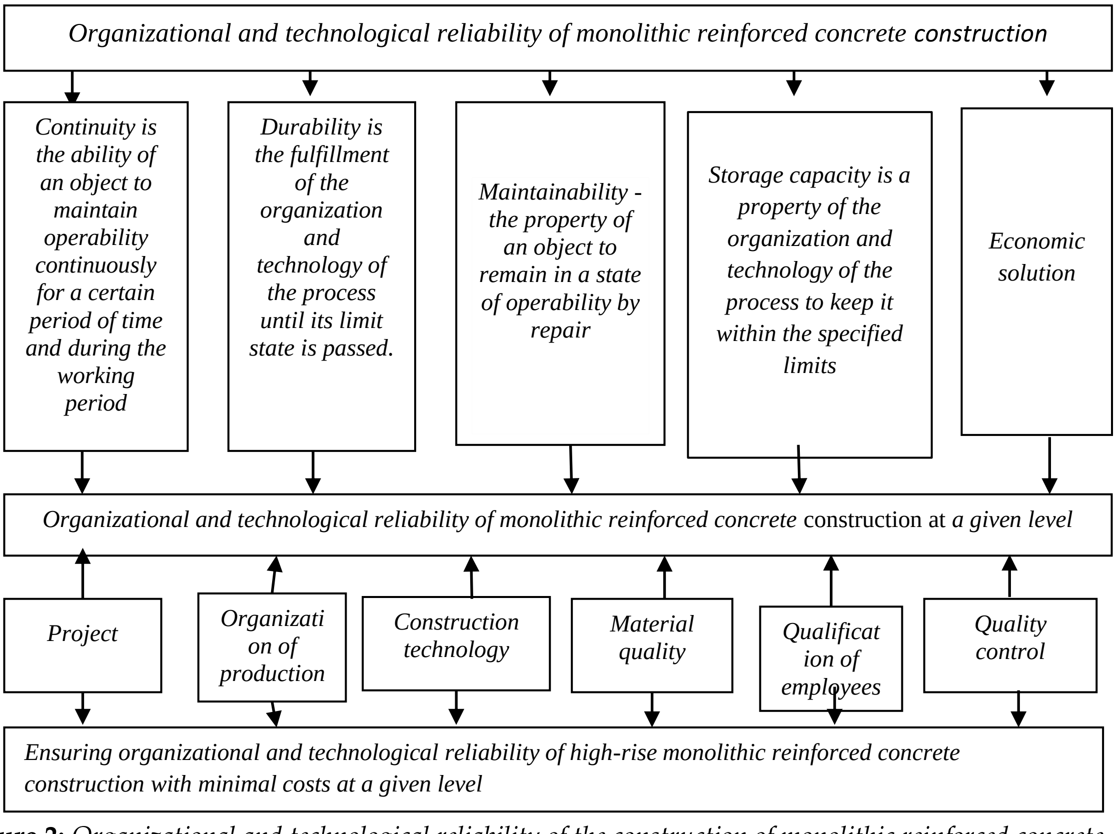

Figure 2: *Organizational and technological reliability of the construction of monolithic reinforced concrete buildings*

The features of monolithic reinforced concrete construction consist in the relationship of reliability, technology and organization of work of OTR in a timely manner and with a given quality of work project development, as well as quality control of materials and work at all stages of the life cycle of a construction object [4]. The task of OTR is to significantly reduce the cost of operating the facility and maximize the compliance of the production system with the reliability level set in the project.

The description under consideration allows us to understand that each stage of the object's life cycle affects the reliability of monolithic reinforced concrete construction. At the same time, the object itself may be in one of several states during the life cycle (serviceable, faulty, inoperable, inactive, extreme, defensive, dangerous). The transition of an object from one state to another occurs as a result of defects, injuries and failures, restorations and repairs.

A defect is a phenomenon of violation of the serviceable condition of an object.

Damage is a defect in which an object is in a faulty state, but at the same time is able to perform certain functions.

A break is an event associated with a malfunction of the object [6]. In order for the construction object to be in working condition, it is necessary to eliminate defects, damages and ruptures of the production system in a timely manner, while the values of all parameters comply with the requirements of regulatory and technical documentation. To do this, it is necessary to determine the factors that have a greater impact on the functional state of the object.[7]. Earlier, we found that the reliability of the facility is disrupted as a result of interruptions.

The failure of the production system is considered as events that occur under the influence of many random factors. Quantitative indicators of random events are based on a probabilistic measure and are determined statistically. The construction of monolithic reinforced concrete buildings is a complex probabilistic system in which it is impossible to take into account in advance all the circumstances affecting the functioning of the technological process. When erecting a building, the construction time, estimated cost, labor intensity, etc. are taken into account. such indicators as may be possible as a result of the influence of random factors, therefore they should be characterized by distributions reflecting the probability of achieving the projected number of these indicators [2]. This requirement fully applies to the construction of monolithic reinforced concrete buildings within certain limits and depends on the likely change in the initial data (design decisions) and the influence of external conditions (construction and operation processes, both internal and external influences). Based on the study of a large set of random events, collecting data on violations and interruptions of a typical production system, it is possible to conduct a systematic analysis and identify the most significant factors that ensure the reliability of the construction of monolithic reinforced concrete buildings.

A quantitative assessment of reliability is the probability of an object performing its functions. The assessment of the organizational and technological reliability of the construction of monolithic reinforced concrete buildings is possible due to the assessment of the probability of fulfilling the construction goal, that is, the successful implementation of the construction project on time within the established budget with the necessary quality. Changes in the established deadlines, cost and quality of the construction object are more influenced by violations identified at the production stage [8,9]. Thus, it is necessary to analyze in more detail the factors that form the reliability of monolithic construction, using the methods of probability theory and mathematical statistics.

IV. Discussion

In the production process of construction of high-rise monolithic reinforced concrete buildings, deviations are influenced by the following group of factors: technological, technical, organizational, climatic, social. The influence of external and internal random factors leads to the fact that the course of the production process goes beyond the previously planned factors. In this regard, the management system should develop (B) and implement (P) measures that exclude negative deviations and ensure that the control object achieves the desired result.

The ability to perform these actions at this level of the management system p determines the reliability of the functioning of the management system p (U)considered at the management level U:

$$p(U) = p(B, P). \quad (1)$$

The solution of the reliability problem according to this formula consists in the development and implementation of measures (plans, organizational and managerial decisions) that ensure the achievement of the result set by the management object.

As is known in probability theory, there is a probability multiplication rule, which for dependent events states: the probability of two events occurring together is equal to the conditional probability of the second event calculated from the probability of the first event. Analyzing this rule, it is possible to interpret with the utmost certainty the interaction between the subsystem of solution development and the subsystem of their implementation.

Then the expression can be expressed as follows:

$$p(U) = p(B,P) = p(B) \text{ x } pB(P), \quad (2)$$

where p(B) is the probability of developing solutions that ensure the achievement of a certain goal of the system; pB(P) is the probability of the system implementing the developed solutions to achieve a certain goal of the system.

It follows from expression (2) that the possibility of developing solutions and the possibility of their implementation can be considered separately. This result defines two directions in the practice of solving the problem of reliability: consideration of the reliability of the development of solutions and ensuring the reliability of the functioning of the system in the process of implementing solutions

V. Practical Importance

The results of the study can be applied in the activities of enterprises engaged in the construction of high-rise monolithic reinforced concrete buildings. It can also be successfully used by contractors engaged in the construction of high-rise monolithic reinforced concrete buildings to reduce production risks, increase organizational and technological reliability, improve the quality of construction products, effective management and the development of promising concepts. It is also possible to ensure the creation of a cheap construction product in the construction market.

VI. Conclusions

1. Evaluation of the construction of high-rise monolithic reinforced concrete buildings is possible on the basis of the theory of organizational and technological reliability (OTR).
2. It is possible to increase the manufacturability, efficiency and quality of production processes by increasing the organizational and technological reliability of monolithic reinforced concrete construction.
3. To develop an effective system of technical support for the construction of high-rise monolithic reinforced concrete buildings, such organizational and technological models as the construction organization project (COP) and the work production project (WPP) should be used.
4. As a result of the analysis, it was found that changes in terms of time, cost and quality, which is the main criterion of quality of OTR, are more influenced by violations identified at the production stage.
5. The conducted analyses led to the development of a modern methodology for operational

assessment and management of organizational and technological reliability of the construction of high-rise monolithic reinforced concrete buildings.

6. The conducted analyses require the development of a modern methodology for operational assessment and management of organizational and technological reliability of the construction of high-rise monolithic reinforced concrete buildings.

References

[1] Farzaliev S.A. Modern organizational and technological solutions for improving the quality of construction products. Materials of the scientific and practical conference, Baku, Az.UA and C, (08-09 June 2017).

[2] Farzaliev S.A. Balagezov A.M. Technology of monolithic reinforced concrete works (textbook) Baku – 2018.

[3] Farzaliev S.A., Analysis of factors influencing organizational and technological solutions in the construction of high-rise monolithic reinforced concrete buildings, Collection of scientific papers Az.UA and C 2020 p.80

[4] Ginzburg A.V. Automation of design of organizational and technological reliability of construction - M.: SIP RIA, 1999. 156p.

[5] Shalyagin, G.L. Organizational and technological reliability: a method. manual for conducting practical classes / G.L. Shalyagin, I.V. Potapova – Khabarovsk: Publishing House of DVGUPS, 2006. 52 p.

[6] Abramov D.N., The main causes of defects in concrete structures // Technology of concrete. 2014. No. 8. pp. 42-43.

[7] Alekseev, V.K. Defects of load-bearing structures of buildings and structures, ways to eliminate them, 1982. 176p.

[8] Grozdov V.T. Defects of building structures and their consequences. St. Petersburg, 2007. 136p.

[9] Fizdel I.A. Defects and methods of their elimination in structures and structures. M., Stroyizdat. 1969. 160 p.

ENVIRONMENTAL AND ECONOMIC RISKS OF THE OIL AND GAS SECTOR

Fatima Dakhaeva, Tamerlan Magomaev

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[1]Chechen State University named after A.A. Kadyrov, Russia
[2]Grozny State Oil Technical University named after Acad. M.D. Millionshchikov, Russia
dahaevaf@mail.ru
medic86@mail.ru

Abstract

In order to manage environmental safety in order to fulfill the tasks formulated in the Law of the Russian Federation "On the Basic Principles (Strategy) and State Environmental Policy for the Period until 2020", the problem of assessing the technogenic impact is becoming increasingly relevant. The works of many authors have created methodological and theoretical prerequisites for the further development of the assessment and modeling of environmental risks, taking into account technogenic atmospheric pollution for managing environmental safety. At the same time, there is a need to further improve the mechanisms for managing the environmental and economic safety of technogenically loaded regions, industrial centers and cities. The purpose of the article is to analyze modern methods for assessing environmental risks associated with the exploitation of oil fields.

Keywords: economic risks, environmental safety, environmental problems, technological atmospheric pollution, natural resources, industrial centers

I. Introduction

Under the environmental risk is understood the probability of adverse consequences for the environment of any changes in natural objects and factors. The risk is considered as the probability of occurrence of extraordinary events in a certain period of time, expressed in quantitative parameters. The man-made aspect of environmental risk is more often considered - the probability of man-made accidents that can cause significant harm to the environment or human health. Some risks are specific, others cannot be specifically identified. There are occupational risks – the danger of occupational diseases [1]. Environmental risk is often considered in two aspects - potential risk and real risk. Potential environmental risk is a phenomenon of danger of violation of the relationship of living organisms with the environment as a result of the action of natural or anthropogenic factors. A real environmental risk is formed by a potential one, taking into account the likely frequency of its implementation. According to the nature of manifestation, environmental risk can be sudden (technogenic accident, earthquake, etc.) and slow (displacement, flooding, erosion, etc.). Risk assessment is an analysis of the causes of its occurrence and the extent of its manifestation in a particular situation [2]. The danger of man-made accidents, significant in their consequences, is more associated with chemical and petrochemical enterprises, nuclear and thermal power plants, mines, and sewerage facilities. The probability of occurrence of man-caused accidents is largely determined by the effectiveness of environmental protection activities. Environmental risks when drilling wells. The experience of large offshore oil and gas projects shows that this type of activity is accompanied by a large amount of emissions: into the atmosphere, the marine environment, etc. Even after the cessation of oil or gas production at the field, environmental risks still remain [3]. Well drilling begins already at the stage of geological and geophysical surveys in those areas where seismic surveys indicate the presence of oil and gas bearing structures. Almost all stages and operations of exploration and production of hydrocarbons are accompanied by the discharge of liquid and solid waste. The volumes of these discharges reach 5000 m 3 for each passed well in the form of waste drilling fluids and cuttings, which are rocks drilled in the well. Liquid waste includes a huge number of toxic impurities necessary for the smooth operation of drilling equipment, heavy metals that accumulate from rock workings, as well as clay suspensions that increase the turbidity of water at discharge sites. The use of oil-based drilling fluids is of great danger. Sludges impregnated with such a solution are the main source of oil pollution during drilling operations. Another significant source of pollution is the discharge of formation waters coming from [4] wells. Their composition is distinguished not only by a high content of petroleum hydrocarbons and heavy metals, but also by abnormal mineralization, which is usually higher than the salinity of sea water. This may be the reason for the violation of the hydrochemical regime in the area of formation water discharge. In addition, they contain natural radionuclides, which, upon contact with sea water, precipitate and form local microclusters. The longer the field is exploited, the more formation water is formed. Produced water can be returned to the sea with or without prior treatment, or pumped back into natural reservoirs (wells). According to Russian legislation, used drilling fluid and other wastes must be accumulated and transported for further processing or undergo special treatment before being discharged overboard. Often these precautions are bypassed. Currently, there are no effective technologies for processing petroleum products, and specialized storage facilities are overcrowded. The local impact of waste from one well is noted within a radius of 3–5 km, but if the number of wells is large enough, then their negative impact can "cover" the whole fishing bank. For example, according to the Norwegian Institute for Marine Research, the scarcity of the North Sea ecosystem is the result of oil and gas activities. Oil spills [5]. The development of oil and gas fields, as well as the transportation of hydrocarbons, is accompanied by accidental spills of oil or chemicals. The most common causes of accidents include equipment failure, human error and extreme environmental conditions. The environmental consequences of accidental releases become especially severe when they occur near the coast or in areas with slow water exchange [5-6].

Drilling accidents are unexpected surges of liquid and gaseous hydrocarbons from a well during drilling when opening zones with abnormally high reservoir pressure. In rare cases, with very large pressure drops, the accident will have a long-term catastrophic nature, and deviated wells will have to be drilled to stop the blowouts. Another group of accidents includes regular "normal" blowouts that can be stopped within a few hours without additional drilling. The danger of such releases lies precisely in their regularity, which ultimately leads to chronic impacts on the marine environment. One-time or systematic oil spills can lead to serious disturbances in the functioning of the marine ecosystem [7]:

- deterioration of the chemical composition of water and its physical parameters (transparency, temperature, etc.);
- death of living organisms as a result of the ingress of oil products on the surface layer of the skin and plumage;
- forced change in migration routes, molting, nesting and spawning, etc.

Air emissions.

Emissions of pollutants into the atmosphere always accompany any oil fields. The most common source of such emissions is the flaring of associated gas and excess hydrocarbons during well testing and operation [8]. According to some estimates, up to 30% of flared hydrocarbons are released into the atmosphere and then fall to the sea surface, forming relatively unstable thin films around drilling platforms. Emissions of "greenhouse" gases. The oil and gas industry is a significant contributor to climate change through the release of large amounts of greenhouse gases such as CO2 and CH4. The majority of these emissions result from the burning of oil or gas to generate the energy needed to operate the production platform installed at the field, as well as from the flaring of associated gas. NOx emissions are generated by the combustion of associated gas and gas in turbines needed to generate energy. The influence of this type of emissions is local, but it can cause serious environmental damage to coastal ecosystems, since a large content of this substance in the atmosphere can lead to acid rain. Emissions of nmVOCs (non-methane volatile organic carbons) are generated as a result of the evaporation of crude oil during its storage or transshipment to terminals. When nmVOCs react with NOx in the sun, ozone is formed. High concentrations of ozone in the ground layer can harm human health, vegetation, and buildings.

II. Methods

Developed industry and infrastructure, an increase in the number of vehicles, the placement of a large number of industrial facilities in a small area leads to an increased technogenic load on the environment, causing its change and transformation [3-4]. The formation of an economic mechanism for nature management involves taking into account the consequences of possible environmental and economic risks, the emergence of which is initiated by the processes of anthropogenic activity. To assess the technogenic load, we proposed the concept of the threshold impact of technogenic objects on the components of the natural environment. The assessment of the technogenic load in general terms includes the process of identifying, assessing and predicting the negative impact on the environment and / or human health as a result of the operation of industrial and other industries and facilities that may pose a danger to the population and the environment after reaching a certain value, which can be called threshold of technogenic load [4]. Risk assessment is an environmental safety management tool. Environmental risk assessment is defined as a process that assesses the likelihood of adverse environmental impacts that cause stress and eventually degradation of ecosystems or deterioration in public health in areas with increased anthropogenic pressure. The procedure for conducting an analysis of environmental risk, which is caused by environmental pollution, can be divided into two stages [5]: risk assessment and risk management. A generalized risk assessment includes the identification of hazard factors and the determination of the degree of this negative impact in terms of the level of effects on human health and the state of the environment. In risk management, the tasks of regulating the effects of impact on humans and the environment are solved, the economic block of which is based on an analysis of the effectiveness of measures to reduce the magnitude of effects to a certain level. Depending on the purpose and scope of work, data and means, individual steps (screening analysis) or a complete risk assessment can be performed [6]. For example, if it is necessary to determine the size of the danger posed by one or more harmful environmental factors, a risk assessment is applied due to the action of these factors. If the task is to select technical solutions of various costs that reduce the risk from emissions from any source, it is necessary to use economic approaches to risk management. Comparative risk analysis guides users on how, given limited funds, to choose a priority and easier problem to solve from all possible ones. Assessment and analysis of environmental risks due to constant technogenic load or emergencies that have negative environmental and economic consequences, allow us to evaluate quantitative risk indicators in the form of [7]: 1) damage to natural ecosystems; 2) economic losses in the form of accelerated wear of units, structures, installations; 3) socio-economic damage to the health of the population caused by increased environmental pollution; 4) additional expenses for the elimination of the consequences of accidents and catastrophes. The quantitative value of the economic criteria used depends on environmental risk factors. In general, the economic assessment of environmental risk is based on the calculation of damage and benefits from potential or real changes in the state of the environment due to technogenic load. This assessment is based on the analysis of two main aspects - the state of the recipients of the impact and the characteristics of the technogenic impact [8]. Economic damage from environmental disturbance should be understood as the value of actual and possible losses that are inflicted on economic entities as a result of environmentally destructive impact. Different countries, depending on national characteristics, available resources and other factors, assess environmental and economic risks using various mechanisms. For example, in the Netherlands, the USA and a number of other countries, the principle is used, the essence of which is that the region establishes a general allowable emission rate for a particular pollutant. Within the framework of such a norm, the distribution of the total allowable emission volume between enterprises, as well as the distribution of the emission volume of each enterprise between individual sources of pollution, should be regulated [9].

The concept of environmental risk links the increase in environmental protection costs with the expected value of loss reduction, which are determined not by the established emission standard, but by the level of risk caused by the constant presence of a pollutant in the environment and the corresponding economic damage. At the same time, human health is taken as the main indicator of losses, i.e. The criterion for the cleanliness of the environment is not the normative levels of pollution, but the absence of diseases caused by environmental factors. The advantage in calculating the economic assessment of environmental damage based on the theory of environmental risk in comparison with the normative approach is the desire to obtain the maximum effect due to a more complete (comprehensive) accounting of losses from environmental pollution, reduced to one recipient person or ecosystem, and the choice of a rational investment structure resources in activities for its protection and restoration.

III. Results

Known methods of economic assessment of environmental risk by calculating the specific indicators of technogenic load, which leads to environmental risks. In this case, the environmental load is used as a tool for the economic assessment of environmental safety, the use and setting of the level of which causes the cost of compensatory measures, depending on the specific environmental situation, specific measures and the possibility of implementation. In order to take preventive and prophylactic measures aimed at reducing environmental accidents at oil and gas complex facilities, it is proposed to the heads of the territorial bodies of Rostekhnadzor: to analyze the materials on the state of accidents and injuries at oil and gas complex facilities with the inspector staff and bring the information to the heads of controlled organizations. When conducting inspections [10]:

- strengthen control over the implementation by supervised organizations of measures to eliminate violations of industrial safety requirements, as well as to finance these measures and reduce the time for bringing hazardous production facilities in line with the requirements of federal norms and rules in the field of industrial safety;
- pay special attention to the availability and implementation by organizations of plans for diagnosing equipment in a timely manner; timely decommissioning of defective equipment and its replacement; ensuring production control over the quality of audits, equipment repairs, industrial safety reviews;
- to include in the scope of verification activities the issues of compliance by the production personnel of organizations with technological regulations, instructions for the safe conduct of repair, gas hazardous, hot work and other operational documentation. If there are cases of violation of the requirements of the instructions when performing high-risk work or performing repair work on equipment that is in operation or unprepared for such work, take strict administrative measures against officials responsible for carrying out these works, up to and including their disqualification;
- ensure the verification of the implementation of industrial safety management systems at facilities of hazard classes 1 and 2, as well as the analysis of the developed action plans for the localization and elimination of the consequences of accidents. At the same time, it is necessary to pay attention to the effectiveness of preventive measures, as well as to the readiness of professional emergency rescue teams to localize and eliminate accidents as soon as possible.

The impact on marine organisms and ecosystems begins with geological and geophysical surveys of the seabed, aimed at determining its oil and gas content. Most often, seismic exploration methods are used. Marine seismic exploration is based on the generation of seismic waves and the registration of vibrations reflected from the bottom surface, which makes it possible to judge the structure and oil and gas content of sedimentary rocks. Water hammer effect up to 150 atm. leads to the death or damage to organs and tissues of adult fish and fry. There are known cases of disruption of salmon migration routes in the area of seismic surveys. The noise generated by seismic surveys makes it difficult for marine organisms to identify other sounds, communicate with each other and search for food. This is especially true for whales. There are cases when animals, attracted by sounds unknown to them, received serious, and often fatal injuries from powerful water hammers. Many species of fish are leaving the exploration areas. Following them, predators also leave, leaving their favorite habitats. However, some organisms can exist only under strictly defined conditions, and many of them will die without having time to get used to the new environment [9].

Well drilling begins already at the stage of geological and geophysical surveys in those areas where seismic surveys indicate the presence of oil and gas bearing structures. Almost all stages and operations of exploration and production of hydrocarbons are accompanied by the discharge of liquid and solid waste. The volumes of these discharges reach 5000 cubic meters. for each passed well in the form of waste drilling fluids and cuttings, which are rocks drilled in the well. Liquid waste includes a huge number of toxic impurities necessary for the smooth operation of drilling equipment, heavy metals that accumulate from rock workings, as well as clay suspensions that increase the turbidity of water in places of discharge. The greatest danger is the use of oil-based drilling fluids. Sludge impregnated with such a solution is the main source of oil pollution during drilling operations. Another significant source of pollution is the discharge of formation waters coming from wells. Their composition is distinguished not only by a high content of petroleum hydrocarbons and heavy metals, but also by abnormal mineralization, which is usually higher than the salinity of sea water. This may be the reason for the violation of the hydrochemical regime in the area of formation water discharge. In addition, they contain natural radionuclides, which, upon contact with sea water, precipitate and form local microclusters. The longer the field is exploited, the more formation water is formed. Produced water can be returned to the sea with or without prior treatment, or pumped back into natural reservoirs (wells). According to Russian legislation, used drilling fluid and other wastes must be accumulated and transported to shore for further processing or undergo special treatment before being discharged overboard. Often these precautions are bypassed. Currently, there are no effective technologies for processing petroleum products, and specialized storage facilities are overcrowded. The local impact of waste from one well is noted within a radius of 3–5 km, but if the number of wells is large enough, then their negative impact can cover the whole fishing bank. For example, according to the Norwegian Institute of Marine Research, the scarcity of the North Sea ecosystem is the result of oil and gas activities [8-9].

The development of oil and gas fields, as well as the transportation of hydrocarbons, is accompanied by accidental spills of oil or chemicals. The most common causes of accidents include equipment failure, human error and extreme environmental conditions. The environmental consequences of accidental releases become especially severe when they occur near the coast or in areas with slow water exchange. Drilling accidents are unexpected surges of liquid and gaseous hydrocarbons from a well during drilling when opening zones with abnormally high reservoir pressure. In rare cases, with very large pressure drops, the accident will have a long-term catastrophic nature, and deviated wells will have to be drilled to stop the emissions. Another group of accidents includes regular normal blowouts that can be stopped within a few hours without additional drilling. The danger of such releases lies precisely in their regularity, which ultimately leads to chronic impacts on the marine environment. One-time or systematic oil spills can lead to serious disturbances in the functioning of the marine ecosystem [7-8]: deterioration of the chemical composition of water and its physical parameters (transparency, temperature, etc.), death of living organisms as a result of oil products getting on the surface layer of the skin and plumage, forced rerouting migration, molting, nesting and spawning, etc.

IV. Discussion

The conducted analysis showed that as a criterion for assessing the real environmental risk that is formed on a local and regional scale, a potential characteristic of economic losses quantitatively associated with technogenic factors of industrial production can be used. The mechanism of economic assessment of damage from environmental pollution based on risk theory, in comparison with the normative approach, makes it possible to more fully take into account the consequences of the impact of anthropogenic factors in monetary terms for pollutants and their sources. In this case, it becomes possible to predict environmental pollution factors potentially dangerous for the state of the ecosystem and human health. In the theory of safety in the technogenic sphere, there are dozens of potential hazards that turn into threats and create various risks. In general, the safety of the technogenic sphere can be divided into two aspects [5]: 1) technogenic safety determines the degree of protection of a person, objects and the environment from threats emanating from the created and functioning complex technical systems in the event of the occurrence and development of emergency and catastrophic situations; 2) technological safety determines the degree of protection of a person, society, objects and the environment from threats associated with the unreasonable creation or non-creation of technical systems, technological processes and materials that ensure the achievement of the main national interests of the country. The growth of potential and real threats in the technogenic sphere requires strengthening the role of the state in solving the problems of technogenic and technological security. In the future, risks in the technogenic sphere may change dramatically: technogenic risks will replace technological risks, and damages will arise due to the destruction of the national technological base.

In a number of cases, accidental releases of oil and gas on onshore main pipelines, when they occur at the intersection or near large rivers, are also dangerous for coastal marine ecosystems, since any pollution of river waters sooner or later affects the state of the estuarine zone [6]. One of the main sources of impact on the marine environment during the construction of an underwater pipeline is excavation during trenching and approach channels, deepening and backfilling of pipelines and soil dumping, accompanied by: deposits; a change in the hydrochemical regime of sea water during the release of pollutants from bottom sediments during earthworks. As a result of the transportation of hydrocarbons by an underwater pipeline, the bottom waters are heated and cooled in the pipeline zone. It is likely that there will be no significant temperature changes in a layer of water mass that is significant in thickness, and the effect of temperature changes on benthos will be limited to a very narrow strip along the pipes. At the same time, the possibility of the influence of these changes as a signal factor on migratory demersal fish cannot be completely ruled out. Thus, it is the negative temperature of the bottom waters that under natural conditions limits the migration of some commercial fish, such as cod, haddock, and sea flounder [8-9]. At present, according to experts from the Ministry of the Russian Federation for Civil Defense, Emergencies and Disaster Relief (MES), the accident rate at pipelines is increasing every year. The intensive load of the main oil pipelines, which moved annually in the 80s. more than 500 million tons of oil, has led to the fact that their main part is badly worn out and requires significant reconstruction. Without this, accidents with great environmental damage and large material losses are likely in the coming years.

References

[1] Safety of Russia. Legal, social and economic and scientific and technical aspects. Safety of pipeline transport, 2020, p.752.

[2] Bulatov A.I., Voloshchenko E.Yu., Kusov G.V., Savenok O.V. Ecology at construction of oil and gas wells : manual for students of higher education institutions, 2019, p.603.

[3] Menshikov V.V., Shvyryaev A.A. Dangerous chemical objects and technogenic risk : manual. Publishing house of chemical faculty of MSU, 2019, p.254.

[4] Antoniadi D.G., Savenok O.V. The analysis of a condition of the environment of oil production with the complicated service conditions, 2018, No. 1, p.16–20.

[5] Antoniadi D.G., Savenok O.V., Koshelev A.T. Methods of monitoring of the environment of oil production and development of structure ecological components from an expected, 2019, No. 5, pp.30–36.

[6] Arutyunov T.V., Savenok O.V. Environmental problems when developing fields of slate hydrocarbons // Environment protection in an oil and gas complex, 2019, No. 9, pp.39–42.

[7] Kravtsova M.V., Evseev A.I. Increase in operational stability of difficult technical systems // Vector of science of the Tolyatti state university, 2019, No. 4, pp.67–70.

[8] The World Economic Forum. Energy for Economic Growth. Energy Vision Update; The World Economic Forum: Cologny, Switzerland, 2021.

[9] Osborn SG, Vengosh A, Warner NR, Jackson RB (2011). Methane Contamination of Drinking Water accompanying Gas Well Drilling and Hydraulic Fracturing, 2020, vol, 108 no. 20.

[10] Rubinstein JL, Mahani AB. Myths and facts on Wastewater Injection, Hydraulic Fracturing, Enhanced Oil Recovery, and Induced Seismicity. Seismological Research Letters, 2019, vol. 86 No. 4.

ENVIRONMENTAL PROBLEMS IN THE CONDITIONS OF GLOBALIZATION AND TRANSNATIONALIZATION OF THE WORLD ECONOMY

Zelimkhan Musostov[1], Alisa Olisaeva[2], Isa Basnukaev[3]

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[1]Chechen State University, Grozny named after A.A. Kadyrov, Russia
zmr@hotmail.co.uk
[2]North Ossetian State University named after K.L. Khetagurov, Russia
[3]Grozny State Oil Technical University named after Acad. M.D. Millionshchikov, Russia
i.basnukaev@mail.ru
salamova_chgu@mail.ru

Abstract

The relevance of the topic of the impact of the economy on the environment is evidenced by the current process itself and the large-scale coverage of the consequences of the development of environmental problems. The anthropogenic impact on the environment has reached its maximum level due to the development of scientific and technological progress. The article focuses on environmental issues in the context of the development of the world economy. Ecology is considered from the point of view of the economy and environmental problems are characterized in the context of globalization and transnationalization of the world economy. In accordance with this, the article presents the basic concepts of globalization and transnationalization and ways to solve environmental problems in the framework of improving environmental policy and the supranational environmental management system, unifying and coordinating the methods used.

Keywords: globalization, sustainable ecological development environment, ecology, environmental problems, transnational corporations (TNCs)

I. Introduction

An interdisciplinary approach to the study of complex problems of human interaction with the environment has gone beyond the scope of only biological science, including here the ecological directions of various branches of knowledge, it has been elevated to the category of generalizing sciences.

The existence of ecology today is one of the branches of natural science that studies the historical relationships of organisms with their physicochemical, biotic and anthropogenic nature at the level of species, species populations, biogeocenoses and the whole biosphere in order to identify the patterns of these processes and solve urgent problems of health, economic activity and environmental safety.[7].

Under conditions of increasing anthropogenic load, the central problem of human society is sustainable ecological development or sustainable functioning of the biosphere, since the biosphere is an integral part of the main shells of the earth, and only with this approach is the very existence of mankind possible.

Various interactions, which are the main product of the current biosphere,occurred on Earth for 3-4 billion years. The composition of the atmosphere has remained unchanged for the last 50 million years, but due to anthropogenic impact in recent decades, significant changes in its composition have been observed, an increase in its pollution with sulfur and nitrogen oxides, mercury, lead and carcinogens, in particular benzapyrene, as well as changes such as the appearance of smog, changes in transparency, depletion of the ozone layer.

II. Methods

As we know, all economic activity is directly related to a significant burden on the environment, which, due to the uncontrolled change in economic growth, entails an increasing cost of natural resources. The reasons that reduce the prospects for the formation of the current society and pose a threat to the life of mankind, which began to worsen from about the 1970s, were environmental problems: lack of resources, depletion and pollution of the environment.

Both industrialization and urbanization have led to changes in living conditions and deterioration of human health, as well as to an increase in morbidity, as a result of anthropogenic impact on the environment. During the assimilation of man into the urban environment, the main mechanisms of perception could not adapt to the changed visual environment and changes in the atmosphere, hydrosphere and lithosphere. The population living in ecologically unfavorable areas of the city are more susceptible to various diseases caused by a decrease in immunity, such as endocrine and cardiovascular disorders [3].

III. Results

The greatest damage to the environment has been inflicted since about the middle of the twentieth century due to the increase in the growth rate of the global economy. Compared with 1950, by the beginning of the 21st century, the world's population had increased to 7 billion people, i.e. became 2.5 times more and in connection with this, the industrial production of the world increased seven times. When the population increases by another 50%, the world economy is projected to grow by 500% in the period from the 2000s to the 2050s [2]. By 2030, population growth will lead to an increase in food and energy consumption by 50% (by 2050 - by 70%) and drinking water - by 30% [4].

The impact of an individual on the environment, i.e., anthropogenic impact, according to researchers, by the 1990s, had assumed alarming proportions. The scale of global production and consumption has led to a serious imbalance in social and natural systems and to the fact that the natural environment is unable to cope with anthropogenic impacts. It is estimated that "Humanity's debt to the environment is about 4 trillion US dollars", since the ability of the environment to cope with the consequences of human activity has already doubled [4].

Factors that destroy the natural environment and lead to its degradation, such as the destruction of natural ecosystems, accidents at defense and industrial facilities, which are the consequences of the intensive development of human economic activity, lead to environmental disasters. In this regard, the rational use of natural resources and the effective reduction of emissions from industrial production have become the main tasks of mankind today, although since ancient times many scientists have been dealing with the problems of the relationship between man and nature.

For example, Ashoka, the Indian emperor, in 243 BC. e. developed decrees prescribing the protection of forests, fish and animals. The author of the first environmental decrees in Russia was Peter I (1673-1726); Anaximander the philosopher, he is the author of the first philosophical work in Greek, On Nature; Ramazzini Bernardico (1634-1715) Italian doctor wrote a treatise "On the diseases of artisans. Reasoning". Auguste Comte (17991856) French philosopher, in his writings considered the system "human geography - human ecology - sociology". Due to the fact that the population of the city was suffocating from the stench of coal soot, Edward I, from 1273, the English king, by a special law forbade heating the houses of London with coal.Bthe basics of the system for the safe development of the Russian technosphere were laid by the authors of the fundamental ideaslike: D.S. Likhachev, V.I. Vernadsky, V.P. Kaznacheev, N.F. Reimers, N.N. Moiseev, V.A. Legasov, A.L. Yanshin, G.V. Stadnitsky, DanilovDanilyan, A.I. Rodionov, O.S. Chekhov, G.A. Bogdanovsky, A.V. Yablokov, O.N. Rusak, I.I. Mazur, V.I. S.V. Belov [5].

The era of globalization has become the modern stage in the evolution of thecommunities. Globalization is an inevitable phenomenon at the stage of development of the world community. the essence of globalization lies in the strengthening of integration between countries in all spheres of society, both in political and economic, cultural and spiritual interdependence. Including questions relating to the very existence of mankind.Economic globalization is the main driver of globalization, which has a significant impact on the environment. However, the rapid change in the technological and social spheres lead to new imbalances in the global economy, which is the main problem of globalization. This is mainly due to the uneven formation of national economies. The reason for the increase in the gap between rich and poor countries was the growth in the 20th century of world GDP, less than three times in the poor and six times in the developed countries.

Globalization limits the development and implementation of the environmental strategy of each state. Globalization contributes to the separation and institutionalization of ecological "branches" from the traditional branches of scientific knowledge, and leads to their convergence and merging with other branches of scientific knowledge of the same origin into a single whole, making the interconnection of these spheres such as nature, social and anthropogenetic obvious. This is connected with the circumstance, which was first substantiated by I. Kant, that the aggregation of knowledge, as you know, is the most important condition and prerequisite for their systematization [6].

Today, the world is experiencing globalization, which is changing the nature of nature management. On the other hand, it contributes to strengthening the impact of market forces, competition, stimulates environmental policy. But, globalization enhances the influence of international economic institutions on national relations, exposing them to adverse economic conditions. Therefore, it is necessary to create supranational environmental management systems, unifying and coordinating the methods used. At the same time, it is necessary to take into account the socio-cultural characteristics of the country when conducting environmental policy in the country and in its regions.

Therefore, we can conclude that there are links between the processes of globalization and the mechanisms for the transformation of scientific fields into institutions that change the art of building a system and the purposefulness of scientific policy. Therefore, it can be said that the very birth of environmental science can be partly seen as an indirect consequence of globalization. This conclusion is especially important, since the intensive interaction between such disciplines as scientific policy, environmental policy and economic policy destroy the traditionally drawn boundaries [1].

Transnational corporations (TNCs), which are a subject in modern economic relations between countries, are the structures that have the greatest impact on the environmental situation in the context of globalization. The production of goods and services that are competitive in the market is the basis for the formation of an effective economic system, the socio-economic development of any country and economic growth in general. Economic entities, such as transnational corporations and all countries of the world, are competing to increase their international competitiveness. Some states, namely national ones, in many respects turned out to be marginalized due to the fact that the basis of the process of strengthening the interdependence of national economies, i.e. economic globalization have become transnational companies.

Competition, which leads to lower costs when introducing the latest technologies and increasing the scale of production, the search for cheap labor, the location of production in countries with relatively low taxes, is the reason for such a large increase in the scale of TNCs. Transnational corporations are the main consumers of natural resources, the main producers of goods and service providers that pollute the environment. To minimize environmental costs, TNCs transfer their "dirty" production to more favorable and favorable conditions in terms of politics and economics, thus causing significant damage to the habitat in some countries. The exploitation of differences in investment and environmental laws between developing and developed countries is common among TNCs, often saving costly environmental investments in least developed countries and thereby circumventing environmental laws.

At the same time, in recent years, TNCs began to improve their environmental practices and began to use the environmental factor in their competition, as with the development of the world economy, consumer demand has become more environmentally oriented. For example, in Canada, the oil and gas company Shell deserved high praise from environmentalists, although this company did not find recognition among the “greens” in such countries as Nigeria, the Netherlands, Russia. This serves as an example of the fact that the environmental policy of the same TNC is carried out in different countries in different ways.

We single out 2 main hypotheses, according to economists, which allow us to identify which trends in the environmental practice of transnational corporations are the main ones:

- Transnational corporations play a positive role, since the environmental corporate standards of international companies are higher than those of domestic producers with smaller capitalization and lower financial capabilities.
- Multinational corporations move production to countries with weak environmental legislation

It was TNCs that played a special role in solving environmental problems. This became clear in the 1960s and 1970s, with the realization of the importance and magnitude of environmental problems. The development and implementation of "green" technologies takes place at the corporate level. Today a large number of people are willing to overpay for a highly economical product with an appropriate certificate. Although obtaining the necessary licenses and producing organic products requires a lot of financial and capital investment, some of the largest companies are engaged in environmentally friendly products, which bring them large profits. Increasing demand for green goods is the main goal of corporate marketing campaigns, the quality of which determines the number of consumers who are ready to buy green goods, despite their high cost.

IV. Discussion

After the creation of such a new direction as a "green" brand, the current marketing has reached a new level, and as a result, the largest companies are embarking on the path of greening their production. One of the most profitable and successful areas of strategic development for a multinational company is eco-marketing with great potential. The main reasons for the introduction of environmentally oriented ideas around the world are the limited natural resources, increased resource consumption and environmental pollution. In recent decades, taking into account compliance with environmental requirements has become a strategic priority in the activities of leading TNCs, which was influenced by a combination of the following factors: public influence, the need to comply with strict legal norms, opportunities to increase the competitive advantages of TNCs abroad,

Only with a harmonious relationship between society, technology and nature, a comprehensive solution of environmental problems is possible. The reproduction of natural resources, as well as environmentally modern production, are the basis of industrial complexes, which necessarily include decisive tasks, the main of which is the rational use of natural resources.

In its essence, the natural environment has the ability to self-heal, i.e. has the ability to perceive on a certain scale some of the impact of an individual on the environment without changing its basic properties, but a person seeks to consume, rather than preserve, and the natural exceeds the established ecological limits. On the one hand, the economy must develop, on the other hand, it is economic efficiency that is the main factor in the development of environmental problems.

A rational approach to nature management, as well as the integrated use of natural resources, is the main way to obtain socio-economic and environmental benefits from the use of natural resources, which pushes humanity to the widespread use of waste-free technologies and the reuse of depleted resources. This approach will save raw materials and reduce the negative impact on the environment.

References

[1] Akimova T.A. State environmental policy of the Russian Federation and the practice of its implementation // Ecology and life, 2006, No.2, pp.18-23.

[2] International partnership for sustainable resource management. Examining elements for a work plan (2008-2010). – NEP. – UNEP/IRM/SC/0711/06.].

[3] Savina S.A., Human habitat. [Electronic resource]. - Access mode: http://www.ecospace.ru/ecology/science/space/ (Date of treatment: 04/01/2022).

[4] Modern International Relations: Textbook / Ed. A.V. Malgina, A.V. Torkunova. - M.: Aspect Press, 2014. 699p.

[5] Sytnik M.A., Nazimko V.I. Industrial Ecology: Textbook. - Kerch: publishing house of the Kerch State Marine Technological University, 2019. P. 10. 137p.

[6] Schukina A.Ya. Theoretical foundations of sustainable development. - M.: NOTA-BENE, 2005. 168p.

[7] Chelnokov, A.A. Fundamentals of Ecology: textbook / A.A. Chelnokov, L.F. Yushchenko, I.N. Zhmykhov; edited by A.A. Chelnokov. - Minsk: Graduated school, 2012. 543 p.

FORMATION OF AN ASSESSMENT MODEL AND PREVENTION OF TECHNICAL RISKS IN ECONOMIC MANAGEMENT SYSTEMS

Salekh Khodzhaliev[1], Zainodin Rasulov[2], Umar Khadzhiev[3]

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[1]Chechen State University named after A.A. Kadyrov, Russia
[2]Baltic State Technical University Voenmekh named after D. F. Ustinov, Russia
[3]Grozny State Oil Technical University named after Acad. M.D. Millionshchikov, Russia
tankaevz@mail.ru
salamova_chgu@mail.ru

Abstract

Modern studies on the causes and consequences of the global financial crises confirm that the growth of the uncertainty factor in the global economy has a detrimental effect on the development of the world economy, provoking a slowdown in the economic activity of business structures. A slowdown in economic activity triggers responses from decision makers in commercial organizations, such measures include, for example, curbing investment, reducing spending through increased savings, increasing interest rates through a risk premium. According to a study by the Confederation of British Industry (CBI), 42% of UK companies say leaving the EU is hurting investment activity. Of these, 98% of companies characterized this impact as negative. The increase in uncertainty due to the exit from the EU also affected the UK economy itself, which is confirmed by the estimates of the Bank of England, which indicate a decrease in investment within 3 years from 2016-2019. by 11%. Such studies confirm the relevance of the topic of managing business structures in conditions of uncertainty, which create risks for the implementation of the strategy and achievement of the goals of commercial organizations. The increase in the significance of the uncertainty factor is due to the fact that the world economy for the first time faced a significant number of large-scale changes, increasing exponentially. Change creates risks that can be sources of both favorable and unfavorable outcomes.

Keywords: global financial crises, business structures, global economy, strategy

I. Introduction

The main large-scale changes taking place in the world economy are associated with the high rate of development of scientific and technological progress, provoked by the "Fourth Industrial Revolution" [1]. The technologies that enable the Fourth Industrial Revolution affect the form and quality of products and services, shape consumer behavior, and create new models for the growth of commercial companies. Thus, only artificial intelligence (AI), one of the technologies related to the digital industrial revolution, according to the McKinsey Global Institute, will create an economic effect for the global economy in the amount of 13 trillion dollars a year by 2030. According to the same institute, in the next 20 years, 50% of the operations in the world will be automated [2]. The global technological transformation driven by the digital revolution will not only lead to business process automation, thereby increasing labor productivity (according to the consulting audit campaign Deloitte, the annual growth rate of labor productivity will be 2.3% during 2025-2030), but and will be accompanied by new risks associated with these changes ("cyber attacks", "data theft"). According to the World Economic Forum's 2019 WEF (World Economic Forum) Global Risks report, the economic cost of cybercrime will reach $3 trillion by 2020 [2-3]. Such risks are among the five most likely global risks. The most significant in terms of damage, according to the 2019 WEF report, is the risk of "weapons of mass destruction". The ongoing "trade war" between the US and China, Brexit, the nuclear programs of Iran and North Korea, the growing tension between Russia and the West - all this increases the uncertainty in the development of the world economy. The growth of the uncertainty factor in the economic policy of EPU (Economic Policy Uncertainty Index) in Russia, caused by external political events and high volatility in energy prices, in 2014 reached its maximum value since 1995 [3]. The values of the EPU indicator decreased only by 2016. Such changes led to the formation of a new economic environment in 2015, expressed in a general decline in GDP by 2.5%, stagnation in production volumes (industrial production index according to Rosstat was 99.2% in 2015, which is 2.5% less than than in 2014), a decrease in investment in industry by 5.8%, a decrease in real wages of industrial workers by 6.9%, an increase in unemployment of the economically active population of Russia by 0.3%. One of the reasons for such indicators is the unwillingness of businesses (entrepreneurial structures) to work in harsh conditions of limited financial resources, a general decline in demand for manufactured products, increased inflationary threats, which is due to an underestimation of the risk of crisis events. Industrial development indicators returned to the values of 2013 only in 2017. Entrepreneurship is the most important factor in the development of the Russian economy. The presence of a large number of internal and external risks is the reality of the modern Russian economy that affects the functioning of business entities working in the field of entrepreneurship [5-6]. According to the Global Entrepreneurship Monitor (GEM) report of St. Petersburg State University, risk factors that do not contribute to improving the business climate in Russia include: "unpredictability of state policy", "high level of bureaucracy", "limited financial resources", "corruption as a factor hindering doing business in the country". A separate place in entrepreneurial activity is given to industrial enterprises that form industrial entrepreneurship. Industrial entrepreneurship occupies a central place among entrepreneurial structures in the development of high value-added innovations, which form the basis of the competitiveness of firms and contribute to the modernization of the economy through scientific and technological progress. Industrial entrepreneurial structures involved in the Fourth Industrial Revolution are subject to constant changes in the external environment, technological changes, political and social risks, and are also forced to control the risks that arise within the organization. The success of industrial enterprise structures, taking into account significant structural changes in the industry, will depend on the choice and implementation of a strategy that allows you to plan ways to achieve goals. The right choice of a new strategic position for a commercial company will make it possible to make the right decisions in the face of uncertainty and effectively manage risks, which will create additional opportunities and lead to an increase in the value of the company through an increase in profits. The spread of entrepreneurial activity to the latest achievements of science and technology with the ongoing aggravation of socio-economic problems entails a sharp increase in uncertainty and an increase in its influence on the results of economic activity, which is associated with the need to further improve the methodological apparatus of risk management theory.

II. Methods

Despite the significance of the problem of risk management, the analysis of the production sector shows the low efficiency of risk management in Russian business structures. The main reason is the weak integration of risk management with the overall management system. Risk management is considered as an autonomous system, isolated from the main activities of a commercial organization [7]. Such an approach can lead to ineffective risk assessment and, consequently, to significant losses or bankruptcy. It is necessary to improve the risk management system, integrating it into key business processes and taking it into account when making decisions. The process of integrating risk management for business structures is associated with a number of organizational, methodological, technical problems, the solution of which can lead to additional unreasonable costs and entail the diversion of funds from core activities and ultimately adversely affect the development of the company. Therefore, the process of integrating risk management into the management system requires the development of new methods, practical recommendations and additional tools, which is part of the current scientific direction in the development of risk management theory and methodology [8].

III. Results

Based on the above definitions, the author believes that in the context of the activities of a commercial organization, the following can serve as a more accurate definition. Risk is a state of uncertainty in the activities of business structures associated with various possible outcomes (loss, loss or favorable outcomes) that affect the implementation of the strategy and the achievement of the organization's goals [9].

Table 1: *Basic definitions of risk*

ISO 31000 2018	Risk - Impact uncertainty on the target. Influence is a deviation from what is expected (positive and/or negative)	Definition in context organization activities and risk associated with impact uncertainty on the target organizations
Douglas Hubbard	Risk is a state uncertainty when opportunities include losses, disaster or other unwanted outcomes	Definition in context uncertainty associated with negative outcomes
Committee of Sponsoring Organizations of the threadway (COSO)	Risk is the possibility that events will occur that will affect the implementation strategies and achievement of business goals	Definition in context organization strategy. Risk is defined as possibility
Mathematical concept of risk (Pugachev V.S.)	$r(z\|x) = M\,[\|z - Y\|2\|x] = \int \|z - y\|\,2\, f(y\|x)\,dx$, where $r(z\|x)$ is the risk, i.e. losses, to which the decision leads; z is the totality of all quantities, characterizing the solution; x is the totality of all quantities, characterizing the initial decision data	Risk is defined as losses to which gives a solution

Each company seeks to avoid threats, damage, i.e. trying to achieve a certain sustainability of development. According to ISO, sustainability is the degree of sustainable development. Sustainability (as applied to the organization) is development that meets the needs of the organization without compromising future opportunities to achieve its business goals. Sustainable development allows businesses to strike a balance between remaining competitive, stimulating innovation and preserving the environment in the external and internal business environment. In order to ensure sustainable development, commercial companies, when making decisions based on risk in a business environment, must properly understand and classify the risks that arise.

A holistic view of risk management in long-term forecasting will contribute to sustainable business development. The author believes that ensuring sustainable development (Business continuity management and disaster recovery (ISO standards 22301 and 22313) is reduced to ensuring business continuity, crisis management, incident management, cybersecurity, capacity management. The author refers to the main classification of risks that are significant for the organization, i.e., those that can affect the achievement of the organization's goal and the implementation of the company's strategy [5-6].

IV. Discussion

Risk management is an integral part of the planning process and the control process, but at the same time it implements an independent operation for analyzing and making management decisions taking into account risks. Risk management can be attributed to a subsystem of an organization's management system or a set of risk management measures. The author calls a subsystem (or subsystem) a system of a smaller scale than the original one, organizationally included in the last, realizing an independent operation, the purpose of which is subordinate to the purpose of the operation carried out by the original system, which is a supersystem in relation to the subsystem. The author believes that the essence of risk management, first of all, is to create such a culture within the organization that would facilitate the analysis of risks when making managerial decisions. No company can manage risk if employees and managers reject the risk management process itself. The author introduces such a concept as a risk-oriented culture. A risk-based culture is a part of corporate culture that provides for the creation of an environment in the organization that would facilitate the identification, assessment and mitigation of risks, as well as open communication about risks. Table 2 shows the main components of a risk-based culture, proposed by the author [10].

A risk-based culture reflects the organization's core values: beliefs, attitudes, desired behaviors, and the importance of understanding risk [8]. An organization with a culture of risk awareness emphasizes the importance of risk management and encourages the creation of a transparent and timely flow of risk information. A risk-based culture includes requirements for the organization's governing body (the board of directors), which plays an important role in corporate governance and has a significant impact on the organization's risk management.

Economic risk arises in cases where the probabilistic nature of the situation arises as a result of the action of certain dangers and threats, that is, under certain objective circumstances, due to which there is a possibility of an unfavorable development of a particular economic situation [9].

It should be noted that there are a number of threats specific to individual sectors of the economy, that is, threats are associated with industry specifics. In particular, industrial enterprises are most characterized by the following threats:

1) use of administrative opportunities to obtain benefits;

2) the use of administrative opportunities to increase pressure from competitors or so-called raiders;

3) the growth of the influence of administrative risks. This is a change in legislation, regulatory documents, a change in administrative and regulatory bodies, a change in his position in relation to the company for any reason;

4) the enterprise becomes dependent on officials or intermediaries, including its employees.

Table 2: *Basic definitions of risk*

Events	Content
Maintaining leadership	– Clear and consistent risk management expectations from management. – Leaders should lead by example on how to approach risk when discussing it. – The board of directors and management attach great importance to the awareness of employees about risks. Risk culture cannot be changed by a team or a second-level department alone, the top management of the organization must be a real driver of change
Using participatory management style	Management encourages staff to participate in discussions about risks to the strategy and business goals of the organization
Implement accountability for all actions	Management encourages and adheres to a policy of accountability, demonstrating to staff that lack of accountability is unacceptable, and putting the principle of accountability into practice is rewarded
Aligning risk-based behavior and decision making with performance	Reward and incentive programs are aligned with the core values of the organization, including expected behaviour, adherence to codes of conduct, accountability for decision-making and risk-based judgment
Considering risks in the decision-making process	Management systematically considers risks when making key business decisions. Risk scenarios are discussed and analyzed to help everyone understand the relationship and impact of risks before making final decisions.
Holding open and honest discussions about the risks the organization faces	Management does not view risks as a negative phenomenon and understands that risk management is critical to the implementation of the strategy and achievement of business goals
Promoting risk awareness throughout the organization	Management constantly signals to employees that risk management is part of their day-to-day responsibilities and that it is not only valued but critical to the success and survival of the organization.

In addition, most industrial enterprises have a specialization in any direction. The nature of production does not allow, if necessary, a quick transition to the production of other products. It also poses certain threats:

1) increased competition in the market for products manufactured by a highly specialized enterprise;

2) increased competition in the region, which is important in cases where the transportation of products leads to a significant increase in prices for the consumer (primary industry, production of a number of goods);

3) a drop in demand for manufactured products due to objective reasons;

4) unfair competition in all its manifestations;

5) monopolization of the market.

In addition to the existence of individual threats, there are also many factors that contribute to the emergence of threats to the economic security of the company. Knowledge of these factors will help to identify and eliminate them and, therefore, reduce the possibility of threats to the economic security of the company [7]:

It should be noted that there are a number of threats specific to individual sectors of the economy, that is, threats are associated with industry specifics. In particular, industrial enterprises are most characterized by the following threats:

1) use of administrative opportunities to obtain benefits;

2) the use of administrative opportunities to increase pressure from competitors or so-called raiders;

3) the growth of the influence of administrative risks. This is a change in legislation, regulatory documents, a change in administrative and regulatory bodies, a change in his position in relation to the company for any reason;

4) the enterprise becomes dependent on officials or intermediaries, including its employees. In addition, most industrial enterprises have a specialization in any direction. The nature of production does not allow, if necessary, a quick transition to the production of other products. It also poses certain threats:

1) increased competition in the market for products manufactured by a highly specialized enterprise;

2) increased competition in the region, which is important in cases where the transportation of products leads to a significant increase in prices for the consumer (primary industry, production of a number of goods);

3) a drop in demand for manufactured products due to objective reasons;

4) unfair competition in all its manifestations;

5) monopolization of the market.

In addition to the existence of individual threats, there are also many factors that contribute to the emergence of threats to the economic security of the company. Knowledge of these factors will help to identify and eliminate them and, therefore, reduce the possibility of threats to the economic security of the company [8-9]:

1) a significant degree of market monopolization, partially preserved from the former administrative-command system, was partially revived. At the same time, the level of competition in the Russian markets is growing from both domestic and foreign manufacturers. Given this condition, the entrepreneur must plan the activities of his enterprise in accordance with the current situation;

2) establishing control of criminal structures over a number of sectors of the economy and business entities;

3) maintain significant pressure on commercial organizations from government agencies (for example, in the field of licensing, taxation). Although a sufficient number of legal acts have been adopted to protect small businesses, the problem remains relevant;

4) an increase in the criminalization of Russian business (hostile takeovers, hostile takeovers);

5) the presence of various social problems - low income, unemployment, staff turnover - all this reduces the degree of responsibility and increases the likelihood that an employee will sell company secrets and other illegal activities;

6) the imperfection of the legislation regulating relations in the field of entrepreneurship (expressed, for example, in the orientation of legal norms to combat the consequences of crimes, and not the causes, in the failure of the damage caused and the sanctions applied);

7) lack of unity of action and mutual coordination of various law enforcement agencies. Thus, one can see many factors that create threats to the economic security of the enterprise, which once again proves the need for careful monitoring of situations that contribute to the emergence of threats to the economic security of the enterprise and constant readiness to neutralize them.

References

[1] Anshin V.M. Project management based on the concept of sustainable development. Scientific research and development. Russian journal of project management, 2019, 313-339.

[2] Ilyina O.N. Project management methodology: formation, current state and development, 2020, 153.

[3] Andrea, J.J., Burns, C., Touza, J. Renewable Energy as a Luxury? A Qualitative Comparative Analysis of the Role of the Economy in the EU's Renewable Energy Transitions During the 'Double Crisis'. Ecological Economics, Vol. 142, 2020,81–90.

[4] Yang, J., Zhang, F., Jiang, X., Sun, W. Strategic Flexibility, Green Management, and Firm Competitiveness in an Emerging Economy. Technological Forecasting and Social Change, Vol. 101, 2018, 347–356.

[5] Dulal, H.B., Dulal, R., Yadav, P.K. Delivering Green Economy in Asia: The Role of Fiscal Instruments. Futures, Vol. 73, 2019, 61–77.

[6] Mauritzen, J. Cost, Contractors and Scale: An Empirical Analysis of the California Solar Market, 2018, 105-214.

[7] Meckling, J., Hughes, L. Protecting Solar: Global Supply Chains and Business Power. New Political Economy, Vol. 23, No. 1, 88–104.

[8] Monasterolo, I., Raberto, M.The EIRIN Flow-of-Funds Behavioural Model of Green Fiscal Policies and Green Sovereign Bonds. Ecological Economics, Vol. 144, 2018, 228–243.

[9] Molchanova Ya.P. 2019. Hydrochemical indicators of the state of the environment, 192.

[10] Braverman A., Saulin A. 2019. Integral assessment of the performance of enterprises Economic issues, 6 (1), 108.

PROJECT RISK MANAGEMENT

Deshy Musostova[1], Valentina Dzobelova[2], Varvara Markaryan[3]

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[1]Chechen State University, Grozny named after A.A. Kadyrov, Russia
goldzr@yandex.ru
[2]North-Ossetian State University named after K.L. Khetagurov, Russia
dzobelova@mail.ru
[3]Krasnodar Branch of Financial University under the Government of the Russian Federation
markarianvr@gmail.com

Abstract

In modern conditions, an increasing number of organizations are implementing a project management method, in which each unique business process is considered as a separate project that has phases of initiation, preparation, implementation and completion. Each project generates certain financial flows and at the same time provokes the risks associated with them. The technology of risk management in the project has certain specifics, which determines the relevance of its comprehensive study.

Keywords: risk, risk management, project risks, project management, project risk management

I. Introduction

Risk is one of the characteristics of the political, social and economic life of any society, and it is present in all aspects of the existence of a commercial organization operating in a market environment. The Civil Code of the Russian Federation defines entrepreneurial activity as risky and associated with regular profit. Researcher A.N. Fomichev believes that risk is the danger of loss of profit, income or property associated with changes in economic conditions and the emergence of certain external obstacles [2].

The concept of risk is inextricably linked with the concept of uncertainty - a state in which there is a lack of information about the prospects for the organization's activities and the conditions accompanying this activity. American economist F.H. Knight in his works defines risk as a situation when an economic operation leads to different results that can be calculated by their probabilities, and uncertainty as a situation in which it is not possible to calculate the probability distribution [1].

An important task of the organization is a well-established risk management process, which includes a number of activities aimed at monitoring and analyzing the risks that arise in the course of the financial and economic activities of the organization. Risk management is designed to reduce them to a value at which they cannot threaten the effective functioning of the organization. In the risk management system, strategy and tactics are distinguished: strategic management is aimed at identifying mechanisms to reduce risks, and tactical management includes the implementation of methods for implementing the chosen strategy.

The level of risk largely depends on the type of project (Figure 1).

The presence of dependence between the listed types of projects and the level of risk of their implementation is associated with an uncertain market reaction to various categories of investments. Obviously, the probability of negative consequences of investing in proven goods and services is much lower than the risks associated with bringing innovative products to the market.

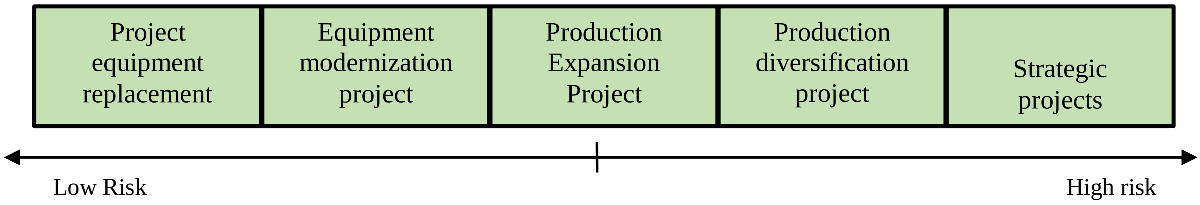

Figure 1: *Relationship between types of projects and their level of risk*

II. Methods

When analyzing the appropriateness of costs, the theory is adopted, according to which the increased consumption of resources during the implementation of the project can be caused by the following factors:

- initial error in the calculation of the cost of the project or its individual components;
- modification of the current conditions of project activities;
- insufficient performance of equipment that does not meet the requirements of the project;
- an increase in the cost of the project due to inflation or changes in tax legislation.

The analysis allows you to consider these factors in detail and make a list of possible cost increases for each of the options for an innovative project.

The analogy method consists in studying the available data on similar projects and studying the influence of negative factors on them in order to identify potential risks in the implementation of a new innovative project. Information about projects can be obtained from the reliability ratings of companies published by Western insurance companies. The ratings reflect such positions as the level of demand for different types of products, the cost of raw materials, fuel and other resources. Domestic databases have also appeared that analyze innovative projects based on a survey of managers, analysis and study of printed sources.

The complexity of the method lies in the competent choice of an analogue, while there are no exact criteria that would make it possible to establish the similarity of the project. There are also difficulties with the formulation of analysis factors that allow taking into account all options for the development of the situation. The reason is that the complexities that arise in the implementation of projects can overlap and the effect is the result of a complex interaction. No less difficult is the assessment of the degree of accuracy of applying the risks of another project to the one under consideration. There are no methodological developments in this area that allow to take into account the details and logic in risk assessment. Thus, the analogy method is more suitable for describing possible adverse situations than for obtaining an assessment of the risk of an innovative project.

III. Results

The method of expert assessments consists in the analysis of project risks with the involvement of qualified project specialists. As part of this methodology, experts are provided with questionnaires containing a list of factors that may have a negative impact on project activities. Expert evaluation is based on the Delphi method, methods of pairwise comparison, scoring, ranking, and others.

The statistical method is based on the analysis of changes in the analyzed indicators for a selected period of time. At the same time, it is assumed that the established regularity will be observed in the future.

The method of sensitivity analysis considers the risk of the project as the level of sensitivity of its final indicators to changes in the conditions of the project. The conditions include such factors as the amount of taxes, the level of prices in the industry, the amount of costs and others that affect the functioning of the organization. The final performance indicators of the project implementation are investment analysis indicators (NPV, IRR, PI, payback period), as well as annual levels of net profit and profitability.

The sustainability test method is based on the creation of several scenarios for the implementation of the project: under optimal, probable and risky conditions. All scenarios are analyzed according to the following parameters: the size of the expected profit and costs, the efficiency index for individual investors, the region and the country as a whole. The project is considered potentially effective if NPV is positive in one of the scenarios.

The scenario method involves the analysis by experts of all potential conditions for the implementation of the project in the form of scenarios. Each scenario takes into account the level of costs and performance criteria. Based on the information received, the success indicators of the innovative project are calculated.

The simulation modeling method is a numerical method based on the determination of specific indicators using multiple runs carried out by a machine method using special computer programs. When generating a set of factors, each scenario receives its own NPV value, and the result of the study is the probability distribution of the possible outcomes of the project.

Another way to evaluate a project is to adjust the discount rate. The discount rate is the interest rate required to convert the expected return into a total present value. When adjusting the discount rate, the risk adjustment is included in the discount rate in advance.

To assess project risks, such a universal tool as a risk map can also be used, which allows you to assess risks by their degree of criticality. All of the listed methods of project risk assessment are designed to make the right choice in favor of the most effective scenario.

The project risk management process is based on four basic principles. The first principle is the awareness of making a risky decision. This principle means accepting the existence of risks, working on their analysis and developing measures to reduce and neutralize risks. The second principle is the correlation of the level of risks of economic activity with the size of the expected profitability. This principle means that decisions should not be made, the costs of implementation of which may be higher than the expected profit. The third principle is reasonable economy. The cost of activities should not exceed the potential adverse effects. The fourth principle is taking into account the time factor and its influence on the nature of financial and business operations.

Let us consider the spectrum of the listed risk management methods in more detail. Risk avoidance is a universal way, which consists in refusing to use borrowed capital, investing current assets, cooperation with a specific partner, as well as other business transactions. This method allows you to completely eliminate financial losses, but at the same time, its application does not allow you to receive additional income. Avoidance of all types of risks leads to a loss of efficiency in the use of equity capital and slow growth of economic indicators and, ultimately, to the bankruptcy of the company.

It is also possible to reduce project risks by partially transferring them to a third party: the relevant contracts are concluded with partners or an insurance company. At the same time, in exchange for appropriate financing, part of the risks is transferred to partners, for the neutralization of which they have the appropriate tools. So, for example, to reduce the risks of settlements with debtors, such a tool as factoring is used - a type of trade and commission operation, combined with financing of the client's working capital against the assignment of a monetary claim. In modern practice, factoring with the right of recourse and factoring without the right of recourse are distinguished. Recourse factoring assumes that the factor acquires from the

RT&A, Special Issue № 4 (70)
Volume 17, November 2022

seller the right to the entire amount of the debt, but if it is impossible to collect it, the bank will demand it from the client. With non-recourse factoring, the risk of non-payment is fully borne by the bank, and the cost of this service increases significantly. Insurance allows you to avoid the risks associated with various force majeure circumstances - loss of property as a result of theft, fire, traffic accidents.

The project risk localization method is used if it is possible to identify specific risk sources with sufficient accuracy. Thus, to manage the risks of innovative projects, separate venture enterprises can be created that accumulate project resources received from the parent company and investors. Also, the project can be developed and executed within the framework of a special unit within the corporation. At the same time, internal standards for the allocation of financial, material and human resources within the framework of the project are used.

IV. Discussion

An effective method of risk management is their diversification, that is, the distribution of risks by investing in various projects. The company can diversify its products, investments, securities, portfolio of loans and deposits. Diversification can be carried out both on the scale of all activities and individual projects, which allows you to neutralize the consequences of management errors and underestimation of the negative consequences of individual management decisions. This tool is of the greatest importance for neutralizing technical, technological, marketing, financial and complex risks, while diversification is completely ineffective against political, legal, inflationary and tax risks that affect all areas of the organization.

Risk compensation in the project belongs to the category of proactive management methods of influence, which are designed to create optimal conditions that exclude the occurrence of causes and risk factors. Thus, marketing analysis allows you to accurately determine the needs of the market, monitoring the economic and legal environment allows you to avoid mistakes when concluding contracts, effective strategic planning, forecasting and budgeting make it possible to ensure the predictability of financial indicators of project activities. Self-insurance creates a reserve to finance unforeseen costs.

The choice of risk management methods in the project involves the use of both stereotypical and original solutions containing economically sound recommendations and measures aimed at reducing the initial level of risk to an acceptable level.

References

[1] Knight, F.H. Risk, uncertainty and profit / F.H. Knight. - M: Delo, 2019. 360p.

[2] Stupakov V.S. Risk management / V.S. Stupakov, G.S. Tokarenko. - M.: Finance and credit, 2019. 460p.

[3] Fomichev, A.N. Risk management: Textbook / A.N. Fomichev. - 4th ed. – M.: Dashkov i K, 2019. 372p.

RT&A, Special Issue № 4 (70)
Volume 17, November 2022

THE INFLUENCE OF EXTERNAL FACTORS ON THE CHANGE OF PLANT COMMUNITIES IN THE LANDSCAPE COMPLEX OF THE CHECHEN REPUBLIC

Idris Bayrakov

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Chechen State University named after A.A. Kadyrov, Russia
idris-54@mail.ru

Abstract

The forms of anthropogenic impact and its degree were not the same in different epochs, changing, of course, with the development of the economy of farms. In the Chechen Republic, the processes of pollution, degradation and desertification occur on more than half of the territory. As a result, the water-regulating role of forests disappeared, rivers became shallow, and many sources were depleted. The influence of human activity on the vegetation cover in the steppe and semi-desert landscape complexes of the Chechen Republic is no less powerful than in other regions, they differed not so much in the ways of influence, but in the scale of the changes caused, in some cases larger, in others less. The deforestation of forests on the territory of the Chechen Republic was carried out in two stages. The first in the middle of the 19th century, the tsarist troops reduced forests on an area of more than 70% of the territory, the forest cover decreased from 80% to 35%. The second stage covers the Soviet period, when the forests of the Black Mountains were subjected to continuous logging in the mountain forest belt, freeing up land for tobacco culture. As is known, after these deforestation, landslide processes intensified in the areas of forest information. On significant areas there was a cooling, forests were replaced by meadow plant formations. In the territories subjected to economic activity, the spread of new plant species occurs, causing radical changes in vegetation, still leaves a certain imprint on the formation of various associations. First of all, it is necessary to focus on the spread by anthropogenic activity of various weed species of grasses that grow next to cultivated ones, are unpretentious to new living conditions, adapt well, give a lot of seeds, and also have the ability to vegetative reproduction. Deforestation and fires lead not only to the disappearance of individual species, but also leave a certain imprint on the vegetation cover of adjacent meadows and steppes, the herbage of which changes in the direction of increasing xerophytization. The purpose of the study is to study the influence of anthropogenic factors on landscapes and the patterns of changes depending on the stages of development of degradation processes.

Keywords: Chechen Republic, landscapes, mountain-forest landscapes, semi-desert, steppe, disturbed landscapes

I. Introduction

The study of the influence of anthropogenic factors on changes in plant associations is always a priority, due to the preservation of biodiversity, especially in regions such as the North Chechen Lowland with arid climatic conditions that caused a sharp change in meteorological climate parameters.

Economic activity causes fluctuations in the main parameters of phytocenosis if the intensity or form of exposure changes over the years. Entropic fluctuations are always combined with ecotopic and other types of fluctuations.

The aim of the study was to identify the degree of transformation of some vegetation parameters under the influence of cattle grazing. The object of the study was the territory of the North Chechen lowland. The region under study is located in a semi-desert zone. The climate of the territory is continental. Average temperature in January: - 4.4 ° C, July +24 ° C; precipitation - 200-300 mm per year.

II. Methods

To assess the state of phytocenosis, 18 geobotanical descriptions and 34 characteristics of the floristic composition of the forest community registration sites were used by the author of the study in the period from 2019 to 2021. Field observations and collections were carried out in the summer months.

Geobotanical descriptions were made and processed using the floristic approach adopted in phytocenology. The total number of species (α-diversity), projective cover, and biomass were used as criteria for assessing the state of phytocenosis. Changes in the parameters were analyzed taking into account the weather characteristics of each year of the study: air temperature and precipitation.

Assessment of the degree of anthropogenic disturbance of forest phytocenoses was determined by stages:

1) intact forest condition; 2) disturbed; 3) severely disturbed.

Type of phytocenosis: weeds. The composition of trees: oriental beech, hornbeam, ash, oak. The closeness of the crowns is 0.4. The average age of the trees is 60-80 years; the average height is 17 m; the bonus is 2-3 grade. Anthropogenic impact – areal logging. However, typical vegetation begins to recover as anthropogenic pressure is removed.

III. Results

I. Consequences of anthropogenic influence on humid landscapes

Anthropogenic pressure over the past 50 years, due to the intensification of agricultural production, has increased several times, and deflationary processes have taken on threatening dimensions in terms of the coverage of the territory by de-traditional processes.

But at the same time, soil and climatic conditions are of no small importance, which either enhance or reduce the intensity of erosion processes. For the development of water erosion, it is necessary to have large masses of precipitation, which can create a surface runoff forming a washout of soil soils poorly protected by vegetation. So. Almost the entire southern part of the Chechen Republic is in the zone of development and possible development under favorable climatic conditions for its development, namely atmospheric precipitation. From 600 mm in the extreme south of the Chechen plain to more than 1000 mm in the mountainous part of precipitation, with such a strongly dissected and with large steepness up to 900 slopes in the mountainous part, water erosion processes occur in an active mode, despite the forest cover of this territory.

In the territories subjected to economic activity, the spread of new plant species occurs, causing radical changes in vegetation, still leaves a certain imprint on the formation of various associations. First of all, it is necessary to focus on the diversity of anthropogenic activities of various weed species of grasses that grow next to cultivated ones, are unpretentious to new living conditions, adapt well, give a lot of seeds, and also have the ability to vegetative reproduction.

Deforestation and fires lead not only to the disappearance of individual species, but also leave a certain imprint on the vegetation cover of adjacent meadows and steppes, the herbage of which changes in the direction of increasing xerophytization.

Predatory destruction of forests leads to different results depending on habitat conditions. In steppe depressions and along temporary watercourses, trees are completely destroyed, continuous afforestation of such territories occurs, and only by chance single specimens of common oak and poplar or small areas of stubbornly restoring oak–hornbeam forest on the slope of the Tersk ridge near the village of Tolstoy–Yurt still survive in them, but in most cases thickets remain witnesses of the former woody vegetation medlars of German, blackthorn and forest pear.

Economic activity destroyed primarily the most valuable hard rocks – oak, beech, ash, hornbeam, birch, yew berry, which led to their complete disappearance in many places, especially in the flat part. Only the floodplain oak forests have been preserved as islands in the floodplains of the Terek, Sunzhi, Argun and Hulkhulau rivers, although they are in a deplorable state today.

Landscape and ecological diagnostics of geosystems made it possible to carry out zoning of the landscapes of the republic according to the degree of anthropogenic disturbance (fig.1).

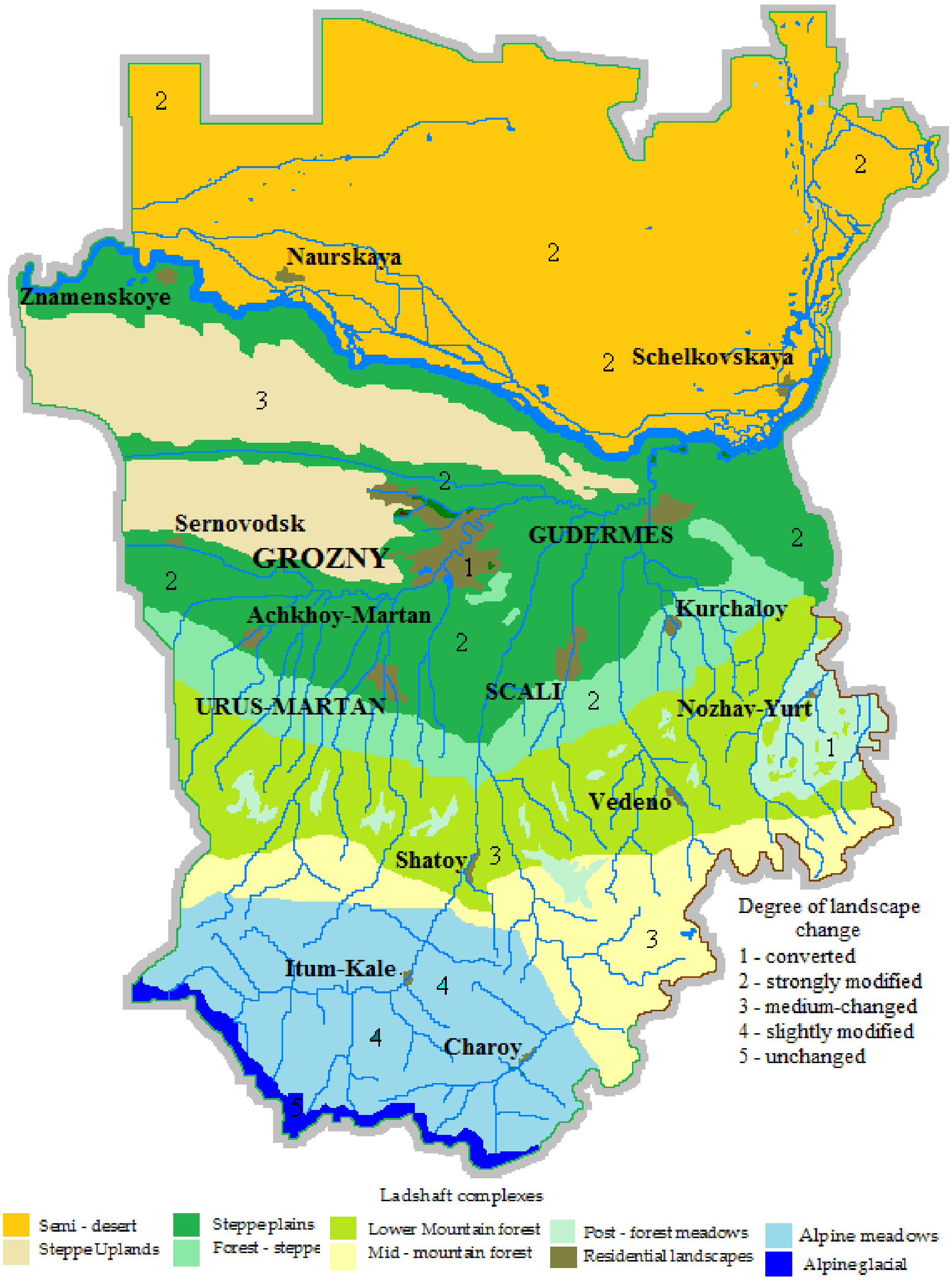


Figure 1: *Map diagram of anthropogenic disturbance of landscapes of the Chechen Republic*

In somewhat better conditions, there was woody vegetation in the mountainous part of the Chechen Republic, with the exception of evergreen pines and berry yew, which were almost completely destroyed and preserved only in hard-to-reach places. Based on the analysis of the maps of the stability of landscapes to the effects of economic activity on their natural components, the following conclusions can be drawn: - soils of arid and mountain geosystems have a very low degree of resistance to anthropogenic influences; - average stability indicators are characteristic of soils of mountain and forest landscape complexes; - a significant part of the industrial potential of the Chechen Republic is located in the steppe zone, natural conditions existing in steppe landscapes (high wind speed, low frequency of calm) contribute to the rapid dispersion of pollutants entering the atmosphere, soil cover is also highly resistant to anthropogenic impact, surface waters have low stability in the steppe zone, where they have the greatest anthropogenic impact.

High-mountain landscapes are mainly affected by pasture, within the subalpine and alpine zones. Values of disturbance of pasture lands of landscapes within the values of 0.4-0.6. In the Alpine zone, the disturbance coefficient varies from 0.2 to 0.4. The same disturbance indicators characterize the mountain forests on the Lateral Ridge and its spurs. The landscapes of the nival belt are practically untouched by economic activity. In the north of the republic, the meadows in the Terek floodplain have been slightly changed, and are mainly used as hayfields. The lands under pastures and arable lands were the most destroyed. Within localities, the disturbance coefficient reaches 1.0.Continuous deforestation and fires lead not only to the disappearance of individual species, but also leave a certain imprint on the vegetation cover of adjacent meadows and steppes, the herbage of which changes in the direction of increasing xerophitation. In the area of art . Petropavlovsk on the slopes of the Tersky ridge there was a change of the wheatgrass–fire meadow by the Tipchakov–zhitnyakov community associated with the cutting down of a large area of the nearby broad-leaved forest. Very soon, within two years after that, clover (Trifolium species), Sangui–sorbaofficinalis, Filipendulaulmaria, Viciacracca, Lathyrustuberosus and a number of other mesophytes disappeared in the grasslands of neighboring meadows.

Birch and aspen trees are slightly better preserved. In relatively good condition, except for military operations, beech forests, which occupy almost 65% of the forest area. The ratio of areas with different values of landscape disturbance (NL) is given in table 1.

Table 1: *Areas of landscape complexes of the Chechen Republic with different degrees of disturbance*

Landscapes	The Importance of Landscape Disturbance	Square, %
Converted	0,8–1,0	15
Heavily modified	0,6–0,8	25
Changed averages	0,4–0,6	35
Slightly altered	0,2–0,4	15
Unchanged	0,0–0,2	10
Total		100

Thus, the immediate results of deforestation should include, firstly, a sharp afforestation of the territory, secondly, the reduction or even disappearance of certain species of trees and shrubs, and thirdly, a change in the herbage of adjacent territories, expressed in increased xerophyte.

II.Consequences of anthropogenic influence on arid landscapes

The situation is different in the north of the Chechen Republic, where soil and climatic conditions are different from the mountainous part. Here, the amount of precipitation does not exceed 300 mm, the soils are composed of loose, unrelated, fine particles or open masses of sand, which become easy prey even to winds with low speed.

However, along with those soil and climatic conditions, the main reasons that caused the development of erosion processes here of such intensity, which led to the loss of natural fertility of soil differences, are large overloads of arid pasture ecosystems by overgrazing livestock without observing pasture rotations.

Excessive grazing of livestock, on loose sandy soil massifs leading to rapid destruction of sod, loosens the top layer of soil, where there are no organic substances and there are pockets of razevaniya [1;2].

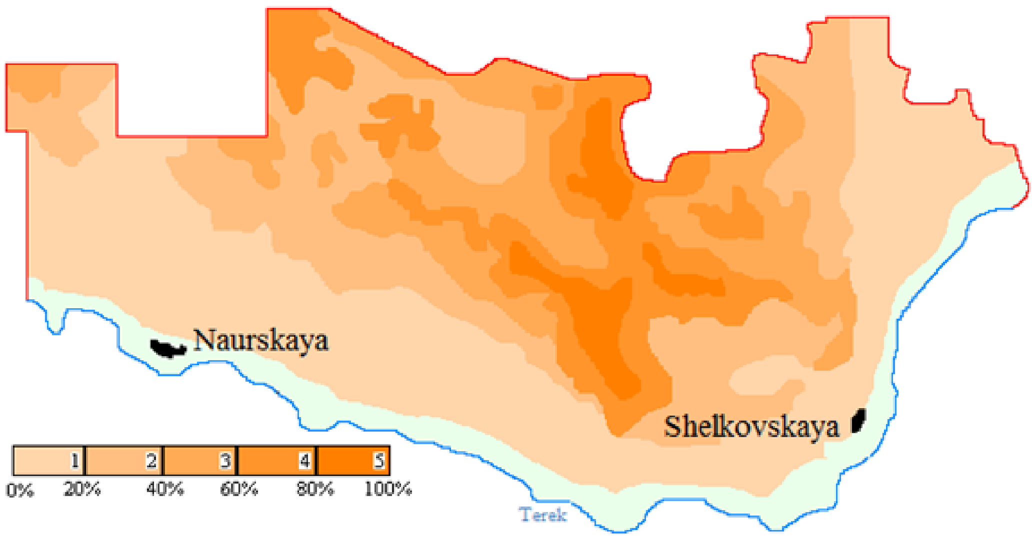
The development of deflationary processes is also facilitated by plowing soils with a light mechanical composition without observing the rules of anti-erosion agrotechnologies necessary in these cases (fig. 2).

Often land users violate elementary norms of protective land use, plow and sow in the direction of the prevailing air flow.

Huge areas of potentially dangerous land subject to deflationary processes are immediately plowed, plowed with the turnover of the soil layer, using heavy machinery and trailed equipment, which greatly enhance erosion processes, in the structure of agriculture, large areas are occupied by row crops, a lot of annual grasses, very slow introduction into practice of techniques where strip and backstage placement of crops.

Large areas have been developed in arid ecosystems by erosion processes intensified by climate warming, which have led to irreversible modifications of the landscape of the arid zone complex, very serious threats to its soils and land resources. The analysis of soil and climatic maps of the Chechen Republic has shown that almost the entire territory has the conditions for the occurrence of deflationary processes, with the exception of the nival zone, where only water-glacial processes are active.

As noted above, deflationary processes are actively occurring in the northern and central part of the region, which is facilitated by the temperature regime with an average monthly +23-26^0 with the indicators of the summer months, characterized by sandy and sandy loam soils with light mechanical composition, with precipitation from 200 mm in the North Chechen lowland, up to 450-500 mm per year on the Chechen plain, the soil cover consists of chernozems with medium and heavy mechanical composition, wind erosion is poorly developed [1;2].



1. Area of weak deflation; 2. The area is subject to weak and medium deflation; 3. An area of medium and strong deflation; 4. An area of strong deflation; 5. An area with exposed sands.

Figure 2: *Map-scheme of zoning on the manifestation of deflationary processes*

Soil erosion studies have shown that 599 thousand hectares of the area of agricultural land resources in the region have potential dangers for manifestations of deflationary processes, and 330 thousand hectares are already in degradation. Erosion processes affected 23.8% of arable lands, 53% of hayfields ecosystems and 64% of pasture ecosystems of the ecosystem area of the Chechen Republic (fig.3).

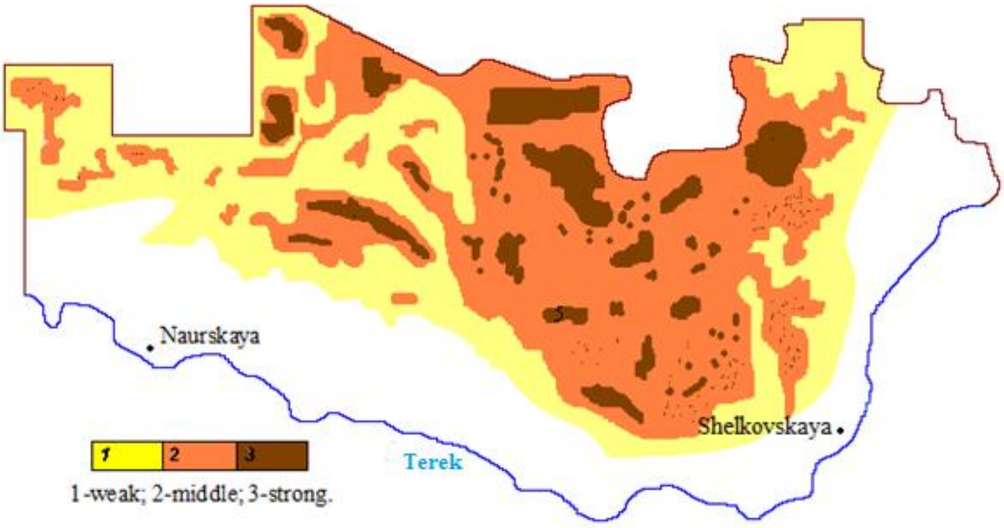


Figure 3: *Degree of manifestation of desertification processes in landscapes*

Eroded arable ecosystems that need to be planted with perennial grasses and then used as hayfields for 3-5 years, and forage ecosystems need to be afforested on areas of more than 4 thousand hectares, it is necessary to carry out terracing of steep slopes - by 2.7 thousand hectares, it is necessary to carry out radical improvement on an area of more than 48.2 thousand hectares of pasture ecosystems, excluding from Pasture turnover for 3-4 years is 21.3 thousand hectares. Geobotanical and agroecological surveys have shown that surface improvements of pasture ecosystems need to be carried out on areas of more than 527 thousand hectares. hectares. In the arid ecosystem, the cooling of the blowing basins was provided, followed by fixing them by sowing perennial grasses. In each landscape zone, special crop rotations are needed to protect the soil, which would contribute to the formation of a closed canopy of vegetation, this is the most reliable means of protection against wind forces destroying the soil surface [3;4;5].

Erosion zoning of the territory of the Chechen Republic was carried out based on the conducted research, assessments and analysis of all available material on soils, erosion processes, climatic fluctuations of the last 50 years, geomorphological and geological studies were carried out taking into account all types of management.

4 erosion areas have been identified:

1. Strong wind erosion;
2. Average wind erosion;
3. Weak wind erosion;
4. Weak water erosion (fig.4) [6].

Erosion zoning of the Chechen Republic should be taken as the basis for further development of soil protection measures, as well as for the prospects of agricultural development. The agricultural sector of the Chechen Republic is located in five depression zones, there is intensive production. Areas where deflation processes occur intensively in the soil-protective crop rotation, the use of perennial grasses is recommended.

There are 52.8 thousand hectares of arable land under the soil protection crop rotation, they are allocated taking into account geomorphological conditions and the degree of manifestation of soil erosion processes.

Taking into account the nature and intensity of the manifestations of erosion processes, it is necessary to develop a set of agrotechnical measures for each selected erosion area, providing for soil treatment, which increases its water-absorbing properties, increases resistance to flushing and wind blowing. Protection of soils from erosion processes with the help of plant formations.

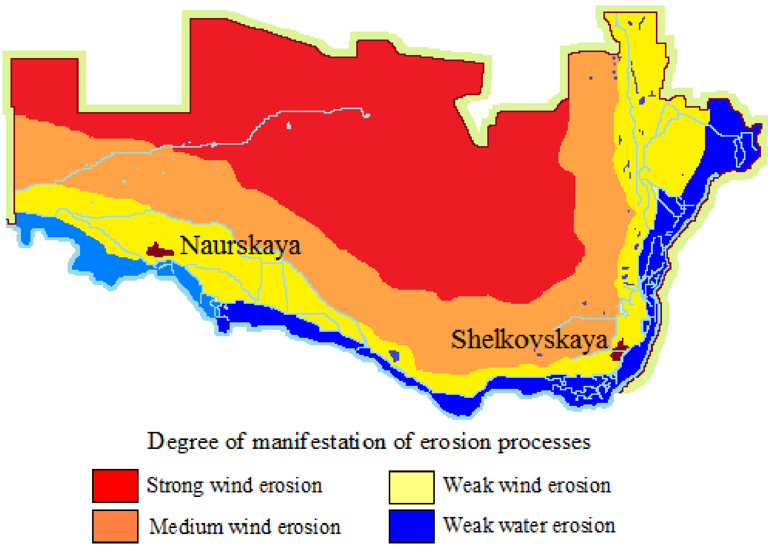


Figure 4: *Zoning of territory according to the degree of mani station of erosion processes*

The soil cover, which is located under vegetation, is not subjected to deflationary processes by water flows. The planned erosion control measures should be based on the protective properties of vegetation.

In arid ecosystems, which will, depending on the nature of the physical properties of the composition of the rocks composing the soil, should be connected, the following agrotechnical techniques are proposed:

- minimization of pre-sowing soil treatment;
- root and surface land improvement;
- rational use of pastures (hay – pasture turnover, normalized grazing);
- strip placement of crops;
- waste-free tillage with flat-cutting tools;
- sowing on stubble;
- backstage crops;
- cross-sowing.

The territorial coverage of the activation of erosion processes in the Chechen Republic is large, and as a consequence – a significant decrease in the natural fertility of soil differences, hence the qualitative state of soil and land resources stimulates the scientific community of the Chechen Republic to develop and implement a scientifically based general scheme of anti–erosion measures, which formed the basis of the program to optimize the environment.

IV. Discussion

Of all the environmental factors affecting the change of vegetation cover, anthropogenic impact (areal logging, grazing, fires) has a significant impact.

The study of the reviews of vegetation cover and its individual groups, as well as the peculiarities of the transformation of plant communities, have become the subject of close study by an increasing number of researchers, among whom one can name Yu. Ya. Anikin, [7], M. A. Berezutsky [8;9;10;11], P. L. Gorchakovsky [12;13;14] and others. However, almost all researchers, including our studies of the past years of the transformation of vegetation under the influence of anthropogenic activity, are devoid of completeness.

The analysis of the above mentioned works, as well as the results of our own long-term research, allowed us to identify the main factors of anthropogenic transformation of plant communities on the territory of the Chechen Republic. The degree of impact was assessed by us visually using the following scale: very low; low; medium; high; very high; highest.

Summing up, we can conclude that the high degree of development of the territory of the Chechen Republic and intensive economic activity contribute to the degradation and radical transformation of natural landscapes, where the main restoration process can be considered self-growth of natural pastures.

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References

[1] The Chechen Republic: nature, economy and ecology. Textbook /I.A. Bayrakov, E.B. Bolotkhanov, A.I. Autorkhanov, H.E. Taymaskhanov, I.Ya. Shakhtamirov. – Grozny: Publishing House of the Chechen State University, 2006. – 375 p.

[2] Bayrakov I.A. (2013) Climatic conditions of the Chechen Republic.– Grozny: Publishing house of CHSPI,.– 186 p.

[3] Chirkov Yu.I. (1975) Fundamentals of agrometeorology. – L.: Hydrometeosidate. - 138 p

[4] Rozhanets-Kucherovskaya S.E. Geobotanical landscapes of the southern part of the Tersko-Kuma massif // Izv. RGO. 1925. Vol.68. Issue 4.

[5] Gozhev A.D. (1930) Types of sands of the western part of the Tersko-Dagestan massif and their economic use/ Gozhev A.D. Izv. GGO..Vol.52. Issue 4. pp.463-529.

[6] Bayrakov I.A. (2014) Problems of desertification of arid landscapes of the North Chechen lowland/ Bayrakov I.A. – Grozny: Publishing House of CHPI,.-170 p.

[7] Anikin Yu.A. (1988). Izmeneniye rastitelnogo pokrova Volgogradskoy oblasti pod vliyaniyem antropogennykh protsessov // Voprosy ekologii i okhrany prirody v Nizhnem Povolzhye: Struktura i analiz populyatsiy i ekosistem. Saratov. S. 30-33.

[8] Berezutskiy M.A. (1999). Antropogennaya transformatsiya flory // Botan. zhurn. T. 84. №6. S. 8-19. Berezutskiy. M. A. Antropogennyye transformatsii flory pravoberezhia basseyna r. Volgi na primere Saratovskoy oblasti / M. A. Berezutskiy // Bot. zhurn.. 1998. № 9. - T. 83. - S.

[9] Berezutskiy. M. A. (1999). Antropogennaya transformatsiya flory / M. A. Berezutskiy // Bot. zhurn. - T. 84. - №6. - S. 8-17.

[10] Berezutskiy. M. A. (2000). Antropogennaya transformatsiya yuzhnoy chasti Privolzhskoy vozvyshennosti : avtoref. dis. . d-ra biol. nauk / M. A. Berezutskiy. Voronezh. - 36 s.

[11] Berezutskiy. M. A. (1998) Tolerantnost sosudistykh rasteniy k antropogennym mestoobitaniyam ; na primere flory okrestnostey g. Saratova / M. A. Berezutskiy // Bot. zhurn... T. 83. - №9. - S. 77-84.

[12] Gorchakovskiy P.L. (1979). Tendentsii antropogennykh izmeneniy rastitelnogo pokrova Zemli // Botan. zhurn.. T. 64. № 12. S. 1697-1714.

[13] Gorchakovskiy P.L. (1984). Antropogennyye izmeneniya rastitelnosti: monitoring. otsenka. prognozirovaniye//Ekologiya. №5. S. 3-16.

[14] Gorchakovskiy P.L. (1999). Antropogennaya transformatsiya i vosstanovleniye produktivnosti lugovykh fitotsenozov. Ekaterinburg: Ekaterinburg. 156 s.

DISTRIBUTION AND ECOLOGICAL GROUPS OF BIVALVE MOLLUSKS OF THE FAMILIES UONIONIDAE AND SORBICULIDAE IN THE AQUATIC ECOSYSTEMS OF THE KYZYLKUM NATURE RESERVE

Husniddin Boymurodov
•
Samarkand Veterinary and Medical Institute, Uzbekistan
boymurodov1971@mail.ru

Abstract

In the part of the Amudarya river flowing through the territory of the Kyzylkum Nature Reserve, 9 species and 2 subspecies of bivalve mollusks of the families Unionidae and Corbiculidae were found. The acclimatization of White Amur (Ctenopharyngodon idella) and White Hummus (Hypophthalmichthys molitrix) has led to the spread of Sinanodonta gibba, S.orbicularis and S. puerorum into aquatic ecosystems. In the Amudarya, Sinanodonta seed species have led to an expansion of their distribution areas. For the first time in the reserve, 5 species included in "Red Book" of Uzbekistan Corbicula cor, S. purpurea, S.fluminalis, Colletopterum syreum sogdianum, C. bacterianum.

Keywords: reserve, aquatic ecosystems, *Unionidae* and *Corbiculidae* families, *Colletopterum syreum sogdianum, C. bacterianum*

I. Introduction

Malachological research in the world focuses on the identification of biological diversity of natural and artificial water bodies, the study of mollusk fauna in aquatic ecosystems of reserves, the assessment and use of the degree of transformation of mollusks in areas with strong anthropogenic impact. The study of regional fauna creates important conditions for the complex solution of theoretical and practical problems. The study of the fauna distribution and ecological groups of dicotyledonous mollusks of the families *Uonionidae* and *Sorbiculidae* in the aquatic ecosystems of the Kyzylkum nature reserve is one of the current issues. Here, along with the complex distribution of individual species, a whole faunistic complex, the existing differences in the ecology of different populations of the same species are also manifested. Careful study of the fauna, species diversity and distribution patterns of bivalve mollusks of the Kyzylkum terrestrial aquatic ecosystems is both theoretically and practically important. Bivalve mollusks play an important role in the purification of contaminated water among invertebrates.

They completely pass water through the body and filter it, i.e. these mollusks are natural water purifiers.

III. Materials and methods

The study of mollusks and collection of materials from the aquatic ecosystems of the Kyzylkum Nature reserve began in 2004. Aquatic ecosystems of the Kyzylkum Nature reserve the

RT&A, Special Issue № 4 (70)
Volume 17, November 2022

species composition, ecological characteristics, interspecific distribution and importance of bivalve mollusks still have not been sufficiently studied. Materials for research were collected in spring, summer and autumn materials of 2004-2021. (Figure 1).

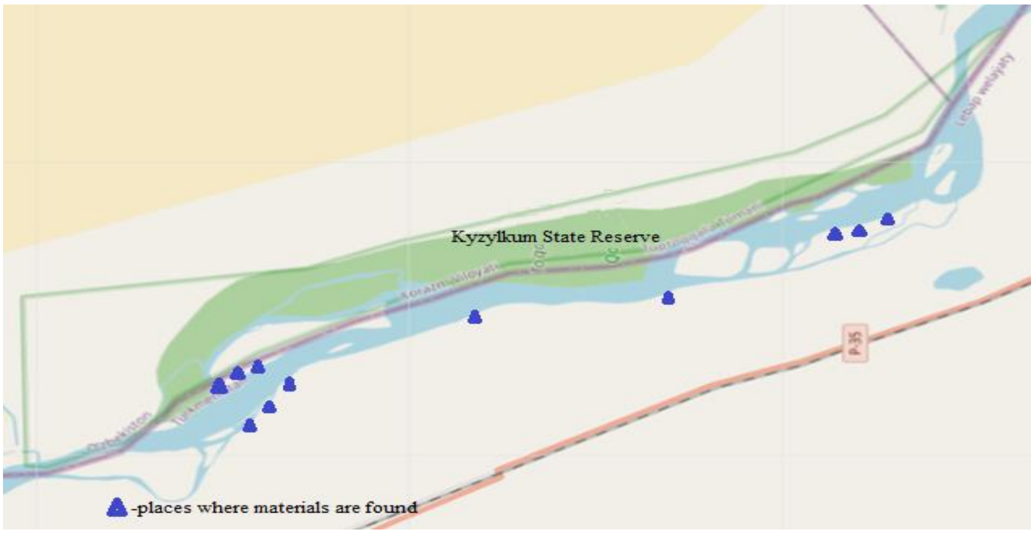

Figure 1: *Places where species of families Uonionidae and Sorbiculidae are found in the territory of Kyzylkum reserve.*

In aquatic ecosystems, there are several ways to manually collect mollusks. Mollusks were collected from the mud near the shore with a steel net, and underwater with a metal net with a sieve [1, 3-5]. The volumes of the large shells were measured using a caliper and the small ones using an MBS-1 ocular micrometer.

IV. Analysis and results

Kyzylkum nature reserve is located in the Bukhara region of Uzbekistan and in the middle reaches of the Amu Darya, on both banks of the river. The area of the reserve is more than 10,311 hectares, the forested area is 5,338 hectares, the sandy desert is 800 hectares, and the tugai forest area is 1,883 hectares. The reserve stretches 30 km from northwest to southeast and 3 km from east to west along the banks of the Amudarya. The Amudarya river flows through the Kyzylkum nature reserve. We studied the distribution of species of the families Uonionidae and Sorbiculidae in the river. The Amudarya is the wettest river in Uzbekistan and the largest in terms of catchment area. The river begins at an altitude of 4950 m on the northern slopes of the Hindu Kush Mountains. The length of the Amudarya is 2540 km. Based on the study of Central Asian aquatic mollusks, ZI Izzatullaev provided the first information about bivalve mollusks in the lower reaches of the Amudarya river and introduced several new species [2, 6].

In the aquatic ecosystems of the Kyzylkum Nature Reserve, river water temperature, groundwater content and river saturation play an important role in the distribution of mollusks belonging to the Unionidae and Corbiculidae families in the Amudarya. As the Amudarya is mainly saturated with ice and snow, it has affected the distribution of some bivalve mollusks. In particular, according to Izzatullaev ZI in the mountainous part of the territory of Tajikistan, its rapid flow and the almost absence of planktonic organisms led to the absence of bivalve mollusks of the family Unionidae [6].

Large bivalve mollusks are widespread only in the plains of rivers - throughout Uzbekistan, due to environmental factors such as slow water flow in this part of the river, favorable water temperature and the abundance of planktonic organisms for feeding mollusks. In addition, it should be noted that in the Amudarya basin, changes in the composition, number and habitat of species of bivalve mollusks occur naturally and under the influence of human activities.

As a result of the research, 9 species and 2 subspecies of bivalve mollusks of the families Unionidae and Corbiculidae were found in the part of the Amudarya flowing through the territory of the Kyzylkum Nature Reserve (Table 1). They are distributed in rocky soils (11,7%), sandy soils (47,0%) and muds (41,3%), depending on the specific characteristics of the river (Figure 2).

Table 1: *Unionidae and Corbiculidae families in the part of the Amudarya flowing through the territory of the Kyzylkum Nature Reserve*

№	Types	Density in river flow, m² (n = 10)		Biotop			Ecological groups
		The middle part Latitude: 40.62255237092874 Distance: 62.11395263671876	Lower width: 40.54433048799512 Distance: 62.17300415039063	rocky soils	sandy soils	muds	
1.	*Sinanodonta orbicularis*	1,0±0,3	-	-	-	+	Peloreofil
2.	*Sinanodonta gibba*	1,9±0,4	1,2±0,2	-	+	+	Peloreofil
3.	*Sinanodonta puerorum*	1,8±0,4	1,1±0,1	-	+	+	Peloreofil
4.	*Colletopterum bactrianum*	0,8±0,1	-	-	-	+	Reofil
5.	*Colletopterum cyreum sogdianum*	1,1±0,3	-	-	-	+	Reofil
6.	*Colletopterum ponderosum volgense*	1,2±0,3	0,7±0,1	-	+	+	Pelolimnofil
7.	*Corbicula cor*	-	1,1±0,2	-	+	-	Peloreofil
8.	*Corbicula purpurea*	-	0,8±0,1	+	+	-	Peloreofil
9.	*Corbicula fluminalis*	0,3±0,1	0,9±0,1	-	+	-	Peloreofil
10.	*Corbiculina tibetensis*	1,6±0,3	2,6± 0,4	-	+	+	Peloreofil
11.	*Corbiculina ferghanensis*	1,9±0,4	2,8± 0,5	+	+	-	Peloreofil
Total types:		**9**	**8**	**2**	**8**	**7**	

We conducted our research in the area of the Kyzylkum nature reserve which coordinate of the middle part of the Amudarya is latitude: 40.62255237092874, the distance is 62.11395263671876, and the coordinate of the Amudarya sheep is latitude: 40.54433048799512, the distance is 62.17300415039063 analyzed the distribution, density biotopes, and ecological groups of species of the Unionidae and Corbiculidae families.

We found that 9 species are distributed in the muddy and sandy soils of the middle part of the Amudarya with latitude: 40.62255237092874 and latitude: 62.11395263671876. Their density per 1 m² is based on the average *Uonionidae* family *Sinanodonta gibba* 1,0, *S. orbicularis* 1,9, *S. puerorum* 1,8, *Colletopterum bactrianum* 0,8, *C. cyreum sogdianum* 1,1, C. *ponderosum volgense* 1,2 from the seeds of Colletopterum. Sorbiculidae family *Corbicul fruminalis* 0,3 from Corbicul seed, *Corbiculina tibetensis* 1,6 and *C. ferghanensis* 1,9 from Corbiculina seed studied.

Z.I.Izzatullaev's researches in 1980-1992 did not show the species *Sinanodonta gibba, S.orbicularis* and *S.ruerorum* from Amudarya. However, research has shown that these species are distributed in the middle part of the Amu Darya - Surkhandarya and lower - Khorezm region [6]. It should be noted that gloxidia *of Sinanodonta* seed species are exoparasitic for some time in fish for reproduction and spread. These species are specific to the territory of China and are associated with the development of non-traditional Chinese complex fish species infested with *Sinanodonta* gloxidia for the development of fisheries in our country - white amur (*Ctenopharyngodon idella*) and whitefish (*Hypophthalmichthys molitrix*). It should be noted that as a result of acclimatization and reproduction of these fish species in fisheries near the Amudarya basin, the influx of white amur and khumbosh into the river under human influence has led to the spread of *Sinanodonta* species in the Amudarya (Figure 3).

Corbicula cor and *S.purpurea* are not found in the aquatic ecosystems of this region because these species cannot live in muddy biotopes, which are mainly adapted to live in sandy and rocky biotopes. 8 species of *Sinanodonta orbicularis* 1,2, *S. puerorum* 1,1, *Colletopterum ponderosum volgense* 0,7, *Corbicula cor* 1,0, *C.purpurea* 0,8, *C. fluminalis* 0,9, *Corbiculina tibetensis* 2,6 *and C. ferghanensis* 2,8. (Figure 4).

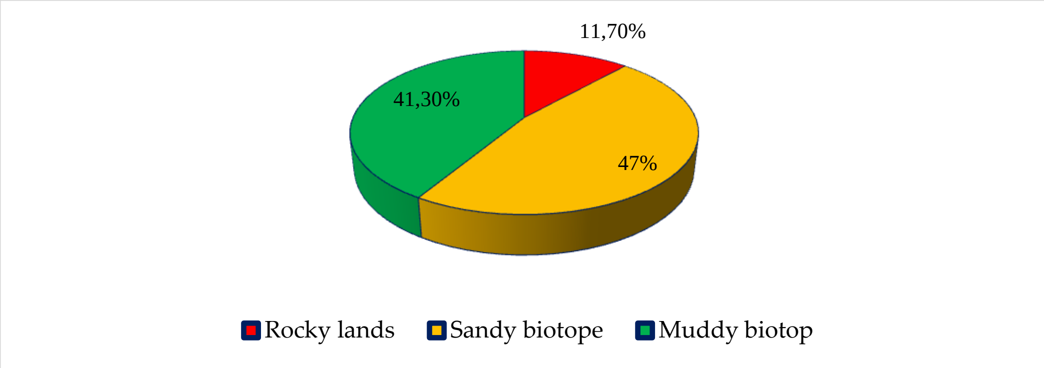

Figure 2: *Distribution of Unionidae and Corbiculidae families in biotopes*

We found that *Sinanodonta orbicularis*, *Colletopterum bactrianum, C. cyreum sogdianum* were not distributed in the waters of this region. The variability of the water level in the lower reaches of the river and the scarcity of muddy biotopes may have contributed to the absence of the species. 5 species included in the Red Data Book of Uzbekistan in the reserve *Corbicula cor, S. purpurea, S.fluminalis, Colletopterum syreum sogdianum, C. bacterianum.* We learned that these species differ from other species in the reserve by a lower distribution density.

The species of the Unionidae and Corbiculidae families distributed in the Kyzylkum Nature Reserve were divided into ecological groups depending on their habitat. All species were found to belong to 3 different ecological groups. Eight species of peloreophiles (*Corbicula cor, S. purpurea, S.fluminalis, Corbiculina tibetensis, C.ferghanensis, Sinanodonta gibba, S.orbicularis, S. puerorum*) are common in the Amudarya, accounting for 73% of the total mollusks. Rheophiles 2 species (*Colletopterum syreum sogdianum, C. bacterianum*) were found to be 18% and 1 species (*Colletopterum ponderosum volgense*), pelolemnofil 9%.

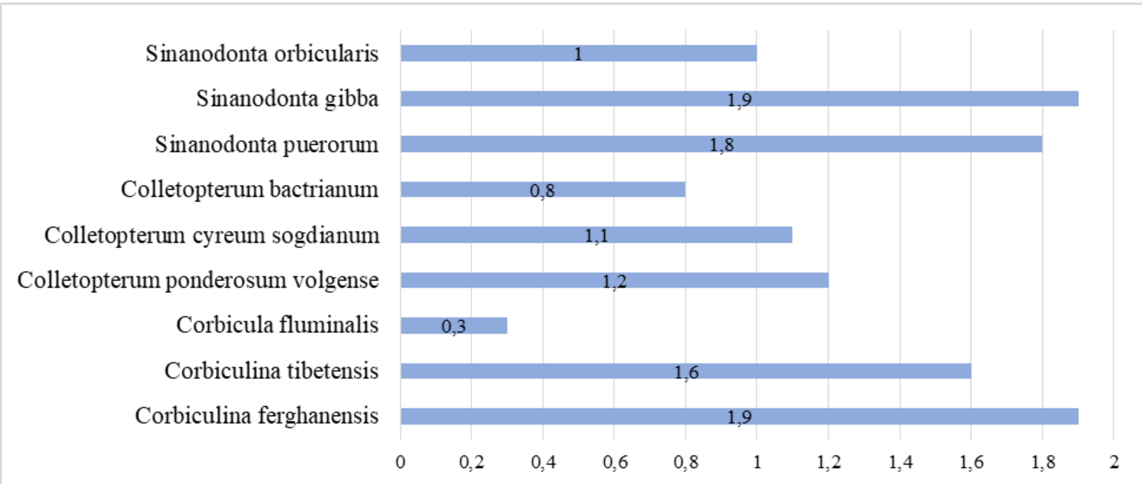

Figure 3: *Distribution density indicators of bivalve mollusks in the middle part of the Amudarya*

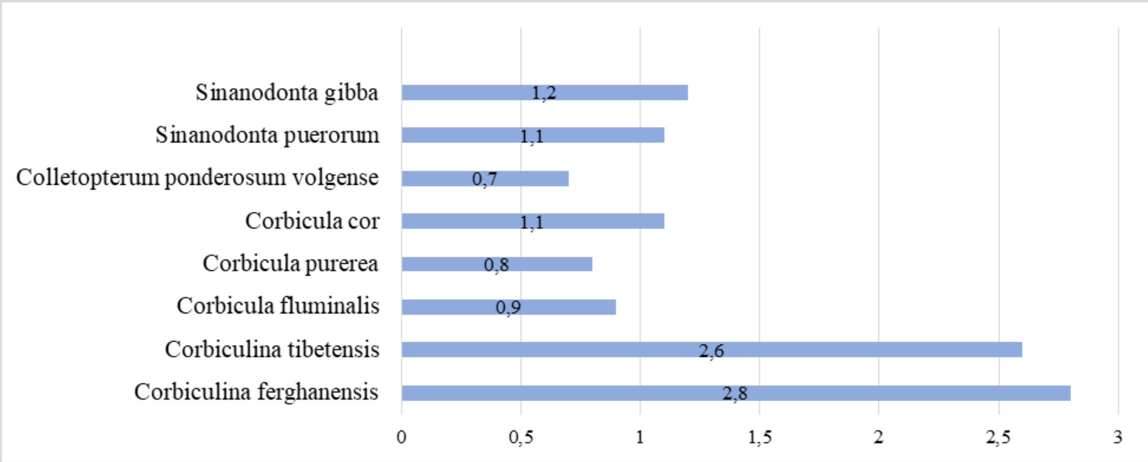

Figure 4: *Distribution density of bivalve mollusks in the lower reaches of the Amudarya.*

V. Conclusions

In the part of the Amudarya flowing through the territory of the Kyzylkum Nature Reserve, 9 species and 2 subspecies of bivalve mollusks of the families Unionidae and Corbiculidae were found. 2 species in rocky biatops, 8 species in sandy biatops and 7 species in muddy biatopes survival were studied. With the acclimatization of the Amudarya aquatic ecosystems in 1985-2000 to breed Chinese complex fish species-white amur (*Ctenopharyngodon idella*) and whitefish (*Hypophthalmichthys molitrix*), the distribution of *Sinanodonta gibba, S.orbicularis and S. puerorum* seeds in the aquatic ecosystems of this region led to the expansion of their range. The extension of 5 species *Corbicula cor, S. purpurea, S.fluminalis, Colletopterum cyreum sogdianum, C. bacterianum* which included in the Red Book of Uzbekistan were found in the reserve.

References

[1] Boymurodov Kh.T. The degree of content of natural radionuclides in mollusks // Uzbek Biological journal. –Ташкент, 2011. –№5. –P. 41-42.

[2] Izzatullaev Z.I. Mollyuski vodnikh ekosistem Sredney Azii. // Monografiya. – Toshkent: Lessonpress, 2018.

[4] Boymurodov Kh.T. Development of Producing Pearl of Bivalve Molluscs (Mollusca: Unionidae, Corbuculidae) in Uzbekistan // Eastern European Scientific Journal. – Germany, 2015. – №4. –P. 44-47.

[5] Boymurodov Kh.T. Two Subspecies Mollusks Fauna, Biologic Difference and Ecologic Groups in the Water Reservoirs in Nearby Mountain // Eastern European Scientific Journal. – Germany, 2015. –№5. –P.15-19.

[6] Izzatullaev Z.I., Boymurodov X.T. Results of the development of two-limbed preservative mollusks (Bivalvia: Unionidae, Anadontinae) in Uzbekistan // Journal of the Moscow Society of Experimental Nature. –Moscow, 2016. t. 121. Pub. 5 p.16-19.

BIODEGRADATION OF PHENOLS AND HALOGENATED DERIVATIVES OF AROMATIC CARBOHYDROGENS BY BACTERIA SPECIFIC TO THE GENUS *PSEUDOMONAS AND ARTHROBACTER*

Aynur Babashli, Nazilya Akhundova, Natavan Gadimova

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Azerbaijan State Economic University
aynurb@list.ru
nazilya.akhundova@mail.ru
natavan.qadimova@mail.ru

Abstract

As a result of the research, active phenol-absorbing bacterial strains belonging to the genera Pseudomonas and Arthrobacter were isolated from the Azerbaijani shores of the Caspian Sea. Biodegradation of chlorinated derivatives of phenols and aromatic hydrocarbons by isolated bacteria was studied. Investigation of biodegradation products of phenols and halogenated derivatives of aromatic hydrocarbons (p-, m-, o-chlorophenol, p-, m- process, o-chlorotoluene, chlorobenzene) and formation of halogen forms of benzene and toluene using the technology of reversed-phase liquid chromatography method. as the degradation mechanism of benzene and toluene goes through the system.

Keywords: bacteria, biodegradation, oil pollution, halogenated derivatives of phenol, halogenated derivatives of aromatic hydrocarbons

I. Introduction

In the last 50-60 years, the environmental condition of the Caspian Sea has deteriorated under the influence of anthropogenic factors. In modern times, oil and oil products are considered one of the most important and dangerous pollutants of modern water ecosystems [3]. Since the distant past, the southern part of the Caspian Sea - Azerbaijan has been exposed to oil pollution.

However, all ecological contradictions existing in the Caspian Sea are not only related to hydrocarbons of petroleum origin. In addition to oil hydrocarbons, more dangerous pollutants, xenobiotics, and carcinogens enter the Caspian Sea every year. The composition of these compounds in seawater depends on the design of wastes coming in from the outside, and changes under the influence of abiotic and biological factors.

The entry of oil and oil products and sewage into the Caspian Sea strongly impacts the vital functions and gene pool of marine hydrobionts, reducing their effectiveness. In addition, separate areas of the Caspian Sea lose from self-purification and become unsuitable for fish farming [2].

Permanent pollution causes the infection of some fish with various parasites, pathogenic microbes, and fungi, which causes serious consequences. Phenol pollution gives a foul smell and taste to the water and its inhabitants, and in addition, to the fish. A high concentration of phenols has a lethal effect on hydrobionts.One of the main ways in which phenols, aromatic hydrocarbons, and their derivatives pollute the seas is wastewater from the processes of oil extraction, oil transportation, and oil and oil product processing [2,3].

The study of the role of microorganisms in the biological purification of water bodies from phenols and halogen derivatives of aromatic hydrocarbons is one of the urgent issues of the modern era [4,5,6]. Degradation of halogenated derivatives of phenols and aromatic compounds by phenol-absorbing bacteria isolated from the Azerbaijani shores of the Caspian Sea has been studied.

II. Methods

During the research, 44 active bacterial strains isolated from the Azerbaijani shores of the Caspian Sea were planted with 50, 100 and 300 mg/l halogenated derivatives of phenols and aromatic hydrocarbons (p-, m-, o-chlorophenol, tetrachloropyrocatechin, tetrabrompyrocatechin) as the sole source of energy and carbon, p-, m-, o-chlorotoluene, chlorobenzene, bromobenzene) were added.

The molecular level study of the intermediate products formed in the biodegradation of phenols and halogenated derivatives of aromatic hydrocarbons was carried out by the reversed-phase liquid chromatography method. The structural composition of biodegradation products of the compounds was confirmed by IR and NMR^{1}H spectral analysis.

III. Results

As a result of preliminary studies, it has been determined that bacterial strains do not develop in an environment containing toxic substances at a concentration of 300 mg/l. Therefore, all subsequent studies have been carried out in a medium containing halogenated derivatives of phenols and aromatic hydrocarbons at a concentration of 100 mg/l.

As a result of the research, it has been determined that 73% of the 44 active bacterial strains isolated from the shores of the Caspian Sea developed in an environment containing p-chlorophenol at a concentration of 100 mg/l as the only source of energy and carbon. 66% of bacterial strains grew in o-chlorophenol and 36% in m-chlorophenol.

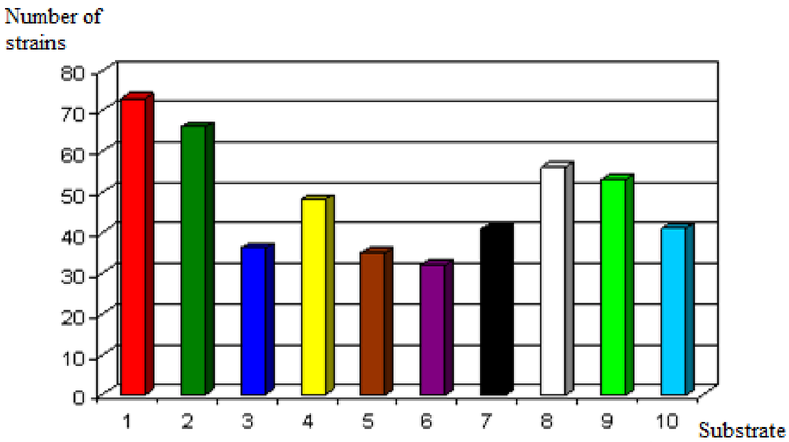
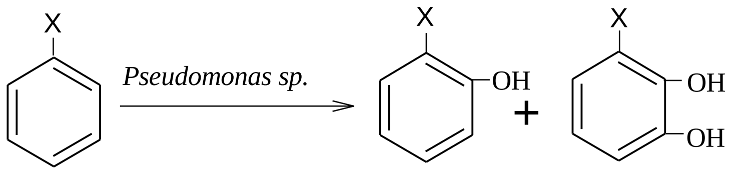


Figure 1: *The number of bacteria growing in halogenated derivatives of phenols and aromatic hydrocarbons (at a concentration of 100 mg/l) in %: 1-o-chlorophenol, 2-p-chlorophenol, 3-m-chlorophenol, 4-chlorobenzene, 5-bromobenzene, 6- tetrachlorpyrocatechin, 7-tetrabrompyrocatechin, 8-p-chlorotoluene, 9- m- chlorotoluene, 10- o-chlorotoluene*

It was determined that 58% of the bacteria assimilated chlorobenzene as the sole source of energy and carbon, and 35% assimilated bromobenzene. 32% of the studied bacterial strains grew on tetrachlorpyrocatechin, and 41% on tetrabrompyrocatechin. 56% of bacteria assimilated p-chlorotoluene, 53% m-chlorotoluene, and 41% o-chlorotoluene as the sole source of energy and carbon. As can be seen from the picture, most of the bacteria isolated from the Azerbaijani shores of the Middle and South Caspian had the characteristic of growing in an environment containing halogenated derivatives of phenols and aromatic hydrocarbons as the only source of energy and carbon at a concentration of 100 mg/l.

During the studies, *Pseudomonas sp., Arthrobacter sp.* The composition of the biodegradation products of halogenated derivatives of phenols and aromatic hydrocarbons (p-, m-, o-chlorophenol, p-, m-, o-chlorotoluene, chlorobenzene, bromobenzene, tetrachlorpyrocatechin, tetrabrompyrocatechin) was studied with the participation of strains of has been shown to follow a similar mechanism. In both cases, it was determined that the directions for purchasing biotransformation products are the same. The similarity was observed even in the proportions of the amounts of degradation products. As can be seen from the chromatographic curve in Figure 2 (curve a), chlorobenzene is mainly converted to 2,3-dihydroxy chlorobenzene (30%) and o-chlorophenol (65%) in the intermediate stage of the degradation process (peaks 1 and 2).



X=Cl, Br

During the studies, the process of degradation of p-chlorotoluene (curve b) according to the degradation of toluene with a mixed mechanism, i.e., in the direction of simultaneous oxidation of the methyl radical in the side chain and the aromatic ring, phenolic acids: 2,3-dihydroxy-p-chlorobenzoic (25%), it was determined that 2-hydroxy-p-chlorobenzoic (30%) and p-chlorobenzoic acids (20%) were obtained (peaks 1, 2 and 4). The formation of 2-hydroxy-p-chlorotoluene (15%) (peak 3) was observed in the degradation process that occurred only as a result of the oxidation of the aromatic ring.

From the results obtained during the research, it can be concluded that the decomposition of chlorine ions does not occur at the initial stage of the degradation processes of chlorobenzene and chlorotoluene. This shows their stability in the composition of transformation products under selected conditions.

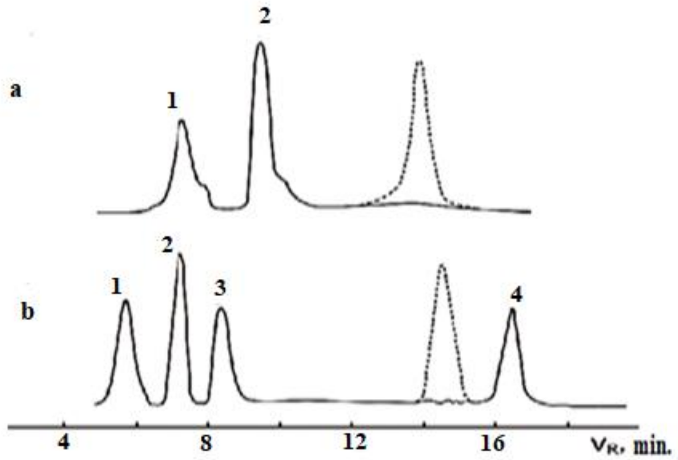
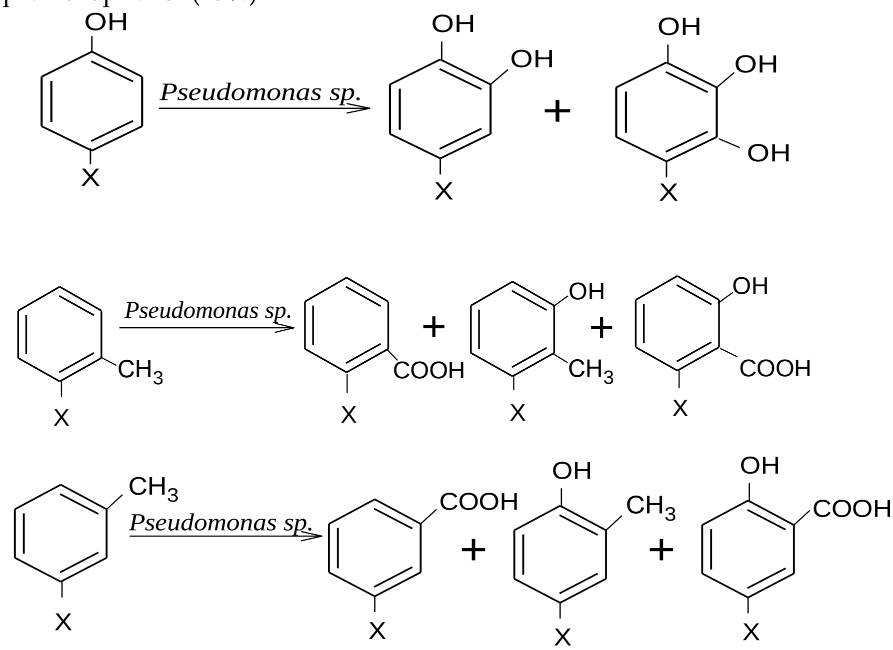


Figure 2: *Chromatography curves of chlorobenzene (a) and p-chlorotoluene (b).*
a) Peaks 1-2: 2,3-dihydroxychlorobenzene and o-chlorophenol;
b) Peaks 1-4: 2,3-dihydroxy-p-chlorobenzoic acid, 2-hydroxy-p-chlorobenzoic
The structure of degradation products was confirmed by IR- and PMR-spectra.

In the IR spectra, in addition to absorption bands (600-750 cm^{-1}) characteristic of the C-Hlg bond, bands characteristic of the aromatic ring (860, 1600-1635, 3050 cm^{-1}) and 3465-3600 cm^{-1} of the hydroxyl group were found. PMR spectrum of chlorobenzene d=7.70-9.00 m.h. in the field (in singlet form) and d=6.70-6.85 m.h. in the area, signals characteristic of chemical shifts (in the form of multiples) of protons of aromatic ring and hydroxyl group (3H, C_6H_3; 4H, C_6H_4) were found.

The degradation of o-chlorotoluene followed a similar process to the degradation of p-chlorotoluene. Thus, among the degradation products of o-chlorotoluene, 6-hydroxy-o-chlorotoluene (25%), o-chlorobenzoic acids (20%) and 6-hydroxy-o-chlorotoluene (15%) were observed. Analogous compounds were also noted in the process of degradation of m-chlorotoluene.

A faster disintegration process was observed in the degradation of p-chlorophenol. The biotransformation product of p-chlorophenol was mainly 2-hydroxy-p-chlorophenol (15%) and 2,3-dihydroxy-p-chlorophenol (25%).



X=Cl, Br

A faster disintegration process is observed in the degradation of p-chlorophenol and tetrachlorpyrocatechin (Figure 3). The biotransformation product of p-chlorophenol was mainly 2-hydroxy-p-chlorophenol (15%) and 2,3-dihydroxy-p-chlorophenol (25%) (curve a). During the transformation of tetrachlorpyrocatechin, only one more stable substance - tetrachlormuconic acid - was fixed in the intermediate stage of the degradation process (curve b). It was determined that the degradation of these compounds, unlike the previous combinations, occurs with the breaking of the phenyl ring.

It should be noted that unlike chlorinated derivatives of phenols and aromatic hydrocarbons, the biodegradation of brominated derivatives of these compounds is complex, and the amount of biotransformation products formed corresponds to 5-7%.

Absorption bands characteristic of the aromatic ring and hydroxyl group were found in the IR-spectra of the degradation products of chlorophenol. In addition, bands related to the C-Hlg bond were also observed in the 600-750 cm^{-1} region. d=7.65-9.00 m.h. characteristic of protons of the hydroxyl group (Ar-OH) and aromatic ring (3H, C_6H_3; 2H, C_6H_2) in PMR-spectra. Singlet shape in the field and d=7.65-9.05 m.h. Multiplet signals are recorded.

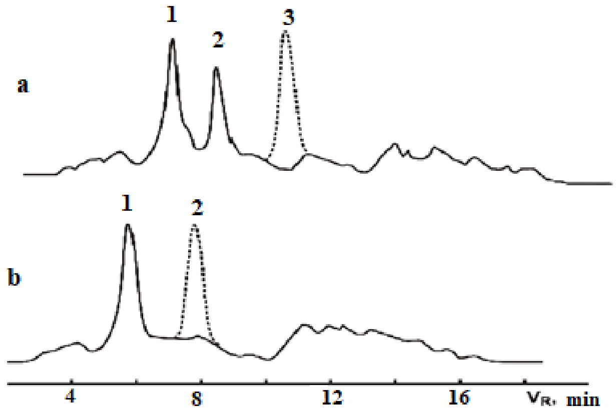
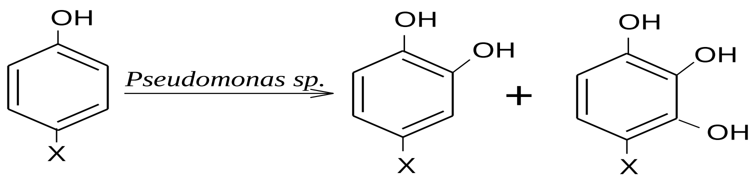


Figure 3. *Chromatography curves of biodegradation of chlorophenol (a) and tetrachloropyrocatechin (b).*
a) Peak1- 3: 4-chloropyrocatechin, 2,3-dihydroxy-p-chlorophenol and starting chlorophenol;
b) Peak 1 and 2: tetrachloromuconic acid and starting tetrachlorpyrocatechin.



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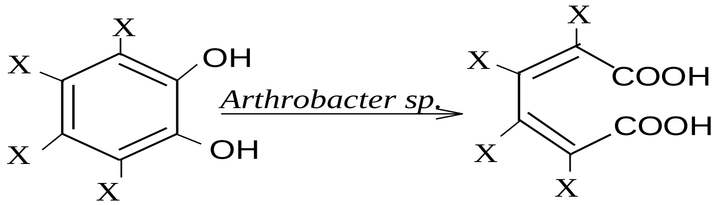

X=Cl, Br

As a result of the research, it was determined that the isolated active phenol-absorbing bacterial strains degrade not only phenols, but also halogenated derivatives of phenol and aromatic hydrocarbons. This shows that it is possible to use those bacterial strains in cleaning the waters and soil contaminated with hydrocarbons and provides a basis for the preparation of biopreparations.

References

[1] Babashli A.A., Salmanov M.A., Veliev M.G. Degradation of phenol and its derivatives by microorganisms isolated from the Azerbaijan coast of the Caspian Sea / Proceedings of the II International Scientific and Practical Conference. Ecology of biosystems: Problems of study, indication and forecasting, Astrakhan: Astrakhan University, 2009, p.130-132 (in Russian).

[2] Barkhalov R.M., Shikhshabekov M.M., Gadzhiev A.A. Ecological problems of the Caspian Sea and ways to resolve them / Mat. int. Conf., "Modern problems of biological resources of the Caspian Sea" Baku: 2003, p. 54-57 (in Azerbaijan).

[3] Gasimov A.G. Caspian Sea. Baku: Elm, 1999, p. 204 (in Azerbaijani).

[4] Salmanov M.A., Veliev M.G., Babashly A.A. The ability of bacteria isolated from the Azerbaijani coast of the Caspian Sea to absorb phenolic compounds // Proceedings of the Institute of Microbiology of the National Academy of Sciences of Azerbaijan, 2008, volume 6, p. 36 – 41 (in Azerbaijani).

[5] Veliev M.G., Salmanov M.A., Alieva S.R., Babashli A.Ə., Bektashi N.R. Biodegradation of Aromatic Hydrocarbons and Phenols by Bacteria Isolated from Caspian Waters and Soils / Petroleum Chemistry Vol. 53, No. 6, pp. 426-430, (2013).

[6] Veliev, M.G., Danielsson, B., Salmanov, M.A. *et al.* Biodegradation of Baku oil and hydrocarbons by micromycetes. Petroleum Chemistry **48**, 56–62 (2008).

LOW-CARBON DEVELOPMENT STRATEGY INTERNATIONAL EXPERIENCE AND RUSSIA'S PRIORITIES

Muslim Eskiev, Laila Satueva, Aishat Baysangurova
•
Chechen State University named after A.A. Kadyrov, Russia
sll-72@mail.ru
salamova_chgu@mail.ru

Abstract

The national climate policy of Russia against the international background has been developing quite slowly. Its development entered an active phase in the 2010s with the adoption of the Climate Doctrine of the Russian Federation at the end of 2009, and is now detailed in action plans aimed at achieving the goals of reducing GHG emissions and adapting to climate change. The climate doctrine has secured the priority of national interests in the development and implementation of climate policy, but the driver of its current development is the international agenda and climate initiatives of Russia's main trading partners (primarily the EU). According to a VTsIOM survey from September 202067, the majority of Russians agree that climate change is taking place on the planet (93% of respondents), and notes that they have an impact on their lives (57%). At the same time, if 52% of the Russians surveyed consider global warming to be a really serious problem, then 40% characterize this problem as far-fetched and inflated (8% found it difficult to answer). Russians are generally not ready to pay more for goods and services, even if these funds are used to introduce alternative energy sources or improve energy efficiency (62%–76% of respondents, depending on the product or service). Russian business is also against the introduction of additional climate fees. Strengthening the national climate policy in Russia is supported by the majority of the scientific community (although there are also climate skeptics in Russia) and by a number of experts who point to a significant potential increase in costs associated with both the need to adapt to climate change and the further spread of climate initiatives in the world. Thus, the climate policy in Russia can be attributed to one of the most controversial and difficult areas to develop.

Keywords: national climate policy, climate initiatives, climate change, environmental problems, environmental protection, global warming

I. Introduction

Russia supports international efforts aimed at combating climate change and is ready to cooperate in this area with all states, but considers it unacceptable to consider climate change and environmental protection issues from a biased point of view, infringing on the interests of energy-producing states and deliberately ignoring aspects of sustainable development such as universal access to energy and the development of clean hydrocarbon energy technologies. It is a party to the UNFCCC, its Kyoto Protocol, the Paris Agreement and international treaties for the protection of the ozone layer, and also participates in ICAO and IMO. Russia signed the UNFCCC on June 12, 1992 and ratified it on November 4, 1994 (Federal Law No. 34-FZ of November 4, 1994), becoming an Annex I country (developed countries and countries in transition to a market economy) [1]. On March 11, 1999, Russia signed the Kyoto Protocol, but ratified it on November 4, 2004 (Federal Law No. 128-FZ dated November 4, 2004), assuming quantitative obligations to maintain the level of GHG emissions in the first period of the Kyoto Protocol (2008– 2012) at the

1990 level [2]. The Conference of the Parties to the UNFCCC in Doha in 2012 determined the second period of the Kyoto Protocol - 2013-2020 [3]. Russia refused to secure for itself the quantitative obligations of the second period, formally remaining a party to the Kyoto Protocol. On April 22, 2016, Russia signed the Paris Agreement (in accordance with the Decree of the Government of the Russian Federation of 14.04.2016 No. 670-r), but acceded to it on September 21, 2019 (Decree of the Government of the Russian Federation of 21.09.2019 No. 1228). The Paris Agreement, including at the insistence of Russia, includes articles that fix an adequate account of the forest factor and the importance of global adaptation. On November 25, 2020, Russia announced its first nationally determined contribution as part of the implementation of the Paris Agreement.

The problem of climate change is interdisciplinary in nature, therefore the development and implementation of climate policy in Russia is under the jurisdiction of several executive authorities, and interdepartmental groups are created to coordinate it. The Government Commission on Nature Management and Environmental Protection will solve the following tasks. coordination of actions of federal government bodies, executive authorities of the constituent entities of the Russian Federation and other bodies and organizations on the implementation of the national action plan for the first stage of adaptation to climate change for the period up to 2022 and the conservation and efficient use of forest resources and the development of the timber industry complex. Information and analytical support for the activities of the Commission is carried out by the Ministry of Natural Resources of Russia on issues of nature management and environmental protection, the Ministry of Economic Development of Russia - on issues of adaptation to climate change. Measures to combat climate change (mitigation) are aimed at reducing anthropogenic GHG emissions and improving the quality of sinks and reservoirs. In a narrow sense, they can be limited to the introduction of GHG emissions pricing (carbon pricing), in a broad sense, which is more common, they can include all measures that directly or indirectly lead to the reduction of GHG emissions. There are various classifications of climate policy measures, for example, depending on the coverage: general economic and sectoral [4]. General economic experiment on the establishment of special regulation in the Sakhalin Region in order to create the necessary conditions for the introduction of technologies aimed at reducing GHG emissions, working out the methodology for creating a system for verifying, accounting for GHG emissions and removals (the corresponding roadmap was approved in January 2021 by the Deputy Prime Minister of the Russian Federation V. Abramchenko) The introduction of mandatory carbon reporting and the creation of conditions for the implementation of voluntary initiatives to reduce emissions and increase absorption of GHGs (drafts of the Federal Law On the Limitation of GHG Emissions and the Concept of a system for accounting, registration, issuance for circulation, transfer and offset of climate change results) are being considered. projects implemented in the Russian Federation) The introduction of public non-financial reporting is being considered (the Russian Ministry of Economic Development prepared and submitted to the Government of the Russian Federation the draft Federal Law financial reporting - as part of the Action Plan for the implementation of the Concept for the Development of Public Non-Financial Reporting (Decree of the Government of the Russian Federation dated May 05, 2017 No. 876-r) [6]. The development of a national taxonomy of sustainable financing is being considered (as part of the Order of the Government of the Russian Federation dated November 18, 2020 No. 3024-r) Payment for negative impact on the environment: for emissions of pollutants into the atmospheric air by stationary sources, for discharges of pollutants into water bodies and during waste disposal (Federal Law No. 7-FZ of January 10, 2002 On Environmental Protection) Subsidies from of the federal budget to Russian organizations to reimburse the costs of paying coupon income on bonds issued as part of the implementation of investment projects to introduce the best available technologies (Decree of the Government of the Russian Federation dated April 30, 2019 No. 541) the efficiency of the economy of the Russian Federation - with an emphasis on the most energy-intensive sectors of the economy (energy, industry, transport and housing and communal services) [3-4].

Strategies and measures to combat climate change are becoming more widespread in the modern world. Thus, according to some estimates, in 2007-2017, the number of countries that adopted climate strategies increased from 9 (5% of a sample of 194 countries) to 48 (25%), and the number of countries with climate legislation that enshrines mandatory measures increased from 32 (16%) to 46 (24%). At the same time, these 94 countries with climate strategies and measures accounted for 69% of global GHG emissions in 2017 [5]. Along with the growth of climate policies and measures, there has been an increase in targets for the reduction of GHG emissions, the development of renewable energy sources and energy efficiency. The number of countries with nationally linked GHG emission reduction targets increased from 39 (20%) in 2007 to 147 (76%) in 2017; with targets for renewable energy (both in the energy balance as a whole and only in the electric power industry), respectively, from 39 (20%) to 137 (71%); with energy efficiency targets — from 36 (28%) to 59 (31%) [6]. The most typical climate strategies, measures and goals for European countries. In Russia, at the national level, strategic documents in the field of combating climate change have been adopted and are being developed, measures are being taken to reduce GHG emissions, and a goal has been set to reduce them by 2030. The target indicators for the volume of production and consumption of electric energy using renewable energy sources (except for hydroelectric power plants with an installed capacity of more than 25 MW) are fixed at the level of 4.5% by 2024 (Decree of the Government of the Russian Federation dated July 28, 2015 No. 1472-r). The goal of reducing the energy intensity of Russia's gross domestic product by at least 40% by 2020 compared to 2007 (Decree of the President of the Russian Federation dated June 4, 2008 No. 889), according to the Russian Ministry of Economic Development, while maintaining the current pace, will be achieved with a large lag behind plan, in 2043 [7]. The draft of a new comprehensive plan to improve energy efficiency assumes a reduction in the energy intensity of Russia's GDP by 35% by 2017 by 2030 (20% of which will be provided by the technological factor). The number of climate strategies, measures and goals reflects the attention of countries to this area, and qualitative (expert) assessments are formed to evaluate their efforts. Such an assessment, in particular, is offered by the Climate Change Performance Index, an integral component of which is Climate Policy (at the national and international levels). Its assessment is formed by climate and energy experts from non-governmental organizations, universities and research centers. The 2020 Climate Change Performance Index ranks Russian efforts in the Climate Policy component as very low (54 out of 58), including very low at the national level and low at the international level. It should be noted that not a single country of the ranking received a very high score in this component for 2020. As in the previous year, G20 countries scored low and very low, South Africa was able to improve its score to medium, and Saudi Arabia's score deteriorated to low [8].

Russia’s «Climate Policy» assessment does not take into account the approval of the 2030 GHG emission reduction target, but experts in the assessment note strong opposition to the country’s increased climate ambitions from carbon-intensive industries. According to their assessment, this overpowers such positive signals as improved regulation in the housing and communal services for the national dimension and accession to the Paris Agreement for the international dimension. Some potential has been noted for energy efficiency, GHG reduction and land use initiatives under discussion in Russia (including protected areas and reforestation projects).

II. Methods

The challenges posed by current global climate policy trends dictate the need for further development of strategies and measures to counteract climate change in Russia, along with adaptation strategies and measures. It seems important to identify measures on the implementation of which a relative consensus can be expected in Russia and which can be implemented in the first place. Such measures can include [7-8]: improving the accounting and protection of the forest fund; introduction of a national system for reporting and monitoring GHG emissions (the relevant draft law has been prepared by the Ministry of Economic Development of Russia); creating conditions for the implementation of voluntary initiatives to reduce GHG emissions (the Russian Ministry of Economic Development has prepared a corresponding concept); shaping the image of Russia as a climate-responsible country; expanding opportunities for promoting Russian low-carbon technologies to foreign markets.

When formulating climate goals, Russia focuses on taking into account the absorptive capacity of forests. Despite the existence of an approved methodology for taking into account the absorption capacity, the discussion of preferred approaches to accounting continues, in particular, it is proposed to: the formulation of Russia's new climate goal for 2030 [9]. Develop methods for accounting for GHG emissions by product range and offsetting GHG emissions by forests and soils with reference to the product range; Agree on new methodologies at the international level of the UNFCCC. In Russia, the development of carbon landfills (farms) can help improve the accounting of GHG emissions and the absorptive capacity of forests and agricultural lands. They are experimental territories (enterprises) where technologies for remote and ground-based calculation of the absorbing (sequestration) potential are being tested. The development of a network of such carbon landfills can ensure the creation of a national system for calculating the carbon balance based on internationally verified technologies and methods. It is assumed that the national system will provide an objective calculation of the carbon balance; its results can be used at the international level, incl. in the framework of international trading in quotas for GHG emissions. In the world, the sequestration industry aims to produce and sell carbon credits (offsets) to reduce the carbon footprint of enterprises, industries and countries. As of 2020, carbon farms of various designs and functions occupy hundreds of millions of hectares worldwide with a trend of reaching $3-4 trillion per year by 2030. In September 2020, the first carbon farm in Russia was created in the Kaluga Region (within the boundaries of the Ugra National Park), within which it is planned to implement a set of innovative and technological solutions, the use of which will create scientifically based methods for objectively calculating the carbon balance of territories [10].

In December 2020, the Russian Ministry of Education and Science announced84 the launch in 2021 of a program to create carbon polygons based on Russian universities located in different regions (10-12), with the involvement of regional authorities and businesses. In order to create a network of carbon landfills, the Ministry of Education and Science of Russia sent a proposal to the Ministry of Natural Resources of Russia to include the relevant measure in the plan to reduce GHG emissions. At the same time, it is necessary to continue work in Russia to improve the quality of data on Russian forests, completing the formation of a full-fledged forest registry (which digitalization can contribute to), and to expand and protect the forest fund of Russia [9].

Reporting on GHG emissions can be considered at the aggregate level and at the level of economic entities (export requirements, investor preferences, exchange rules). Aggregate level It is important to develop a national reporting system that will provide up-to-date information on GHG emissions at the level of regions, municipalities and sectors of the economy, as well as create a basis for modeling and forecasting the consequences of climate policy and climate risks (including the use of mechanisms for assessing the regulatory and actual impact of measures climate policy based on correct data). In the future, it is possible to expand such a system to the level of the EAEU. Corporate Level Another direction is the need to disclose the carbon reporting of companies in accordance with the requirements of international organizations and investors. In this regard, it is important for Russia to implement as soon as possible a national system for reporting and monitoring GHG emissions, which would allow Russian companies to comply with external "climate" requirements in terms of information disclosure, and would also not require companies to report simultaneously on different external and internal requirements. The concept of forming such a reporting system has been approved, and a number of methodological guidelines and recommendations have been developed at the level of the Ministry of Natural Resources of Russia and the Ministry of Economic Development of Russia, but legislative registration of the process of its formation is required. As part of the prepared draft law on limiting GHG emissions into the atmospheric air, basic approaches are outlined, which require detailing at the level of by-laws [7-8]. Against the background of the strengthening of the climate agenda, the importance of carbon footprint assessments will increase - the measurement of GHG emissions generated as a result of the activities of an organization, the holding of an event or the production of a product. It is advisable to study the methods and methods for assessing the carbon footprint, as well as ways to verify the data obtained.

Currently, the alternative of carbon pricing in Russia is causing a sharp negative reaction from large industry and is perceived by it as an additional fee, so the introduction of obligations (quotas, taxes, fees) for a wide range of economic entities may be premature. Nevertheless, conditions should be created for the implementation in Russia of voluntary initiatives to reduce GHG emissions. Such initiatives may be needed to support Russian exporters in the near future, primarily in connection with the planned introduction of a transboundary carbon mechanism in the EU, so they will require consultations with the EU. Russian exporters can independently participate in the trading of carbon units in foreign markets, observing the established requirements and standards, but such an approach creates risks for the Russian economy and budget.

III. Results

Countering climate change, which contributes to the solution of one of the global problems, is an area of unification of the efforts of almost all countries of the world [5]. Since Russia is one of the largest emitters of GHGs, more attention should be paid to highlighting the country's efforts (with an indication of existing restrictions and further intentions) and look for opportunities to promote such climate initiatives that would meet national interests - for example, international cooperation in terms of adaptation to climate change or support for carbon capture and storage (CCS) projects. In addition, it is possible to intensify work on creating alliances with countries that have similar interests in order to strengthen the negotiating position during international climate negotiations. So far, Russia has mostly been out of associations: formally, it is a member of the Umbrella Group, organized in 1997, but at the current stage, Russia has few similarities in positions with the developed countries of this group. The creation of associations with developing countries is partly hampered by Russia's belonging to Annex I of the UNFCCC [7]. Financing is one of the most difficult issues to agree on in international climate negotiations, but this does not affect Russia much: it is neither a recipient of financial assistance (as an Annex I party) nor a major donor (the status of an economy in transition allows it to provide assistance on a voluntary basis). It is advisable to consider the development of an index that assesses the efforts of countries to combat climate change in Russia or within a regional association with Russian participation (for example, the EAEU or BRICS) [8].

In Russia, stimulating non-commodity non-energy exports is one of the national priorities. The development of high-tech and low-carbon technologies in Russia (RES, hydrogen, energy efficiency technologies, etc.) for exports and the domestic market can become one of the significant growth points for the national economy. Moreover, under the auspices of the Paris Agreement, the Sustainable Development Mechanism (SDM) is being finalized. It implies joint actions of countries to reduce GHG emissions (both market and non-market) and opens up opportunities for promoting low-carbon technologies to foreign markets. In light of the promotion of non-commodity exports, these opportunities deserve careful study in Russia. The mechanisms being developed in Russia to provide sustainable (including «green») financing can also contribute to the promotion of low-carbon technologies. They are formed by the Ministry of Economic Development of Russia and VEB.RF, which has already submitted Methodological recommendations for the development of investment activities in the field of «green» financing in Russia. Further, issues are considered, the solution of which is important, but for the current period there is no relative consensus on them.

At the same time, it is equally important, but much more difficult in an economy where traditional energy resources play a leading role, to agree on medium and long-term guidelines for national climate policy, which should indicate the direction of the transition to a low-carbon development path - in line with international trends. This is the aim of the draft Strategy for the socio-economic development of the Russian Federation with low GHG emissions until 2050, prepared by the Ministry of Economic Development of Russia [6]. It is also preferable to determine the conditions under which the introduction of carbon pricing is possible in Russia. The draft Strategy for Social and Economic Development with Low GHG Emissions provides for the formation of an integrated national system for monitoring and forecasting GHG emissions. In addition, we can consider the organization of monitoring the challenges of the development of climate regulation in the world for the Russian economy and a comprehensive assessment of their impact [7].

The most contentious issue is the introduction of carbon regulation in Russia to maintain payments for GHG emissions when EU cross-border carbon regulation is introduced. Russia is one of the few countries that currently lack such regulation, which creates significant risks. In parallel, it is necessary to consider compensatory measures for the most sensitive industries and consumers, as well as the possibility of a symmetrical response for importers to Russia. It seems important to move to proactive actions in terms of climate policy measures. In the light of the planned introduction of a transboundary carbon mechanism in the EU, it can be expected that the problem of carbon regulation will reach the level of international relations. Russia is one of the major trading partners of the EU, which currently lacks any system of carbon regulation (carbon taxes or emissions trading). The lack of such regulation deprives Russia of flexibility in terms of the possibility of offsetting payments for GHG emissions on its territory. As a result, in order to maintain (full or partial) payments for greenhouse gas emissions in Russia, as well as for a symmetrical response, it is advisable to take the following steps: the initial stage will work on a voluntary basis [8]. However, if relevant requirements from the EU appear for certain groups of goods (which are covered by the TUR), the introduction of a mandatory regime will be required. It is proposed to hold timely consultations with the EU on issues of compliance with the EU decarbonization practice (in particular, to study the example of introducing the Chinese trading system). Explore the possibility of introducing symmetrical measures for imports from the EU (to equalize conditions with the EU and other countries that may introduce regulation in response to EU measures) with simultaneous compensation for consumers in Russia. Work out support (compensation) measures in Russia for enterprises and industries most affected by the introduction of TUR and carbon regulation measures, including benefits within the national trading system, as well as tax incentives.

IV. Discussion

Energy companies responsible for the majority of GHG emissions follow market and regulatory signals and set targets to reduce GHG emissions. In some European retail markets, consumers can already indicate their preferences for renewable energy or change their electricity supplier. The development of green certificate systems for gas and electricity contributes to the development of markets in the energy and related sectors. Energy consumers have the opportunity to take part in mitigating climate change by reducing their consumption or using cleaner energy sources, including their own, such as rooftop solar panels or home fuel cell energy centers [5-6]. Environmental friendliness, reducing the burden on the environment, climate protection are becoming important consumer motives. In this regard, energy companies around the world are deploying corporate strategies to move towards carbon-free solutions and assets.

In Russia, the situation is somewhat different from the world [4]: Unlike many other countries of the world, in Russia the problem of climate change is still a low priority for the population, business, and government, which slows down the process of decarbonization of the oil and gas sector compared to the best international practices. The established national goal of reducing GHG emissions by 2030 to 75% of the 1990 level allows the Russian Federation not to introduce any control measures during this period, since already in 2017 GHG emissions amounted to 50.7% of the 1990 level. climate strategy leads to the absence, in turn, of real government incentives for decarbonization strategies in general and in the oil and gas sector in particular. The regulation of GHG emissions in the Russian Federation is at an early stage, only in February 2021 the Russian Government prepared and submitted to the State Duma a draft law on limiting GHG emissions. While government requirements to reduce GHG emissions remain extremely fragmented (reduced to requirements to reduce associated petroleum gas flaring and control methane emissions), there are no CO2 pricing rules, no GHG emission intensity standards [8].

Regulators would do well to develop a climate strategy with more ambitious climate targets and a comprehensive strategy to reduce GHG emissions in the oil and gas sector (including a strategy to reduce methane emissions). It may include a variety of regulatory mechanisms - standards, targets, requirements for monitoring, reporting and pricing of GHG emissions, rules for certification and verification of projects to reduce emissions, etc. It is also important to approve public funding for R&D and pilot projects to reduce GHG emissions, especially in areas of deep decarbonization. It is necessary to further analyze the competitive advantages of Russia in the field of decarbonization, and then promote them both domestically and on the world market. Corporations should incorporate decarbonization into their overall business strategy and investment plans, rather than limiting it to just health, safety, environment and investor relations departments. To implement an effective decarbonization strategy for any company, it is necessary to review the strategy and corporate governance as a whole [9-10]. A comprehensive analysis of GHG emission sources will allow oil and gas companies to identify measures that allow them to reduce GHG emissions as quickly as possible and with maximum economic effect, and present them to clients and investors. Companies can also build networks with partners who support their decarbonization strategies. Such partner networks may include educational and research institutions, international R&D exchange partners, venture capital investors working on deep decarbonization projects, technology companies that can help improve GHG emissions measurement and disclosure, and local suppliers and customers. facing similar problems.

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References

[1] Piskulova N.A., Kostyunina G.M., Abramova A.V. Climate policy of the main trading partners of Russia and its impact on the export of a number of Russian regions - M .: World Wildlife Fund (WWF), 2019, p. 223.

[2] Ritchie H., Roser M. CO_2 and Greenhouse Gas Emissions, 2020.

[3] Romanovskaya A.A. et al. Greenhouse gas fluxes and mitigation potential for managed lands in the Russian Federation. - Mitigation and Adaptation Strategies for Global Change, 2020.

[4] Gakaev R.A., Bayrakov I.A., Bagasheva M.I. Ecological foundations of the optimal structure of forest landscapes in the Chechen Republic. In the collection: Environmental problems. A look into the future. Proceedings of the III scientific-practical conference. Executive editor Yu.A. Fedorov. 2006.S. 50-52.

[5] Hallding, K.; G. Han and M. Olsson, China's Climate- and Energy-security Dilemma: Shaping a New Path of Economic Growth. Journal of Current Chinese Affairs, 2020, 83(3), pp. 119-134.

[6] Hansen, J.; M. Sato; R. Ruedy; K. Lo; D. W. Lea and M. M. Elizade, Global Temperature Change, PNAS, 2020, 103(39), pp. 14288–14293.

[7] Leggett, J. A.; J. Logan and A. Mockey, China's Greenhouse Gas Emissions and Mitigation Policies, CRS Report for Congress 2008.

[8] Verfaillie, H., and R. Bidwell, Measuring Eco-efficiency: A Guide to Reporting Company Performance, World Business Council for Sustainable Development, Geneva, 2020.

[9] Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Kadner, S., Minx, J. C., Brunner, S., Zwickel, T. Technical Summary. In Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2019.

[10] Yulkin M.A. Energy and climate. The Shale Revolution and the Global Energy Transition, 2020, pp.451-465.

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CLIMATE RISK ASSESSMENT TO DEVEPLOP SECTOR CLIMATE CHANGE ADAPTATION PLAN

Elena Arefyeva, Irina Oltyan, Viacheslav Krapukhin

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All-Russian Scientific Research Institute for Civil Defense and Emergencies of the EMERCOM, Moscow, Russia,
elaref@mail.ru
irenaoltyan@mail.ru
info_sapphir@mail.ru

Abstract

The article provides an analysis of emergency situations caused by natural hazardous processes with a climatic factor on the territory of the Russian Federation. There is an increase in economic damage from emergencies. The constituent entities of the Russian Federation that are most vulnerable to climate change have been identified. The analysis was carried out as part of the development of a sectoral action plan for the first phase of adaptation to climate change for the period up to 2022.

Keywords: dangerous natural process, emergencies, climate change, sectoral adaptation plan

I. Introduction

Since the 60s of the 20th century, climatologists from most countries of the world have noted an increase in anomalous surface temperature, global changes in the direction of changes in atmospheric flows, long periods of high temperature increase and a decrease in pressure over the territory. All these phenomena have received a common name – global climate change. The origin of this phenomenon has caused controversy between the export of natural climate variability and the export of human impact on allergic climate change. But regardless of the causes that caused climate change, the climate changes that have occurred have already led to an increase in the number of dangerous natural phenomena that lead to loss of life and damage to human health, direct and indirect material losses. The combination of climatic hazards affecting the population and leading to material damage makes it possible to distinguish the concept of climate risk from the general set of natural risks.

The study of the impact of climate change on the socio-economic development of the Russian Federation and individual sectors of the economy in terms of taking measures to mitigate the impact of climate risks, the so-called adaptation measures, makes the study of emerging phenomena and adaptation measures very relevant [1].

Decree of the Government of the Russian Federation of December 25, 2019 No. 3183-r approved the National Action Plan for the first stage of adaptation to climate change for the period up to 2022 [2], paragraph 26 of which provides for the development of a sectoral plan for adaptation to climate change in the field of civil defense, protection population and territories from natural and man-made emergencies.

The legal basis for taking measures to adapt the EMERCOM of Russia system to climate change is the Constitution of the Russian Federation, the Federal Law “On the protection of the population and territories from natural and man-made emergencies” [3], the Fundamentals of state policy in the field of ensuring the protection of the population and territories from emergencies for the period up to 2030 [4], the Strategy for the Development of Civil Defense, the Protection of the Population and Territories from Emergencies, Ensuring Fire Safety and the Safety of People at Water Bodies [5], the Climate Doctrine of the Russian Federation [6] and the National Action Plan mentioned above the first stage of adaptation [2].

To develop a national action plan, the Ministry of Economic Development of Russia developed and approved guidelines for climate risk assessment, for the formation of sectoral, regional and corporate climate change adaptation plans, as well as guidelines for ranking adaptation measures according to their priority [7]. Climate risk analysis is necessary to assess the exposure of territories to hazardous natural processes (hazardous geological, hydrological, meteorological phenomena and processes, as well as space hazards and natural fires), which can be sources of emergencies. Therefore, the analysis of emergency situations in the constituent entities of the Russian Federation, caused by natural processes with a climatic factor, with an assessment of damage from large-scale emergencies, is an important point for developing adaptation measures.

II. Analysis of emergency situations caused by natural processes with a climatic factor

Based on the data of state reports on the protection of the population and territories from natural and man-made threats [8], a comparative assessment of the large-scale emergency situations that occurred due to hazardous natural processes with a climatic factor was performed. Below are diagrams of the number of emergencies caused by some natural processes with a climatic factor, obtained on the basis of an analysis of state reports and works of employees of the All-Russian Scientific Research Institute of Civil Defense and Emergencies of the EMERCOM of Russia (the Federal Science and High Technology Center) [9-11]. The number of emergencies associated with dangerous meteorological phenomena (storms, hurricanes, tornadoes, squalls, strong snowstorms) registered in the constituent entities of the Russian Federation for the period 01.01.2013-12.31.2020 is shown in Figure 1.

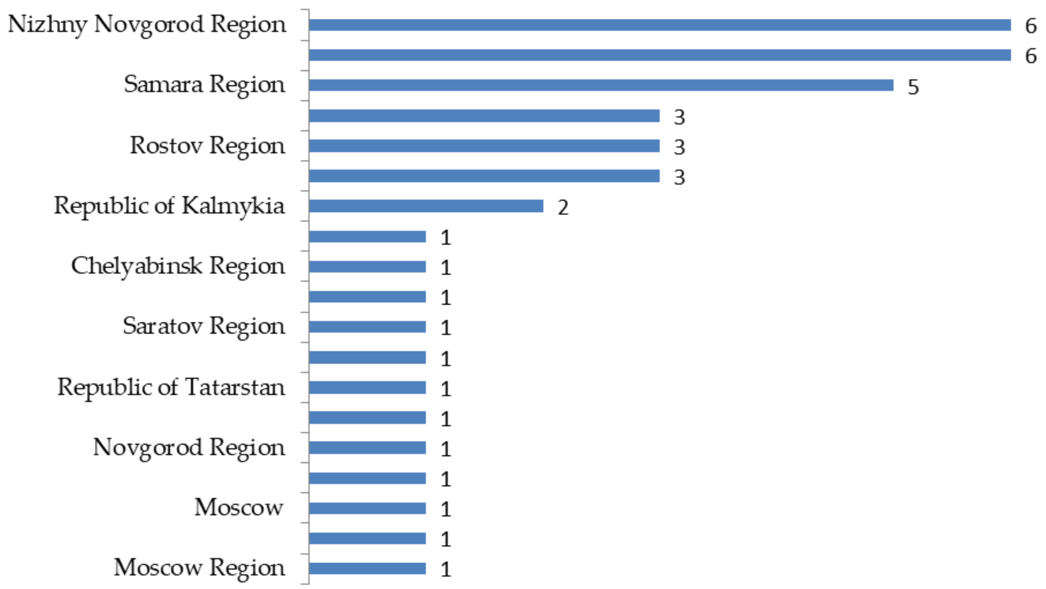

Figure 1: *The number of emergencies for 2013-2020 associated with storms, hurricanes, tornadoes, squalls, heavy snowstorms recorded in the constituent entities of the Russian Federation.*

The number of emergencies associated with dangerous meteorological phenomena (frost, drought, dust storms) registered in the constituent entities of the Russian Federation for the period 01.01.2013-12.31.2020 is shown in Figure 2.

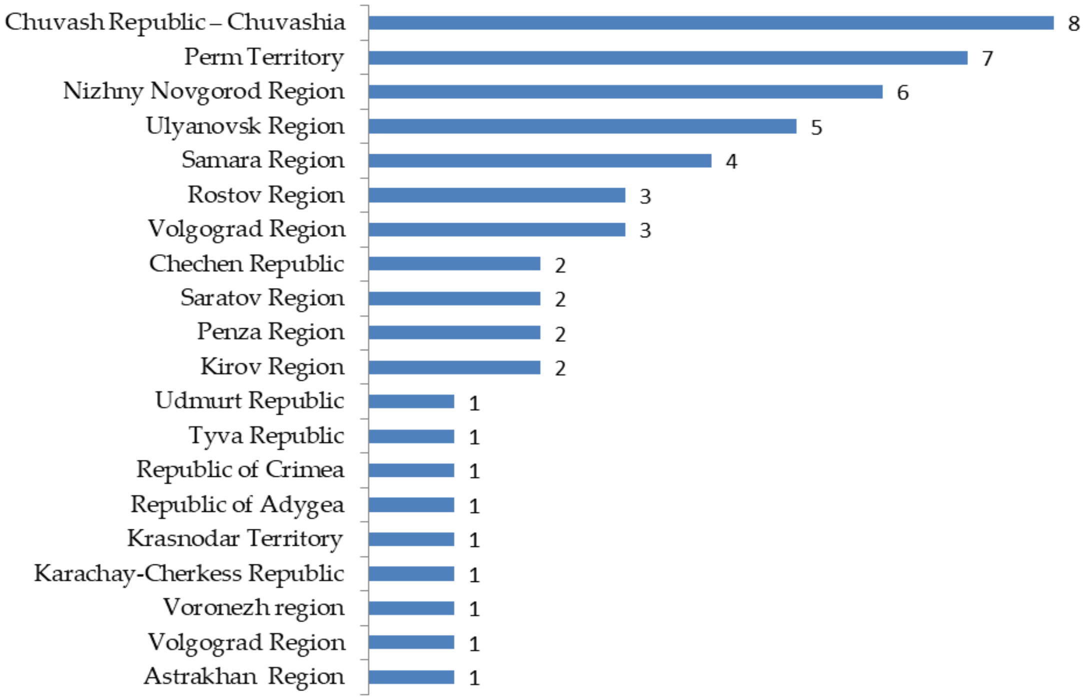

Figure 2: *Frosts, droughts, dust storms recorded in the constituent entities of the Russian Federation in 2013-2020.*

Large natural fires include large uncontrolled fires in the area: for ground protection of forests – 25 hectares or more; for aviation protection of forests – 200 hectares and more. The number of emergencies of this type registered in the constituent entities of the Russian Federation for the period 01.01.2013-12.31.2020 is shown in Figure 3.

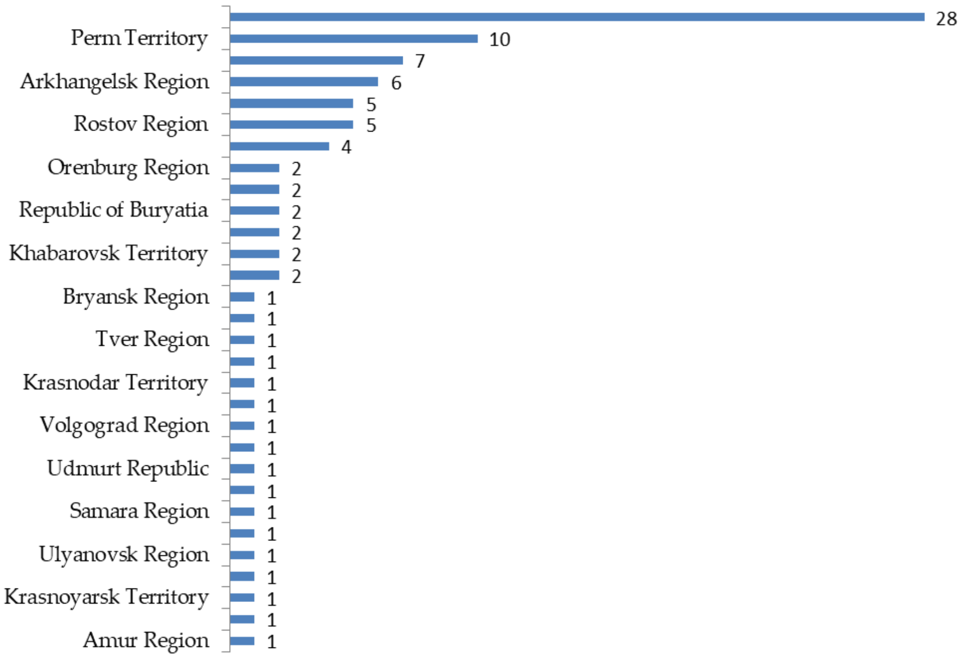

Figure 3: *Large natural fires recorded in the constituent entities of the Russian Federation in 2013-2020.*

An analysis was made of damages from large-scale emergencies [9,10] caused by natural hazardous processes and phenomena with a climatic factor. Direct economic losses from climate emergencies in the Russian Federation for 2014-2020 are shown in Figure 4.

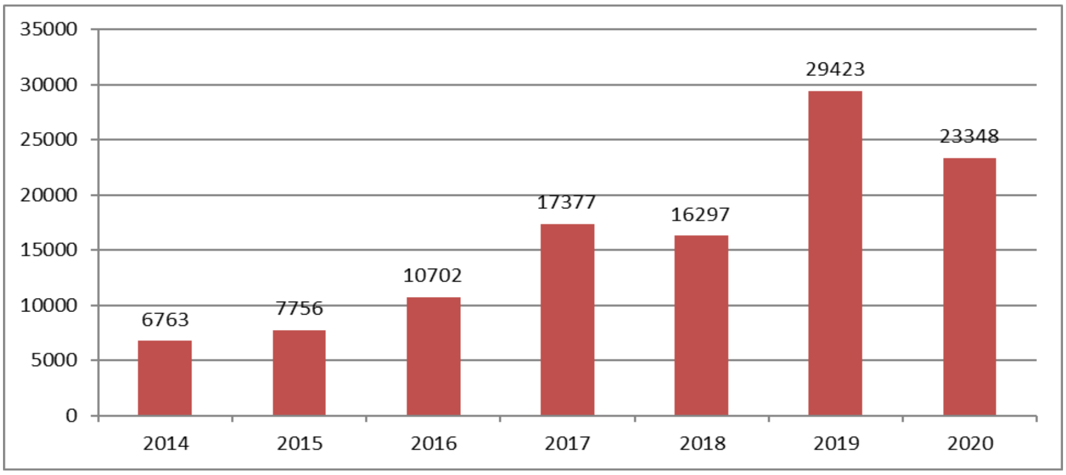

Figure 4: *Direct economic losses from natural emergencies caused by the climatic factor in 2014-2020, million rubles.*

The growth of direct economic losses from natural emergencies is associated with an increase in the exposure of the regions of the Russian Federation to climate risks, an increase in the scale and frequency of natural hazards associated with climate change [12]. Based on the data on exposure to climate risks of the constituent entities of the Russian Federation and data on the number of large-scale emergencies caused by natural processes with a climatic factor, a table was formed containing a list of constituent entities of the Russian Federation in which the most emergencies were recorded due to natural hazards with a climatic factor, and measures on adaptation (see table) [10, 11].

Table: *Constituent entities of the Russian Federation in which large-scale emergencies occurred due to hazardous natural processes with a climatic factor for the period 2013-2020 and exemplary adaptation activities*

№	Constituent entity/entities	Dangerous natural process	Adaptation activities
1.	Krasnodar Region, Nizhny Novgorod Region, Samara Region	Storms, hurricanes, tornadoes, squalls, strong snowstorms	Forecasting and early warning of the population about dangerous meteorological phenomena; strengthening industrial and residential buildings; dismantling of fragile buildings and structures; cutting down old trees
2.	Chuvash Republic – Chuvashia, Perm Territory	Freeze, drought, dust storms	Development of water management infrastructure; rehabilitation of river systems to increase water storage capacity; hardening of linear structures, monitoring of their icing; use of drought-resistant and frost-resistant crops
3.	Khanty-Mansi Autonomous Okrug – Yugra, Perm Territory, Republic of Tyva, Arkhangelsk Region, Republic of Karelia, Rostov Region	Major wildfires	Control over compliance with the requirements of fire safety rules in natural areas; prevention of unauthorized burning of dry grass; creation of a fire barrier system; forest stand composition regulation; clearing the forest from clutter
4.	Khabarovsk Territory, Leningrad Region	Dangerous hydrometeorological phenomena	Development of forecasting and emergency warning systems for the population; coast protection; training and informing the population about safe behavior
5.	Krasnodar Region	Dangerous geological processes	Regulation of surface water runoff; arrangement of anti-mudflow systems; agromelioration
6.	Khabarovsk Territory, Perm Territory, Kostroma Region, Republic of Sakha (Yakutia)	Dangerous hydrological phenomena	Improving the forecasting system in areas of possible flooding; definition of zones of flooding; planning measures to prevent the negative impact of water (bank protection and clearing of river beds, regulation of river flow, construction of dams, embankments)
7.	Khabarovsk Territory, Primorsky Territory, Tyva Republic	Dangerous meteorological phenomena	Development of systems for forecasting and warning the population; informing the population about the threats of dangerous meteorological phenomena

Reducing the risks of emergencies caused by the climatic factor requires the development of systems for monitoring, forecasting and early warning of the population about possible emergencies. Preventive work with the population to prepare for a possible increase in the scale and frequency of recurrence of emergencies typical for territories, as well as the possibility of new sources of emergencies of a natural, man-made and biological and social nature, is essential for protecting the population and territories from emergencies in the context of climate change.

The problem of climate change and ways to adapt to it should be addressed in a comprehensive manner, using to the maximum the full potential of the unified state system for preventing and eliminating emergencies. In order to increase the resilience of cities and municipalities to natural emergencies, taking into account existing and predicted climate changes, the Ministry of Emergency Situations of Russia is implementing the project "My city is safe". The purpose of this project is to intensify the work of the executive authorities of the constituent entities of the Russian Federation and local self-government to reduce the risks of emergencies and ensure the safety of the population. For this, methodological materials have been developed, and an exchange of best practices for reducing the risks of natural emergencies has been organized, including the implementation of adaptation measures to reduce climate risks at the local level.

IV. Conclusion

Taking into account climatic changes in the listed constituent entities of the Russian Federation, an increase in emergencies is predicted. Accordingly, measures to protect the population and territories in these constituent entities of the Russian Federation should be adjusted. Based on the data on exposure to climatic risks of the constituent entities of the Russian Federation and data on the number of large-scale emergencies caused by natural processes with a climatic factor, a list of constituent entities of the Russian Federation was compiled, in which the most emergencies were recorded due to natural hazards with a climatic factor, and adaptation measures.

Adaptation measures should include measures aimed at reducing the risks of emergencies caused by the climatic factor, which requires the development of systems for monitoring, forecasting and early warning of the population about possible emergencies. Also essential for the protection of the population and territories from emergencies in the context of climate change is preventive work with the population in preparation for a possible increase in the scale and frequency of emergencies typical for territories, as well as the possibility of new sources of emergencies of a natural, man-made, biological and social nature [11].

Thus, the problem of climate change and ways to adapt to it should be addressed in a comprehensive manner, using to the maximum the full potential of the unified state system for preventing and eliminating emergencies.

References

[1] Doklad ob osobennostyah klimata na territorii Rossiyskoy Federacii za 2020 god. – Moscow, 2021. – 104 p. URL: http://cc.voeikovmgo.ru/images/sobytiya/2022/03/doklad_klimat2021.pdf

[2] Nationalny plan meropriyatiy pervogo etapa adaptacii k izmeneniyam klimata na period do 2022 goda. URL:https://docs.cntd.ru/document/564102934, (07.08.2022 г.).

[3] Federalny Zakon ot 24 decabrya 1994 goda "O zaschite Федеральный закон «O zashchite naseleniya i territorij ot chrezvychajnyh situacij prirodnogo i tekhnogennogo haraktera».

[4] Osnovy gosudarstvennoj politiki Rossijskoj Federacii v oblasti zashchity naseleniya i territorij ot chrezvychajnyh situacij na period do 2030 goda», utv. ukazom Prezidenta Rossijskoj Federacii ot 11 yanvarya 2018 g. № 12.

[5] Strategiya v oblasti razvitiya grazhdanskoj oborony, zashchity naseleniya i territorij ot chrezvychajnyh situacij, obespecheniya pozharnoj bezopasnosti i bezopasnosti lyudej na vodnyh ob"ektah (utverzhdena Ukazom Prezidenta Rossijskoj Federacii ot 16 oktyabrya 2019 goda № 501)

[6] Klimaticheskaya doktrina Rossijskoj Federacii (rasporyazhenie Prezidenta Rossijskoj Federacii ot 14 dekabrya 2009 goda № 861-rp.

[7] Metodicheskie rekomendacii po ocenke klimaticheskih riskov, po formirovaniyu otraslevyh, regional'nyh i korporativnyh planov adaptacii k izmeneniyam klimata ranzhirovaniyu adaptacionnyh meropriyatij po stepeni ih prioritetnosti, utverzhdennye prikazom Minekonomrazvitiya Rossii ot 13 maya 2021 № 267 «Ob utverzhdenii metodicheskih rekomendacij i pokazatelej po voprosam adaptacii k izmeneniyam klimata».

[8] Gosudarstvennye doklady «O sostoyanii zashchity naseleniya i territorij Rossijskoj Federacii ot chrezvychajnyh situacij prirodnogo i tekhnogennogo haraktera v 2013-2020 gg.» M.:MCHS Rossii.

[9] Artyuhin V.V., O.A. Morozova «Krupnomasshtabnye chrezvychajnye situacii. Ponyatie i statisticheskaya povtoryaemost'». Tekhnologii grazhdanskoj bezopasnosti, №1. 2021, s. 8-15.

[10] Akimov V.A., E.V. Aref'eva, E.O. Ivanova, S.P. Sushchev. Predvaritel'naya ocenka klimaticheskih riskov v oblasti grazhdanskoj oborony, zashchity naseleniya i territorij ot chrezvychajnyh situacij prirodnogo i tekhnogennogo haraktera. –Tekhnologii grazhdanskoj bezopasnosti. T.18, 2021, №2 (68). s.4-9

[11] Akimov V.A., V.V. Krapuhin, E.O. Ivanova, S.P. Sushchev. Predvaritel'noe ranzhirovanie adaptacionnyh meropriyatij po stepeni ih prioritetnosti v oblasti grazhdanskoj oborony, zashchity naseleniya i territorij ot chrezvychajnyh situacij prirodnogo i tekhnogennogo haraktera. – T.18, 2021, №2 (68). s.9-14.

[12] Doklad o nauchno-metodicheskih osnovah dlya razrabotki strategij adaptacii k izmeneniyam klimata v Rossijskoj Federacii (v oblasti kompetencii Rosgidrometa), Klimaticheskij centr Rosgidrometa, Sankt-Peterburg; Saratov : Amirit, 2020 g. – 120 s.

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PURİFİCATİON OF ASSOCİATED GASES UNDER FİELD CONDİTİONS

Fikrat Seyfiyev, Sahib Abdurahimov, Irada Hajiyeva

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Azerbaijan State Oil and Industry University

Fikrat17fs@gmail.com sahib-mathematic@rambler.ru irada-niqar@mail.ru

Abstract

The article considers the issue of extraction of aggressive components from the associated gases produced from the oil and gas wells. The presence of hydrogen sulfide and CO_2 in the gas causes corrosion of equipment and pipelines on the one hand, and pollution of the environment, the emergence of technogenic risks on the other. A 15% aqueous solution of monoethanolamine has been proposed as an absorbent for H_2S and CO_2 capture.

Keywords: dry gas, hydrogen sulfide, absorption, absorbent, sodium hydroxide, technogenic risks

I. Introduction

The presence of a wide range of aggressive components, such as hydrogen sulfide (H_2S) and carbon dioxide (CO_2), during the transportation of associated gases produced by the Oil and Gas office can lead to corrosion of equipment and pipelines, environmental pollution, deteriorating gas quality and thus lead to technogenic risks. The combustion of these gases produces sulfur dioxide, which is a major threat to wildlife.

In addition, hydrogen sulfide is a valuable raw material for the production of elementary sulfur, which is widely used in industry. CO_2 is considered a ballast in the gas and increases its transportation costs. The presence of CO_2 in the gases in some cases complicates its processing. Thus, the formation of hydrate compounds during the processes of deep cooling of the gas causes certain problems. Therefore, both from economic and environmental points of view, the extraction of aggressive components from the gases in the mining environment is of great importance and, as a result, serves to reduce technogenic risks.

II. Methods

Thus, during the preparation of associated gases for transportation, physical absorption, combined processes, i.e. chemical and physical absorbents, oxidation and adsorption processes are used to remove aggressive components.

The choice of process for the purification of associated gases from aggressive components depends mainly on the composition of the raw gas and the parameters of energy resources. In world practice, absorption processes are mainly used to purify large volumes of hydrocarbon gases before transportation. Other purification methods, such as oxidation and adsorption, are commonly used to purify small amounts of associated gas streams. The following requirements are set for absorbents used in industry: high absorbency, low vapor pressure, chemical and thermal stability under operating conditions, low viscosity, low heat capacity, non-corrosive, selective and non-toxic properties. Absorption capacity and viscosity determine the cost of electricity consumed for the circulation of the absorbent. The more stable the absorbent and the lower the saturated vapor pressure, the lower its loss. Based on the corrosion properties, the requirements for the materials of the gas treatment plant equipment are determined.

In the world practice, amine processes take the leading place in the field of purification of gases from aggressive components. In this process, ethanolamines, monoethanolamine (MEA), diethanolamine (DEA), triethanolamine (TEA), diglicolamine (DGA), etc. are used as absorbents to purify gases from H_2S and CO_2. The most commonly used of these amines are mono- and diethanolamines. Triethanolamine is not widely used due to its low absorption properties. Other amines are used for selective removal of aggressive components. [1,2]. Pure amines are highly viscous liquids with a high freezing point. However, their aqueous solutions have low viscosity and low freezing point (below – 10^0C). Therefore, in industry, aqueous solutions of ethanolamines are used as absorbents in the process of purification of gases from aggressive components by absorption [3,4]. The concentration of amines in solution can vary widely. Thus, this value is selected based on the results of research and in terms of corrosion control. One of the important indicators of gas treatment plants is the consumption of amines. Thus, the cost of absorbents is very high, and the absorbent expenses are the majority of operating costs.

In some cases, very small amounts of hydrogen sulfide and other sulfur compounds are found in the gases produced in some oil and gas fields of the country. However, some oil and gas companies have high levels of hydrogen sulfide in their gases. The presence of hydrogen sulfide causes corrosion of equipment and pipelines during the preparation of gases for transportation on one hand, pollution and poisoning of the environment on the other hand. The component composition of the gas is shown in Table 1.

III. Results

Concentrations of CO_2 and H_2S up to 10.1308 g/m^3 in the associated gases lead to corrosion of the transport system and process equipment and reduce the efficiency of transport processes and the quality of transported products.

Table 1: *The component composition of the gas*

№	Components	%, weight
1	2	3
1	Methan	96,57
2	Ethan	1,59
3	Propane	0,21
4	n-butane	0,06
5	i-butane	0,08
6	n-pentane	0,03
7	i-pentane	0,05
8	hexane	0,03
9	N_2	0,21
10	CO_2	1,16
11	O_2	0,01
	Total:	**100**
	Density	0,700kg/m^3
	H_2S	10,1308g/m^3

Therefore, the extraction of CO_2 and H_2S from these gases is of great importance. The process of purification of gases from hydrogen sulfide by the absorption method consists of 2 blocks - absorption and regeneration (desorption) blocks of saturated 15% aqueous solution.

A 15% aqueous solution of monoethanolamine is used as an absorbent.

Some properties of a 15% aqueous solution of monoethanolamine are given below.

- Thickness, kmol/m^3	2,5
- Boiling point, ^{0}C	118
- Freezing temperature, ^{0}C	– 5^0
- Viscosity, at 40^{0}C, 10^3 Pa·S	1,0
-Vapor pressure at 40^{0}C, kPa	7,4

The basic technological scheme of the proposed device for purification of gases by absorption method is given in Figure 1. Dry gas containing H_2S, obtained in the absorption and gas fractionation section, enters the absorber 1 with pressure P = 1.1 ÷ 1.4MPa, temperature t = 40^{0}C through line I for purification from hydrogen sulfide. To remove H_2S from the gas, a 15% aqueous solution of monoethanolamine from capacity 3 is supplied to the upper part of the absorber by means of line N-1 / 1,2 pump. The purified gas in the absorber passes through 2 separators and is released from the monoethanolamine particles it carries with it and is sent to the pipeline of "Azerigaz" PU for further processing through line II. Monoethanolamine solution saturated with hydrogen sulfide from 1 absorber is supplied to line 4 with line IV. The hydrogen sulfide-saturated MEA solution is pumped through the N-2 / 1,2 pump to the inter-pipe area of 7 heaters for regeneration, where it is heated to 90^{0}C and then enters line 8 through the VII desorber.

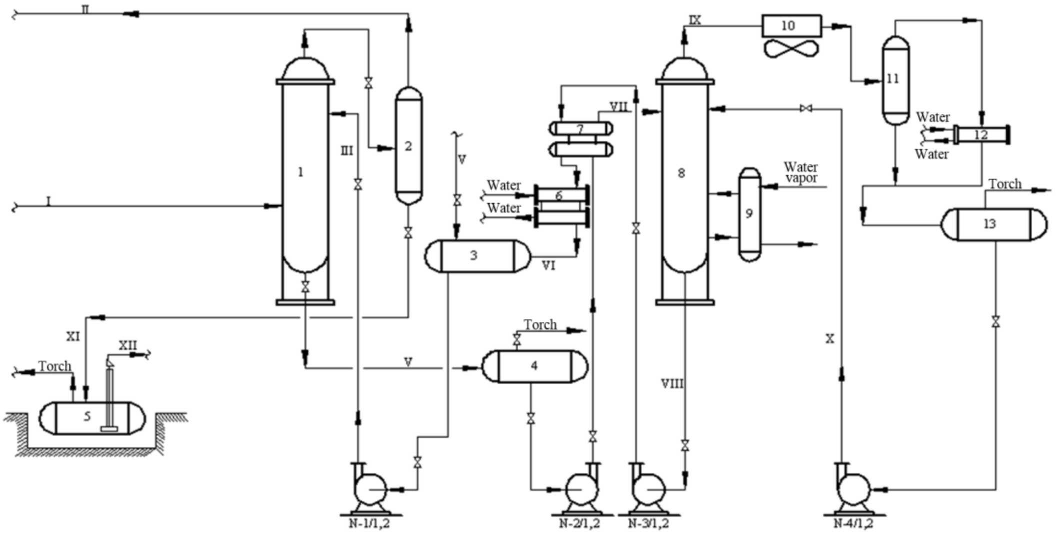

Figure 1: *Schematic diagram of the H_2S gas purification plant.*

1- absorber; 2,9,11- separator; 3- capacity for regenerated (pure) MEA; 4- capacity for saturated MEA solution; 5- drainage capacity; 6,12- water coolers; 7-heat exchanger; 8- desorber; 9- evaporator; 10- air cooler; 13- capacity.

I- dry gas; II- purified gas; III- absorbent (15% aqueous solution of MEA); IV- saturated MEA solution; V- freshly prepared 15% MEA solution; VI- regenerated MEA solution; VII-steam-gas phase; VIII- desorber irrigation; IX- liquid drainage capacity in separators; X- liquid 4 capacity.

The temperature in the bottom of the desorber is 120^{0}C, and at the top is 110^{0}C. The heat of the lower part of the desorber 8 is provided by water vapor at a pressure of 1.0 MPa by means of an evaporator 9. Hydrogen sulfide and water vapor from the top of the column are condensed in air condenser-coolers 10 and being cooled enter separator 11, and then additionally cooled in cooler 12 enter capacity 13. The separated gas phase (H_2S) is transferred to the torch, and the liquid phase is fed to the upper part of the desorber by line X by means of the pump N-4/1,2. Monoethanolamine solution regenerated from desorber 8 is supplied to the pipeline area of heat exchangers 7 through line VIII by means of pump N-3/1,2. Here, it is cooled to 62^{0}C, enters water cooler 6 and then it is cooled to 40^{0}C. From there it is fed to capacity 3.

In order to maintain the required level of circulating MEA solution in the purification process of gases from hydrogen sulfide, fresh MEA solution is added to the system periodically along the V line. Technological reports were made to determine the performance and operating modes of the main apparatus of absorption and desorption processes. During the report, the amount of raw gas was assumed to be 11000nm^3/h.

The summarized data of the technological reports are given in Tables 2, 3 and 4.

Table 2: *Column type devices*

Name	Working conditions					The height of the column, m	The diameter of the column, m	Number of plates, pcs.	Type of plates	The distance between the plates, m
	Location on height	t, ^{0}C	P (abs), MPa	Consumption, t/h						
				liquid	steam					
Gas absorber	up down	40 45	1,3 1,3	- 15,2	11,3 -	18,8	1,2	21	Valved, single-flow plate	0,6
Desorber for regeneration of MEA solution	up down	110 120	0,2 0,2	- 10	0,44 -	18,8	1,2	21	Valved, single-flow plate	0,6

Table 3: *Separators*

Name	The environment	Consumption, t / hour	Working conditions		Basic dimensions			Time of gas presence in the separator, min.
			t, ^{0}C	P (abs), MPa	Capacity, m^3	Diameter, m	Height, m	
1	2	3	4	5	6	7	8	9
Gas separator	Purified gas	11,324	40	1,3	4,0	1,2	4,4	0,22
Sour gas separator	Sour gases	0,184	40	atm	6	1,2	5,2	0,22

Table 4: *Heaters and refrigerators*

Name	The direction of flows	The environment	Consumption, kg / h	Temperature		Heat load kcal / hour	Heat transfer coefficient (K), kcal / $m^2 hour^0C$	Surface area, (F), m^2
				At the inlet	At the outlet			
1	2	3	4	5	6	7	8	9
Heater of saturated MEA solution	pipe area inter-pipe area	Regenerated MEA solution Saturated MEA solution	10000 10182	120 40	67 90	534665	200	41x2=82
Water cooler of regenerated MEA solution	pipe area inter-pipe area	Water Regenerated MEA solution	29000 10000	29 67	40 35	320000	150	101x2 =202
Water vapor condensate and H_2S mixture water cooler	pipe area inter-pipe area	Water hydrogen sulfide	153,5 184	29 40	35 35	921	50	3,5
Air condenser cooler	pipe area	Water vapor hydrogen sulfide	445 184,096	110	40	150000	6,8	848

The application of this device will reduce the amount of hydrogen sulfide in the gas to 0.001%.

IV. Conclusions

The presence of hydrogen sulfide in the composition of gases leads, on the one hand, to corrosion of equipment, pipelines, and on the other, to pollution and poisoning of the environment and, as a consequence, to the emergence of technogenic risks.

It was proposed to use the absorption process to remove hydrogen sulfide from the gas.

A 15% aqueous solution of monoethanolamine was suggested as absorbent.

Application of this device will allow to reduce the amount of H_2S in the gas to the amount required by the regulatory documents.

References

[1] Miralamov H., Gurbanov R. "Technology of gas transportation in offshore oil and gas fields" Baku, Science – 2002.

[2] F.I. Afanasyev, V.M. Stryuchkov, N.N. Podlegaev and et.al., Technology of processing of natural gas: Guidebook/ under the edition. A.I. Afanasyev - M .: Nedra, 1993.- p. 152.

[3] Jou F.Y., Otto F.D., Mather A.E / Journal of Chemical Engineers.- 1994.-V.33, №1.- pp. 2002-2005.

[4] Nasteka V.N. New technologies of purification of high-core natural gases and gas condensates.-M: Nedra, 1996.- p. 108.

IMPROVING THE ACCURACY OF MEASURING SOIL MOISTURE FOR EARLY WARNING OF RISKS ASSOCIATED WITH EXCESSIVE WATER CONTENT IN THE SOIL

Rena Huseynova[1], Amida Aliyeva[2]

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[1]Azerbaijan University of Architecture and Construction
renahuseynova55@gmail.com
[2]National Aerospace Agency, Azerbaijan
amidec.b@mail.ru

Abstract

Early warning of the risks associated with excessive soil moisture is important for various areas of production. For example, during the construction of multi-storey buildings, a hydrophysical examination of the soil is necessarily carried out, its water content is measured. In the field of flood forecasting, the sites of previous floods and the residual water content and water capacity of the soil are necessarily investigated. In agriculture, in order to avoid water stress of cultivated plants, the water content of the soil is examined before irrigation. All these examples show that in order to reduce risks, it is necessary to investigate the factors that create these risks and, if possible, more accurately assess the current values of these factors. The article is devoted to the issues of improving the accuracy of determining the spectral indices used to determine soil moisture. The main disadvantage of such indices is that they use the spectral absorption lines of water vapor. Consequently, the use of these indices requires adequate compensation for the influence of the atmosphere. The solution of this problem was carried out on the basis of the following provisions (a) for seven classes of soils, a model expression for the dependence of the reflection spectrum on the moisture content in the soil is known; (b) they have experimentally taken curves of the indicated dependence; (c) a function of the dependence of the experimentally measured value of soil reflection on the degree of soil moisture is introduced; (d) the search for the optimal form of the introduced function is carried out at which the square of the difference between the experimentally measured reflection value and the known model function reaches a minimum value. In this case, this search is carried out by the method of variational optimization, subject to the introduction of some restrictive condition on the desired function, using the form of continuous recording of discrete sums; (e) by equating the calculated optimal function with the experimentally obtained reflection value at a particular wavelength, calculate the water content of the soil. Use the wavelength where the estimate of water content is minimal is recommended.

Keywords: soil, water content, spectral indices, water vapor, risks, early warning

I. Introduction

Early warning of the risks associated with excessive soil moisture is important for various areas of production. For example, during the construction of multi-storey buildings, a hydrophysical examination of the soil is necessarily carried out, its water content is measured. In the field of flood forecasting, the sites of previous floods and the residual water content and water capacity of the soil are necessarily investigated. In agriculture, in order to avoid water stress of cultivated plants, the water content of the soil is examined before irrigation. All these examples show that in order to reduce risks, it is necessary to investigate the factors that create these risks and, if possible, more accurately assess the current values of these factors. The moisture content of the surface layer of the soil is an important factor influencing the energy exchange between the earth's surface and the atmosphere. Soil water content (hereinafter referred to as SMC) can currently be determined by three spectral methods:

1. The method of combining spectral bands [1÷ 3];
2. Spectral Model Method: Exponential or Gaussian Model [4,5];
3. Geostatistical methods [6-8].

The first method includes the use of such well-known indices as the Water Index of Soil (WISOIL) [9]; shortwave angular slope index (SASI) [3]; Normalized Soil Moisture Index (NSMI) [1].

The main disadvantage of these indices is that they use the spectral absorption lines of water vapor. Hence, the use of these indices requires adequate compensation for the influence of the atmosphere.

The second method includes the spectral exponential model, which is most suitable in the short-wave infrared range [5]. The same method applies to the model of the inverted Gaussian function in the range (1.8÷2.8 μm), denoted as SMGM. The main disadvantage of this method is the deterioration of its accuracy at high SMC.

With regard to geostatistical methods, these methods require data on the spatial distribution of soil moisture and use interpolation methods to determine the moisture in a given area [6÷8]. This method depends entirely on the reliability of data on the distribution of SMC in the study area.

In [10], a semi-empirical soil model was proposed, in which the relationship between the reflective characteristic of the soil and the SMC index was determined in relation to a priori formed soil classes.

According to [10], for each of these classes, the following analytic formula is true

$$\rho_i(\lambda) = a_i(\lambda) \cdot SMC^2 + b_i(\lambda)SMC + c_i(\lambda) \tag{1}$$

where i is an index indicating the number of the class; **a, b, c** are the spectral coefficients.

In [11], a method was proposed for determining SMC based on model (1), as applied to one of the seven above classes.

According to this method, for a certain soil class, the actual value of SMC should minimize the sum below

$$E = \sum_{i=0}^{q} [\rho_i - (a_i \cdot SMC^2 + b_i \cdot SMC + c_i)]^2 \tag{2}$$

where i – indicates a specific wavelength; q – the number of such wavelengths; ρ_i – experimentally taken reflective characteristics.

The disadvantage of this method lies in the need to carry out relatively more calculations to determine the actual value of SMC.

The solution to this problem, in our opinion, lies in the transition to a conditionally continuous form of model (2) as applied to a certain fixed wavelength.

II. Methods

For some fixed wavelength λ_i we have

$$E(\lambda_i) = [\rho_i - (a_i \cdot SMC^2 + b_i \cdot SMC + c_i)]^2 \tag{3}$$

Let us introduce for consideration the following functional dependence

$$\rho_i = \varphi(SMC) \tag{4}$$

Obviously, function (4) is a decreasing function. We impose the following integral constraint on function (4):

$$\int_0^{SMC_{max}} \varphi(SMC)dSMC = C; C = const \tag{5}$$

The geometric form of some functions that satisfy condition (5) is shown in Fig. 2.

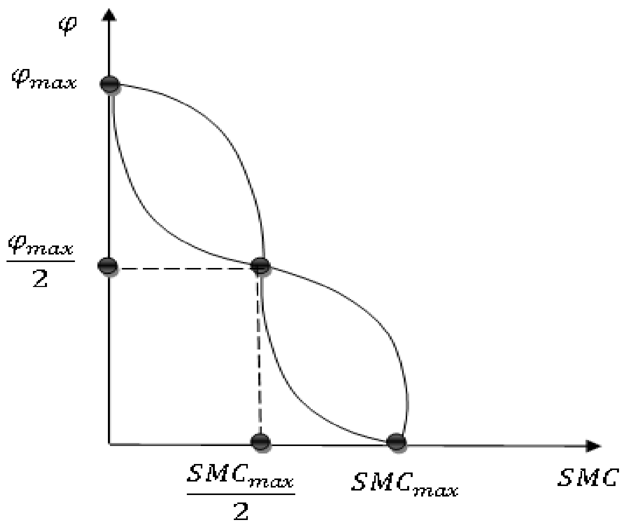

Fig. 2: *Geometric interpretation of the restrictive condition (4) as applied to the function* $\varphi(SMC)$

On the basis of expressions (3) and (4), we form the following quadratic target functional F

$$F = \int_0^{SMC_{max}} [\varphi(SMC) - (a_i \cdot SMC^2 + b_i \cdot SMC + c_i)]^2\, dSMC \tag{6}$$

Taking into account expressions (5) and (6), we form the problem of unconstrained variational optimization

$$F_1 = \int_0^{SMC_{max}} [\varphi(SMC) - (a_i \cdot SMC^2 + b_i \cdot SMC + c_i)]^2\, dSMC + \int_0^{SMC_{max}} [\varphi(SMC)dSMC - C] \tag{7}$$

where, γ – Lagrange multiplier.

Obviously, the solution of problem (7), i.e. calculation of such a function $\varphi(SMC)_{opt}$ at which $F_1 \to \min$ at the chosen wavelength will open the way to determining the SMC at that wavelength by solving the following equation

$$\varphi(SMC)_{opt} = a_i \cdot SMC^2 + b_i \cdot SMC + C_i \tag{8}$$

III. Results

We give a model solution of the optimization problem (7). According to [12], the solution of the problem must satisfy the condition

$$\frac{d\left\{[\varphi(SMC) - (a_i \cdot SMC^2 + b_i \cdot SMC + C_i)]^2 + \gamma \cdot \varphi(SMC)\right\}}{d\varphi(SMC)} = 0 \tag{9}$$

From (9) we get

$$2[\varphi(SMC) - (a_i \cdot SMC^2 + b_i \cdot SMC + c_i) + \gamma = 0] \tag{10}$$

From (10) we find

$$\varphi(SMC) = \left(a_i \cdot SMC^2 + b_i(SMC) + c_i - \frac{\gamma}{2}\right) \tag{11}$$

Calculate the value γ. From expressions (5) and (11) we obtain

$$\int_0^{SMC_{max}} \left[a_i SMC^2 + b_i(SMC) - c_i - \frac{\gamma}{2}\right] dSMC = C \tag{12}$$

From (12) we get

$$C + \frac{\gamma}{2} \cdot SMC_{max} = a_1 \frac{SMC_{max}^3}{3} + b_i \frac{SMC_{max}^2}{2} - c_i \cdot SMC_{max} \quad (13)$$

or

$$\gamma = \frac{2a_1 SMC_{max}^2}{3} + b_i SMC_{max} - 2c_i - \frac{2C}{SMC_{max}} \quad (14)$$

Taking into account (11) and (14), we get

$$\varphi(SMC)_{opt} = a_1 \left(SMC^2 + \frac{SMC_{max}^2}{3} \right) + b_i \left(SMC + \frac{SMC_{max}}{2} \right) + \frac{C}{SMC_{max}} \quad (15)$$

It can be shown that with the obtained solution (15), the target functional (7) reaches a minimum, because SMC_{max} is always a positive value.

IV. Discussion

Based on the solution that we got (13), we can propose the following method for determining SMC:

1. To find SMC in all wavelengths, the equation is solved:

$$\rho_i = \varphi(SMC)_{opt}$$

with respect to SMC.

2. The wavelength at which SMC has the smallest value is fixed.
3. The resulting SMC value is determined at this wavelength.

Accuracy İncrease of measuring of SMC make it possible to construct more reliable early warning systems designated for prediction of flooding events.

References

[1] Haurbrock S., Chabrillat S. and Lemmnitz C.,Kaufmann H. (2008). Surface soil moisture quantification models from reflectance data under field conditions// Int. J. Remote Sens., Vol. 29. pp. 3-29.

[2] Liu W., Baret F., Gu X., Tong Q., Zheng L. and Zhang B. (2003). Evaluation of methods for soil surface moisture estimation from reflectance data// Int. J. Remote Sens. Vol. 24.,pp. 2069-2083.

[3] Khanna S., Palacios-Orueta A., Whiting M. L., Ustin S. L., Riano D., Litago J.(2007). Development of angle indexes for soil moisture estimation, dry matter detection and land-cover discrimination// Remote Sens. Environ. Vol. 109, pp.154-165.

[4] Whiting M. L., Li L., Ustin S. L. (2003). Predicting water content using Gaussian model on soil spectra// Remote Sens. Environ. Vol. 89. 535-552.

[5] Lobell D., Asner G. (2002). Moisture effects on soil reflectance// Soil. Sci. Am. J. Vol. 66.pp. 722-727.

[6] Ben-Dor E., Patkin K., Banin A., Karnieli A. (2002). Mapping of several soil properties using DAIS-7915 hyperspectral scanner data – A case study over clayey soils in Israel// Int. J. Remote Sens. Vol. 23. pp. 1043-1062.

[7] Brocca L., Morbidelli R., Melone F., Moramarco T. (2007). Soil moisture spatial variability in experimental areas of central Italy// J. Hydrol. Vol. 333. pp. 356-373.

[8] Sanchez F. Soil moisture estimation by hyperspectral remote sensing in the Doode Bemde area in the valley of the Dijle River, Flanders, Belgium// Masters Thesis, Universiteit Gent, Brussel, Belgium, 2003.

[9] Bryant R., Thoma D., Moran S., Holifield C., Goodrich D., Keefer T., Paige G., Williams D., Skirvin S. (27-30 October 2003). Evaluation of hyperspectral, infrared temperature and radar measurements for monitoring surface soil moisture// In Proceedings of the First Interagency Conference on research in the Watersheds, Benson, Arizona. pp. 528-533.

[10] Lesaignoux A., Fabre S., Briottet X. (2013). Influence of soil moisture content on spectral reflectance of bare soils in the 0.4-14μm domain// Int. J. Remote Sens. Vol. 34. pp. 2268-2285.

[11] Fabre S., Briottet X., Lesaignoux A. (2015). Estimation of soil moisture content from the spectral reflectance of bar soils in the 0.4-2.5μm Domain//Sensors. Vol.15.pp.3262-3281.DOI: 10.3390/s150203262.

[12] E`l`sgol`cz L.E`.(1974). Differenczial`ny`e uravneniya i variaczionnoe ischislenie // Nauka. M.

INCREASING THE ENERGY EFFICIENCY AND TECHNOLOGICAL SAFETY OF SOLAR WATER HEATERS TO ENSURE SANITARY REQUIREMENTS AND INDOOR MICROCLIMATE

Jemil Kuliev[1], Konstiantyn Predun[2]

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[1]Azerbaijan Architecture and Construction University
[2]Kyiv National University of Construction and Architecture, Ukraine
cemil_95@inbox.ru
31172@ukr.net

Abstract

The main part of this article describes the solution of the technical problem of creating a solar water heater device that allows to increase energy efficiency while ensuring safety, sanitary requirements and indoor microclimate. Information is given about the proposed device and method for eliminating leaks on heat-transfer pipes and their connections by automatically sealing poisonous (antifreeze), limiting the risk of its possible ingress into heated water for domestic needs. The report also provides a brief rationale for introducing a new discipline into the educational process related to the tasks under consideration.

Keywords*:* solar water heater, antifreeze, sealant, expansion barrel, heat transfer system, storage tank

I. Introduction

The rapid development of technology and the intensive growth of the population gave rise to intractable problems for mankind. Among them, the main place is occupied by the relationship between man and the environment, as well as technology. Over the past one hundred and twenty years, the population has increased more than 4 times, and the volume of production over 20 times. Due to the anthropogenic impact on the environment, serious problems have arisen in nature and society. At present, in all regions of Azerbaijan, as well as throughout the world, the risk of infectious diseases and pandemics is not sufficiently reduced.

The purpose of this work is to improve the efficiency, reliability and safety of human health in the operation of solar water heating installations intended for the preparation of hot water. There are many schemes of solar water heating installations, arranged basically on the same principle of operation.

II. Existing devices and methods

To describe the developed method and device for ensuring safety, consider the selected basic piping scheme for a standard installation for preparing hot water. Known installation for hot water using solar energy. For the round-the-clock use of this solar water heating installation, it is made of two contours. Where in the primary circuit there is a solar collector, which is a heat exchanger with antifreeze. The primary circuit consists of solar collectors, piping system, pump, expansion tank and coil heat exchanger. Due to the fact that high temperatures are possible in solar collectors, the pipelines are made of copper pipes and connected by hard soldering.

The serpentine heat exchanger is built into the storage tank. The antifreeze used as a coolant circulates through the pipelines of the primary circuit and the heat received from the solar collector is transferred to the water in the boiler. The device has an expansion tank (hermetic container) made of metal, in which there is a supply of coolant in case of thermal contraction during fluid circulation. If the coolant, expanding when heated, creates too much pressure in the system, then the hydraulic tank compensates for this. And with a decrease in the amount of antifreeze, due to evaporation and cooling, it contracts, a vacuum is created in the system and the pipes bend inward. All this reduces the reliability of the system.

To achieve this goal, a lot of designs and methods on this issue are considered. Of these, the closest and most appropriate, in terms of technical essence, is the well-known design of a simple carburetor, which is described in the book [2]. So, this scheme of the simplest carburetor consists of a float chamber with a float, a jet with a sprayer, a diffuser and a throttle valve. Fuel enters the float chamber from the tank through a pipeline. The chamber contains a float that acts on the locking needle. When the fuel reaches the limit level in the float chamber, the float presses the needle against the seat, cutting off fuel access. When the fuel level drops, the float is released and fuel enters the chamber. During operation of the engine in the suction stroke, a vacuum is formed in the mixing chamber due to the downward movement of the piston. Due to the difference in atmospheric pressure in the float chamber and reduced pressure in the diffuser, fuel flows out of the atomizer hole. The advantage of this principle of operation is that it can be used in another way to automatically add sealant to antifreeze when repairing emergency cracks and leaks in the primary circuit of a solar water heater.

There is known a method for sealing a leak in the core of a cooling radiator using shaping adhesive compositions, which consists in the fact that a rubber gasket is applied to the supposed radiator leak, lubricated with a layer of oil so that after curing the compound it can be easily separated without damaging the coating. From above, thin-walled tubes with increased thermal conductivity are inserted into the damaged area of the radiator and filled with a shaping adhesive composition with fillers having increased thermal conductivity, which maintains the high thermal conductivity of the repaired section of the radiator. The main disadvantage of this method is that the radiator leak must be degreased with acetone, blown with compressed air, dried, auxiliary materials must be used, and this repair method cannot be applied without disassembly.

It is known a vehicle with an internal combustion engine and a method for preventing the failure of such an engine during the operation of vehicles, consisting of an engine stop mechanism, an alarm, a coolant pressure drop indicator. failure of the engine is carried out by automatic shutdown on the signal of the pressure drop of the coolant (antifreeze). The main disadvantage of the known device are high operating and maintenance costs, low reliability. In addition, the elimination of an emergency problem in this way is generally impossible.

It is known as RF patent No. 2462604 Expansion tank, which contains a channel with an outlet for liquid filling, a cover, the first and second expansion chambers, respectively, to contain the liquid that circulates in the first and second system. This expansion tank has the ability to fill liquid from two separate systems. The main disadvantage is that this tank cannot be used to mix the liquid from the two systems at the right time, for example, mixing antifreeze and sealant during pipe cracks.

III. Developed device and recommendations

After the analysis, it should be noted that the goal is realized due to the fact that, as in the well-known device for round-the-clock use, the solar installation system is made double-circuit where in the primary circuit the solar collectors are a heat exchanger in which antifreeze is used. Antifreeze is poisonous and quickly penetrates through micro cracks. If it gets into the heated water available in the boiler, drinking water is poisoned. To implement the new idea, a solar water heater was chosen as the basic device, which contains a coil heat exchanger built into the storage tank, consisting of copper pipes connected by hard soldering. As a result of forced circulation of antifreeze in the primary circuit, the water in the storage tank is heated. This process has the risk of emergency deviations in the heat transfer circuit, due to the possible occurrence of cracks in copper pipelines due to high temperatures in the system. However, unlike the closest analogue, the basic solar water heater, the device uses a method to prevent possible emergency deviations in the process of heating water and to prevent the ingress of toxic antifreeze into the boiler tank. As a leak prevention unit for copper tubes of the coil, a float chamber vented to the atmosphere having a float with a needle valve and atomizer is used. They are functionally connected to the expansion tank. When an emergency leak occurs in the primary circuit, there is a decrease in pressure-discharge in the expansion tank; the sealant entering the float chamber through the sprayer is mixed with antifreeze and closes the crack in the coil of the copper pipeline and in other damaged areas of the coolant circulation line. Timely supply of sealant to the coolant circulation system is carried out automatically by a special unit functionally included in the primary circuit of the solar water heating installation.

The technical result is to prevent the leakage of antifreeze in the heat transfer system during operation of the solar water heater and to ensure safety in cases of cracks and leaks in the pipes. The analysis of technical solutions in this area did not reveal any similar to the declared one.

The way to ensure safe operation is that during operation, if poisonous antifreeze enters the domestic water in the boiler, the hot water supply path to the consumer is automatically blocked. Overlapping occurs during rarefaction, when the sealant inlet valve (expansion barrel air valve) opens, it closes the contact and the signal enters the electric valve for shutting off the hot water supply at the outlet of the storage tank. Another variant of the technical solution to the problem of ensuring the operation of this valve is that a hydraulic sensor is installed on the circulation line of the coolant-antifreeze with the transmission of an electric signal to the valve for shutting off the supply of hot water to the consumer. Since the minimum allowable circulation pressure is set in the heat transfer system of the antifreeze circuit, then a decrease in pressure below the permissible level occurs as a result of a liquid leak due to microcracks and non-densities in copper pipes. In this case, the disturbing signal is recorded by the sensor, transmitted to the valve, and the hot water supply path is blocked.

By using the hydraulic sensor latch signal, the task of ensuring the operation of the sealant inlet valve can also be solved by another option. If the hydraulic sensor has determined that there is an antifreeze leak, it sends an electrical signal to the sealant inlet valve, it works and opens. Due to the pressure difference between the mixing chamber and the expansion tank, the sealant is poured into the antifreeze circulation line to eliminate the leak.

The essence of the technical solution is illustrated in Figure 1, which illustrates a schematic diagram of the proposed method and device.

The device works as follows. To heat the water in the boiler, ball valves 3 and 4 are opened, designed to turn on / off the heat exchanger from the storage tank. The flow of solar radiation falls on the surface of the solar collector 20, there is a direct heat transfer of solar energy to the heat receiving surface of direct heating, and then the coolant-antifreeze is heated. As a result, due to the heat exchanger (coil) placed in the tank of the storage tank 19, water is heated. Cold water from the cold water supply system through the check valve 14 and tap 2 enters the boiler. Heated water with the heat of antifreeze circulating through the copper pipes of the coil through tap 1 is supplied to the consumer. Taps 7 and 8 are designed to shut off the pump. Valve 7, together with valves 9 and 10, is used to fill antifreeze. The ball valve 12 is designed to release air through the air outlet 17 in the process of filling the system with coolant. In the well-known basic solar water heater, also for these purposes, there is a safety valve 16 at 6 bar and an air outlet valve 5 of the secondary circuit. The valve 11 is used as a drain valve when draining the coolant-antifreeze. During preventive and technical work, the water from the storage tank is drained using tap 6.

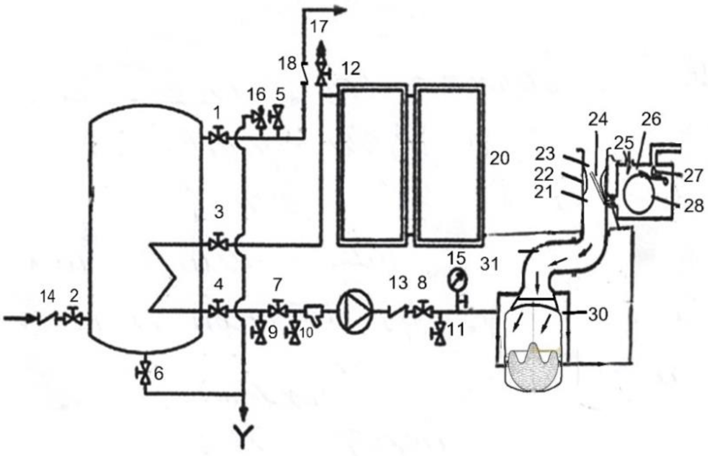

Figure 1: *Schematic diagram of the proposed water heater*

Check valve 13 eliminates the possibility of reverse circulation. The primary circuit has a solar collector 20, an expansion tank 30 with a lid 30 and a sealant supply unit, a pressure gauge 15, a pump, taps, a heat exchanger-coil, a safety valve 31 on the expansion tank 30 set to the maximum pressure of the system. One of the features of the water heating system with a heat carrier-antifreeze is the presence of a special expansion tank, which contains antifreeze and is connected by pipes to the main part of the system. When the antifreeze is heated, if an excess appears, then the excess liquid is discharged into the expansion tank 30. When the volume of the coolant liquid decreases, for example, when it cools, the inlet valve opens and the liquid from the expansion tank returns to the heating system. Thus, a constant volume of circulating fluid is maintained in the system. Another feature of the heating system is the method of preventing antifreeze from entering the storage tank with water when cracks appear in the copper tubes of the coil located inside the boiler through which circulation occurs. In some cases, it is necessary to cut off the heat exchanger from the storage tank. For this, ball valves 3 and 4 are used.

The pressure of the expansion barrel's air chamber during normal operation must correspond to the operating pressure of the unit. The establishment of a constant pressure of the coolant-antifreeze is carried out with cold solar collectors with the circulation pump not working. Insufficient pressure leads to the fact that it is impossible to determine the timely supply of sealant to eliminate leaks in places where cracks appear. A unit is functionally connected to the expansion barrel for filling and supplying sealant in case of cracks in the copper pipeline of the primary circuit. With a critical pressure drop in the air part of the expansion tank chamber due to antifreeze leakage in the event of a crack or damage to the heat-carrying copper pipes, the sealant enters the float chamber 26 from the tank through the pipeline. The chamber contains a float 28, which acts on the shut-off needle 27. When the sealant reaches the limit level in the float chamber 26, the float 28 presses the needle 27 to the seat, stopping the access of the sealant. If a vacuum (pressure reduction) occurs in the expansion tank due to a malfunction, then the sealant, sprayed, mixes with the circulating antifreeze. The circulating liquid at the leak site closes the crack with the help of a sealant by a chemical reaction. When the sealant level decreases, the float 28 descends and opens the access of the sealant to the chamber 26. The greater the sealant flow, the lower its level and the greater the flow area for the sealant is created between the needle and the seat 27. The end of the sprayer 24 is brought out into the narrowest part of the diffuser 22. Therefore diffuser 22 increases the vacuum at the atomizer 24 that appears when damaged. The air pressure difference between the float chamber 26 and the diffuser 22 creates the conditions for leakage from the sprayer 24 of the sealant. Due to the chemical reaction in the places of cracks, micro-slits are closed and emergency leakage of antifreeze in the primary circuit of the solar water heater is prevented.

When solving the problems of ensuring the microclimate of premises, a wide variety of areas for accounting for climatic factors are determined. Almost all technical issues are related in one way or another to climate, taking into account weather conditions, temperature, radiation, wind and other characteristics. Engineers and technicians involved in indoor microclimate systems need to have a perfect knowledge of meteorology and climatology, which are an integral part of solving the problems of designing, building and operating communal systems, that is, all the necessary acquisition of which should be provided for in the programs of the new discipline *Communication (communal) climatology. Particular attention in the program should be given to the theory of geography, statistical and reference data of metrological stations in Azerbaijan.

IV. Conclusion

1. In research and design, higher and secondary technical educational institutions that work to improve solar water heating installations, it is advisable to expand the scope of research aimed at reducing the technological risks of emergencies and increasing energy efficiency in ensuring sanitary requirements and indoor microclimate.
2. In the curricula of higher and secondary technical educational institutions involved in the training of personnel in engineering and communication systems, to provide a new discipline "Communication (communal) climatology".

References

[1] Scheme of piping and filling with coolant of a solar water heating installation http://kassol.ru/article/6.html (accessed 12.07.2022)

[2] Vakhlamov V.K. Cars: Design Basics: a textbook for students. / M .: Publishing Center "Academy", 2008. 528s.

[3] Nikishina O.S. "Development of a method for sealing radiators with adhesive composition at consumer service enterprises." Abstract of the dissertation on Ph.D., Russian State University of Tourism and Service, 2012. Moscow. -24s.

[4] A vehicle with an internal combustion engine and a method for preventing the failure of such an engine during vehicle operation - RF Patent 2526132 (20.08.2014).

[5] Expansion tank - RF Patent 2462804 (27.09.2012).

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OPTIMAL POLLUTION CONTROL ENVIRONMENT

Alexander Chupin, Alexander Priymenko, Alexey Ukhanov

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RUDN University, Russia
Chupin-al@rudn.ru
information@rudn.ru

Abstract

In this article, pollution is defined as the stock or flow of physical substances that diminish one's ability to enjoy life. In this definition, pollution includes a wide range of phenomena. The authors identify the following elements of pollution: natural waste, pollution of air and water pollution, depletion of soil from excessive use, radiation, intensive use of natural resources, exceeding the rate of their renewal. The authors have identified a fundamental similarity between tasks that at first glance appear to be different. The structure of control theory enables us to apply its apparatus to simple models of production and consumption. Optimal pollution control may require reducing some consumption, limiting the use of some production processes, and perhaps even limiting population growth. Pollution problems are problems of processes that change over time; this fact The problems of pollution are time-varying processes; this fact emphasizes the need to apply a dynamic control theory approach.

Keywords: risks, environmental, mathematics, dust pollution

I. Introduction

Everyone wants to live in a safe and comfortable place with clean air, food and water, but modern megacities cannot be called that. The abundance of industrial facilities, densely populated and increasing number of vehicles every year leads to a deplorable state of ecological situation around large cities. The problem of atmospheric air pollution has only become more acute over the past ten years, but the situation began to change in 2017 [1], which was the year of ecology in Russia. This year, a lot of attention was paid to the legislative aspect in terms of the Federal Law "On Environmental Protection". Thus, the changes state that from 2018 to 2022, industrial facilities that pollute the environment to a significant extent, must install specialized means of measuring emissions of pollutants into the atmosphere, with automatic transfer of information to the state environmental monitoring fund.

Before turning to the formal model, let us point out three crucial differences related to the effect of pollutants from an economic point of view. First, it is essential whether the pollutant has the main effect on production, on consumption, or perhaps on both at the same time. The pollutant is clearly part of the utility function with negative marginal utility. At the same time, its presence may have a detrimental effect on production. However, in many cases, which will be studied below, pollutants have positive marginal productivity. Second, we must distinguish what exactly has an effect-the stock of pollutant or its flow. Often the pollutant acts in both roles at the same time [1, 2]. For example, the flow of DDT has a positive marginal capacity for agricultural production, and its stock has negative marginal utility [3, 4, 5]. This is a typical example of pollutant. The stock is harmful either because of its direct effecton consumption, or because it harms production; whereas flow is useful-either because it itself has positive marginal productivity, or because it is an undesirable byproduct, the removal of which requires the expenditure of resources. Pollutants of this kind are in their nature are the opposite of the capital stock. The stock of the latter has positive marginal productivity, and the flow has negative marginal utility (since as capital accumulation reduces consumption in the present). It seems to us that the basic problem of pollution, that the presence of pollution reduces the ability of humans to enjoy life, is the problem of stockpile management. However, if pollutants have a very high rate of natural purification, then the concept of stockpile loses its meaning. In some cases of this kind, the value of the stock becomes proportional to the size of the flow, and it is quite natural then to consider the management problem as a flow management problem. Noise as a pollutant is a limiting case of such a situation, although it is more convenient to consider an air pollution problem as a about a flow. The stressed distinction between stock and flow is directly related to our third - traditional in control theory - distinction between state variables and control variables [6, 7]. We believe that the only acceptable characteristic of stock is that it can never be viewed as a a tool (i.e., a control variable). It follows that tradition can be called a tool, and a variable that is functionally related to it [8]. To contaminate the social problem, it is important to stress that we are often unable to exercise direct control over unwanted products [9, 10, 11]. Planning becomes an urgent necessity. Ignoring the problem or exaggerating it leads to a huge waste of resources [12, 13, 14].

II. Method of determination based on the choice of pollution control model

We have studied optimal equilibria and approximate trajectories in two similar models in which we want to control pollution stocks. These models differ in the structures of the production functions and in the way, pollution is controlled. The target function for both models is the same. It is defined in terms of society as a whole, but it can equally be defined in terms of the individual. To avoid difficulties in estimating the structure of the objective function, we will assume that the supply of labor does not change over time.

The welfare of society at any point in time is a function of the flow of consumption c and the stock of pollution P. The time-independent utility function can be denoted by

$$u(c, P). \quad (1)$$

The first argument gives a positive contribution, the second negative, i.e., $u_c > 0$, $u_P < 0$ and the second derivatives of the of the utility function are negative: $u_{cc} < 0$, $u_{pp} < 0$.

It is assumed that $u_c = \infty$ at $c = 0$. Indifference curves have a simple form. Neither consumption nor reduction (in the most ordinary sense) is reducible to one another.

Utility flow is estimated taking into account the subjective rate of discounting r. The total welfare W, which corresponds to any particular trajectory $c(t)$ and $P(t)$. Thus, the total welfare has the form:

$$W = \int_0^\infty u(c, P) e^{-rt} dt. \quad (2)$$

Model I. Pollution control through processes cleanup. The two factors of production in Model I are labor and production inputs. This model has one additional feature: output can be used not only for capital accumulation and for consumption, but also for pollution control. It assumes that the useful cleanup costs are used to deal with a wide range of pollutants. For example, many types of controls on of water pollution are perfectly consistent with Model I.

It is assumed that the production function satisfies the usual concavity conditions. Since labor is fixed, this means that output z is an increasing concave function of the fixed capital K, i.e.

$$y = f(K), \quad (3)$$

where $f' > 0, f'' < 0$. Fixed capital decreases at a fixed rate a.

In this model, the pollutant is not used in production as a useful product. It is assumed that its flow is a byproduct of production and is proportional to it; the products of production and the pollutant are related to each other. Under this scheme fit: whey in a dairy plant, waste of plants that pack meat, organic residues from paper production, etc.

The product-pollutant relationships in co-production allow us to measure pollution in the same units as the main product. Naturally, the necessary refinements are made in the choice of the utility function. Our unit selection technique is equivalent, for example, to measuring the amount of wool in pounds of its corresponding lamb. Fortunately, empirical observations show that the stock of pollutants dwindles naturally. The purification rate b is assumed to be non-negative. (In situations such as bacterial contamination, b can also be negative).

Model II. Pollution control by choice of production process. We now describe a pollution model in which the pollutant stock is part of a utility function with a negative marginal productivity, and the stream has a positive marginal productivity. The insecticide DDT is a good concrete example of the dual role of pollutants of this type. For simplicity, let's assume that a pollutant soon appears, then it can dwindle naturally. To avoid irrelevant complications, assume that labor is the only scarce production factor. So, the management task in this model is to choose of the production process - this choice is manifested in between the sector producing the commodities and the sector producing the goods consumption, and the sector producing pollutants.

The target function is the same as before. For simplicity, we will assume that consumption and pollution are included in the utility function separately, i.e.

$$u(c, P) = g(c) - h(P), \tag{4}$$

where $g'(0) = +\infty$, $g' \geq 0$, $g'' < 0$, $h'(0) = 0$, $h' \geq 0$, $h'' > 0$.

The supply of labor L, the only factor of production, is fixed. Part of them is used in the production of pollutants. We will assume that $j'(L_1) > 0, j''(L_1) < 0$ and $0 \leq L_1 \leq L$.

The rest of the labor force $\mathrm{L} - \mathrm{L}_1$ is used in the production of consumer goods. The pollutant, being an intermediate product, serves as the second argument of the production function in the production of consumer goods. This function, therefore, has the form:

$$c = F(L - L_1, j(L_1)). \tag{5}$$

Necessary conditions of optimality. Convert the expression by discarding e^{-rt}

$$H = g(f(L_1) - h(P) + \pi(j(L_1) - bP + q(L - L_1) + sL_1. \tag{6}$$

Here q and s are time-dependent non-negative multipliers corresponding to the constraints on L_1. It is clear that it is inefficient to use more than $\tilde{L}$ labor to produce the pollutant because the pollution has a non-positive productivity. Hence, $L_1 < \tilde{L}$ and $\mathrm{q} = 0$.

An interesting aspect of the problem is that the multiplier s can be positive.

III. Results

The two models we have considered lead to completely different conclusions. This distinction suggests that there are no general rules for solving pollution problems and that there is no single, sufficiently well-defined model that would lead to important conclusions without further its details. Nevertheless, we believe that it is possible to generalize our models so that they will encompass pollution problems, which stand in the spirit of the following assumptions (tab. 1).

Consider the problem of river pollution. If a plant is engaged in to treat its wastewater, it thus chooses a more expensive manufacturing process. Reducing the flow of pollution is achieved at the cost of reducing productivity: one must use Model II. On the other hand, if pollutants are still discharged, but there is a purification of the water river, say by means of the aeration process, then the logical structure in this situation is the same as in model I.

A good illustration for the upper right-hand corner of the table is the paper industry. In this industry, the production process can be chosen in various in different ways; the less organic residue is discarded in an individual process, the higher the unit price produced. Model II can be used in this or some other situation where it is necessary to choose production process under the assumption that the process with the greater productivity yields more byproducts pollutants.

Table 1: *Pollution problems*

		Controlling the flow of contamination is carried out with the help of	
		processes cleaning	choosing production process
Contaminants are included in the models	as a byproduct product of production	Model I	-
	as intermediate product production	-	Model II

The field of application of the models considered is broader than the field of purely production processes. For example, the "producers" beverage producers are paid more by consumers if they use production processes in which bottles are not returned (the price goes up for convenience), but processes where bottles can be returned produce less pollution.

The gain from not throwing bottles away, is low, but the disposal of discarded bottles is expensive and sometimes too expensive. Thus, applying to these cases is justified. A prohibition on throwing away bottles may also be appropriate for aesthetic considerations. Another example is transportation "corks"; they can be seen as a by-product of transportation.

Further research should weaken the three assumptions in our models. (1) The pollution control sector capital must be used. (2) Technical progress, especially in the abatement sector, where progress can and should occur in the near future. (3) Labor must be considered as an endogenous value in order to establish the relationship between population growth population and pollution and to illustrate the possible need for some means of regulating population.

IV. Discussion

If the pronounced social and political concerns reflect suboptimal situations, our society is currently operating at pollution levels well above the optimal equilibrium. There seems to have been too much emphasis on building capital assets and maintaining high levels of consumption. The sheer number of factors external to the economy affecting the free market leads to sub-optimal outcomes. Therefore, some form of centralized coordination is necessary to remedy this situation. Such coordination can be accomplished either by policy directives, or by the sale of pollution rights, or perhaps by methods of direct control. Our models show that, generally speaking, no application of drastic measures. In many cases, the significant danger is a drastic response. In fact what is needed is a controlled movement toward optimal trajectory. Unfortunately, a policy of gradual changes in behavior is sometimes impossible due to of the current political environment. Prohibition may be feasible where gradual change would require a bloated administrative apparatus. Radical measures or absence of any measures may be the best of all those measures that can be implemented. The role of economists in real life is not only to identify optimal trajectories, as we have done, but also to suggest practical ways in which by which these trajectories can be approached. But this is precisely is an area in which our contribution is, as usual, very small.

References

[1] Li, Z., Chen, Y., Meng, F., Shao, Q., Heal, M. R., Ren, F., Xu, W. (2022). Integrating life cycle assessment and a farmer survey of management practices to study environmental impacts of peach production in Beijing, China. *Environmental Science and Pollution Research*, 29(38), 57190-57203. doi:10.1007/s11356-022-19780-0

[2] Li, Y., Xiao, G., Li, F., Chen, C., Chen, C., Li, R., . . . Zhang, M. (2022). Response surface analysis (RSA) optimization of temperature-resistant gel foam fabrication and performance evaluation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 655. doi:10.1016/j.colsurfa.2022.130260

[3] Liu, C., Bao, Q., & Nie, W. (2022). The influence of ventilation parameters on dust pollution in a tunnel's environment using the CFD method. *Journal of Wind Engineering and Industrial Aerodynamics*, 230 doi:10.1016/j.jweia.2022.105173

[4] Nie, W., Guo, L., Liu, Q., Hua, Y., Xue, Q., & Sun, N. (2022). Study on the coupling pollution law of dust and gas and determination of the optimal purification position of air duct during tunnel excavation. *Powder Technology*, 411 doi:10.1016/j.powtec.2022.117843

[5] Sun, C., Yi, X., Ma, T., Cai, W., & Wang, W. (2022). Evaluating the optimal air pollution reduction rate: Evidence from the transmission mechanism of air pollution effects on public subjective well-being. *Energy Policy*, 161 doi:10.1016/j.enpol.2021.112706

[6] Alharbi, O. A., & Rangel-Buitrago, N. (2022). Scenery evaluation as a tool for the determination of visual pollution in coastal environments: The rabigh coastline, kingdom of saudi arabia as a study case. *Marine Pollution Bulletin*, 181 doi:10.1016/j.marpolbul.2022.113861

[7] Buribayev, Y., Khamzina, Z., Suteeva, C., Yermukanov, Y., Turlykhankyzy, K., & Kuttygalieva, A. (2021). Analysis of the possibilities for improving the environmental legislation of kazakhstan. *Fronteiras*, 10(3), 78-88. doi:10.21664/2238-8869.2021v10i3. p 78-88

[8] Chen, X., Zhu, Y., & Shen, J. (2020). Input-output dynamic model for optimal environmental pollution control. *Applied Mathematical Modelling*, 83, 301-321.

[9] Flaksman, A. S., Mozgovoy, A. I., Lopatkin, D. S., Dikikh, V. A., Shamsov, I. S., Romanova, J. A., . . . Bovtrikova, E. V. (2021). Prospects for the development of alternative energy sources in the world energy. Paper presented at the IOP Conference Series: Earth and Environmental Science, 723(5) doi:10.1088/1755-1315/723/5/052040.

[10] Liu, X., Wang, Y., & Li, M. (2021). Theory, method and technological application of territorial spatial development suitability evaluation. *Journal of Geo-Information Science*, 23(12), 2097-2110. doi:10.12082/dqxxkx.2021.210037

[11] Luo, L., Sun, H., Gai, C., & Liu, Z. (2021). Application of synchrotron radiation-based spectroscopic techniques in pollution control and utilization of organic solid waste. *Chinese Journal of Environmental Engineering*, 15(12), 3830-3843. doi:10.12030/j.cjee.202109148

[12] Lutoshkin, R. V., Morkovkin, D. E., & Sadriddinov, M. I. (2020). II international scientific and practical conference "actual problems of the energy complex: Mining, production, transmission, processing and environmental protection". IOP Conference Series: Materials Science and Engineering, 976(1) doi:10.1088/1757-899X/976/1/011001

[13] Prenner, S., Allesch, A., Staudner, M., Rexeis, M., Schwingshackl, M., Huber-Humer, M., & Part, F. (2021). Static modelling of the material flows of micro- and nanoplastic particles caused by the use of vehicle tyres. Environmental Pollution, 290 doi:10.1016/j.envpol.2021.118102

[14] Shamraeva, V. V., Kalinin, V. M., Morkovkin, D. E., Koryakov, A. G., Zakharova, M. V., & Perfilyev, A. A. (2022). Mathematical model of optimization of repair activities of power equipment. Paper presented at the IOP Conference Series: Earth and Environmental Science, 990(1) doi:10.1088/1755-1315/990/1/012042.