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## SPECIAL ISSUE

## 3 (66)

January 2022

# 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-2021 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.

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**The Third 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;
- Technical university, Georgia;
- City university of Hong Kong;
- International Group on Reliability, Gnedenko Forum;
- Institute of Petroleum Geology and Geophysics, Russia.

## 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 Reduction2015-2030.

# Table of Contents

# THE FINAL DECISION

Third Eurasian Conference and Symposium RISK-2021

**"Innovations in Minimization of Natural and Technological Risks"**

December 7 – 9, 2021, Tbilisi, GEORGIA

We are the participants of the 3rd 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-2021 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 3rd 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 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 RISK-2022 in Baku, Azerbaijan, in mid-2022.

On behalf of the Organizing Committee of RISK-2021 Conference and Symposium,

**Acad. Nikolai MAKHUTOV**
**Prof. Vugar ALIYEV**

# ON THE CONCEPTS MEANING, THEIR MEASUREMENTS AND USE IN PRACTICE OF RISK ASSESSMENT

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**Abstract**

*In this talk we discuss the basic concepts used in axioms of sciences, their meaning explained through the axioms and measurement that follow afterwards. There are situations where meaning comes first, then axioms then measure. And there are situations where measurements come first and meanings – later. Things may look elementary, but they are supposed to build a solid background when make a system to analyze the risk. We illustrate this approach on examples from classic sciences as geometry and algebra, from examples of recent times as for uncertainty and probability and focus our attention on the concept of risk ant its measurements.*

**Keywords:** Axioms, concepts, dependence, meaning, measurement, probability, risk, uncertainty.

## I. Introduction

In this article I present my personal understanding about the terms listed in the above key words. These words are used in the everyday conversations between people and researchers, media, and publications. But my focus is on the scientific world. Basic concepts in sciences are usually names of some imaginary objects whose meaning can be understood after they are related to some explanations through appropriate axioms. For example, let look at the basic concepts in geometry: point, straight line, circle, angle; or at the algebraic concepts like number, zero, infinity; ... When a theory is built on the base of axioms, then measurements could be introduced and many other consequences related to measurements, involving more than two areas of science. For instance, in geometry we can talk about lengths, angle's measurements, comparison, areas, volumes, in algebra – about real and complex numbers, etc.

In this talk I will not go to details. An extended version can be presented to anyone, who would like to have it.

Without axioms and without basic rules that relate their basic elements it is impossible to use their consequences. And since our focus is on this work on uncertainty and risk, we continue with these basic concepts and related measurements to the uncertainty.

## II. Uncertainty and probability

Risk is related to uncertainty. Here we explain how and why we need to understand and model the uncertainty to correctly introduce its measures, namely the probability associated with the risk. Examples we give for uncertainty models and ways to introduce probability are very important. They determine the probability space where we work on the risk. Otherwise, probability spaces needed to assess the risk cannot be understood.

Both concepts, uncertainty and probability are basic concepts. No definitions can be given. But axioms, examples, additional basic concepts and rules, together with serious practice will help for easy work and use the Probability Theory.

## 1.1. Introduction to the Uncertainty and its meaning

**The Set theory** lies in the foundation of any axiomatic setups. It uses a *basic concept of a set*. There is no definition of set (as any other basic concept in any theory). A set can be informally described as collections of objects possessing some common features. Although objects of any kind can be collected into a set, here we see replacement of a name "set" by another name "collection". Many times, we observe explanations of a basic concept with the help (in terms) of others through the axioms, and we will mark such facts in the sequel. Here we refer to the *Set Theory* just because it introduces some symbolic notations and meaning of operations with sets. These are needed to understand most mathematical fields.

Set theory begins with a fundamental relation between an object $\omega$ and a set $A$. If $\omega$ *belongs to the set* $A$ (or $\omega$ is an *element* of $A$), the notation $\omega \in A$ is used. Objects can be undefined concepts which could be explained through the axioms (see e.g., Euclidian axioms). A set is described by listing its elements when possible, or by a characterizing property of its elements, or just by description in words. Sets are also objects; the membership relation explain sets as well. A derived binary relation between sets is the subset relation, also called *set inclusion*. If all the elements of set $A$ are also elements of set $B$, then $A$ is subset of $B$, denoted $A \subseteq B$. As implied by this definition, a set is a subset of itself. And if $A \subseteq B$. and $B \subseteq A$, then the two sets are identical. Relationships and operations between sets are also important and used in many models based on the set theory. No axioms are known in this relation, but that the sets do exist and satisfy some relationships, which were imitating operations with numbers. The following is a partial list of these:

- The union of the sets $A$ and $B$, denoted as $A \cup B$, is the set of all elements that are members of $A$, of $B$, or of both.
- The intersection of the sets $A$ and $B$, denoted as $A \cap B$,[7] is the set of all elements that are members of both $A$ and $B$.
- Cartesian product *of* $A$ and $B$, denoted as $A \times B$, is the set whose members are all ordered pairs $(a, b)$, where $a$ is a member of $A$ and $b$ is a member of $B$.
- The empty set is the unique set containing no elements. For it the usual symbolic notation is Ø.
- The **power set** (or powerset) of a **Set** $A$ *is* the **set** (actually, *the number) of all subsets of A* including the **set** $A$ itself and the empty **set.**

These operations with the sets are extended to unions and intersections between more than 2 sets.

Examples of sets helped to create theory of numbers, real numbers, continuity, the Boolean algebra, Discrete Mathematics, and many other theories used in computer sciences.

To start with **Uncertainty,** we need to introduce some more basic concepts for which there are no definitions, like the concepts of points, lines, numbers referred above.

First is in Uncertainty the concept of *Experiment*. This word has many determinations, and no description According to Probability Theory *an experiment is just a collection of conditions that produce results*. This is not a definition, just a description. We denote this concept by the symbol $E$.

Another basic concept is the *outcome* $\omega$, a *simple result* from $E$. It is called a *simple event*.

Then we can define the set of all possible simple events under the $E$, and denote it with $S$. This set $S$ contains no more, nor less but every outcome $\omega$, *obtained as a* simple result from $E$. And we call $S$ is a *sure event*.

Every subset $A$ of $S$ is called *random event.* A *random event* $A$ occurs only when $\omega \epsilon A$.

The empty set Ø is called *impossible event*.

The specific situation allows to introduce some additional extra random events (subsets of $S$) – the *complement* $\bar{A}$ to a random event $A$. This is *the event that happens only and always when A does not happen.*

Also, the operations with events become specific interpretations:

- The *union* of the events $A$ and $B$, denoted $A \cup B$ is the set of all elementary outcomes $\omega$ that favor $A$, $B$, and that are members of $A$, or $B$, or both. It is read "*at least one of the two events occurs*". Meanings matter.
- The *intersection* of the events $A$ and $B$, denoted $A \cap B$ is the set of all elementary outcomes $\omega$ that favor both $A$ and $B$. It is read as "*both events occur*" in $E$.
- If $A \cap B = \varnothing$, then the events $A$ and $B$are called *mutually exclusive*, and their union will be symbolized as $A + B$ (meaning it is *union of mutually exclusive events*)

These meanings and operations with symbols will be used in full scale in the next. For instance,

$$\bigcup_{k=1}^{n} A_k = A_1 \cup A_2 \cup \ldots \cup A_n$$

means "at least one event in the list will occur in $E$: Also

$$\bigcap_{k=1}^{n} A_k = A_1 \cap A_2 \cap \ldots \cap A_n$$

means that each one event in the list will occur in $E$.

This is how the operations with events stated in the set theory, become important meaning. It is used thorough the entire axiomatic of the Uncertainty where sets become meaning. For simplicity, we introduced specific symbols in operations with sets that do not change the meaning of unions of events and include knowledge about their mutual intersections. Operations between sets (events) and their meaning should be known to everyone familiar with the basics of Probability theory.

## 1.2. Axioms of Uncertainty and Examples

Uncertainty is related only with certain experiment, frequently understood in a broad and imaginary sense. For instance, a human being $\omega$ can be considered random outcome because of many circumstances (conditions) at the place he/she is born, country, parents, growth, friends, ethnicity, education, politics during growth, etc. Experiment is not well defined but results $\omega$ are clear and may serve as a set of outcomes undoubtedly.

The axioms of uncertainty should be now clear: This is a system F of random events $\omega$ which satisfies the following rules (axioms):

1. The sure event S and the impossible event Ø belong to F;
2. If the random events A, B, …, C belong to F, then their unions A ∪ B, A ∪ C, … , intersections A ∩ B, A ∩ C, …, and complements $\bar{A}$, $\bar{B}$, …, $\bar{C}$ also belong to F.

The following models will illustrate the flexibility of this presentation of the uncertainty. Each model corresponds to the resolution of what one can recognize as a random event in an experiment. In definition of the risk corresponding explicit model is of high importance.

3. $F_0 = \{S, \varnothing\}$. It corresponds to the situation where one sees only the sure and impossible events. This is the *model of certainty*.
4. $F_A = \{S, \varnothing, A, \bar{A}\}$. This model corresponds to a situation, where one sees only when a random event $A$ occurs or not (then occurs the complement $\bar{A}$).
5. The sure event $S$ is partitioned in a particular cases (mutually exclusive events $A_1$, $A_2$ , …, $A_n$) so that $S = A_1 + A_2 + \ldots + A_n$. This means that in the experiment only some finite, or countable number of mutually exclusive random events can be recognized. The uncertainty system F consists of any union of events from these in the above partition. As an example, in roulette game there are 37 positions, but colors, odds, neighbors make combination of this partition. In natural numbers (is considered as a particular case, odds, evens, multiple to an integer number $k$, are combined events. Here are many models we do not consider in detail, and they represent a better resolution in the set of outcomes of the experiments.

6. F $_\infty$ - the uncertainty consists of any particular outcome $\omega$ in the experiment and contains every subset of the sure event *S*. This is the maximal resolution one can see in the outcomes of an experiment.

## 1.3. Measures of Uncertainty. Axioms of Probability

The uncertainty as introduced is just to register existence and what is the resolution of events in the experiments. To measure and study its properties comes the mathematics with all its power. And mathematics comes with another basic concept still not defined. This is the concept of probability, also introduced with axioms [1]. There is no definition of probability, again, it has just an explanation:

*Probability is a measure of the chance that a random event will occur under the conditions E of an experiment. For a random event A probability is denoted as P(A).*

*The* word *measure introduces mathematics in the analysis of uncertainty*. And any time when one introduces this measure should have in mind the conditions *E* of this experiment and the uncertainty model F associated with this measure. Uncertainty model F is necessary whenever probability is introduced. Probability is introduced for what is visible according to the uncertainty model F.

Therefore, we need the uncertainty model F and only within a model the probability measures can be introduced. Then the axioms of probability can be applied. They are:

1. For any event $A \in$ F the probability P($A$)≥0;
2. P(S)=1;
3. If $A = A_1 + A_2 + \dots + A_n + \dots$ , then $P(A) = P(A_1)+P(A_2)+ \dots + P(A_n)+ \dots$

The triplet {S, F, P} is then called *probability space.* The rules that are derived from the axioms work only in this probability space.

These axioms [2] do not explain how the probability must be calculated. But they are sufficient to derive all the mathematics for Probability Theory and all the rules and properties which govern any application of this theory. Axioms do not assign any numeric value for P($A$). But to make sure that any method used to assign such numeric values for which the relationships, like these

$$0 \le P(A) \le 1; \qquad P(\varnothing) = 0; \qquad P(A) = 1 - P(\bar{A}); \; P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

are valid. An important interpretation: The probabilities P($A$) and P ($B$) are called *marginal probabilities*, while P ($A \cap B$) is called *joint probability*. This meaning is essential later when we introduce measures for dependence and the strength of dependence.

## 1.4. Methods for establishing numeric values of probability P(A)

Axioms do not provide ways to assign any numeric values of P($A$) in any probability space {S, F., P}. However, practical needs and theoretical results of probability theory created the following approaches: Classic Definition, Statistical approach, and Subjective approach. Their use depends on certain assumptions (0mpoortant inn risk assessments), and we explain it shortly.

**Classical probability definition**

It is used when the following assumptions are legal to be applied:

The uncertainty model of an experiment shows that the sure event *S* is equivalent to the occurrence of *finite number of mutually exclusive* and *equally likely* outcomes $\omega_1, \omega_2, \dots, \omega_n$. i.e. $S = \omega_1 + \omega_2 + \dots + \omega_n$ as in Model 3 of the uncertainty F.. Every random event is equivalent to the occurrence of some k of these outcomes, i.e. $A = \omega_{i_1} + \omega_{i_2} + \cdots + \omega_{i_k} \in$ F. Then P($A$) is determined as the ratio of the numbers *k* of the outcomes that favor *A* and the total number *n* of all possible outcomes i.e.

$$P(A) = k/n = \#(A)/\#(S).$$

Here I use the sign "#" as a symbol for the counts of the distinct elements in a set. Then the Classical definition of probability works. However, if $S$ is a *finite geometric space* (line segment, plane region or a multidimensional region *with finite volume*), and the outcomes of the experiment are equally likely to appear as random points in $S$, then thinking $\#(S)$ and $\#(A)$ as respective *geometric measures* (length. area, volume), the same Classic definition applies, and the probability -- is then called *Geometric Probability*. And all rules of combinatorics (counting techniques) and the geometry measures can be used in numeric calculations of the measures of the chances random events to occur in a single experiment.

**Statistical determination of probability**

This approach is the most real one. It can be used when *the experiment E can be repeated* without changed conditions many times. When repeated $N$ times and a random event $A$ is observed $N(A)$ times its relative frequency $P(A)$ *is* defined as the ratio of number of times $A$ occurs and the total number $N$ of experiments performed**.**

$$f_N(A) = N(A)/N$$

The probability $P(A)$ is then defined as the limit of $f_N(A)$ when $N$ tends to infinity, i.e.

$$P(A) = \lim_{N \to \infty} f_N(A) = \lim_{N \to \infty} N(A)/N,$$

The legality of this approach is proven based on axioms of Probability, known as the *law of large numbers*. It has been used many times in practice to discover frauds in hazard games. And it is widely used in simulations.

**Subjective determination of probability**

This approach usually is applied when any experiment cannot be used. It is subjected future events with known or guessed conditions. The experts are used to give their forecasts. And the user may use then the statistical approach to manipulate the expert's opinion. In absent of expert, just an opinion can be used. But any consequences should be delivered only when the axioms of the probability theory are verified and fulfilled.

We leave this discussion and assume, basic rules and meanings of probability (conditional probability, multiplication rules, total probability, and Bayes rule) are known to the audience, as well as definitions of random variables, their numeric summaries (mean values, variance, conditional expectations, regression equations, etc.) are familiar to the readers. Ways of calculations of probability and its determination are very, very important in measuring the risks. This is our reason to focus your attention on this necessary initial step.

In the next part of the talk, we will focus your attention on some issues, which might be less familiar and discussed mostly in scientific publications.

## 2. Important and less known approaches and results

### 2.1. Independence and dependence strength measured

Let stop for a minute on the concept of independence, its definition and on the ways of measuring dependence, and their use There are many trials to define this very complicated concept (Declaration of Independence in USA, memorandum of independence from various countries in the World, independent people, independent students, etc.). But the only definition of independency in this world of uncertainty, that can be verified is given through the Probability theory. For two random events *A* and *B* independence is defined as satisfying the mathematical equation:

$$P(A \cap B) = P(A)P(B).$$

It means that the joint probability of the two events under the same experimental condition is equal to the product of their marginal probabilities. Independence is symmetric. It is **mutual.** Moreover, any pair *A* and $\overline{B}$ (the complement of *B*), $\overline{A}$ and B, $\overline{A}$ and $\overline{B}$ are mutually independent too. And all textbooks stop discussions here. But it can be continued. In a series of publications [5-7] I used an idea of Bulgarian mathematician N. Obreshkov [8] to introduce several measures of discovering dependence and to measure its strength for the case of pairs of random events. Then it was extended to measure the local dependence between pairs of random variables, no matter of their types (numeric or non-numeric, or mixed). I see here a huge area of future studies, since joint distributions between random variables and their marginal distributions are defined as probabilities of random events. What is worked out for relationships between random events will be valid for random variables too.

Let us see the measures of dependence between two random events, as proposed by Obreshkov [8].

*Connection* between random events. The number

$$\delta(A, B) = P(A \cap B) - P(A)P(B)$$

is called *connection between events A and B.*

The full list of **properties of the connection** can be found in [5]: I cite here the most important,

**δ1)** The connection $\delta(A, B)$ equals to the covariance between the indicators of the two random events *A* and *B;*

**δ2)** The connection $\delta(A, B)$ equals to zero if and only if the events are independent (something not valid in case f r.v.'s);.

**Δ3)** The probability for occurrence of one of the two events can be recalculated as the conditional probability after the occurrence of the other event when their connection is known. The following relation holds:

$$P(A \mid B) = P(A) + \frac{\delta(A, B)}{P(B)}.$$

*This equation* indicates that the knowledge of the connection is very important and *can be used for calculation of the posteriori probabilities similar to when we apply the Bayes' rule*!

Connection function just shows *direction of dependence* – positive or negative. But it is not good for measuring the strength of dependence. Next measures serve better for measuring the strength of dependence.

**Regression coefficients as measure of dependence strengths**

Regression coefficient $r_B(A)$ of the event *A* with respect to the event *B* is called the difference between the conditional probability for the event *A* given the event *B,* and the conditional probability for the event *A* given the complementary event $\overline{B}$, namely

$$r_B(A) = P(A \mid B) - P(A \mid \overline{B}).$$

This *measure of the dependence of the event A on the event B,* is *directed dependence*.

The regression coefficient $r_A(B)$ of the event *B* with respect to the event *A,* is defined analogously:

$$r_A(B) = P(B \mid A) - P(B \mid \overline{A}).$$

**The whole list of statements about regression coefficients can be found in [5]. We present the most important here.**

(**r1**) The equality to zero $r_B(A) = r_A(B) = 0$ holds if and only if the two events are independent.

(**r2**) The regression coefficients $r_B(A)$ and $r_A(B)$ are numbers with equal signs and this is the sign of their connection $\delta(A, B)$. The relationship

$$\delta(A,B) = r_B(A)\ P(B)[1-P(B)] = r_A(B)\ P(A)[1-P(A)]$$

holds.

The numerical values of $r_B(A)$ and $r_A(B)$ may not always be equal. There **exists an asymmetry in the dependence between random events, and this reflects the nature of real life.**

To be valid $r_B(A) = r_A(B)$ it is necessary and sufficient to be fulfilled

$$P(A)[1-P(A)] = P(B)[1-P(B)].$$

(**r3**) The probability for occurrence of one of the two events can be recalculated as the conditional probability after the occurrence of the other event when their regression coefficients are known. The following relation holds:

$$P(A \mid B) = P(A) + r_B(A)[1-P(B)],$$

and vice versa.

(**r4**) The regression coefficients $r_B(A)$ and $r_A(B)$ are numbers between –1 and 1, i.e. they satisfy the inequalities

$$-1 \le r_B(A) \le 1; \qquad -1 \le r_A(B) \le 1.$$

(**r4.1**) The equality $r_B(A) = 1$ holds only when the random event *A* coincides with (or is equivalent to) the event *B*. Then it is also valid the equality $r_A(B) = 1$;

(**r4.2**) The equality $r_B(A) = -1$ holds only when the random event *A* coincides with (or is equivalent to) the event $\overline{B}$ - the complement of the event *B*. Then it is also valid $r_A(B) = -1$, and respectively $\overline{A} = B$.

**We interpret the properties (r4) of the regression coefficients in the following way:** As closer is the numerical value of $r_B(A)$ to 1, "as denser inside within each other are the events *A* and *B*, considered as sets of outcomes of the experiment". In a similar way we also interpret the negative values of the regression coefficient: "As closer is the numerical value of $r_B(A)$ to -1, as denser within each other are the events *A* and $\overline{B}$ considered as sets of outcomes of the experiment".

The regression function possesses the property

$$r_B(A \cup C) = r_B(A) + r_B(C) - r_B(A \cap C).$$

These properties are anticipated to be used in simulation of dependent random events with desired values of the regression coefficients, and with given marginal probabilities *P*(*A*) and *P*(*B*). Some restrictions must be satisfied when model dependent events by use of regression coefficients.

The asymmetry in this form of dependence of one event on the other can be explained by the different capacity of the events. Events with less capacity (fewer amounts of favorable outcomes will have less influence on events with larger capacity. Therefore, when $r_B(A)$ is less than $r_A(B)$, the event A is weaker in its influence on *B*. We accept it as reflecting what indeed exists in the real life. By catching the asymmetry with the proposed measures, we are convinced about their flexibility and utility features.

**Correlation between two random events** *A* and *B* we call the number

$$R_{A,B} = \pm\sqrt{r_B(A) \cdot r_A(B)},$$

where sign, plus or minus, is the sign of the either of the two regression coefficients.

An equivalent representation of the correlation coefficient $R_{A,B}$ in terms of the connection $\delta(A, B)$ holds,

$$R_{A,B} = \frac{\delta(A,B)}{\sqrt{P(A)P(\overline{A})P(B)P(\overline{B})}} = \frac{P(A \cap B) - P(A)P(B)}{\sqrt{P(A)P(\overline{A})}\sqrt{P(B)P(\overline{B})}}.$$

We do not discuss the properties of the correlation coefficient $R_{A,B}$ between the events *A* and *B*. Just notice that it equals to the formal correlation coefficient $\rho_{I_A,I_B}$ between the random variables $I_A$ and $I_B$ - the indicators of the two random events *A* and *B*. This explains the terminology proposed by Obreshkov, 1963.

The knowledge of $R_{A,B}$ allows how to calculate the posterior probability of one of the events under the condition that the other one occurred. For instance, *P*(*A* ∣ *B*) will be determined by the rule

$$P(A|B) = P(A) + R_{A,B}\sqrt{\frac{P(\overline{B})P(A)P(\overline{A})}{P(B)}}.$$

This rule reminds again the Bayes' rule for posterior probabilities. The net increase, or decrease in the posterior probability compared to the prior probability equals to the quantity $R_{A,B}\sqrt{\frac{P(\overline{B})P(A)P(\overline{A})}{P(B)}}$, and depends only on the value of the mutual correlation $R_{A,B}$ (positive or negative).

A new interesting approach in measuring the strength of dependence between random events, based on the use of entropy, was recently introduced to me by another Bulgarian mathematician Dr. Valentin Iliev.

A preprint of his work can be found at https://www.preprints.org/manuscript/202106.0100/v3. No official publication of this work is known to me yet. However, lots of research in this direction is needed. One is about the dependence between two variables in many of the important situations. The other one is about the extension of the dependence measures between more than two variables. Good luck for those who start working on this. Use of these measures can play significant role in the studies of risk analysis!

#### 3.2.1. On the axioms of statistics and classes of variables

Statistics also uses several basic concepts, most of which are explained in terms of sets. These concepts *are population, sample, variables, measurement, data set.* Most of the textbooks on Probability and statistics start their introductions to uncertainty with these concepts.

**Population** – this is the set that contains no more, nor less, but all the individuals targeted in a statistical study.

**Sample** – this is the set of *n* individuals selected from the population, whose data will be used for information about properties of various characteristics of the population.

**Measurement**s – this is a sequence of characteristics $\vec{x_i}$ = $(x_1, x_2, \ldots, x_k)_i$ one can get after recording the data inspecting the selected individuals *i, i=1,2,…,n.*

**Data set** – or *data matrix* is the matrix of all recorded observations $\ddot{X} = \{ (x_1, x_2, \ldots, x_k)_i \}_{i=1,\ldots,n}$.

**Variables** – these are the recorded values of the measured/observed characteristics for individuals in the sample, located in any of the columns of the data set. These can be:

- Non-numerical or nominal, like names, symbols, labels (like gander, color, origin, etc);
- Ordinal, where categories could be ordered (good, better, best), like preference, age groups etc;
- Numeric (relative or absolute), like temperature, weight, scores, income, etc. Here digital records work.

No axioms of statistics are known. It works mainly with meanings and data. All statistical manipulations with the statistical data sets are based on assumed probability models for the data in a column, i.e., axioms and rules of probability theory start work and used. And here we observe a change of the concept of the population, called sample space. This is the set of all the possible values of the variables in a column (as a population) and parameters of the distributions assumably presenting what is going on in the original population, are called population parameters. Usually in statistics the targets are the estimation of these population parameters. Further various hypotheses are built and tested according to the huge set of algorithms developed in statistics. And there we face the concept of risk, related to many, if not to all decisions based on statistical data, or on probability models applied in the real life.

## III. Uncertainty and related risks in applications

My extended searches for definition of the concept of risk faced different opinions. One of it https://rolandwanner.com/the-difference-between-uncertainty-and-risk/ seems reasonable:

*A risk is the effect of uncertainty on certain objectives. These can be business objectives or project objectives. A more complete definition of risk would therefore be "**an uncertainty that if it occurs could affect one or more objectives.***

A risk is the effect of uncertainty on certain **objectives**. These can be business objectives or project objectives. A more complete definition of risk would therefore be "an uncertainty that if it occurs could affect one or more objectives". Objectives are what matters! I agree with this description. But how to measure the risk? How close are we at certain moment to some risk?

This recognizes the fact that there are other uncertainties that are irrelevant in terms of objectives, and these should be excluded from the risk evaluation. With no objectives, we have no risks. Linking risk with objectives makes it clear that every case in life is risky. Everything we do aims to achieve objectives of some sort, including personal objectives, project objectives, and business objectives. Wherever objectives are defined, there will be risks to their successful achievement will be completed.

The PMBOK guide https://www.amazon.com/Project-Management-Knowledge-PMBOK%C2%AE-Sixth/dp/1628251840 defines risk as an *uncertain event* or *set of circumstances*, and if it occurs has a positive or negative effect on achievement of objectives. Both definitions are alike. Well. but how to measure the effects? Moreover, conditooons change during the time. Therefore, risk assessment also will change, depending on the current conditions. Risk assessment is a process to be observed and followed!

There are events and circumstances/conditions mentioned in these definitions. That's obviously something separated from event. There are *uncertain future events* and if they occur, they could affect achievement of objectives, and that's been in the focus. So what does it mean? Where events correspond to the event called risk? This distinction may still be strange. Moreover, conditions may change over the time. Therefore, risk assessment is a process that must be controled over the time.

The above online referenceces built in me the incentives, that ***the risk is something objective, and it is accepted subjectively.*** Without measures of the risks it does not make any sense to discuss it further. I hope, my examples below related to various understandings of the risk could explain my feelings, and will rise much of questions more to think about. Scientists use the concepts of risk in various situationsam\nd his is what I would like to present.

## 2.2. Risks in hypotheses testing and their measures

In testing hypotheses we have the folloowing situation: a *null hypothese* $H_0$ is tested versus some *alternative hypothese* $H_a$ and some appropriate test, based on certain model assumptions are app;ied. After a test is performed, the statistician shoud take a decision, not reject the null hypothesis, or reject it. Since the nature (uncertainty) is not known, such personal decision contains some risk, which has measures, probability to admit error of tipe 1 (usually denoted by the symbol $\alpha$) meaning to reject the correct null hypothesis. And if the statistician accepts the null hypothesis as being correct, there is another risk for this decision to be incorrect. Its measure is given by the probability $\beta$ to admmit this errot of type 2.

Here we observe the risk of taking wrong decisions of any kind based on incertain data. No more discussions but the tw faces of a riskk are in froonnt of us.Letus continur with other informative values.

**The p-value**

Whenever you run a statistical package with some statistical data set and use some probability model to test, at the output you get a list of numerical results. In its you will find lots of these labeled as p-values, either for the model itself, or **for parameters used in it. Each p-value corresponds to some specific pairs of hypotheses (formally as described above**) and taking decisions one needs tp take is based on their meaning. The p-values in my understanding, are hidden measures of the risks in taking decisions. This meaning of the p-value is very important and needs to be understood. The book [9] of A. Vickers is an interesting place to look at. It offers a funny introduction to the fundamental principles of statistics, presenting the essential concepts in thirty-four brief, enjoyable stories. Drawing on his experience as a medical researcher, **Vickers** blends insightful explanations and humor, with minimal math, to help readers to understand and interpret the statistics they read every day. And there is no explanation what the p-value means.

***My own simple definition-explanation (MEANING) of the p-value*** should be clear for any user and should be used in decisions:

***The p-value is the measure of the chance for the null hypothesis to survive in the conditions provided by the statistical data used in its evaluation.***

You cannot find the explanation of p-value concept in any textbook or books related to its discussion like in [9]. Lately the ASA (American Statistical Association) also made a huge discussion on this issue https://www.bing.com/search?form=MOZLBR&pc=MOZD&q=asa+p-value gives the following definition:

*A p-value is the* ***probability under a specified statistical model that a statistical summary of the data*** *(e.g., the sample mean difference between two compared groups) would be equal to or more extreme than its observed value.*

Can you find any useable meaning in this definition? I cannot. Other definitions in the textbooks are focused on the riles of its numeric calculations (since it depends on the null and alternative hypotheses formulations, on the tests applied, targeted parameters, and many other things) and do not give any understandable meaning. *But meaning is the most stable something, that does not depend on any method of calculation and anything else*. **Measures of the meanings are numbers and should be used as measures of the risk taken in decisions (look at the chance that the null hypotheses are correct in this particular discussion, when statistical data is available and used).**

## 2.3. Other visions on the risk and their numeric measures

Risk is a complex concept. It is met in old times manly in the hazard games. Then (and even in now days) it was measured in terms of "odds".

**Odds**

A true definition of the odds should be the ratio of the probability that a random event $A$ will happen in the condition of an experiment, and the probability that another event $B$ will occur. So.

$$\text{Odds of (A versus B)} = P(A)/P(B).$$

This ratio should be read as ratio of two integers, therefore these probabilities are usually multiplied by 10, or 100, or even by thousand (and then fractional parts are removed) for easy understanding on behalf of users not familiar to probability. Best is the example in case of classic probability

$$\text{Odds of (A versus B)} = \#(A)/\#(B).$$

According to the web information https://www.bing.com/search?form=MOZLBR&pc=MOZD&q=odds or https://www.thefreedictionary.com/odds odds provide preliminary information about bidders in games what are their chances to win after the experiment is performed if the player bet is for event $A$. There usually for $B$ satays the complement of $A$. In my opinion, the odds are kind of hints given by experts to the players what is their risk when in games they bid for the occurrence of certain random future event. However, I think this measure is good also when people talk about risks. In my opinion, odds could be used for comparing chances of two events even when they are results in different experiments. However, the next measure also makes sense.

**Relative Risk when tests are used**

In medicine, biology, and in many actuarial, social, and engineering business the usual practices are to apply a test for establishing if an individual in the population possesses some property (let use terminology "category B ") or is not in this category. As a current example let me notice the popular PCR test for establishing if a person has a COVID 19 virus or not.

Therefore, let *B* and *A* are two events where *A* has the sense of test factor (for example, an environment, habitat, or type of training, temperature different from the normal, etc.), that an individual belongs to the category *B*. The relative risk (Relative Risk, denote it briefly RR) of event *B* with respect to event A is defined by the rule

$$\textbf{\textit{RR(B versus A)}} = \frac{P(B\,|\,A)}{P(B\,|\,\bar{A})}\,. \qquad (*)$$

The point is that the larger the RR, the more test (risk factor A is increasing the probability of occurrence of *B*) effects the category *B* to be true. For example, if we want to evaluate the influence of some risk factors (obesity, smoking, etc.) on the incidence of a disease (diabetes, cancer, etc.), we need to look at the value of the relative risk , when test *A* is applied and indicates such categorization of the risk to be a fact. It is kind of "odds measure" useful to know. We illustrate such situationn with an example from biostatistics below.

**Tests for the Truth**

It is well known that in medicine research and in other experiential sciences to discover the presence of certain diseases there are used specific tests. When the result of the test is positive it is considered that the object owns the quality of what it is tested. However, tests are not perfect. They are very likely to give a positive result when tested objects really have that quality, for which they are tested. Also, it happens to get a negative test although the object possesses that property. And there is another possibility, although unlikely, the test gives a positive result, even when the subject does not possess the property in question. These issues are closely related to the conditional probability. The biostatistics has established specific terminology in this regard which should be known and used. It is known that in carrying out various tests among the population that suffers from something it is possible to get a positive test (indicating that the person may be ill), or negative test. In turn, the latter is an indication that the person is not sick. Unfortunately, there are no tests that are 100% truthful. It is possible that the tested is sick, but the test may not show it, as well as being positive, although inspected subject is not sick. Here the concepts of conditional probabilities play a special role and are important in assessing the results of the tests.

**Screening tests for a risk**

**Predictive value positive, $PV^+$** of a screening test is called the probability of a tested individual to possess tested quality, (such as being sick), when tested positive, ($T^+$) i.e.

$$PV^+ = P(\text{sick} \mid T^+);$$

**Predictive value negative, $PV^-$** of a screening test is called the probability that the tested individual does not have the tested quality (is not sick), on condition that the test was negative ($T^-$) i.e.

$$PV^- = P(\text{healthy} \mid T^-).$$

**The sensitivity of the test** is determined by the probability that the test will be positive, provided that the individual has the tested quality, i.e.

$$\text{Sensitivity} = P\,(T^+ \mid \text{sick}).$$

**The specificity of the test** is determined by the probability that the test gives a negative result, provided that the tested individual does not possess the quality for which is being checked, i.e.

$$\text{Specificity} = P\,(T^- \mid \text{not sick}).$$

In words Specificity = P (no symptom detected | no disease).

**False negative** is determined the outcome of the test where an individual, who was tested as a negative, is sick (possessing the tested quality).

To be effective a test prediction the disease should have high sensitivity and high specificity. The relative risk to be sick if tested positive is then the ratio

$$RR(\text{risk to be sick when tested positive}) = P(\text{sick} \mid T^+)/\, P(\text{sick} \mid T^-) = PV^+/[1 - PV^-].$$

The use of RR in terms of odds is a very good and useful idea in risk assessment ia tests.

If we replace here the word "sick" by the word "risk" in technical items or systems, we will see how good these methods for estimation fit in a wider area of the life.

## 2.4. Reliability and risk

Possibly for many natural reasons, the **Risk concept** is most related to another complex concept - the Reliability. This is an exciting area of discussions, and in my opinion, not finished yet, probably will never be finished. I studied the web opinions and have had detailed discussions with my Gnedenko Forum colleagues, and still did not come to any determined conclusions. Here are some brief results of my research.

In my modest opinion, first and foremost important thing is to understand what the risk is? Then discuss ways to assess or measure it. According to me, the risk is an objective-subjective feeling that something undesirable, dangerous event may happen under certain conditions. While one can explain in words what it is to everyone else, this is not sufficient without some general frames and numeric measure of that risk.

Let see what the wise sources about the risk concept are talking.

### 4.3.1. Definition of Risk Related to Reliability (from the web)

Creating a reliable product that meets customer expectations is risky.

What is risk and how does one go about managing risk? The recent set of ISO (International Organization for Standards) updates and elevates risk management. Here are given some detais:

ISO 9000:2015 includes the definition of risk as "the effect of uncertainty on an expected result. ISO 31000:2009 includes the definition of risk as "the effect of uncertainty on objectives."

The origin of the English word '*risk*' traces back to the 17th century French and Italian words related to *danger*.

A dictionary definition says "the possibility that something unpleasant or unwelcome will happen."

Risk from a business point of view may need a bit more refinement. The notes in the ISO standards expand and bound the provided definition as *definition away from unwanted outcomes to include the concept of a deviation from the expected.*

Surprise seems to be an appropriate element of risk. Surprise may include good and bad deviations from the expected.

For the purposes of the ISO standards, *risk includes considerations of financiality, operations, environmental, health, safety, and may impact business or society objectives at strategic, project, product or process levels*.

The discussion about a specific risk should include the events and consequences. While we may discuss the risk of an event occurring, we should include the '*so what*' element as well. If an event occurs, then this consequence is the result. Of course, this can get complex quickly as events and associated consequences rarely have a one-to-one relationship.

Finally, the ISO notes on risk as including a qualitative element to characterizing risk.

As reliability professionals, these ISO definitions may seem familiar and comfortable. We have long dealt with the uncertainty of product or process failures. We regularly deal with the probability of unwanted outcomes. We understand and communicate the cost of failures.

What is new is the framework described by the ISO standards for the organization to identify and understand risk as it applies to the organization and to the customer?

Reliability risk now has a place to fit into the larger discussions concerning business, market, and societal risk management. I agree that reliability risk is a major component of the risks facing an organization in regard of its products an processes of operations. We witness the news making recalls in recent years (nucleat plant's accidents, plane crashes). We are treatened that sometiing may happen, e.g. some companies may be ruined. As reliability professionals, we use the tools to identify risks, the tools to mitigate or eliminate risks, and the tools to estimate future likelihoods and consequences of risks. How do we view the connection between risk and reliability? Why car commpanies recall some vehicles from users to make a free replace of some parts in order to prevent unexpected failures?

### 4.3.2. Discussions on Risk Related to Reliability (at Gnedenko Forum)

As reliability professionals, these ISO definitions may seem familiar and comfortable. We have long dealt with the uncertainty of product or process failures. We regularly deal with the probability of unwanted outcomes. We understand and consider also the cost of failures.

What is new is the framework described by the ISO standards for the organization to identify and understand risk as it applies to the organization and to the customer?

Reliability risk now has a place to fit into the larger discussions concerning business, market, and societal risk in management. I agree that reliability risk is a major component of the risks facing an organization in regard of its products and processes of operations. Witness the news making recalls in recent years (nucleat plant's accidents, plane crashes, product ecalls). We are treatening what sometimes happen, when companies are ruined. As reliability professionals, we use the tools to identify riskiest events, the tools to mitigate or eliminate risks, and the tools to estimate future likelihoods and consequences of risks. How do we view the connection between risk and reliability? Why car commpanies recall some vehicles from users to replace some parts in order to prevent unexpected failures?

We usually connect the risk to some specific vision on characteristic in the reliability terms. Here I present some points of view of my Gnedenko Forum associates, and this is not an exhaustive review.

**The vision of I. A. Ushakov - the founder of Gnedenko Forum on the risk issues**

It is based on the fo;owinng items:

- *Choice* – start or do not start the process of steps moving towards a target with some risk;
- *Event* – a one tiмe threat at $t_1$ realized once, when something happened;
- *Phenomenon* – an event of some duration $t_2 - t_1$ when qualitative changes in state take place;
- *Uncertainty* - some unknown time during which the chabge occurs, place of manifestation, duration and force of impact;
- *State* - in each state the object is characterized by a number of attributes (properties).
- *Reliability* - the property of an object is securely functioning without fails with a 100% level of efficiency. Refusals are considered. The criterion for refusal is determpned as YES / NO.;
- *Operational efficiency* of functioning t (the term introduced by Ushakov and Dzirkala) is a system that functions continuously, albeit with a reduced level of input parameters. Faithfully, this is the same reliability without a strict failure criterion, but with several levels of quality / efficiency;

- *Stability* - the property of the system to return (within a reasonable time) to the previous 100% level of functionality after the breakdown of some separate components;

- *Vitality* - the property of the object to continue function within acceptable limits after the failure of some separate components;

- *Safety* is a property of the object to perform its functions without causing any damages to the operating personnel, the environment, and so on.

***The Risk*** is a measure of the quality of a particular process to achieve the goal, taking into account the uncertainties on the road. The risk for an object (process) is a value proportional to the deviation of its current state from a certain standard of quality for that object (process).

I see here – *risk is identified as a measure* (a number), without meaning. But I am lookomg for a meaning, like the meaning of probability as the measure of the chance something to happen. Possibly this "something" is the risk. In my opinion there are too many conditions unril some risk is identified and measured. The measure seems to me not clearlyset up.

**Professor V. A. Kashtanov – Risk is a property of a real and modeled process**

Slightly different opinion is expressed by **V. Kashtanov**, **another member of the Gnedenko Forum advisory board.** Here I present his vision. Everything is based on the possibility to present the situations by an appropriate mathematical process in development.

Let me first present his overall opinion about the risk.

**SOME METHODOLOGICAL ASPECTS OF CONSTRUCTION AND ANALYSIS MATHEMATICAL RISK MODELS**

Before talking about the features and construction technology mathematical models of risk, specifics of the mathematical apparatus should be used in the analysis of such models. It is necessary to define the concept of risk. The proposed definition of risk is based on the obvious existence in everyday understanding of the relationship between the risk and the concept of danger. The risk situation in everyday practice is associated with the occurrence of danger events. Note that the danger should be understood in a broad sense, from danger (trouble) of losing a wallet with a small amount of money up to the global danger of a thermonuclear war. Attentive reader will give numerous examples of the presence of the above connections from various life situations. All life situations are developed (change, evolve, vary, etc.) depending on time. They represent processes in which time acts as an independent variable.

Building a model of a process, it is necessary to determine the set of states of this process and consider the process as wandering (changing states) over this set. Further, observing any real life (not mathematical) process, we can talk about changing on time FEELINGS for risk or danger. This change in emotions is since the state of the observed process changes over time. Risk (danger) is a PROPERTY of the states of the real life or model process. Therefore, we can give such a qualitative definition.

Risk (danger) is a PROPERTY in the real life or in a model process. The discussed approaches so far concern only qualitative definitions and assessments

If we understand a safe situation as a situation of no risk, then the opposite of the above concept of risk should be considered no risk concept, or safety concept (no danger). Therefore, with this approach (identifying risk and danger) could not use the term "risk" and will be limited to terms "danger" and "safety". The concept of risk uses only a measure of hazard assessment (this will be discussed below). In some works, safety is also defined as a property of the process functioning in the system.

In the Law of the Russian Federation "On Safety" in determining the quality the term "sensation" is used in the concept of security. When building mathematical models with emotionality it is impossible to work with any concepts. Required measure for the defined above property of the process functioning in the system under study we spell it as follows:

DEFINITION (measure). Risk is a quantitative indicator that evaluates the danger.

If we are talking about assessment, then there must be an observer, implementing this observation process. When assessing a hazard (as in in many other cases) opinions may differ, that some situation (condition) is very dangerous, for some it might be not. So, risk assessment could be subjective. Objective (consistent) assessment should be linked to a process describing the evolution (functioning) of the system under study. Hence, we come to the next

DEFINITION. Risk as a quantitative indicator that evaluates danger, is some functional (operator) defined on the set of trajectories of the process describing the evolution (functioning) of the system under study. Let us note some features of the processes describing the functioning of the system under study:

- An observer can interfere with the operation of the system, that is managing the process. In this case, you can and should put the problem of optimization and search for an optimal strategy management.
- Uncertainty factor (randomness, limited information, the inability to observe the state of the process or observe them with errors).

OUTPUT. A controlled random process on the trajectories of which the functional is defined and for which the optimization problem is set (search for the optimal control strategy) can be interesting and a promising model for researching the problems of risk analysis.

Let me resume and present details in this discussion:

**A qualitative definition:** *The risk (danger) is a property of a real or modeled process.*

It is common to talk on political, social, economic, technologic, and other processes possessing risks. Then in modeling such processes it is needed to determine sets of states of each process and look at it as a random walk within the set of all states. Then the above definition of the risk makes sense and can be understood. The danger is when the process passes into the set of risky states. Safety is when the process is out of there risky states. Such an approach allows to **understand the concept of risk and the ways to assess the risk (author's note) as probability to pass from a safety set into the risky ones with a use of respective model.** Risk (maybe catastrophe) is to be in that set of risky states. Assessment of the risk is to measure the chance to get there from a one that you currently are.

Therefore, without mathematical models we may not be able to give good definitions for concepts widely used in our scientific and social life. According to Kashtanov the following definition should be valid:

*Risk as a quantitative indicator* assessing the danger of some functional operator calculated on the set of trajectories of the process that describes the evolution (the functional behavior) of the studied system.

By the way, a controller may interfere the system work, and have some control on the process. Uncertainty factors (randomness, limited information, impossibility to observe process states or making measurements with errors) create additional challenges in the risk evaluation and control.

I like this approach since it explains the models of risky events and allows to measure the chance to get into it from the safety states. This opinion of our Gnedenko Forum panelist Dr. V. Kashtanov is close to the ISO understandings.

**Dr. A. Bochkov – Risk as a value proportional to the deviation current state from the ideal**

Here is the opinion of **A. Bochkov**, our Gnedenko Forum https://gnedenko.net/ corresponding secretary and since many years the motor in issuing 4 quarterly *refereed and free of charge* publications of our journal "Reliability – Theory & Applications" (RTA, please visit http://www.gnedenko.net/Journal/ index.htm):

*Risk and safety* relate to the humanity. Namely the human assesses the degree of safety and risk **considering** to his own actions during the life, or the reliability of used systems as a source of potential danger, or risk that such thing may happen. *Tools. machines, systems, technical items do not feel the risk. Risk is felt by people*. How do people estimate the risk is a different question? *Safety* in most tools that people use is depending on its ergonomic design, its instructions for use, and the care of organizations and producers of items for common use. There are ergonomic decisions that help such use and users to follow these instructions, which are always in process of improvement.

*Safety* is also a kind of complicated concept. It does not have unique definition neither some unique measure. Everything is specific and kind of mixture between objective and personal. There are no numeric measures for the safety. But I (BD) agree with the statement that *as higher is the safety, as less is the risk*. And still the measurement for the risk as (one that could introduce mathematics in its study) is missing. This is a number which should make aware people and companies, and governments to pay attention on some existing coming in the future risks but is still not clear. According to Bochkov, the *risk* should be measured as a *degree of difference of the current estimated state from the ideal*. Degrees are usually measured in percentages, or in points on some scale (BD). Here is no probability to be used. Humans usually assess the probability. But humans always do not understand what they risk with. The maximal price of the risk for humans is their own life. For the one who takes such risk the price has no numeric expression. Such a loss cannot be compensated. However, when a risk is not related to loses of life's, the maximum loses are estimated by the means available by those who take decisions on actions against risks. And usually, the human lives are priced by the money insurance agencies are paying for the lost lives.

The described approach assumes the availability of retrospective information on the implementation of the risk. The risk of an object (process) is defined as a value proportional to the deviation of its current state from a certain standard of quality of the object (process). In fact, risk is a measure of the quality of an object (process). The measure of the risk itself is the threat of changes in the composition or properties of the object (process) or its environment, or the appearance of changes associated with the occurrence of undesirable processes caused by arbitrary influences. The measure of the threat of failure to achieve the goal is considered in this case as a variable that represents a function relative to the current state of the object (process): it increases when the estimated situation approaches a certain acceptable limit, after which the object (process) cannot achieve the corresponding goals.

The problem is formulated as follows. Let there be a set of features $X$ (risk factors), a set of acceptable implementations of situations $O=(o_1,\dots,o_D)$, For example, the risk was realized or not realized, and there is an objective function $o^*: X \to O$, whose values $o_i=o^*x_i$ are known only on a finite subset of features $(x_1, \dots, x_l) \subset X$. The "sign – response" pairs $(x_i, o_i)$ are called precedents. The set of pairs $X_l = (x_i, o_i)_{i=1}=1$ will make a training sample. It is required to restore the dependence o* on the sample $X_l$, that is, to construct a separating function o/Hππ: $X \to O$, which would approximate the objective function $o^*(x)$, and not only on the objects of the training sample, but also on the entire set $X$. The separating function $\pi(o)$ is called the logical selection function: $\pi(o)\to\{0,1\}$, indicating that the situation $\pi(o)$ is selected into some subset of $\pi(o)$: $(\pi(o)=1)$ , or not $(\pi(o)=0)$.

In general, the separating function can be arbitrary, but for its use to be correct, it is necessary to impose several restrictions on the form $\pi(o)$ (axioms of choice).

Axiom 1 (inheritance): if $O` \subseteq O$, then $\pi(O`) \supseteq (\pi(O) \cap O`)$.

Axiom 2 (consent): $\prod_i \pi(O_i) \subseteq \pi(\cup_i O_i)$.

Axiom 3 (of discarding): $(\pi(O) \subseteq O` \subseteq O) \Rightarrow \left(\pi(O`) = \pi(O)\right)$.

Axiom 4 (path independence): $\pi(X_1 \cup X_2) = \pi(\pi(X_1) \cup \pi(X_2))$

The accepted axiomatic assumptions show that the constructed separating rule should be a monotone function with respect to the set of situations identified as risk-free. As a result, the resulting situation classifier monotonically turns into a product of rules. This important property can be used so as not to retrain the classifier when data about new situations arrives.

To identify the features that need to be considered in the separating rule, it is proposed to use the Hamming metric. The value of this metric – the distance between one-dimensional objects of the same type (rows, columns) is measured by the number of pairs that do not match them. Since the problem of risk identification can be limited to a natural class of monotone functions, not all mismatches in a pair are interesting, but only "ordered" ones, i.e. use the semi-Hamming metric, which reflects only the number of" successful "features for which the value" correct "(equal to 1) in the description of the first of the compared situations, and" erroneous " (equal to 0) in the second situation.

For risk-free situations, the risk measure is chosen as the minimum of the half-Hamming metric, which determines the distance to the interface of the analyzed situations, and for risky situations, respectively, the maximum.

Graphically, the algorithm is illustrated by the scheme shown in Fig. 1.

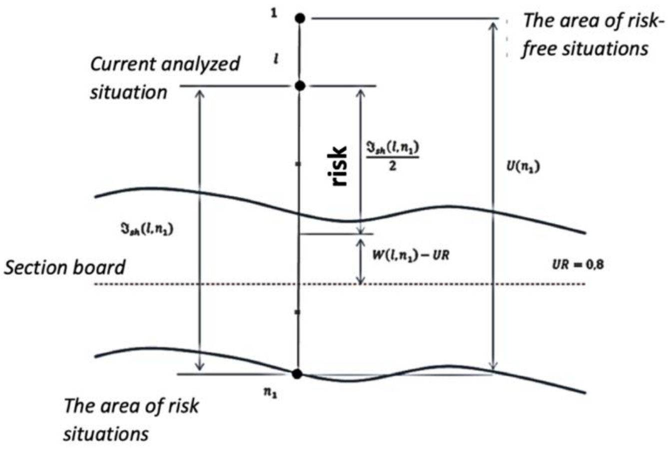


**Figure 1.** Illustration of the definition of the threat measure of the failure of an object (process) to reach the target state for situations with positive dynamics

**Prof. Isaak B. Russman – Risk as measure of the achievability of the target**

The number and variety of Professor Russman scientific works is striking - more than 100 in total, from astrophysics, to modeling structural changes in the economy, trading in securities and assessing the quality of knowledge. Possessing a systematic view of the essence of objects, he preferred to highlight a common basis in all the variety of objects and processes, the modeling and description of which he was engaged in. In this systematic approach, Dr. Russman used many original ideas, for example, allowing one to formalize control tasks using the mechanism of "difficulties in achieving the goal" (a description of the idea in a popularized form can be found here), or graphically present the control task using risk zones and the object's trajectory to goals.

These ideas, one way or another, were used in many of his works and used in the works of his followers. We hope that this page https://www.adeptis.ru/russman/scientific_heritage.html will serve not only the memory of Isaak Borisovich, but will also serve as a serious source of new ideas, both for theorists and for practitioners working in the field of modeling and optimization of control processes for various systems. The main work of this author (in Russian) concerning the risk issues is Об оценке интегрального риска инвестиционных проектов (геометрический подход) In English "On the assessment of the integral risk of investment projects (geometric approach)", published in *Научно-практический вестник "Энергия", №3(41), 2000, с. 111-116(Russian)* (Scientific and practical bulletin "Energy", No. 3 (41), 2000, p. 111-116 ) .

Dr. Russman opinion deserves a bit more detailed description.

The risk estimates the difficulty of obtaining the declared result $d_k$ with the existing estimates of the quality of the resource ($\mu_k$), and the requirements for this quality ($\varepsilon_k$). The concept of the difficulty of achieving a goal for a given quality and requirements for the quality of the resource and the result follows from the considerations that it is more difficult to obtain a result of a certain quality, the lower the quality of the resource ($\mu_k$) or the higher the requirements for its quality ($\varepsilon_k$).

From general considerations, the (leading measure of the risk, BD) difficulty $d_k$ of obtaining the result should have the following basic properties:

- at $\mu_k = \varepsilon_k$ be maximal, i.e. equal to one (indeed, the difficulty of obtaining a result is maximum at the lowest permissible quality value);

- for $\mu_k$= 1 and $\mu_k$> $\varepsilon_k$, be minimal, that is, equal to zero (for an extremely high possible value of quality, regardless of requirements (for $\varepsilon_k$<1), the difficulty should be minimal);
- for $\mu_k$> 0 and $\varepsilon_k$= 0 be minimal, i.e. equal to zero (obviously, if no requirements are imposed on the quality of the resource component, and $\mu_k$ is greater than zero, then the difficulty of obtaining a result for this component should be minimal).

For these three conditions, for $\varepsilon_k < \mu_k$, a function of the form is valid:

$$d_k = \frac{\varepsilon_k(1-\mu_k)}{\mu_k(1-\varepsilon_k)}$$

We also assume that $d_k = 0$ for $\mu_k = \varepsilon_k = 0$ and $d_k$ =1 for $\mu_k = \varepsilon_k = 1$.

The functioning of a reliable system is characterized by maintaining its main characteristics within the established limits. The actions of such a system are aimed at minimizing deviations of its current state from some given ideal-goal. In relation to the system, the goal can be considered as the desired state of its outputs, i.e. not only the value of its target function.

Consider a system in the process of achieving a goal, moving from its current state to some future result, the quantitative expression of which $is\ A_{pl}$. Let's assume that the goal is completed in time $t_{pl}$. We also assume that there is a minimum speed vmin of movement to the target in time and a maximum speed vmax. It is most convenient to measure the quantitative expression of the result and the time required to achieve it in dimensionless quantities; for this purpose, we assume $A_{pl}$ and $t_{pl}$ equal to one or 100%. In Figure 1, the minimum and maximum velocity trajectories of the systemcorrespond to the OD and OB lines.

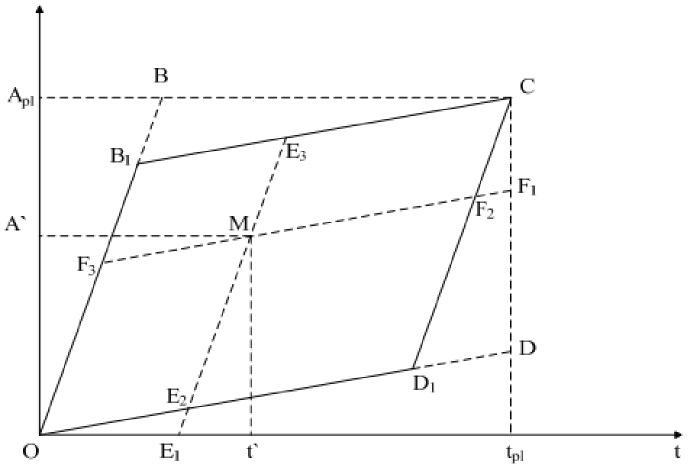


**Figure 2.** Geometric interpretation of the system's movement towards the goal

The polyline $OD_1C$ is the boundary of the restricted area, and for any point $M$ with coordinates $(t', A')$ that describes the position of the system on an arbitrary trajectory to the target within the parallelogram $OB_1CD_1$, the distance is taken as the risk of not reaching the target:

$$r(M) = \max\left\{\ln\frac{1}{1-d_1}, \ln\frac{1}{1-d_2}\right\},$$

where $d_1 = \frac{\varepsilon_1(1-\mu_1)}{\mu_1(1-\varepsilon_1)}, d_2 = \frac{\varepsilon_2(1-\mu_2)}{\mu_2(1-\varepsilon_2)}, \varepsilon_1 = \frac{|E_1E_2|}{|E_1E_3|}, \mu_1 = \frac{|E_1M|}{|E_1E_3|}, \varepsilon_2 = \frac{|F_1F_2|}{|F_1F_3|}, \mu_2 = \frac{|F_1M|}{|F_1F_3|}$

**Dr. V. V. Rykov – Risk as a two-dimensional process**

One more opinion of our RTA chief editor V. V. Rykov, an established expert in reliability is briefly shown hwre. I is well presented in his book [10]. He relates almost each system reliability characteristic to some respective rusk, with an emphasize on the economic consequences when a risky event happens. And probability models are used in each situation. My brief review (BD) follows.

Variety of risks accompanied individual people during their life. Same things happen with various industrial product lines, agricultural, financial companies, biological, environmental systems, and many other units. Risk appears due to the uncertainty of some events that may occur with respect of which corresponding decision and actions should be taken. The mathematical Risk Theory is generated and developed on the actuarial science, where the risk is that an insurance company will be ruined and is measured by the *probability of ruin*.

However, nowadays the understanding of risk is related to the occurrence of some "risky" event and with related to it consequences in terms of material or monetary losses to restore. Numerous examples support this position one can read in the Rykov's book [10]. But we focus on situations related to reliability. Before that let see his mathematical definition of the risk given there.

Risk is related to the occurrence of some random (risky) event $A$, which probability $P_t(A)$ varies in the time $t$, depending on current conditions. Occurrence of such event at time $t$ generates some damages measured by a value $X_t$. In this way the risk is characterized by two variables ($T$, $X_T$), where $T$ is the time of the occurrence of the risky event $A$, and $X_T$ is the measure of the damages then. Both components can be random.

In Reliability theory $T$ can be the time of use of a technical system, that may vary according to the reliability model of management of this system and of its structure. Application of this approach is demonstrated in analysis of technological risk for popular reliability systems in the frames of some known failure models. The focus in [110] is on the measured risk.

As a basic measure it is proposed the two dimensional distribution function $F(t, x) = P\{T \leq t, X_T \leq x\}$. I like this approach. It admits lots of analytical analysis of some particular characteristics and cases, as demonstrated in this book [10], and used in many other new research projects.

But this is done just within theoretical frames and assumptions. Practical applications need sufficient data for such a function $F(t, x)$ to be appropriately estimated. I do not refer to any particular result from [10]. Just note that the variable $T$ varies depending on the reliability system model where a catastrophic event may happen. Then the value of the losses $X_T$ will be known. And also, the value of losses which extend some critical value $X_{critical}$ is achieved or is close to be achieved. Then the process should be stopped (times to stop are also interesting to be analyzed in such approach) to be able to *prevent the risk*. Such discussion is not used in that book but deserves attention.

And somehow, I could not see any satisfactory other measure of the risk shown, different from the amount of expected loses. Average characteristics are found in [10] but no clear measure of the risk which could be used as a BELL RING THAT THE RISK IS NEARBY. I believe that if the risk is measured in terms of odds, then when the odds reach certain level, the bell must ring laud to make an alarm for those who are supposed to take care about that risk. Somme odd's addition to Rykov's approach might be interesting and useful. However, it will be nice and useful to havve Dr. Rykov presentation at this Conference talks and discussians.

**Prof. N. Singpurwalla – A Bayesian point of view on the risks in reliability**

This point of view isdiscussed in the book [11]. I do not dare to get into details. JJust recommmend everyone interested in that approach to look in the source. The authoor writes:

There is an increasing emphasis on what is commonly referred to as 'risk', and how best to manage it. The management of risk calls for its quantification, and this in turn entails the quantification of its two elements: the uncertainty of outcomes and the consequences of each outcome. The outcomes of interest here are adverse events such as the failure of an infrastructure element, e.g. a dam; or the failure of a complex system, e.g. a nuclearpower plant; or the failure of a biological entity, e.g. a human being. 'Reliability' pertains to the quantification of the occurrence of adverse events in the context of engineering and physical systems. In the biological context, the quantification of adverse outcomes is done under the label of 'survival analysis'. The mathematical underpinnings of both reliability and survival analysis are the same; the methodologies could sometimes be very different. A quantification of the consequences of adverse events is done under the aegis of what is known as utility theory. The literature on reliability and survival analysis is diverse, scattered and plentiful. It ranges over outlets in engineering, statistics (to include biostatistics), mathematics, philosophy, demography, law and public policy. The literature on utility theory is also plentiful, but it is concentrated in outlets that are of interest to decision theorists, economists and philosophers.

One of the aims of this book is to develop material in reliability with the view that the ultimate goal of doing a reliability analysis is to appreciate the nature of the underlying risk, and to propose strategies for managing it. The second is to introduce the notion of the 'utility of reliability', and to describe how this notion can be cast within a decision theoretic framework for managing risk.

The second aim of this book is to summarize the Bayesian methodology in its broader context. Much of this Bayesian methodology is directed toward predicting lifetimes of surviving units.

The focus has been on the use of concepts and notions in reliability theory that are germane to econometrics and finance, in particular the assessment of income inequalities and financial risk.

I (BD) am not in the positionn to judge the Bayesian approach and, conceppts and modelspresented in [11]. I only notice that I could not find a clear definition of "what is the risk" and how one can measure how close a process is to a risky situation. And llet me share with you an opinion about thid book: "What I liked most about this book, however, is the way it blends interesting technical material with foundational discussion about the nature of uncertainty." (*Biometrics*, June 2008).

**My authors opinion on the risk and its measures**

During my work on this "risk issue" I have seen so many opinions and approaches, as most of you probably met too. Most of these are focused on particular situations, issues, or cases. That's why I got to some general definition of the risk in a random process, and the ways of its evaluation. My vision is as an opinion of a mathematician, experienced in Applied Probability, modeling and data analysis the theory and practice.

First of all, random processes need some realistic adequate probability model where the set of states $\Omega$ of the process are defined (known, well described, observed and controlled) at any time, and dynamic probabilities of changes should be known. In other words, it should be defined a probability space $\{\Omega, @_t, P_t\}$. Here $\Omega$ is the set of all possible states of the process, and their meaning cannot vary in the time; $@_t$ is the uncertainty model at the time $t$, and $P_t$ is the probability that works in that time. Let $B_t$ be the set of undesired (adverse, risky) events. It is an element of $@_t$, and let $A_t$ be the set of current states (also an element of $@_t$). $A_t$ Could be a result of a test performed at time $t$, or a current state.

**Definition:** Risk at time $t$ is the set $B_t$ of undesired (risky) events. Let $A_t$ be the set of current states in the probability space $\{\Omega, @_t, P_t\}$ that describes the evolution of the observed process. Measure of the risk at this moment is the relative risk

$$RR(B_t \text{ with respect to } A_t) = P(B_t \mid A_t) / P(B_t \mid \textit{complement of } A_t)$$

in terms of odds.

This definition is a replicate borrowed foam the measurements of risk in biostatistics presented above. By the way, in the cases discussed in Bochkov terms where safety and risky sets have nothing in common, this measure = 0; In Kashtanov's and Rykov's considerations it needs calculations. Please, notice that $A_t$ and $B_t$ may particularly overlap. As more $A_t$ is covering $B_t$, the higher the risk is (please, look in my measures of dependence discussed above). I think, this is a natural measure. However, the regression coefficients also can be used as measures of dependence of the risk on the current situation.

I am not sure that the risks in reliability analysis should stop here. Reliability itself is defined as the probability that a system functions at a given time. Therefore, the fact that it does not work then it is a kind of risky event. The availability coefficient also is probability of an event, that the system is able to function at a certain time. And many other functions, like failure rates, number of renewals, maintenance costs, effectiveness, expenses for supporting functionality, etc. have quantitative measures that could be used as risky variables. Each of these uses a construction of an appropriate probability space, where the above general definition and evaluation of the risk can be applied. Therefore, the issues for the risk assessments are not finished yet. There is a lot of open questions for researchers to work on.

According to me, the risk is a concept with many faces. Possibly the reliability may high lite some of it. Following to the above views and discussions I got to the following

**Proposition:** The risk (analogously the reliability) is a complex notion that is measured by numerous indexes depending on different applications and situations. But the basic measures should be unique.

## IV. Conclusions

Axioms are the foundation in establishing new areas of theoretical research.

In each theory there arise numerous of new concepts that have meaning, may generate new axioms and areas of studies, which need explanation, metrics for evaluation useful in their better understanding and clear practical use and applications.

*Reliability and Risk* can most profitably to be used by practitioners and research workers in reliability and survivability as a source of information, reference, and rise new open problems.

Our article is tracing some ways of developing useful knowledge in studying the risky events and problems in the real-life.

I am sure that the risks in reliability analysis should not stop here

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# ON PRINCIPLES OF RISK ANALYSIS WITH A PRACTICAL EXAMPLE

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**Abstract**

*As a scientific term "risk'' originally appeared in insurance mathematics and meant the "ruin probability'' in a "collective risk'' model of an insurance company. Recently, this term has become widespread in different spheres of human activity and has been applied to various models of "individual risk". At the same time, despite its increasing popularity, its strict definition still does not exist, and various sources interpret it differently. The report discusses various interpretations of this notion and it reasons. The authors adhere to the concept of risk as a random phenomenon and from this point of view, consider its characteristics and their measuring methods. The risk tree is used for the probabilistic space of the risk phenomenon construction. In the talk, the proposed approach will be demonstrated with the help of one real-world example.*

**Keywords**: individual risk: notion, measurement, risk tree analysis.

## I. Introduction and Motivation

The term "risk" has become very popular recently and used in various fields of human activity. However, an exact definition of this notion still does not exist, and various sources interpret it differently (see, for example, the analysis of sources in [1-5]). Such a variety in the interpretation of this notion relates to the fact that different authors are based on different concepts of "uncertainty", which has recently received several directions of formalization: (a) randomness, which is investigated by probabilistic methods, (b) subjective uncertainty, studied within the framework of subjective probabilities, (c) fuzzy uncertainty, and (c) expert uncertainty (other methods of studying uncertainties may exist or are acceptable). From another side, the variety of characteristics and indicators of risk leads to the fact that different authors use to define it.

From our point of view, to study the risk phenomena and construct its mathematical models, it is necessary, from the very beginning, to define within what type of uncertainties it will be done. In this paper, we will study the risk as a random phenomenon in terms of "objective probability". In the interpretation of A.N. Kolmogorov, a random phenomenon should have two main features:

- the possibility of multiple observation of this phenomenon and
- in homogeneous (identical) conditions.

Then randomness is measured by probability, which is estimated using frequency.

Other concepts of risk considerations are also possible, but we leave them for other authors and other discussions.

This talk deals with the notion of individual risk, its main characteristics, and their measurements based on randomness conception, and uses probabilistic terminology.

## II. Risk: notion and measurements

Analysis of numerous examples of phenomena, in which the term "risk" appears, carried out in [6] and [7], allowed us to conclude that the risk is associated with the occurrence of some random event A, which we will call risk event, from a possible family $\mathcal{F}$ of events describing the considered risk situation. These events are usually distributed in time and accompanied by certain damages (material or other) generally speaking, also random in its magnitude. Thus, the risk is characterized by two values: T time of the risk event nonoccurrence and the value of X the damage connected with them. It gives the right to state the following

**Definition 1**. Risk is a *random phenomenon*, modeled by a probabilistic space (Ω, $\mathcal{F}$, P), on which two-dimensional random variable (r.v.) (T, X) is determined, where T is the time to the risk event A ∈ $\mathcal{F}$ occurs, and the other one X shows a *damage*, connected with it[1].

Thus, as for any r.v. its main characteristic is its cumulative distribution function (c.d.f.)

$$F(t,x) = \mathrm{P}\{\mathrm{T} \le t,\ \mathrm{X} \le x\}, \quad t \ge 0,\ x \ge 0 \tag{1}$$

In the most real cases, the information about the joint distribution of these r.v.'s does not available and one should be limited oneself with one-dimensional distributions of times to risk event and the value of the damage

$$F_{\mathrm{T}}(t) = \mathrm{P}\{\mathrm{T} \le t\}, \quad F_{\mathrm{X}}(t) = \mathrm{P}\{\mathrm{X} \le x\}. \tag{2}$$

All other risk indexes can be found from this one mail characteristics. For example, for risks during fixed time interval instead of time T to risk events one should consider its indicator function $1_{\{\mathrm{A}\}}$, and measured damage by its conditional distribution $G(x;\mathrm{A}) = \mathrm{P}\{\mathrm{X} \le x \,|\, \mathrm{A}\}$. At that unconditional distribution of the damage value is the joint distribution of the risk event A occurrence and conditional damage value distribution that has a jump in zero, since the damage equal zero under the absence of risk event:

$$F_{\mathrm{X}}(x) = 1 - \mathrm{P}(\mathrm{A})(1 - G(x;\mathrm{A}))$$

where $\mathrm{P}(\mathrm{A})$ – is a probability of event A.

In general, it is natural to measure a risk by the distribution of the time moment of risk event occurrence $F_{\mathrm{T}}(t) = F(t) = F(t,\infty)$ and the conditional distribution of a damage $G(x;t) = \mathrm{P}\{X \le x \,|\, T = t\}$. At that its joint distribution is

$$F(t,x) = \int_0^t G(x;u) f_{\mathrm{T}}(u)du\,. \tag{3}$$

The simplest assumption consists in independent of these values

$$G(x) = F_{\mathrm{X}}(t) = F(t,\infty); \quad F(x,t) = G(x)F(t)\,.$$

In the most real situations, this assumption is quite admissible with the only remark that the value of future damage in the recent time evaluated as to its *present value*

$$\hat{\mathrm{X}} = e^{-s\mathrm{T}}\mathrm{X}, \tag{4}$$

where $s$ is a discount factor.

Further, it is supposed that the r.v.'s T, and X are independent and the following notations are used:

[1] The time T can depend on the time $t_0$ of the risk situation beginning. Moreover, the risk situation can change during its development. In this case, one should model the risk situation by the two-dimensional absorbing *risk process* (Z(t), X(t)) with absorption as a risk event. But we leave this construction for another work.

$$F_{T}(t)=F(t,\infty)=F(t);\quad F_{X}(t)=F(\infty,x)=G(x).$$

In practice, for concrete calculations, more simple characteristics of risks are used, such as expectations of the time to risk event $\mu_{T}=M[T]$ and mean value of damages caused by it $\mu_{X}=M[X]$ and their variances

$$\sigma_{T}^{2}=DT=M(T-\mu_{T})^{2};\quad \sigma_{X}^{2}=DX=M(X-\mu_{X})^{2},$$

as well as a probability $q$ of a risk event A в occurrence during the fixed time $t_0$,

$$q=P\{T\le t_0\}=P(A)=M1_{\{A\}},$$

and so on.

## III. Risk tree

For investigation of complex phenomena, such as development of failures in complex systems, the development of risk situations in technique, business, medicine, etc., it is convenient to use an *event tree* notion. Originally this notion has been used under the name of a *failure tree* in the very beginning of the 60-th last century by H.A. Watson from Bell Lab for analysis of systems' reliability. At that as risk events the units, subsystems, and the whole system failures are considered. Further, this idea has been used in other applications: for study business, medicine, biological and other processes. We will use it under the name *risk tree*.

**Definition 2**. A *risk tree* is a labeled graph, the root of which is the main risk event, and the branches associate it with initial (leaf) events, which are taken as elementary.

In practice, it is more convenient to depict the risk tree upside down.

For a description of the events hierarchy in the risk tree, it is convenient to index them with the vector indexes $\boldsymbol{i}_r=(i_1,i_2,\dots,i_r)$, whose components denote the consequence of risk events numbers, beginning from the main up to the elementary one. Thus denote

- $i_0$ is the number of the main risk event in the considered risk situation;
- $i_1$ is the number of the first level event that can be one of the reasons the main event occurrence;
- $i_2$ is the number of the second level event that can be one of the reasons the event with the number $i_1$ of the previous level occurrence; etc.
- $i_k$ is the number of the $k$-th level event that can be one of the reasons the event with the number $i_{k-1}$ of the previous level occurrence; thus
- the vector $\boldsymbol{i}_r=(i_1,i_2,\dots,i_r)$ denotes the number one of the leave (elementary) events; where
- $r$ is a hierarchy level of this event (its *rank*), at that different elementary events can have different ranks;
- by truncated vector $\boldsymbol{i}_k=(i_1,i_2,\dots,i_k)$ the number of the according event of $k$-th level is denoted; and
- the $j$-th event, which can be the cause of the event $\boldsymbol{i}_k$, is denoted by $j(\boldsymbol{i}_k)$;
- at that, the different events are indexed by appropriate indexes $A_{\boldsymbol{i}_k}$

Thus, all events, starting from the main and intermediate ones up to elementary ones, the considered risk situation are completely determined by their numbers.

Further, analogously to the failure tree in reliability, for the risk characteristics calculation, we will use structural variables and functions. Denote *structural variable* of an event $A_{\boldsymbol{i}_k}$ by

$$x_{\boldsymbol{i}_k}=\begin{cases}1, if\ an\ event\ A_{\boldsymbol{i}_k}\ occurs;\\ 0,\quad otherwise.\end{cases}$$

Corresponding *structural functions* of the main, intermediate, and elementary events are

$$\varphi_k\left(x_{(\boldsymbol{i}_k,1)},\dots,x_{\left(\boldsymbol{i}_k,n(\boldsymbol{i}_k)\right)}\right)=x_{\boldsymbol{i}_{k-1}}\tag{4}$$

and they are calculated accordingly to the rules of Boolean algebra. For the risk tree construction, it is convenient to use special symbols of the events and gates that are taken from the book of Henley & Kumamoto [8] and can be found in [6]-[7].

In the talk, this approach will be demonstrated with the help of the example of the risks, connected with the system of underwater pipeline system monitoring.

## IV. Conclusion and the further work

In the talk, the risk notion, its measurements, and its model construction in the framework of Kolmogorov's probabilistic approach are proposed. This approach is demonstrated with the help of some example. The development of a risk situation is considered in an unchanging external environment. More wide risk model investigation is also possible. It must be based on the model of risk process modeling and considering the risk event as an adsorbing of this process. This approach can be the subject of further research.

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# APPLICATION OF ARTIFICIAL INTELLIGENCE IN RUSSIA'S RAILWAY NETWORK ASSET MANAGEMENT

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**Abstract**

*The article presents general information on the system and methodology of asset management and Big Data methods (EKP URRAN) used on Russia's railway network. The relevance of the publication is defined by the requirement of rational management of available resources amidst the stagnation of the global economy. That applies fully to the railway industry, where it is required to ensure an acceptable level of dependability of facilities and processes, while maintaining the traffic safety risks at an acceptable level. The architecture of EKP URRAN is presented. The system's future outlooks are examined, most importantly in terms of application of artificial intelligence in predicting hazardous events in the operation of railway transportation.*

**Keywords:** Big Data, asset management, risk, safety, dependability, artificial intelligence

## I. Introduction

Railway networks represent major assets in most countries and their adequate management has always been a concern for owners and operators. That determined the idea of asset management in the railway infrastructure environment that evolved from a number of sources, including the concept of total system support [1]. That is due to the high rate of digitalization creating enormous amounts of data in the day-to-day operations of many industries, including the railways.

The conventional methods of processing such data are unable to meet the current social and industrial performance requirements, which determined the recent emergence and development of an entirely new discipline, the so-called Big Data analytics [2-5]. As the industry support of asset management systems grew, standardization processes led to the development of the ISO 55000 asset management standards [6]. All aspects of the asset lifecycle, from concept development to disposal, are critical to a company's success [7]. The motivation for asset management and the migration to condition-based maintenance provided stimulated the introduction of Big Data analytics in railway asset management.

Russian Railways Network is the largest owner and operator of transportation infrastructure in Russia [8], holding leading positions worldwide along the US and China, including in terms of traffic volume. Infrastructure accounts for over 60 percent of the total cost of fixed assets, while the operating costs of infrastructure amount to around 35 percent of the total costs. As a result, one of the company's key objectives is to optimize the cost of asset maintenance.

Technical assets benefit a company only if they operate reliably and efficiently. The efficiency of an asset is directly related to its performance, level of functionality and especially safety. Thus, dependability, safety, performance, functionality are the main characteristics of a technical asset. They have a critical impact on the value of an asset's lifecycle.

## II. URRAN Single Corporate Platform (EKP URRAN)

The basic methodology Russian Railway Network uses to manage dependability, safety and risks to technical assets is the methodology for managing resources, risks, and dependability of railway facilities at lifecycle stages (URRAN) that includes guidance documentation and software for management process automation [9].

URRAN-based asset management includes interdisciplinary approaches that require collaboration between business units and integration of short- and long-term decision-making. An asset is placed at the center of a value-oriented management process and its maintenance is one of the activities performed throughout the life cycle of such asset [8]. EKP URRAN contains five functionally complete virtual technical subsystems. Four subsystems (EKP URRAN Track, EKP URRAN Signaling, EKP URRAN Communications, EKP URRAN Power) automate infrastructure facilities management (track, signaling, telecommunications, and power supply), one subsystem (EKP URRAN Traction) automates rolling stock management (locomotive and multiple units).

The subsystems interact through software interfaces (Fig. 1).

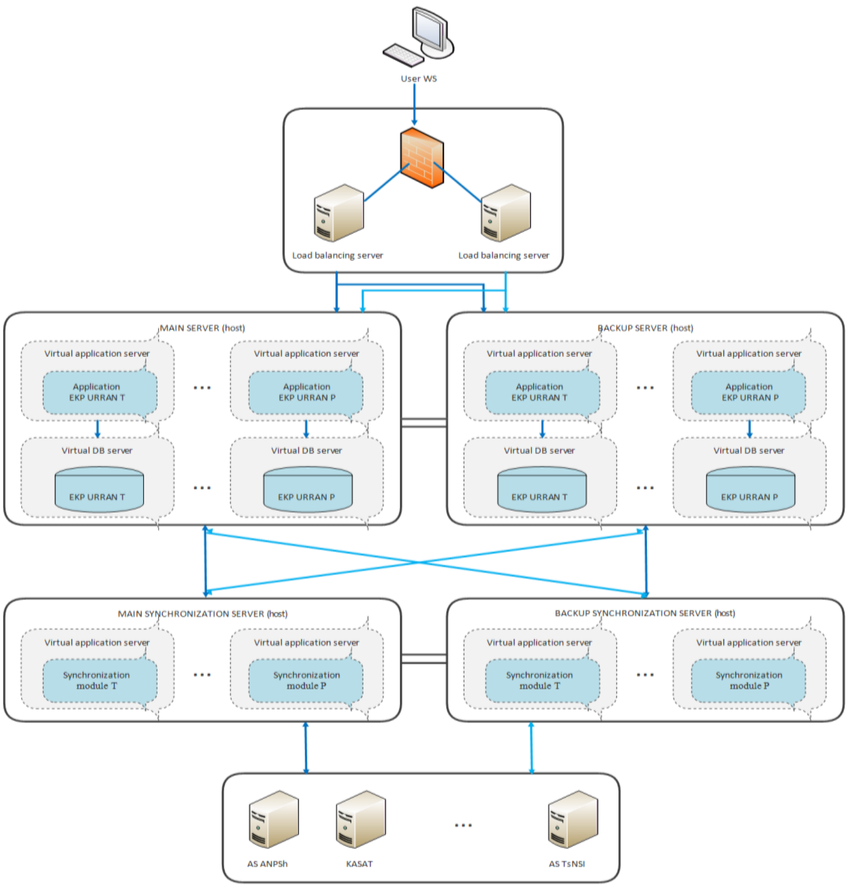


**Figure 1.** *Overall architecture of EKP URRAN*

There is an urgent need for accurate and reliable prediction of non-measurable system states: hazardous failures, pre-failures, failures, process violations. URRAN-based maintenance management involves processing large amounts of data received from the Russian Railway Network integrated automated systems.

# III. METHODS OF DATA SCIENCE AND ARTIFICIAL INTELLIGENCE FOR MANAGING SAFETY, DEPENDABILITY AND RISKS IN RAILWAY TRANSPORTATION

BD analytics slightly change the decision-making method. Instead of choosing the right methods for analysing data, the available data is browsed, and new patterns and correlations are found. That allows making decisions based not only on a common understanding of assets, but also on not yet revealed correlations between different parameters.

## 3.1. Safety management

The specificity of Data Science application clearly shows in the context of hazardous event prediction in railway transportation. High train traffic and speed, environmental conditions, ageing cause tear and wear of railway infrastructure, primarily the track. Rail defects may cause derailments or crashes. Such accidents are associated with damage to the track, power supply networks, as well as cars and locomotive units with potential exclusion from the inventory rolling stock. Derailed units of rolling stock may also intrude into the operational space of the adjacent track, which may cause a collision with an opposing train with catastrophic consequences. A significant share of undesired events being attributed to the condition of track can be observed worldwide. The analysis of derailments and crashes involving units of freight trains identified that derailments/crashes caused by track defects could occur on track sections rated, for instance, as "good". In this context, the aggregated estimate of a kilometer of track is not sufficient for predicting its condition, and it is required to take into consideration other parameters: number of widenings, realignments, etc. Today's methods of multiple factor data analysis and the machine learning technology that allow including over 50 factors into models enable – based on existing knowledge of measured featured that characterize the condition of track – making conclusions regarding the need for urgent repairs to avoid track failures and derailments and crashes caused by an unsatisfactory condition of track [10]. Machine learning is increasingly popular as means of improving the dependability of railway systems. It also allows minimizing the daily cost of asset maintenance [11]. The machine learning methods can be divided into classical algorithms and deep learning methods that primarily differ in terms of the level of representation.

As of late, the academic community has been making use of the advantages of the deep learning methods for studying rail defects (Fig. 2).

Researchers [12] believe that deep learning may become an element of completely automatic railway monitoring systems. Neural network-based algorithms are employed as the primary tool for detecting structural defects in rails. Examples include the convolution neural networks (CNN) that are a special case of artificial neural networks. However, CNN have a major disadvantage as they are a "black box" and practically cannot be interpreted.

In [13, 14], the authors show the results of a numerical experiment of line categorization based on failure prediction. Thus, on the Kuybyshevskaya Railway, between 2014 and 2019, track superstructure condition statistics were collected. Failures of the following types of railway infrastructure elements were registered: isolated joint, concrete tie, rail line, rail joint, geometrical parameters of the track, etc. Over several years, for each kilometer of track the following parameters were measured monthly: number of widenings, number of deviations, number of realignments, number of sags, traffic speed within the specific kilometer, etc. The classification problem was solved with a wide use of machine learning algorithms: logistic regression, solution trees, random forest, support vectors and nearest neighbor. The experiments showed that the mathematical models of decision tree and random forest are most efficient. They enable acceptable prediction accuracy (over 75%) with the minimal rate of "false alarms" (28%).

### 3.2. Dependability management

Railway facilities are operated in a variety of natural (temperature, humidity, wind, pressure, number of precipitations, snow, floods, etc.) and technological (track layout, track class, target speed, etc.) conditions. Additionally, different approaches are applied to the operation of different facilities depending on the load factors. Functionally identical facilities may differ significantly in terms of design. All these circumstances mean that functionally identical facilities may fail at different rates, while the failure rate can vary significantly depending on the operating conditions [13, 14].

Out of that follows that the dependability of a facility cannot be assessed based on the total number of its failures in various parts of a railway network. This problem can be solved by introducing a system of coefficients for operating conditions and facility design, i.e., transforming such facility into a sort of a reference. For that purpose, URRAN was provided with technical characteristics and conversion factors enabling conversion into reference infrastructure facilities (track facilities, signaling systems, railway telecommunications, power supply and electrification) and rolling stock reference facilities (locomotives and multiple units). One of the most important aspects of standardization involves key dependability indicators of transportation facilities.

### 3.3. Risk management

URRAN uses the definitions, approaches to risk classification and safety principles common to International Union of Railways (UIC) member companies. A risk management methodology is employed that includes the stages of risk assessment, processing, monitoring and analysis. An ALARP-based risk matrix is used as one of the key risk management tools. Formulas are used for defining the number of matrix elements depending on the statistics of hazardous event rate and the amount of caused damage. A method has been developed for estimating the integral risk associated with the operation of a set of various types of facilities and a risk-oriented criterion of facility life extension.

If the risk of a hazardous state for a facility in its limit state exceeds the permissible level, the facility is removed from operation. Otherwise, the economic feasibility of further operation is assessed. In respect to facilities that fail suddenly or regularly, the functionality is considered (the functionality of a facility is considered in terms of the quantity and quality of functions that define its applicability in various operating conditions). The facility's life cycle cost is estimated, the optimal strategy is selected for planning maintenance and repair. Taking the examples of a line section, a risk-oriented algorithm of facility maintenance management is shown.

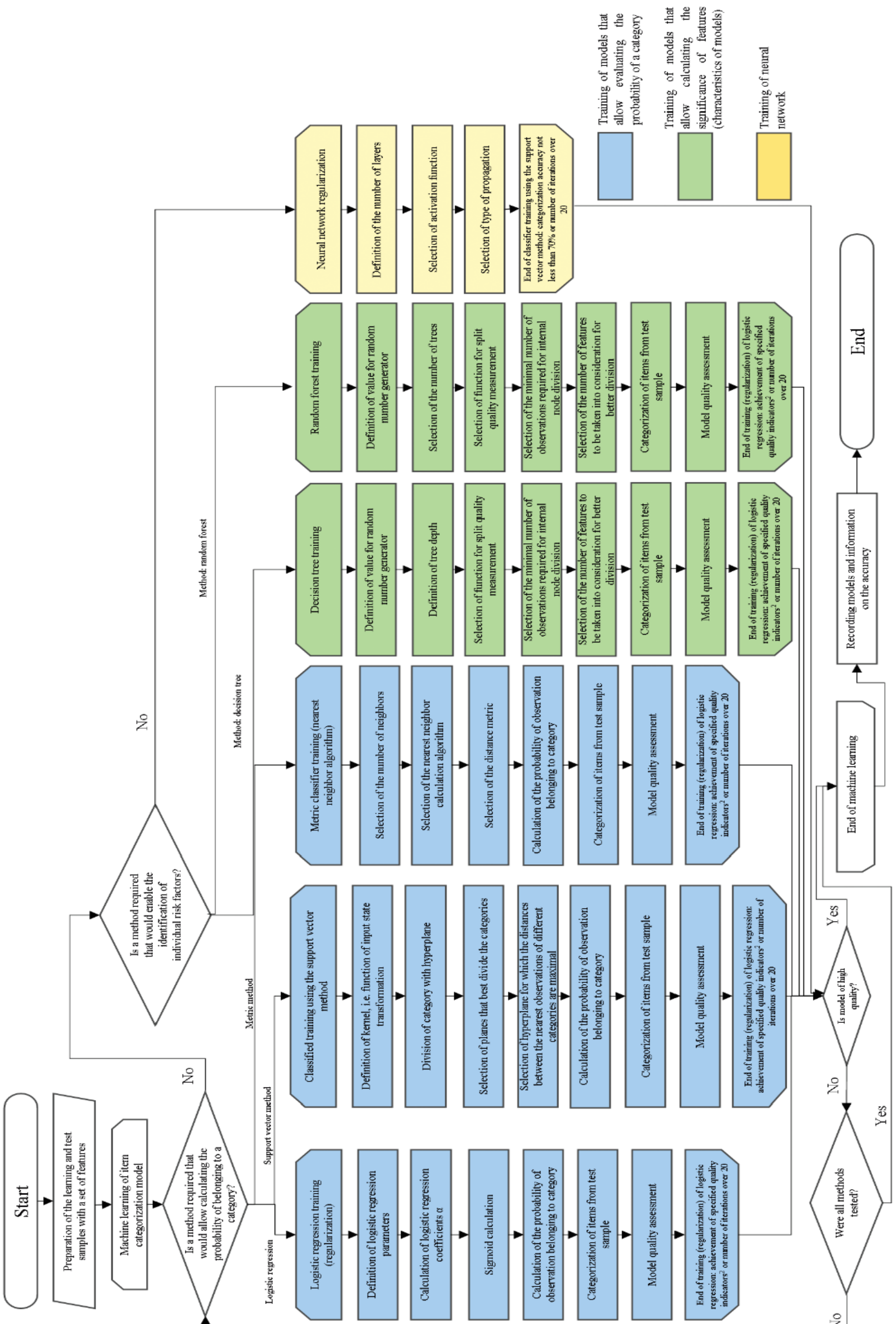


**Figure 2.** *Algorithm of machine learning application*

## IV. FINAL REMARKS

The required levels of safety and dependability of facilities, as well as sufficient performance and functionality with an acceptable life cycle cost, can only be achieved through reasonable, risk-based asset management.

The efficiency of technical asset management is largely defined by the level of artificial intelligence in decision support, including the ability to adapt to the changing conditions of railway facilities maintenance, scope and depth of management using artificial intelligence (in particular, Data Science), evaluation of risks at all levels of management from whole system/facility to a process and, ultimately, a service.

The above tasks have been partially solved and will be further solved as EKP URRAN develops. Whereas the current procedure goes as: facility operation – event (e.g., failure) – reaction (elimination of failure), the now mature Data Science allows migrating towards the innovative asset management process: operation and technical diagnostics – predictive analysis – proactive action. Predictive analysis is an analysis of current and historical events based on mathematical statistics, game theory, etc. for predicting future events. Predictive action is preliminary work aimed at improving the dependability of those facilities where failures, especially hazardous ones, are predicted. Using artificial intelligence, it is planned to predict not only technological but also process-related risks. The large amount of available statistical data on the process violations in railway transportation allows creating for that purpose representative training sets.

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# FAILURE AND ACCIDENT RISKS OF TECHNICAL SYSTEMS IN SIBERIA AND THE ARCTIC

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**Abstract**

*In the paper is presented the complex analysis of object technosphere safety is particular of current interest for Siberian and Artic of the Russian Federation where a wide range of hazards are. The uniqueness of territory (various natural-climatic and geological conditions, huge actual reserves at biogenic and mineral resources, significant industrial protentional with complex transport infrastructure and etc.) causes a large number of hazards. There are some examples of analyses of results technical diagnostic for technosphere objects including fabricated constructions, mainland pipeline, etc. and their using for estimating the reliability and accidents risks as well.*

**Keywords:** reliability, technogenic safety, failures

## I. Introduction

The development of technosphere influences quality of life raise on the one hand, one the other hand – new hazards appear, including accident and emergencies with fatality and severe damage (scientific-technical dilemma of progress). In these terms the safety of every industrial or urban territories which should be considered as socio-naturel-technogenic system (S-N-T system) is one of them most basic indicates for sustainable economic development. Firstly, there are two tasks:

1. Monitoring, diagnostics and expertise of potentially hazardous objects providing safety and function of main production facilities.
2. Assessment of reliability and technogenic risk is on the basis of statistical data on hazardous events and safety theory which are based on the results of model off-nominal conditions and on the conception non-zero accident risk..

The complex research of object technosphere safety is particular of current interest for Siberian and Artic of the Russian Federation where a wide range of hazards are. The uniqueness of territory (various natural-climatic and geological conditions, huge actual reserves at biogenic and mineral resources, significant industrial protentional with complex transport infrastructure and etc.) causes a large number of hazards. Development of natural resources and territories' urbanization effect the increase anthropogenic impact on unique natural complex and decline of common ecologies condition area [1].

Nowadays the main anthropogenic impact for the north territories is going to be contacted with oil and gas complex (OCG) development in Krasnoyarsk region, Tyumen region and Yamalo-Nenets Autonomous Okrug. OCG impact on the environment will have significant sizes and involve all natural constituent (atmosphere, soil, forest, water objects, animal and land scape). The building of gas and oil transmission pipelines with oil transfer (OTF) and compressor facilities (CF) has been planned for organizing oil and gas transportation. Planning emissions from one OTF are equal to 348 t/y and the emissions from one CF – 1131 t/y. Emergency leak of oil products while loss of containment and equipment destruction should be considered strong sources of danger. The failure rate of main OGC equipment figures up to $1{,}2\cdot10^{-5}$ – $3{,}5\cdot10^{-3}$ year-1. The loss of containment rate ranges within $2{,}9\cdot10^{-6}$– $5{,}8\cdot10^{-5}$ year$^{-1}$, flowlines - $7{,}5\cdot10^{-5}$ – $2{,}5\cdot10^{-4}$ year$^{-1}$, transmission pipelines - $6{,}9\cdot10^{-5}$ – $4{,}3\cdot10^{-4}$ year$^{-1}$. Due to complex natural-climatic condition of Siberia and Extreme North OGC objects have to have high levels of safety which provide conservation for unique ecological system. So systematic monitoring and mathematical simulation anthropogenic impact on the environment are required [1].

## II. Cause-and-effect complex of failures.

Analysis and generalization cause-and-effect complex failures of technical system are constituent part pf accident risk assessment [2]. The cause-and-effect complex is formed by main reasons and actual loads which lid to different kinds of damage (fig. 1). The failure and accident are realization and combination several reasons and different events: human factors, changes in operating conditions, weather conditions, technological violations, etc.

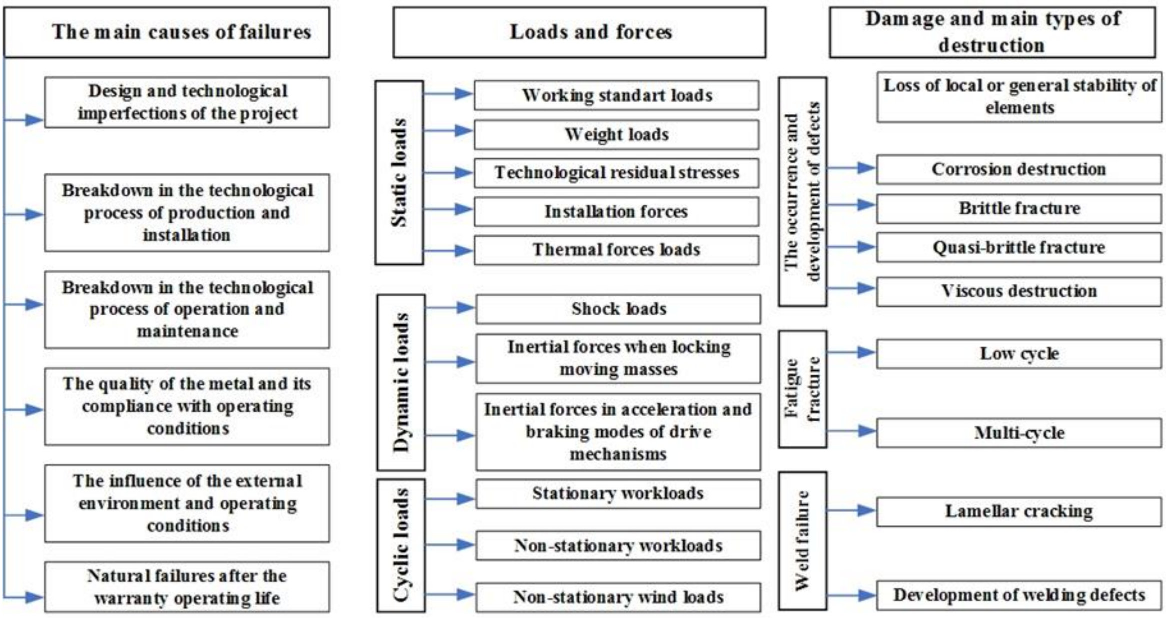



**Figure 1:** *Cause-and-effect complex of failures of technical systems and engineering structures [2].*

Accidents and disasters must be considered as probable events. As a rule similar accidents and disasters can be caused by different reasons. In figure 2 there is a logical schema of accident and disasters. It shows different accident and disasters (the main event F) occurring in various failures technical system (the event E) and trigger factors (the event H). The event E are formed during engineering process producing or operation technical systems on base of logical schema "AND", "OR", "m from n". Trigger factors are formed installation inspection or operation due to systematic develop events ("domino" effect) or they appear as a result of events groups realization which are made from the presented logical schema.

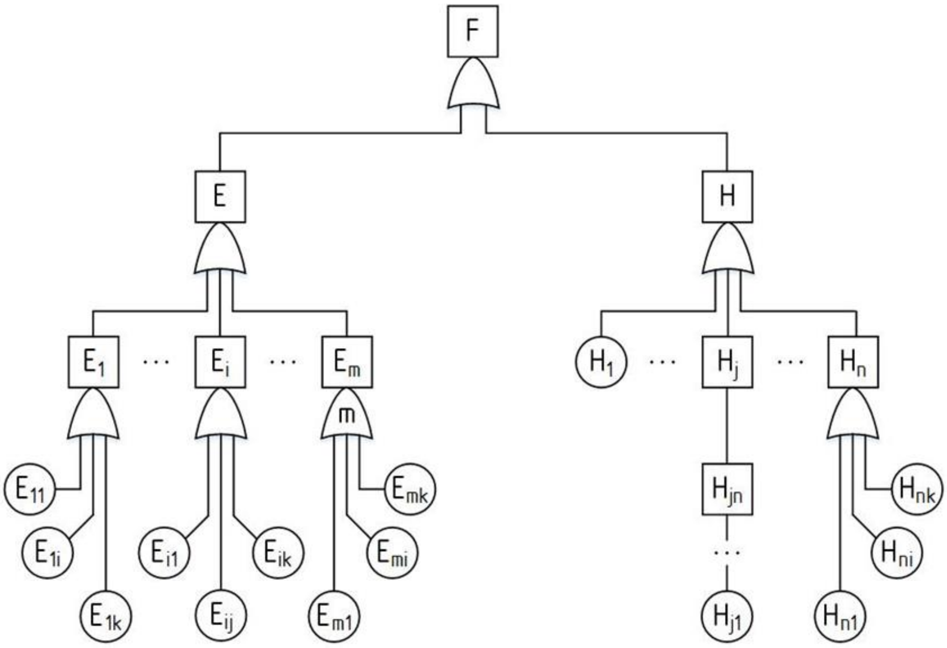



**Figure 2:** *Logical accidents and catastrophes scheme of technical systems*

On bases of logical schema probability of the event can be calculated which is conditional probability:

$$P(F) = P(H/E) = \frac{P(H \cap E)}{P(E)} \quad (1)$$

If *P(E)*>0, *P(H)*>0 probability of the accident will be *P(F)*>0. So creatures of absolutely safety technical system with non-zero risk of accidents and disasters is impossible. This conclusion is the basis of non-zero risk conception.

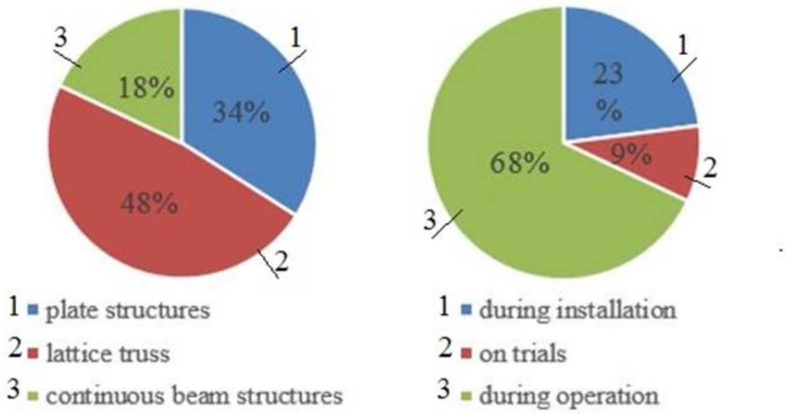
## III. Failure and reliability statistics for technical systems.

Cause-and-effect complex of links forming level operation reliability of constructions are identified by power actions connecting with burden, causes and kinds of failures.

The statistic data are presented below. These data of accident and failures for technical system are given for wide use in Siberia and Arctic: engineering structures, currying-and-lifting and mining machines, objects of power and oil-gas industries.

Engineering metal structures. Due to the analysis of 350 typical situations of steel structures destruction in West and East Siberia areas [2] (fig. 3) the statistical data about engineering metal structure failures were given and the main reasons including factory defects structures (production stage) and mistakes on design stage were discovered (table 1). General percent of failures connected with low level of planning and production quality rans up to 60%.

The influence separate factors on forming failures structures possibility is viewed [1-4]. In figure 4 dependents of structures destruction possibility on relationship between strains acting on the devastating moment $\sigma_d$ and calculating $\sigma_c$ are showed. For engineering constructions (beams, overpasses, trusses) calculated devastated strain range from 0,2 to 1,0 ($\sigma_c$≈0,8 under 50% probability). Calculated strains are about 1,2 $\sigma_c$ for tanks. However, on the other hand approximately 20% tanks destruction happened without external action but from fixed load efforts. Low levels strains are basic for brittle structural failures. The analyze of curve failures (temperature distribution (fig. 5)) shows the rang of temperature failures for majority engineering structures is from -50 to -5 °C.




*a* *b*

**Figure 3:** *The frequency of destruction by types of structure (a) and fracture time (b)*

**Table 1:** *The main failure reasons of engineering metal structures*

| Failure reason | Frequency, % |
|---|---|
| Mistakes made in projects | 27,0 |
| Steel grade mismatch with loading and temperature conditions | 11,0 |
| Defects of prefabricated structures | 30,0 |
| Breakdown during operation of computational model constructions and exceeding of permissible loads | 14,0 |
| Imperfection of existing norms and rules of design and manufacture of metal structures | 6,0 |
| A set of other reasons | 12,0 |

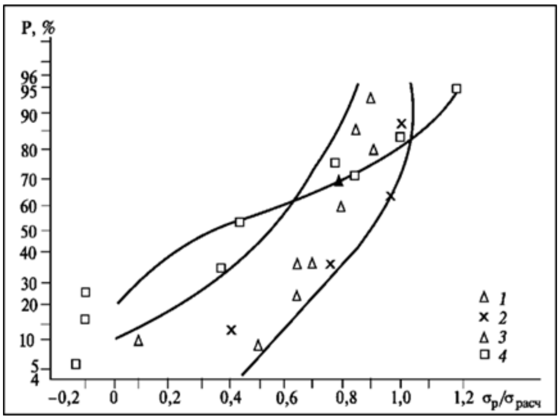



**Figure 4:** *The distribution of the destruction probability of building structures from the level of stress (1 - beams; 2 - flyovers; 3 - trusses; 4 - tanks)*

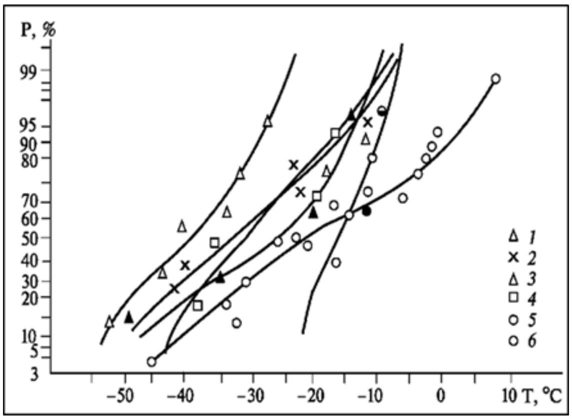



**Figure 5:** *The influence of operating temperature on the accumulated destruction frequency of various building structures (1 - power transmission towers; 2 - trusses; 3 - beams; 4 - flyovers; 5 - tanks; 6 - bridges)*

Realization of any failures is consequence of different influence power (fig. 1) and specified factors combination. These circumstances are complicated by design errors, technology disbalances during installation and deviations from the operating rules. The data analysis has led to per cent rating for main kinds of engineering metal structures destructions (fig. 6) according to fig. 1.

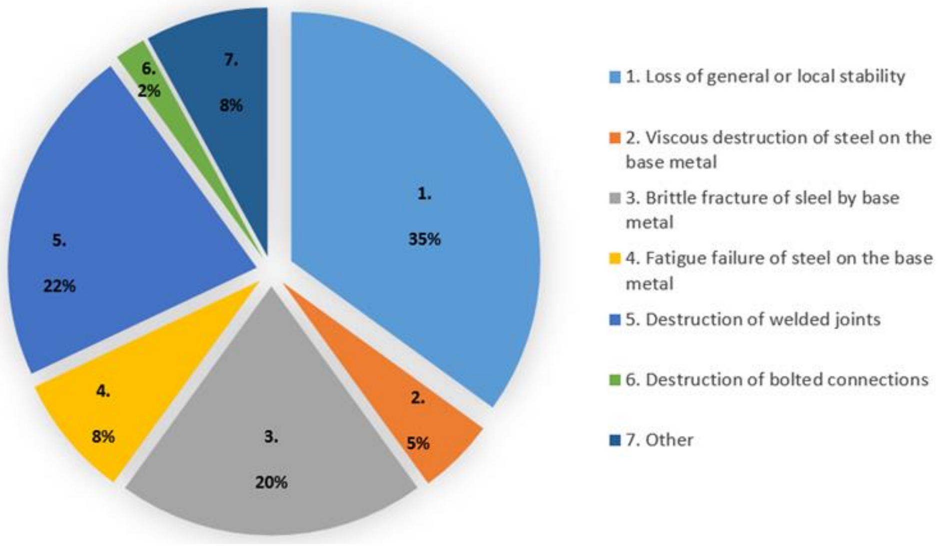



**Figure 6:** *Type and frequency of failures*

Carrying and lifting machines. Crane structures are one of the most common types of industrial equipment. Specificity failures and accidents depends significantly on crane type (overhead traveling, cross gantry and tower cranes) and carrying power. The real practice crane use is marked by numerous destructions of bearing elements. It is connected with fatigue cracks incurrence in structure elements after 15-20 years operation.

The main failures causes are [5, 6]:

- mismatch chemical compound and metal mechanical characteristic to technical requirement;
- fatigue fractures;
- long term operation without diagnosis;
- low operation temperatures;
- strains structures;
- technological defects in welded seams.

As an example of characteristic general reliability for crane construction the results of operation observation of overhead traveling crane failures (period of 7 years) are examined table 2.

**Table 2:** *The main indicators of the overhead traveling crane reliability (Q=125 tnf)*

| Indicator | Mechanical equipment | Electrical equipment | The crane as a whole |
|---|---|---|---|
| The number of failures | 104 | 160 | 264 |
| Average time to failure, full day | 26,90 | 16,59 | 10,36 |
| Mean square deviation of time between failures, full day | 24,87 | 17,96 | 9,66 |
| Average recovery time, h | 1,41 | 0,65 | 0,94 |

As table 2 shows the number of mechanical equipment failures is equal 40% from total number. The average time between failures is mechanical equipment higher than the same electrical facilities measure in 1,62 times. Mechanical equipment is more reliability in terms of faultless but from the point of repairability it worse than electrical facilities. An average measure and failure interval vary less from root-mean-square deviation it allows to accept hypothesis of exponential distribution. In figure 7 reliability crane functions and its main subsystems are shows. The exponential distribution of failure interval proves simple character of failure flow which is typical for multiple system.

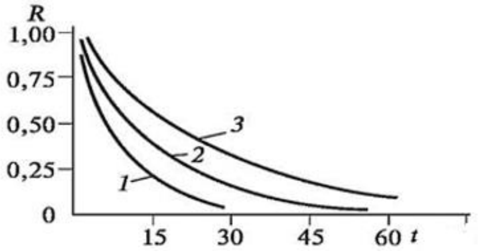



**Figure 7:** *Reliability functions for overhead cranes (1), electrical equipment (2), and mechanical equipment (3)*

Mining equipment. It's presented by mining and rotary excavators, dragline and dump truck of large capacity. Studying of excavators accidents in mining companies [1, 6-8] has allowed to establish than technological and operation defects, conflict between steel parameters and operation conditions play the main role in failure reasons. Wrong structures solutions and human factors make a considerable contribution to forming accident.

Climate conditions of operation are distinguished from main factors leading to excavator failures. The low steel cold resistance is determine factor in failure forming of excavator metal structures of low temperatures. The analysis of node point and metal structures failures (temperature dependence) shows that reduction of temperature from 250 to 230 K results in failures increase twice minimum and at temperature low 250 K it races up (fig.8). According to exponential law of failure interval distribution the functions of excavator reliability and node points are built (fig.9).

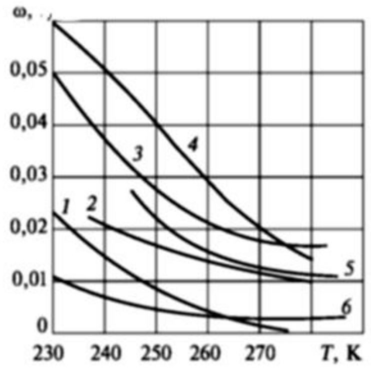



**Figure 8:** *Temperature dependence of the failure flow parameter for excavator metalwork elements.*
*1* – the beam of a handle of an crawler-mounted excavator (CME)-4,6; *2* – two-legged CME stand -12,5; *3* – the CME boom -4,6;
*4* – the CME bucket -4,6; *5* – the beam of a handle of an CME -12,5; *6* – the CME boom -20

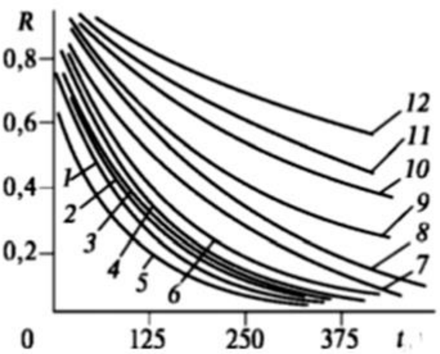



**Figure 9:** *The reliability function excavators.*
*1* – the rotary excavator (RE)-2500; *2* – the CME -12,5; *3* – the RE -1250; *4* – the CME -4U; *5* – the rail-stepping rotary mining excavator -5000; 6 – the CME -8I; *7* – the walking excavator -10/70A; *8* – the CME -6,3; *9* – the mechanical system of CME -6,3 (winter); *10* the mechanical system of CME -6,3 (summer); *11* – the mechanical system of ЭКГ-8I (winter); *12* – the mechanical system of CME -8I (summer)

Among other failure factors there are mining technological and organizational ones which have specificity of statistical methods unpredictability. Due to power machines increasing in cold climate areas probability of occurrence of brittle destruction metal structures enhances and down time from unscheduled repair grows by on 30-40%. The distribution of mechanical part truck failures (capacity until 75 tnf) is presented in fig.10 [9]. Failures of truck technical systems make contribution to forming low parameters of reliability. Percentage of uptime for machines doesn't go beyond 0,6 [8, 9].

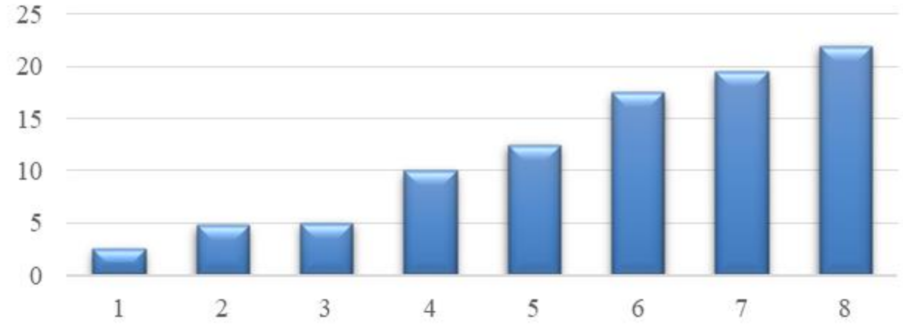



**Figure 10:** *Distribution of failures of the mechanical part of dump trucks BelAZ-75211, -75213: 1-nave; 2-rim; 3-rear axle; 4-frame; 5-platform; 6-front girder; 7-suspension; 8- jet rod*

Thermal power equipment. Period of operation for main part of thermal power technological equipment (boiler systems, steam generators, hot water and steam pipelines, pressure vessels and etc) surpasses significantly design service and economic life [10-12]. The same problem is found in the EU and the USA. The analysis of consumption level of production facilities energy structures in Siberia shows that machine and equipment consumption reaches 63…72%, transfer mechanism – 57…65%. The rake of boiler faults in power generating unit of Russian CHP stations is 30,2…41,8%, in the USA – 42,5…64,2% [10, 11].The specific fault Russian boiler changes from 1,08 to 1,82 failures a year (the number of boiler faults, which crashes power-generating unit). The same numbers for the USA boiler are from 1,8 to 6,89 failures a year. The mass survey for heat-power engineering objects of technical condition shows significant number of defect boiler system elements (the data of Kuznetsk district State Mining and Safety Organization RF) (fig. 11) [12].

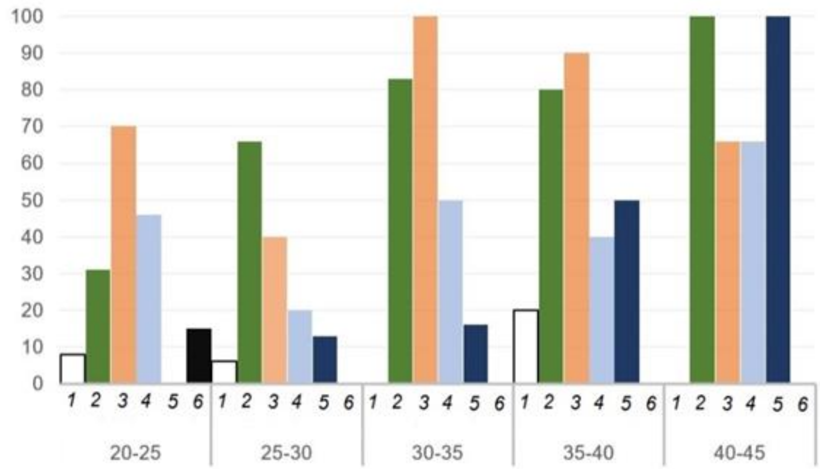



**Figure 11:** *Distribution of defects in boilers depending on the service life. 1-repair welding defects; 2-corrosion ulcers; 3-deposits; 4-thinning of the drum wall below the design value; 5-change in mechanical characteristics; 6-rolling defects*

Histograms and density functions of boiler life length system in power station are shown in figure 12. The boiler system of CHP-1, which have been in operation for more than 40 years and have fully used up the park resource have the most significant level of life lengths.

When analyzing of life lengths for CHP pipeline system using up of designed operation is the main reason. This conclusion is confirmed the data fig. 13 which shows histograms and density function of life length for pipelines CHP. The life length statistical analysis shows that the most acceptable the density function model is normal probability law.

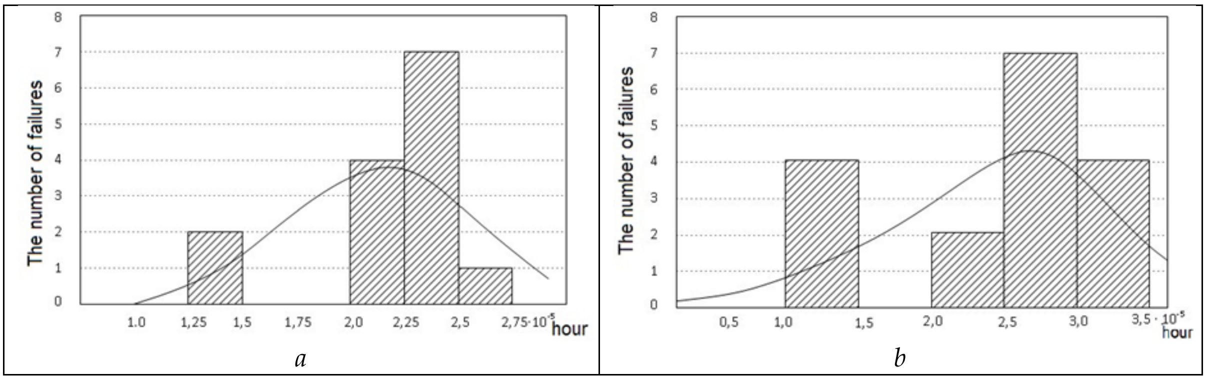



**Figure 12:** *Histograms and distribution density functions of the time between failures for the boiler plants of regional power station (a) and CHP-1 (b)*

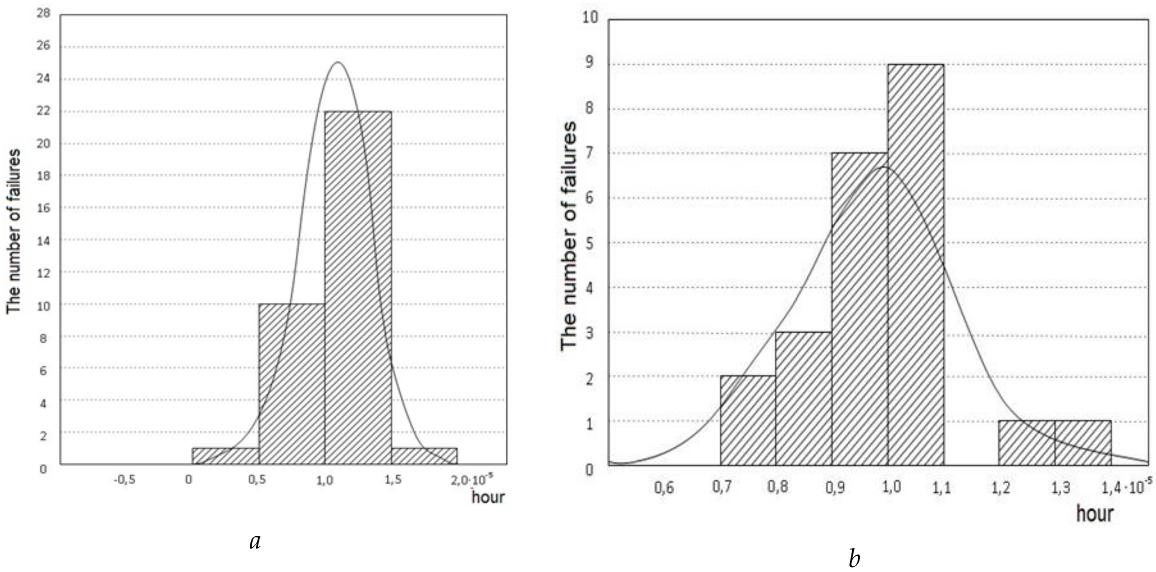



**Figure 13:** *Histograms and distribution density functions for the CHP-1 (a) and CHP-2 (b) pipelines*

General number of pressure vessel in Russian power station and substation is above 150 thousand units. The most dangerous in terms of accidents consequences welded connection faults is the data in table 3. The quantity of seams developing during the operation is 26,2 % from the all defects in basic part welding process. The bigger number of seams notes in high-pressure deaerators (70,6%) and heaters (15%).

In all kinds of pressure vessel undercutting is the most dangerous types of welding defect (10...25 %).

The discovered defects of pressure vessels predetermine raise demands to inspection of technical conditions objects in operation process and dictates necessity of strain-stress state pressure vessel analysis in local areas and the usage of probability methods for crack resistance calculation.

Oil-storage tanks. Destruction of tanks filled petroleum products are often followed by explosions and occurrence fires environmental pollution. A damage can be significantly higher than estimated construction cost of oil tank. The results distribution frequency of failure cases analysis by kind of main reasons show [1, 4, 13, 14] that brittle destruction has dominated quantity accident position (table 4).

**Table 3:** *The distribution of injuries according to the types of welded joints on the vessel*

| Type of damage | Selections by vessel designation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | HPH | HPL | Boilers | Deaerators | Receivers | PPR | Fuel oil heaters | Sulfuric acid tanks | All |
| Undercuts | 22 | 10 | 19 | 20 | 10 | 8 | 3 | - | 92 |
| Pores | 6 | 7 | 10 | 12 | - | 1 | 1 | 4 | 45 |
| Cracks | 16 | 3 | - | 77 | 8 | 1 | - | - | 105 |
| Sinks | 14 | 4 | 1 | 4 | 10 | 1 | - | 1 | 35 |
| Fusion | 6 | 3 | 11 | 16 | 6 | 1 | - | - | 43 |
| The offset edges | 2 | - | 1 | 3 | 1 | - | - | - | 7 |
| Low - quality welding | 12 | 14 | 16 | 28 | 12 | - | 7 | 3 | 91 |
| Cavity | 2 | - | - | - | - | - | - | - | 2 |
| Total | 80 | 41 | 48 | 160 | 47 | 20 | 12 | 8 | 416 |

**HPH, HPL – high and low pressure heaters*
**PPR – petroleum product reservoirs*

Brittle destructions are result of following factors influence:

a). construction elements availability promoting strain concentration;

b). low quality of metal with nonnormality in chemical composition, mechanical features and resistance to cold;

c). local loss of metal ductility (riveting from striking, embrittlement, thermal influence while cutting and welding and etc.);

g). welding defects are stress raisers.

Defects of geometrical shape are secondary among possible accident reasons. However, they are dangerous in terms of brittle destruction because of stress concentration increase in local areas tanks as well as welding concentrators and low quality of steel.

**Table 4:** *Distribution of PPR failures by major causes and brittle failures*

| **Main reasons** | **Number** |
|---|---|
| Brittle destruction | 41 |
| Explosion and fire | 8 |
| Vacuum | 5 |
| Corrosive wear | 2 |
| Hurricane | 1 |
| Drawdown of base | 1 |
| Other | 7 |
| Total | 65 |

| **Causes of brittle destruction** | **Number** |
|---|---|
| Design defects | 9 |
| Low quality metal | 13 |
| Local loss of plasticity | 3 |
| Welding defects | 16 |
| Total | 41 |

## IV. Conclusion

Failures, destruction, accidents are basic to any technical system and there are inevitable at any level of technique and technology development. While designing and creating complex technical system is impossible to force all external factor combinations in operation and take in to account all connection and cooperation between system elements. Technical system in process of operation inevitably attains some extra parameters and possible conditions which don't meet design. This is phenomena of evolutionary unexpectedness of accident initiation in complex technical object [4, 6].

Destruction, accidents and hazards of technical system appear to be one of the most informative sources in researching their real parameters. Accidental situation analysis is the most effective approach to control approximation of calculation and design methods in particular acceptable hypothesis and calculation models.

Therefore, accidental situation researchers of technical system constructions are the most significant stage for analysis and characterization as technosphere object. This requires more advanced approaches to studying and modelling of abnormal operation conditions within the concept of "non-zero accident risk".

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# A NEW METHOD OF OCCUPATIONAL RISK ASSESSMENT, BASED ON UNCERTAINTY

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**Abstract**

*This article aims to present a brand new method of quantitative risk assessment (OHSI method), in line with a modern concept of risk based on uncertainty. The OHSI method has been designed to determine the possibility of dangerous event occurrence through an assessment of the effectiveness of enabled risk controls. The IBT method has abandoned completely the use of the notion of "probability" in risk management context in favor of "likelihood", which enables a quantitative assessment of the magnitude of risk without involving historical data on event rate.*

**Keywords:** Risk, risk assessment, probabilistic risk assessment, OHSI method, likelihood

## I. Introduction

At the beginning of the 21st century, global economy actually adopted a new risk concept based on uncertainty. This turning point has been embodied in the international standard ISO 31000:2009. However, the underlying reason for the adoption of this standard was actual unsuitability for the purposes of risk management of the previous risk concept based on classical (frequency) probability in the new extremely volatile socio-economic situation. Regretfully, scientific community seems to have ignored this groundbreaking shift in the methodology of practical risk management has so far remained virtually unnoticed. Most scientific reports still dwell on outdated probabilistic statistical methods and approaches to risk assessment.

The tenet of the impossibility and inadmissibility of using the concept of "frequency (of past events)" in modern risk management becomes apparent simply by taking a closer look at the concept of the "event", which in modern risk management is interpreted as 'occurrence or change of a particular set of circumstances'. The world today is overwhelmed by multiple, breathtaking changes in technology, social and industrial relations, global (climatic, epidemiological) conditions to such great extent that our times' slogan boils down to the conclusion that "nothing happens twice". In other words, it can be argued that in actuality one can barely assume a likelihood of the occurrence of even two similar risk-relevant "events", to which the concept of "frequency" could be applied.

It follows from the above that the notion of "frequency" has become irrelevant with regard to risk management. However, given no "frequency", then there is no place in risk management for either probability in its classical sense, or probabilistic and statistical methods of risk assessment. Moreover, it will be shown later that in light of modern concept of risk, the following statement is true: "the *higher* the frequency of a dangerous event, the *lower* the risk caused by this event." The above statement, of course, is true only if the concepts of "risk", "event" and "frequency" are understood according to international management standards, which regulate real economy.

As we give up the use of the notions of "frequency" and "probability" in risk management and suggest their replacement with 'likelihood', the following standpoints shall be revised:

- "probabilistic risk assessment" (PRA) - the most common approach to risk assessment in the technosphere is, which is based both in name and in essence on an outdated concept of classical probability, which fails to convey modern and future events of real life economics [1, 2];
- the most common methods (techniques) of risk assessment (event tree analysis (ETA), value tree analysis( VTA), fault tree analysis( FTA), Failure mode and effects analysis( FMEA), human reliability analysis( HRA), common-cause-failure analysis (CCF), etc.).

This work does not contain an extensive references list, since the new concept of risk has not yet gained ground within the realm of economics. As a matter of fact, very few scientific papers tend to explain and support modern concept of risk because, naturally, academic economics lags behind real economy (economic science explains and turns into theory existing patterns of economic relations) and because of subjective factors associated with a need for alternative scientific approach. In addition, the need to publish scientific papers in peer-reviewed periodicals greatly impedes the promotion of "non-classical" scientific views that can affect the author's Hirsch index.

First of all, the transition to a new concept of risk requires an overhaul of scientific toolkit. Instead of probability theory and mathematical statistics, information theory, game theory, fuzzy set theory, and the Bayesian approach (subjective probability) have become the fundamental scientific basis of risk management.

Awareness of the discrepancy between the previous concept of risk, based on the classical probability and, accordingly, on the frequency of past conditionally homogeneous events, and the actual needs of practical risk management led the author to develop a new method of risk assessment, known as the Method of the Institute of Occupational Safety (OHSI method). The method is based on the modern idea of risk as the influence of uncertainty on goals (according to ISO 31000) and is embodied in the national standard GOST R 12.0.011-2017. This, in turn, automatically disables the use of the traditional concept of probability, and prompts to take a closer look at the concept of subjective probability, which in modern risk management practice is actually represented by the term 'likelihood'.

## II. On the interconnection between the 'frequency' of a hazardous event and the 'risk'

According to modern management standards, 'event is occurrence or change of a particular set of circumstances'. It follows from this that the concept of "event frequency" can only refer to events that have completely identical sets of essential circumstances (objects, subjects, conditions, causes, consequences). If such events occur randomly and often enough (there is a representative sample), then we can really estimate the probability of the occurrence of another event through the relative frequency of occurrence *of the same* (!) event in the past. And the higher the frequency of occurrence of event in the past, the greater the probability of its occurrence in a certain future time span. Incidentally, if we do not consider a certain time span, but only consider the "future in general", then the probability of such event occurring in the future will be strictly equal to 1 (certainty of event is confirmed by its assumed regularity in the future).

However, from the point of view of information theory, the higher the objective (frequency) probability of an event, the less new information (uncertainty, risk) it contains. From scientific point of view, the inverse ratio of 'frequency' and 'risk' is confirmed by the following calculations.

The classical *probability* P in the general case is a consequence of the 'frequency' of homogeneous events (cf. 'event' above)

$$P = lim\frac{n}{N}, \text{при } n \leq N \text{ и } N \to \infty,$$

where 'n' is the number of events of interest to us, and 'N' is the total number of events (independent trials).

Claude Shannon [3] suggested that the increase in information is equal to the lost uncertainty. Despite this assumption being self-evident, it has not been applied yet to risk management. However, a logical conclusion follows from this assumption that the amount of information obtained during the implementation of each outcome is inversely related to the *probability* of this event

$$I = -log_2 P,$$

where 'I' *is the amount of information contained in the event that reduces the uncertainty* (the so-called 'negentropy'), bit.

In information theory, the uncertainty (information entropy) 'H' associated with the event 'A' is estimated by the classical formula propounded by Claude Shannon

$$H = -\sum_{i=1}^{N} \{p(A_i) log(p(A_i))\},$$

where 'p' ($A_i$) is the probability of an outcome '$A_i$', an event 'A' having 'N' possible outcomes.

From the above formula for calculating uncertainty, it follows that neither certainly expected events (p (Ai)=1), nor impossible events (p(Ai)=0) contain both uncertainty and information. The maximum uncertainty is achieved when all possible outcomes are equally likely to occur.

Hence, it follows that *random events that often occur* with a high frequency in the past, with no purposeful intervention in the flow of events, are just as often expected in the future. Therefore, they are practically void of uncertainty, hence are 'risk-free', in its modern sense. This is why, the most important prerequisite for the application of the modern concept of risk management is fundamental inadmissibility of risk assessment based on the frequency of past events, the laws of distribution of random variables, statistical hypotheses that have only one bottom line – misleading of decision makers.

When the new measures (risk controls) are applied it means a change in a certain set of circumstances and it means a new event. In the field of risk management, the assumption that "the higher the frequency of hazardous event, the lower the risk caused by this event" is proved by the fact that if a hazardous event occurs frequently (or at least repeats regularly) and no measures are taken to prevent it in the future, therefore:

- either this event does not affect the goals (does not pose an imminent hazard, nor contains an unacceptable risk);
- or this event does affect the goals, but there is no risk management in the organization and, hypothetically, management system in general.

If an effective risk management system is implemented and operates in an organization, then every hazardous event that is relevant for the purposes of the organization can occur exactly once. Subsequently, effective corrective measures shall be taken to eliminate the cause of the event, which has occurred. Consequently, *it is this particular event*, which will never happen again ("nothing happens twice").

Thus, in *effective* risk management systems, the concepts of "frequency" and "probability" in relation to risk assessment in modern conditions have become irrelevant.

## III. The essence of the IBT method

Initially, the IBT method was developed to solve the problems of Occupational Health and Safety (OHS), therefore, we will consider its specifics in this particular context.

As far as the tasks of risk assessment in the field of occupational safety (occupational risk) are concerned, the leading role is assigned to the assessment of the risk of injury to employees as a result of exposure to hazardous factors of the production process (hazard).

Previous probabilistic and statistical concept employed generic approach to determine the risk of injury

$$R = P(F_v)W, \text{при} P(F_v) = const$$

where 'W' is the future eventual damage caused by the occurrence of a random event, and $P(F_v)$'a' is the classical probability of the occurrence of this event, found on the basis of the (allegedly) "known" distribution law $F_v$or directly from the frequency 'v' of (allegedly) "homogeneous" events.

How can classical approach to *risk assessment* ensure risk management, that is, to establish *functional dependence of residual risk on the impact* on the risk? It turns out that only by taking responsive measures that affect the severity of the consequences 'W', since it is impossible to influence the classical probability obtained from historical statistics without the use of a "time machine".

It is for this reason that the use of not classical (objective, not controlled) probability, but subjective (controlled) probability (likelihood) for risk management purposes [4] seems to be not only a reasonable solution, but also a non-alternative solution.

In case of occupational risk assessment, it is no easy to assess the severity of an accident 'W', but the range of severity values obtained by the method of expert assessments (other methods are even less instrumental) is usually within one magnitude order. However, subjectively assessed values of the likelihood of an accident may differ by several magnitude orders. Therefore, the task of the most balanced and reasonable assessment of accident likelihood 'P' is way more important and complex than the assessment of severity W.

The hallmark, scientific and practical novelty of the IBT Method is that it is based on a brand new view of the likelihood of the occurrence of hazardous event, which strictly follows from the modern definition of risk – *the likelihood of the occurrence of a dangerous event caused by an identified danger is determined through overall effectiveness of all protective measures taken to prevent the implementation of this event:*

$$P = 1 - E_{\Sigma}, \quad (1)$$

where 'P' is the likelihood of an event occurring, and $E_{\Sigma}$ is the total effectiveness of all protective measures taken.

It is the essence of the IBT method.

The proposed approach:

- eliminates the need to use frequency and statistical data to assess likelihood and risk (risk assessment can also be conducted with no past events available);
- links in the form of functional dependency the likelihood of accident occurrence (P) on the effectiveness of measures taken to prevent it (given no protective measures, P =1);
- makes it possible to assess the effectiveness and efficiency of risk management measures taken in relation to unacceptable risks, since the preliminary risk assessment and residual risk assessment are enabled via the same methodology toolkit.

## IV. Implementation of the IBT Method in the field of occupational safety

The IBT method can be illustrated by such graphical models as the "bow tie" model or the "Swiss cheese" model with the following features:

- in relation to occupational safety management under the "bow tie" model (ISO 31010), the analysis of the multiplicity of causes and consequences of an event is impractical (as it increases uncertainty). As a result, the "bow tie" model degenerates into a "string tie" (see the figure);
- in the "Swiss cheese" model, which was originally formally propounded by James T. Reason [5] as "slices of cheese", the influencing factors and elements of the process are not taken into account as risk controls (they are risk sources), but only specific organizational or technical measures (actually, "security barriers") with a pre-estimated effectiveness are taken into account.

## V. Graphical model of the IBT Method

The figure shows a graphical model of the IBT Method based on the "bow tie" diagram, according to which the risk associated with the implementation of a dangerous event can be found (calculated) by the formula (1), in which the likelihood is found through the formula

$$P = 1 - \mathrm{E}_{\Sigma} = (1 - E_1)(1 - E_2)(1 - E_3).$$

where $E_1$ ... $E_3$ are preventive (proactive) protective measures, and $E_4$ are response (reactive) protective measures.

As we can see, reactive measures are not excluded from the risk assessment, but are taken into account in the risk assessment as controls that affect the severity of the outcome

$$W_2 = W_1(1 - E_4).$$

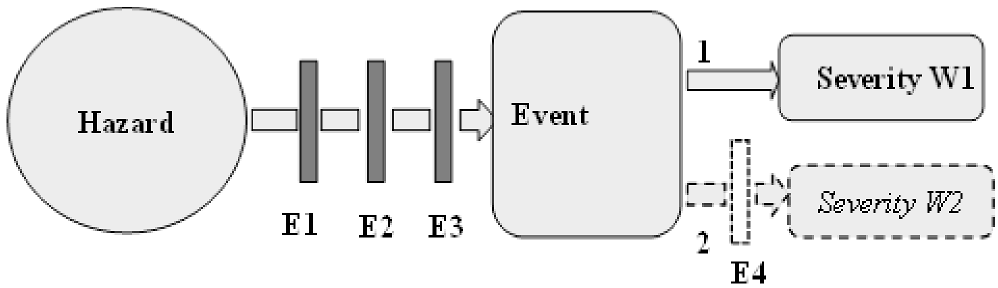
It is noteworthy that an event with a different outcome is already another "event" for which a separate risk assessment is required.

The objectivity of the IBT Method in conducting risk assessment is due to the following features of the procedure for applying the method, which provides for conducting risk assessment in three isolated stages:

- identification of all existing hazards and protective measures applied thereto;
- describing and ranking of hazards according to the severity of the consequences, while applied protective measures are described and ranked according to the degree of effectiveness;
- application of the register of hazards and the register of protective measures to risk assessment as unchangeable (objective) measuring tools.

Despite the simplicity of the mathematical apparatus, conducting a risk assessment using the IBT Method requires an extensive array of elementary calculations. Therefore, at present, a detailed risk assessment methodology has been developed based on the IBT Method, which is automated and practically used by many organizations in the form of a «Risk-Expert» software package, both for their own purposes and for providing risk assessment services.

The implementation of the IBT Method through the Risk-Expert software package has proved the expected advantages of the method for the purposes of assessing risks in the field of occupational safety in organizations aiming to achieve effective and efficient management of occupational risks.




The IBT method unlike qualitative subjective methods ("Matrix Method", "Fine-Kinney method" [6]):

- allows to obtain results of risk assessment that depend not on subjective opinion of an expert, but on identified hazards and objective workplace safety measures;
- provides a reassessment of residual risks (after taking risk management measures) using the same measurement tools (registers), which ensures the objectivity of the assessment;
- allows to evaluate generalized (total) risk levels of production processes, divisions for an objective comparison of the results of their activities, which cannot be achieved by subjective methods.

To date, the IBT method has proven its effectiveness in the field of occupational safety. However, the general principle of the method, i.e. the expression of the likelihood of an adverse event through a coordinated assessment of the effectiveness of security barriers, certainly deserves consideration for use in all High-Level Structure (HLS) management systems that implement risk-oriented thinking (QMS, EMS and others).

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# THE PECULIARITIES OF EROSION AND SOIL PROCESSES IN LOWER KURA RIVER AND THE RISK OF FLOODS

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**Abstract**

*The section of the Kura River from the downstream of the Mingechevir dam to the Caspian Sea is called the Lower Kura. The Kura River flows on an alluvial layer, created by him over the millennia. The water course has turbulent character, with transverse circulation. The dynamic axis of water flow wanders. Water has character of a disperse liquid. In turbulent flow the disperse liquid behaves as an emery paper. It considerably accelerates process of erosion of coastal dams. According to our field investigations and theoretical estimations, in some years of a high water annual displacement of meanders reaches 9 ÷10m. Case studies have shown that the displacement of the meander on the Kura River passing through the villages of Ashagy Surra, Yukhary Garaimanly and Kurgarabujag in the Neftchala region was 450 m over 50 years (1967-2017). The region is densely populated and has a dense infrastructure. The horizontal displacement of the meander leads to the destruction of coastal structures and creates the risk of flooding. The economic damage caused by the flooding in 2010 was over US $ 500 million.*

**Keywords:** Kura River, meander, erosion, channel migration, turbulent flow, flooding

## I. Introduction

The Kura is the largest river in Caucasus and undergoes to seasonal flooding. The growing risk for inhabitant, ecosystems, and the economy of flooding in the lower Kura region were partly due to reclamation of floodplains for agriculture and increasing siltation from erosion in the watershed. Some rivers of the Kura basin have extremely irregular discharge throughout a year. Ratio of extreme average discharge is 1.6-6.6, which makes sometimes difficult to overcome its negative impact. The Kura River was named because of heavy flooding as “Mad River” [1, 2] among the people, to similarly that as the Chinese name Huang He River “Grief of Chine” [3]. The researches have shown that these rivers have many similar features. 80 million persons living in a Huang He valley, and 4 million living in the Kura-Araz lowland, who constantly feels fear of the catastrophic flooding.

The headwaters of the Kura River is in Turkey at the Kizil-Giadik mountain range in Ardahan province, winding its way through Georgia and Azerbaijan into the Caspian Sea. Its main tributary Araz River originates in Erzurum province in eastern Turkey. It flows along the Turkey-Armenia border, along the Iran-Armenia border, along the Iran-Azerbaijan border, before flowing into Azerbaijan, where it joins the Kura in the centre of Kura-Araz lowland. The total length of the Kura river is 1515km (915 km of which are on the territory of Azerbaijan) and the total area of the Kura-Araz basin 188.000km$^2$, occupying the greater part of the South Caucasus. The river is formed by snow (36%), groundwater (30%), rains (20%) and glaciers (14%). In spite of distributing of this area amongst the Turkey, Georgia, Azerbaijan, Armenia and Iran, but neither, except for Azerbaijan, the Kura River is the main source of life for Azerbaijan and its troubles can be nation-wide.

The Lower Kura is the plains river. The longitudinal slope of riverbed from village Yukhari Qarkhun of Yevlakh district (N 40° 37' 24″; E 47° 11' 23″; H =+17m) to a mouth (H = –27m, Caspian Sea) makes only 7‰, i.e. 7cm in 1km. (For comparison, the riverbed longitudinal slope is 600cm and 250cm in 1 km, in Turkey and Georgia, accordingly.

As the Kura River, Araz River runs on plain in the centre of Azerbaijan. Therefore, Azerbaijan, located on low territories of the Kura and Araz rivers receives the great quantity of mud from both river systems. As a result of the mud accumulation in the Kura River, there is vertical dynamics of a riverbed [4].

Flooding is a yearly occurring phenomenon, especially in the Lower Kura. Shore protection works also continually take place during year. In the recent 15 years (in 2003, 2006, and 2010) three catastrophic floods occurred in Lower Kura. The damage to the country's economy caused by the flood in 2010, costs for 500 million US dollar [5, 6].

The increased frequency of dangerous flooding was attributed to a number of causes, including climate changes and non-climatic origins [7], vertical and horizontal dynamics of a riverbed [1], isolation of the riverbed from floodplain [4], continuous rains, anthropogenic factors and etc. Unfortunately, any of the above mentioned approaches does not explain the true reasons of flooding in Lower Kura. Naturally, as result of the erroneous approach, flooding remains the main problem of a sustainable development of the Azerbaijan.

The basic mistake of all existing approaches of the analysis of the reasons of flooding consists that authors of researches do not consider peculiarities of erosion - accumulation processes in Lower Kura.

## II. EXPERIMENTAL RESULTS

Figure 1 shows the horizontal change of the riverbed in the part of the Kura River passing through Neftchala region for 50 years (1967-2017). This place is the part of the Kura River passing through Ashagi Surra, Yukhari Garaymanli and Kurgarabujag villages of Neftchala region.

The average meandering coefficient on the route from the lower part of the Mingachevir dam to the delta of the Kura into the Caspian Sea is $K \geq 2.5$. However, there are such huge meanders in different locations of the channel that the local meandering coefficient is very high. In the above location, the straight line distance between the entrance and exit of the huge meander on the old track (1967) is 1100 m. But the distance along the channel between that entrance and the exit is 6200m. Thus, the meandering coefficient of the huge meander here is 6200m: 1100m = 5.6.

The change of the meander peak is 450 m in 50 years. In other words, the huge meander in the indicated location changes its location by 9 meters in the horizontal direction every year. However, the projected change over the next 50 years could be even greater.

In order to study the flow processes occurring in this meander, we have been conducting bathymetric and flow velocity experiments since 2017. In this meander the flow is directed from Ashagi Surra village to Kurgarabujag village. Because of the studying area is in the northern hemisphere, according to Behr's law, the Coriolis force in the northern hemisphere is directed to the right in relation to the movement of water, and these shores become sharper as the current erodes the right side. The soil mass formed as a result of erosion accumulates on the left bank according to the granulometric parameters depending on the distribution of water velocity in the stream.

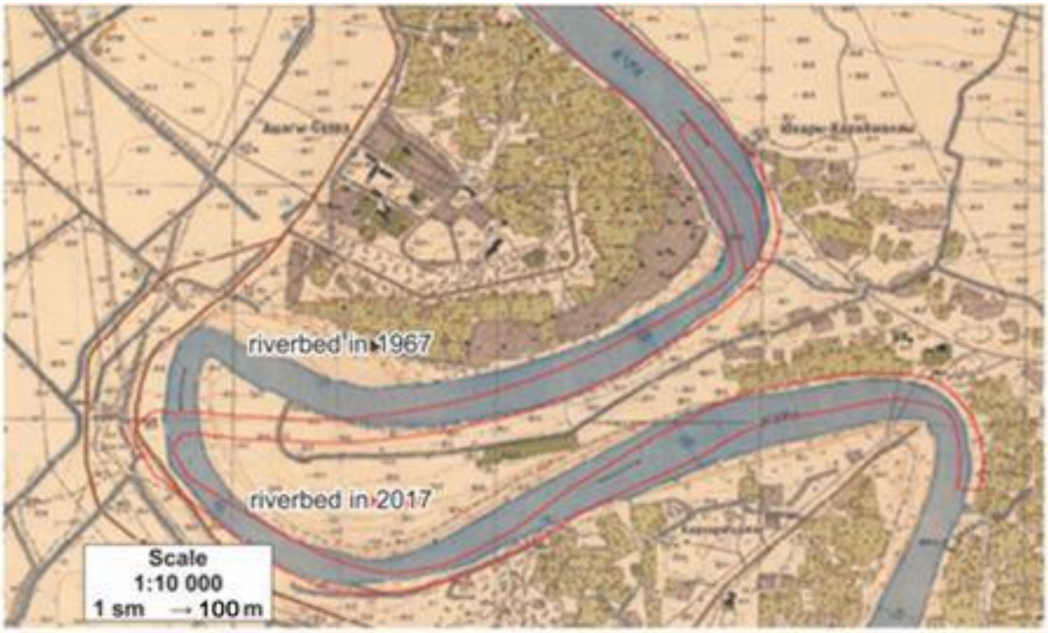
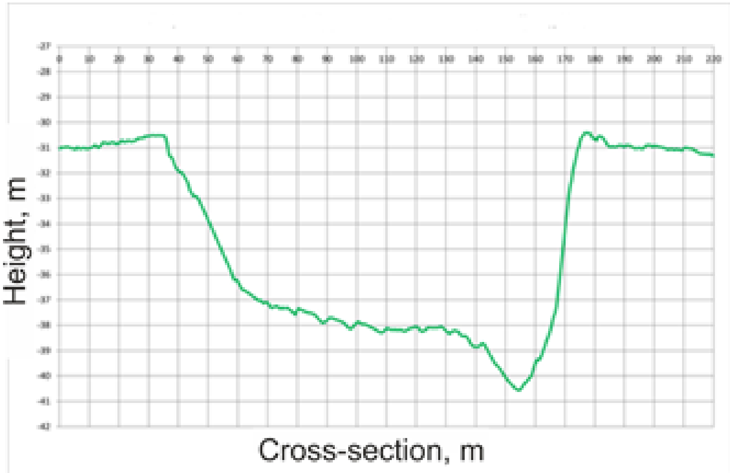



**Figure 1:** *Map of horizontal change of the riverbed in the Lower Kura for 50 years (1967-2017).*

Figure 2 shows the results of bathymetric measurements at that location. The cross-section distribution of the velocity of the water in the same location also proves that water velocity increases sharply as it approaches the right bank. Figure 3. shows the curves of the velocity distribution of water velocity in the absence of turbulence in the curve of the meander we studied.




**Figures 2:** *The result of bathymetric measurements at the peak of huge meander*

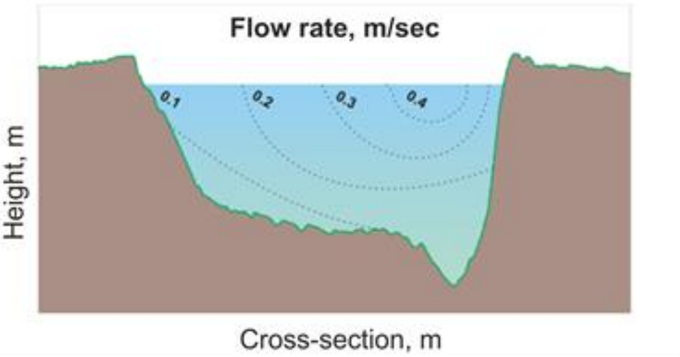


**Figure 3:** *Water velocity distribution curves in the non-existing of turbulence at the peak of a huge meander*

As the water moves in a curved motion at the peak of the meander, turbulence occurs in the flow. Turbulent flow erodes the soil on the right bank. This process is especially widespread in times of drought. Figure 4. shows a schematic of this process.

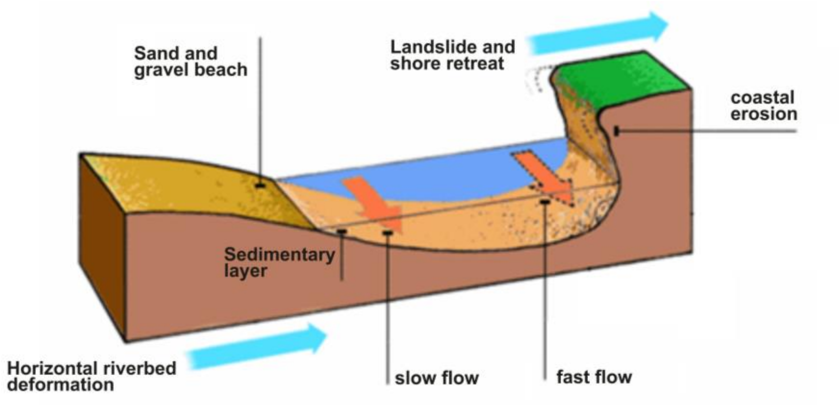



**Figure 4:** *Turbulent flow of water and erosion-accumulation processes at the peak of the meander.*

In order to compare the results of our experimental studies in the huge meander with the calculations of the mathematical model, the granulometric parameters of the impurities in the water were determined at the indicated location. Supplies with granulometric parameters of 0.2-1.0 mm are 5-8%, impurities with 0.05-0.20 mm are 20-25%, and impurities with <0.1 mm are 70-80%. These values are about 20% higher than the parameters given by R.K. Abbasov and R.N. Mahmudov [7] for close locations. It is natural that in the area up to the mouth there is an intensive process of subsidence of large grains. As a result of the formation of "traffic jams", the speed of water flow is reduced to such an extent that "ice jams" observed in the Siberian rivers. The water cannot flow forward in the channel, and gradually there is a backward pressure. Even so, owning one is still beyond the reach of the average person. As we approach the source, the flow is 90-100% with a diameter of <0.1 mm.

Analysis of scientific and technical literature shows that there have been attempts to model the migration of the river bed. Our results are well described by the model proposed by Timothy J. Randle [8]. It has been shown that the coastal erosion rate is a multi-parameter function. To describe the erosion process, the author used many empirical coefficients.

$$B_e = \left\{ \left[ a_1 C_s \left( \frac{W_b}{R_c} \right) \right]_{at\ L} - \left[ a_2 \left( r_\gamma \frac{r_d}{h_b} \right) + a_3 \left( LWD \frac{d_W}{D} \right) + a_4 (PI) + a_5 \left( d_c \frac{h_b}{D} \right) \right]_{at\ L + \text{Phase Lag}} \right\} a_6 V$$

where $B_e$ – rate of bank erosion [*L/T*]; $W_b$ –bankfull channel width [*L*]; Cs – bed-material sediment concentration [ppm]; $R_c$ – channel radius of curvature [*L*]; *L* – distance along the channel; Phase Lag –planform phase lag along the channel (see Figure1); $r_\gamma$ – fraction of bank area covered by vegetation roots [%]; $r_d$ – vegetation root depth [L]; $h_b$ – bank height [L]; *LWD* – fraction of bank area covered by trees or large woody debris [%]; $d_W$ – average height of large woody debris jams [*L*]; *D* – hydraulic depth of the channel [L]; *PI* – plastic index; $d_c$ – portion of bank sediment too coarse for incipient motion [%]; *V* – mean channel velocity [*L/T*]; $a_1$ and $a_6$ are empirical coefficients and $a_2$, $a_3$, $a_4$, and $a_5$, are weighting factors.

As follows from the formula all the parameters on the right-hand side of equation produce dimensionless terms except for the average channel velocity, which provides dimensions for the bank erosion rate [L/T]. As we noted earlier, the Kura river flows on an alluvial layer, created by him over the millennia [1, 3]. To calculate the coastal erosion rate, we used the soil parameters given by R.V. Lodina [9]. The rest of the parameters were obtained from field measurements in the region of the large meander of the Kura River shown in Figure 1. As a result of calculations according to the above formula, the value of the coastal erosion rate was obtained at 8.5 meters per year. This value is in good agreement with the data of cartographic analysis of the Kura river bed in 1967 and 2017.

## III. Conclusions

Erosion and soil processes in Lower Kura, occur under following conditions:

Lower Kura is one of the most turbid rivers of the world and flows on an alluvial layer, created by him over the millennia. Therefore, the river is freely meandering. The water course has turbulent character, with transverse circulation. The dynamic axis of water flow wanders. According to our estimations, the length of meanders accounts for 75 % from total length.

Water has character of a disperse liquid. In turbulent flow the disperse liquid behaves as an emery paper (sandpaper). It considerably accelerates process of erosion of coastal dams. According to our estimations, in some years of a high water annual displacement of meanders reaches 9 ÷10m. Therefore, annual breaks in the coastal dams occur in the same riverbed sites (!). The economic damage caused by the flooding in 2010 was over US $ 500 million.

Because of a large quantity of deposits intake from tributaries, in the conditions of negligibly longitudinal slope of riverbed, there is a strong sedimentation and accumulation of deposits, strong vertical deformation of riverbed. As a result of deforestation in the river basin, deposits intake growth trend is observed.

As a result of vertical deformation of riverbed and permanent shore protection works, forming the anti-valleys, similar to the Huang He, Kuban, Panj, Amu Darya and Syrdarya rivers. All of these rivers tens of years are flowing through countries with socialist agriculture setup (traditions).

Why, coastal dams break occurs in the same riverbed sites of Lower Kura?

The soil material of levee banks consists of alluvial soil, which is easily erosion by a turbulent flow. At shore protection and dike raising works, the state structures responsible for emergency situations use the same accessible (improvised) cheap alluvial material, by the method of excavator dyking (damming-in). Just as it was made in Soviet period. The basic criterion of technical realization of such projects those years was the principle of their minimal cost. Thus question of strategic risk, ecological safety and other, as a rule, at all did not take seriously. Therefore, once dyked in the past banks is repeatedly washed away in a high water.

According to the laws of soil mechanics the levee banks inclined to destructions and washout should become stronger a material with low factor of washout. In due time, Ibad-zadeh Yu.A. has suggested to use loam with 20 % of clay [10].

It is necessary to note, one important fact. The region is of global ecological interest. For example, Conservation International has identified the South Caucasus – an area corresponding closely to the Kura river basin – as being one of the world’s top 25 biodiversity hotspots. Over 115 species of waterfowl live along the shores of the Kura and its associated wetlands including many RDB species [11].

These peculiarities of erosion and soil processes sets the Lower Kura River in a unique position of serving as a model for trial-use standard the most up-to-date approaches to flooding risk mitigation and management. Therefore, the solution catastrophic flooding problems in Lower Kura demands new, innovative approaches. Our researches proceed, and results will be presented in the near future.

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# INFLUENCE OF NATURAL-ANTHROPOGENIC FACTORS ON THE FORMATION OF PINE FORESTS OF LANDSCAPES OF THE CHECHEN REPUBLIC

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**Abstract**

*The analysis of the influence of natural and anthropogenic factors on the formation of the biomass of oak forests in the Chechen Republic allowed us to assess the current state of these geobiocenoses. The territories of oak forests with various anthropogenic disturbances show a clear connection with certain physical and geographical conditions of mountain and forest landscapes that affect the rate of organic recovery. Here, the geomorphological factor in the placement of certain directions of mountain ranges and the steepness of the slopes comes to the fore. In the northern slopes, where they receive more solar heat and drop out, a significant amount of moisture, the growth of phytomass goes much faster than on the southern slopes of the rain shadow.*

**Keywords**: Chechen Republic, oak, pine, phytomass, organic matter

## I. Introduction

The study of the influence of both natural and anthropogenic influences on the formation of organic matter in various landscape complexes, due to the fact that our planet today is experiencing the influence of actively ongoing processes of climate warming and this is directly related to human activity. The situation in mountain and forest landscapes has worsened since the second half of the 20$^{th}$ century, when large areas of loess were cut down by continuous logging, which led to soil depletion, changes in water regime, activation of landslide and erosion processes led to a significant change in the nature of matter flows (mainly carbon and energy).

Due to the close attention of the world community to the problem of climate change and the problems associated with it, they are of great scientific interest, aiming to study not only qualitative, but quantitative descriptions of objects and processes occurring in landscapes.

## II. Materials and Methods

The ecosystem is widespread in the Argun basin and its tributaries Meshe–Hi, Basty–Hi, Gekhi–Chu, Manst–HI, Kerigo, Khorachoy, Zaterki, and is not widespread. It is formed within the northern macroscline of the Lateral, rarely the southern macroscline of the Rocky Ridges, in the Argun, Assi and Fortanga basins [1]. Basically, the ecosystem is widespread and is formed at altitudes from 700 to 1600 m mainly on the north-western, north–eastern, western, rarely eastern and northern slopes. On the slopes of the north-western and north–eastern orientations, phytocenoses of fresh oak-pine snowdrift can be found from 700 m to 1500 m, being replaced above by a moist lime-pine snowdrift. Slightly higher (up to 1600 m) rises along the slopes of the western orientation. A small high-altitude zone of the ecosystem forms on the slopes of the eastern exposure (1450-1600 m), where it acts as a transition from dry oak-pine subori to fresh pine subori. On the slopes of the northern exposure, the ecosystem is formed by fragments at altitudes from 700 to 1300 m, timed exclusively to well-lit and heated ridges. The steepness of the slopes is from 10 to 500.

The litter is composed of the fall of woody vegetation, loose, poorly decomposing, the transition to the soil is gradual. Due to the development of erosion processes on the slopes, it is distributed extremely unevenly. Usually not solid, often completely washed away, accumulates at obstacles with a layer of up to 7 cm. The ecosystem develops on mountain-podzolic soils, underlain by carbonate-free black clay shales and sandstones. Profile depth is 30-50 cm (from 20 to 80 cm). The profile is weakly divided into horizons. It is characteristic that the soils are strongly crushed from the surface, the deeper, the more. Already at a depth of 20-40 cm, the protection reaches 70-90%. Sometimes trees stand on the bottom of clay shales, which is associated with severe erosion that began after logging, or excessive thinning of stands. Such sites are currently closer to the suborns in terms of soil and soil conditions.

The main forest-forming breed is the pine of Sosnovsky, the indigenous stands are two-tiered with the dominance of pine in the first. The tier of hardwoods mainly forms petiolate oak, in admixture you can find common ash, birch, mountain ash, hornbeam, rock oak, Caucasian linden. Rock oak appears in admixture in areas transitioning to a dry oak-pine subori. The participation of Caucasian linden, mountain ash and Litvinov birch increases at the junctions with moist lime-pine snowdrift. It is difficult to judge the productivity of virgin oak and pine stands, since they have not been preserved. According to the 72ubrovn with other pine snowdrifts, it can be assumed that the productivity of pine in the ecosystem should have been no lower than II -III bonus. Only insignificant areas of indigenous stands in hard-to-reach places have been preserved, but they are also heavily overgrown; oak-pine and pine–oak stands are sparse on heavily eroded elephants.

## III. Results and discussions

The obtained results showed that unchanged and very slightly altered landscapes do not exceed 15% of the territory area. Natural landscapes have been preserved in the highlands and in hard-to-reach places of the middle and low mountains. The steppe, forest-steppe and semi-desert landscapes located within the terraced inclined plains are most strongly changed: the Terek River Valley, the Nadterechnaya Plain, the Alkhan-Churt Valley, the Chechen Plain and the Gudermess plane. Within these landscapes, arable land, deposits, gardens and vegetable gardens occupy more than 74%, hayfields – 7%, residential areas – 15%, hydraulic structures – 3% and roads – 1% [2,3,4].

The analysis of the current state of the landscapes made it possible to zone the landscapes of the republic according to the degree of anthropogenic disturbance (Fig.1).

Asa result of unsystematic logging in the past, as well as due to the extremely strong ability of oak to renew vegetatively, about 85-90% of the indigenous stands were replaced by derived oak trees.

Derived oak trees are single-tiered, overwhelmingly overgrown, mainly at the age of 20-50 years, bonitet III -IV, closeness 0.4-0.8.

Young oak trees are characterized by a nesting arrangement of trunks, characterized by strong curvature, low-drooping crown and poor cleanness from twigs.

The undergrowth is developed unevenly, with the closeness of the woody hollow 0.8 and higher, it is represented by single specimens. In low-canopy oak forests (0.3-0.6), shrubs can form a canopy with a closeness of 0.2 to 0.7. Azalea dominates, the amount of which increases as the degree of illumination of the slopes increases. Hazel rarely prevails. From other shrub species, rosehip, dogwood, warty and European birch bark, svidina, rarely goat willow, long-leaved juniper, Caucasian honeysuckle, gordovina, hawthorn, round-leaved irga are noted [4].

The herbaceous cover is uneven, the degree of coverage varies from 1 to 100% depending on the closeness of the tree–shrub canopy and the erosion of the slopes. There are more than 115 species in the composition of the cover, cereals always dominate. The most constant are wild strawberries, volodushka multi–leaved, large-leafed flower, three-pronged astration, blood-red geranium, medicinal herb, willow-leaved lily of the valley, Transcaucasian lily of the valley, whitish psephellus, valantiiform bedstraw, millipede, forest bluegrass, almond-shaped milkweed, horned lyadvenets, hairy knuckle, mountain clover, golden rod, oregano ordinary, vika Balanza.

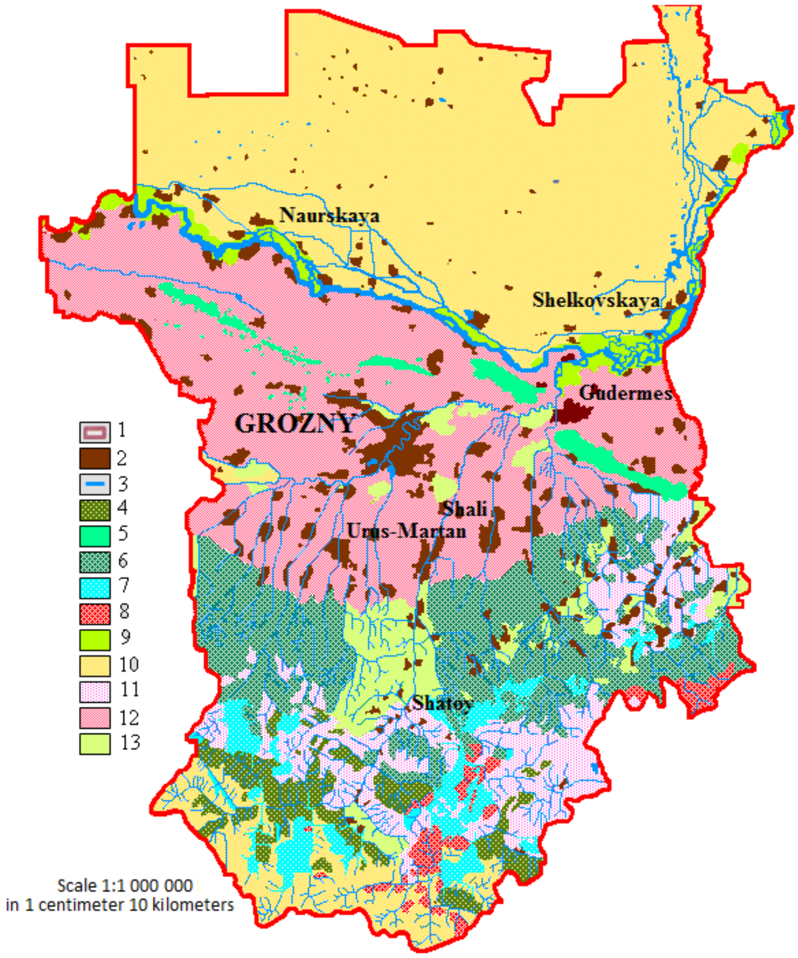


**Figure 1:** *Anthropogenic disturbance of forests Chechen Republic. Symbols for the map: 1 – the border of the republic; 2 – settlements; 3 – rivers and lakes; 4 – pine forests; 5 – oak forests; 6-beech forests; 7 – birch forests and woodlands; 8 – shrubby vegetation; 9 – vegetation of floodplains; 10 – treeless spaces; 11 – forests reduced in the 20th century; 12-forests reduced in the 19th century; 13 – forests reduced by military actions and unauthorized logging.*

Less permanent are the Alpine scythe, Caucasian feather grass, cruciform bedstraw, gentian veronica, sparrow, Alpine clover, segmented bedstraw, red pollen, pink pyrethrum, purple-blue, fluffy geranium, purple 73ubrovnik, St. John's wort, short-legged forest, Caucasian kemulariella, white vole, five-leaved sickle, veinik reed-like, large-flowered beech, flat-leaved geranium, medium wart, Caucasian cupena, lipolistnaya valerian, three-part albovia, etc.

It is difficult to judge the course of natural seed renewal of pine and its companions in the indigenous stands of the ecosystem. In the described preserved pine forests, on which the imprint of human activity has been deposited, the pine tree resumes unsatisfactorily. The number of undergrowth, as a rule, ranges from 0.5-1 to 4-8 thousand per 1 ha, in some cases 22-44 thousand are noted. The undergrowth of pine almost always prevails over the seed stock of hardwoods. In the second tier, petiolate oak, hornbeam and linden are renewed mainly by overgrowth.

The stands of the ecosystem currently have no operational significance, they perform a protective and water-regulating role.

## IV. Conclusions

It is necessary to continue in-depth studies based on complexity (geographical, botanical, climatic, geo-economic), which will determine the course of growth of rocks in the forest ecosystem, will make it possible to establish local characteristics of growth and development with the goals of optimizing rational forest management based on the sustainability of the development of forest ecosystems, while preserving the natural environment.

The analysis of the dynamics of the mountain forest allowed us to draw the following conclusions:

1. The state of the mountain forest ecosystem complex of the Chechen Republic is directly dependent on climatic and anthropogenic factors, which lead to a significant weakening of their geo-economic functions. The importance of their conservation and reproduction, as the basis of the raw material base that provided the demand for valuable wood, but, of course, as the most important environmental-forming natural component from the standpoint of optimal and non-depletion use of forest resources are important for the economy.
2. Ecosystems of beech forests occupy at least 75% of the forest-covered area of the Chechen Republic. For the development of the beech ecosystem, a lot of moisture is needed.
3. During forestry development in the ecosystems of the mountain forest, adjacent to the upper aisles of the forest, should be directed to the formation of a landscape complex.
4. The implementation of the task of improving the geoecological condition of forests will preserve their biological diversity, requiring the improvement of economic activities in forest ecosystems that are subject to degradation, significantly increasing biological measures to combat numerous factors of forest pests.
5. A significant part of the forest areas with growing conditions favorable for hard deciduous and coniferous species began to be mastered by soft deciduous species, which are not indigenous forest-forming species, but transitional. Currently, there is a gradual replacement of transitional rocks by indigenous ones. Under the canopy of aspen, birch, gray-alder plantations, an undergrowth of coniferous and hardwoods appears. It should be noted that the change of breeds naturally can take hundreds of years. Therefore, it is necessary to carry out various reforestation measures depending on the specific conditions of each allotment, promoting natural renewal, contributing to the reconstruction of low-value plantings and the creation of valuable forest crops.
6. Forests suffer significantly from the economic activities of road users. By removing gravel material in floodplains and floodplain terraces of the Argun, Sunzhi, Hulkhulau rivers, and laying highways along them, they uproot thickets of valuable fruit and medicinal shrub – sea buckthorn. The population of the Chechen Republic also contributes to the destruction of sea buckthorn plantings. They harvest berries in the most predatory way by pruning branches and continuous cutting.

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# PROSPECTS FOR USING THERMAL WATER IN KALBAJAR DISTRICT AND OTHER REGIONS (AZERBAIJAN) AS AN ALTERNATIVE ENERGY

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**Abstract**

*One of the essential problems of the present time in the field of natural sciences is saving energy resources and substitution of hydrocarbon energy with solar, wind, and geothermical types of energy. The Republic of Azerbaijan is rich with renewable sources including thermal water deposits being situated in a number of regions of the Greater and Lesser Caucasus, Apsheron peninsula, Talysh, as well as in the bounds of the Kura and Pre-Caspian-Guba depression. The article is based on the analysis of published materials, data from geological prospecting and scientific research work carried out in different time, as well as results of geochemical analyses of water sample. This article discusses issues about utilizing thermal water as an alternative energy. As alternative energy, thermal water of Kalbajar district has been investigated insufficiently for obvious reasons. Nowadays, not deep and low debit wells having bored in due course for balneological goals do not permit to consider thermal water in Kalbajar district as noteworthy sourses of alternative energy.*

**Keywords:** Kalbajar region, thermal water, alternative energy, geological prospecting work, debit of sourses and wells

The material for preparing the given article was the results of analysis of geological prospecting work conducted previously, printed publications, and data from scientific research work carried out in recent years.

In connection with uninterrupted growth of worldwide energy consumption, international organizations on the level UN are raising the issue of sharply reduction of using traditional hydrocarbon resources (oil, gas, and coal) over the next 20-25 years. In this regard, nowadays specialists and scientists focus on prospecting new sources of energy. We consider side by side with wind and solar energy, within the conditions in Azerbaijan, thermal water known in a number of regions of the Greater and Lesser Caucasus, Apsheron Peninsula, Talysh, as well as within the Kura and Pre-Caspian-Guba depression possesses a great significance. The deposits of this water has been revealed by a number of wells drilled for oil and gas, as well as directly for thermal water [2, 3].

Over the past 30-40 years, scientific and experimental investigations relating to solving the problems in using not traditional energy of solar, wind, and thermal water have been realized in the republic. The quality of thermal energy accumulation and high thermal energy capacity counts for to be much significant energy source.

Moreover, in the years of 1964-1970, 17 wells were drilled in the Talysh zone under the one of the author's leadership and high temperature water was obtained from each well on the basis of which 10 greenhouses were constructed for cultivating early vegetables in the winter months by the geologists jointly with agricultural entrepreneurs; and possibility of obtaining two and three harvest during the year was practically proved.

The thermal water in Massally, Lankaran, and Astara districts of Talysh-Lankaran zone are confined to the regional tectonic fault crossing the entire mountainous Talysh. Here, termal water with the temperature of 50$^{o}$C with the debit up to 40 l/sec was exposed from the wells with the depth till 500 meter. The water is mineralized (18-29 g/l) having sodium chloride composition. The total debit from sources and wells of Talysh is amounted to 24,000 m$^3$/day.

The thermal water with hydrocarbonate-calcium-sodium composition with mineralization of 08-1,9 g/l and with the temperature of 50-90$^0$ C, and with the total debit up to 13,000 m$^3$/day was exposed from the specially drilled wells with the depth of 3,000 m in the Pre-Caspian-Guba zone (the southeastern slope of the Greater Caucasus) [2].

On Apsheron Peninsula, the thermal water has been found in the wells with the various depth. So, in the eastern part of Hovsan village, the water temperature in the drilled wells reaches up to 100$^0$C. In Bibi-Heybat, right next to Baku, the well is gushing chloride-hydrocarbonate-sodium water with mineralization of 16,5 g/l and with the temperature of 71$^0$ C, and with the debit of 450 m$^3$/day.

The Kura depression is a single complicatedly constructed artesian basin with complex distribution of temperature and water composition. The thermal water was discovered from 200 till 4,500 m, which were confined to the deposits of Apsheron, Akchakyl layers, productive thick layers, Maikop suite, and Cretaceous. The thermal water was revealed by a number of wells drilled for oil and gas in Babazanan, Neftchala, Khilly, aand Mishovdag fields. That water is enriched with iodine and bromine [5].

İn 1969, in the well number 3 in Jarly area (Kurdamir district) thermal water with the debit of 20,000 m$^3$/day and with the temperature of 100$^0$C was discovered in the Upper Cretaceous deposits. İn Kurdamir district, thermal water with the debit of 10,000 m$^3$/day with the temperature of 80$^0$C was revealed fron another well on the suface of the earth (Table 1, 2).

On the basis of conducting prospecting work it was determined that the southwestern side of the Kura depression possesses sufficient resreves of thermal water. That water can be used comprehensively and profitably for the purposes of heat supply for industrial and residential establishments, for obtaining chemical rare elements, thermic-greenhouse keeping, as well as for balneological goals. [6].

**Table 1:** *Forecast resources of thermal water in Azerbaijan*

| Geothermal regions | Water temperature, $^0$C | Forecast resources, m$^3$/day |
|---|---|---|
| Mountainous-folded zone of the Greater Caucasus | 50-90 | 2000 |
| Gusar foothill lowlands | 40-97 | 22000 |
| Apsheron peninsula | 40-90 | 20000 |
| Nakhchivan AR | 40-53 | 3000 |
| Talysh mountainous-folded zone | 40-64 | 15000 |

Total area of the Lesser Caucasus is approximately 20,000 km$^2$. It occupies the southwestern slope of the Murovdag range of mountain, considerable part of Nagorno-Garabagh, as well as Shahdag ridge and it stretches from the Aras river in the south-east through Hakari and Tartar basins till the lake Sevan and further to the north-west. The north-eastern border of the lake Sevan in Garabagh zone is formed from massive and lasting Murovdag thrust fault getting the fault character in the east and is traced along south-western wing of Aghdam anticlinorium almost till the Aras River.

**Table 2:** *The main parameters of geothermal indices of thermal water in Azerbaijan*

| Geothermal regions | Number of oil and gas bearing structures | T $^0$C in the depth 3000m | Heat flux magnitude mW/m$^3$ | Factors affecting the magnitude of the heat flux |
|---|---|---|---|---|
| Pre-Caspian - Guba | 15 | 90 | 50 | The area is characterized by low 30 mW/m$^3$ HF, to the southeast value of HF reaches 50 mW/m$^3$, which is associated with the fragmentation of deep faults |
| Apsheron | 23 | 74 | 90 | Relatively increased HF is associated with the influence of N-W directions of deep tectonic faults |
| Ganja | 8 | 99 | 50 | The thermal background is mainly formed due to the conductive, as well as the superposition of the convective component of HF |
| Yevlakh - Aghjabadi | 8 | 75 | 50 | The thermal background is mainly formed due to the conductive component of the HF |
| Shamakhy - Gobustan | 6 | 80 | 99 | High HF is due to the fragmentation of the basement by transverse and longitudinal faults |

Kalbajar district is located within the Lesser Caucasus in the valley of the Tartar river at an altitude of 1,800-3,800 meters above sea level. In terms of area, the district is the largest administrative-territorial unit of Azerbaijan. The area of the district is 6,420 km$^2$ that is 7.5% of the total area of Azerbaijan (Figure 1.).

At the present time, a number of draft for infrastructure are being introduced contributing to the reestablishment of economy in liberated regions including Kalbajar district. The territory of the district is rich in vast amount of valuable minerals including mineral and thermal waters.

In the liberated regions, many-sided work is being conducted to reestablish them, the modern types of city building will be applied considering the concepts of "smart" residential complex and modern management models. One of the most important problems of the modern requirements of science, technique and technology is to reduce to minimum and replace hydrocarbon energy with alternative one – solar, wind, geothermal and other types of energy [7, 8].

The advantage of thermal water is that it has opportunity to gain heat, energy, and its reserves are being uninterruptedly renewed, as well as they are worthy for obtaining medicinal properties and for possibility of obtaining valuable chemical products.

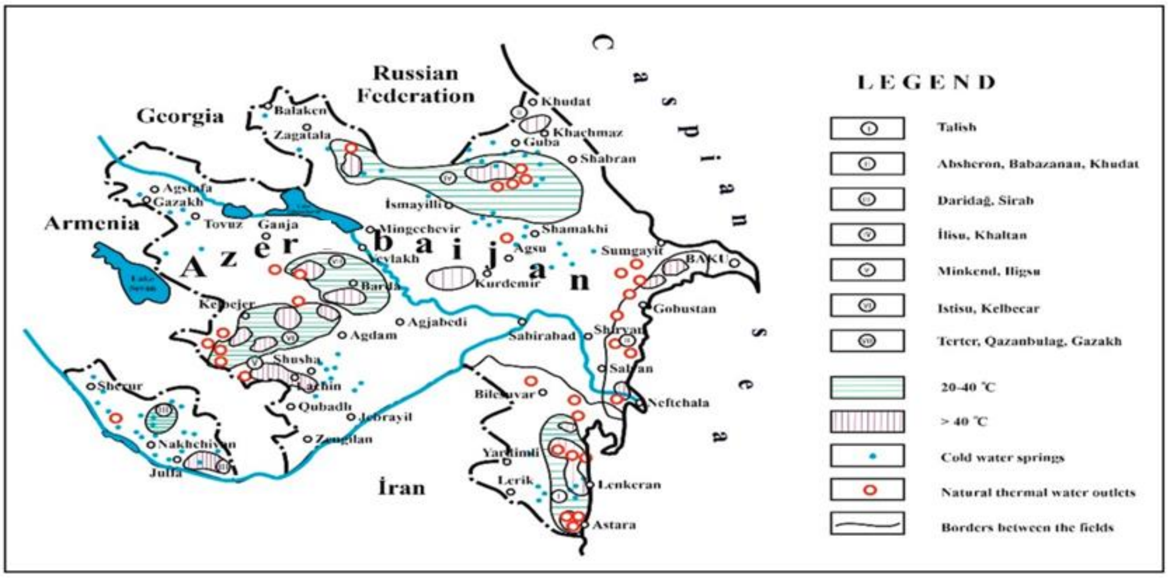


**Figure 1:** *Map of thermal water of Azerbaijan*

According to the conditions of occurrence, the thermal water of investigating area is related to fracture and fractured-veiny type of deep circulation and is cropped out on the day surface as the ascending sources.

Within the limits of this mountainous system, the belted location of separate complexes can be observed perfectly reflecting in the chemical composition of mineral and thermal water confined to the micro and macrotectonic disturbance and contacts with separate layers in the folded areas. Here, the igneous rocks of intrusive and effusive magmatism were widely developed stratifying with carbonate, sandstone, and clay formations.

The thermal water is manifested in the places of obvious and possible hidden tectonic faults, magmatic hotbeds of Paleogen-Neogene age and active volcanic manifestations of the Pliocene and Anthropogen [2].

Within the territory the Kalbajar superimposed trough, basin water with the highest temperature was developed related to magmatic activity during the period of manifestation and extinction of recent volcanism. Evidently, existing magmatic chambers in the depths up to now feed underground water with heat and enrich with carbon dioxide, and with several other ingredients (Table 3). Hydrogeological properties of the thermal water deposits in Kalbajar district is given below [4, 6].

Summing up, geothermal conditions in the regions considered above are changed under the total influence of many factors effecting on the heat flux density. The revealed anomaly of geothermic regime can be explained by the lithological properties of rocks, tectonic phenomena, and volcanism of the Quaternary period.

## CONCLUSIONS

1. In the Kalbajar zone, prospecting and exploration work was conducted 40-50 years ago, exclusively for the development of health resort complexes. Nowadays, exploitation of the drilled sallow wells (up to 700 m) is used for obtaining an alternative energy ($80^0$C). Analysis of hydrogeological, geological, and tectonic materials shows that the thermal water with the temperature of $100^0$C can be obtained from the wells of 1,000-1,500 meters.

2. In the investigated region, anomalous thermal regime is characterized over more than 40 km along the river Istisu valley. The geothermic step in the south slopes (the resort Istisu and

Bagyrsag area) is decreased up to 2-5 m and less, and for the entire resort region it is close to 18 m/ °C.

**Table 3:** *Hydrogeological properties of the thermal water deposit in the Kalbajar region*

| Deposit names | Water-mixing rocks | Chemical composition | | | | | Water temperature, $^0$C | pH | Water debit, l/day | Appro-ved reserves |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water points | Gas composition | Mineralization, g/l | Formula of ionic composition | Specific compo-nents mg/l | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| Upper Istisu | Volcanogenic strata, limestones and chalk sandstones | Source | $CO_2$ | 4,1-5,8 | $\frac{HCO_3 51Cl32}{Na91Ca9}$ | Ba, Cu, Cr | 54 | 6,7 | 200 thousand | 825 |
| Upper Istisu | Volcanic strata, (limestones) Cretaceous | well 700 m | $CO_2$ | 4,4-7,6 | $\frac{HCO_3 50Cl39}{Na90Ca8}$ | Ba, F, Cr | 71 | 6,7 | 3 milli-on | - |
| Lower Istisu | Quaternary lavas, dacite-andesites | Source | $CO_2$ | 4,6-6,9 | $\frac{HCO_3 69Cl24}{Na88Ca10}$ | Pb, Mn, Cu | 39,5 | 6,8 | 800 thousand | 180 |
| Lower Istisu | Fissure Limestones, Marls, Sandstones | well | $CO_2$ | 3,2-7,4 | $\frac{HCO_3 70Cl23}{Na89Ca11}$ | -- | 67 | 7,1 | 20 thousand | - |
| Bagyrsag | Cracks. Granite-diorite intrusions of the Santonian Stage | well 250 m | $CO_2$ | 4,1-5,8 | $\frac{HCO_3 69Cl29}{Na91Ca8}$ | Sr, Zn, Ni | 64 | 6,5 | 2 milli-on | - |
| Geshtek | Limestones, chalk sandstones | well 700 m | $CO_2$ | 4,1-6,1 | $\frac{HCO_3 72SO_4 18}{Na88Ca11}$ | Pb, Ni, Cu | 51 | 7,1 | 50 thousand | - |

3. In the tectonic fractured areas, increasing the temperature with the release of carbon dioxide components is sometimes traced. As it was shown by drilling operations, the temperature of thermal water in Bagyrsag area increases rapidly, and at the depth of 100 m it reaches 80$^0$C.

4. Anthropogenic greenhouse gas emissions have had noticeable influence on the global climate change, $CO_2$ that is formed from the combustion of hydrocarbon fuel, methane ($CH_4$) forming as a result of various processes basically during the decomposition of biomasses, and several other gases not decomposing in the environment during hundreds of years.

5. Analysis of materials from thermal water deposits have determined that Azerbaijan possesses extremely favorable natural conditions for developing reestablishment of energy sources. Within the limits of the Kura depression, the thermal water up to $100^0$C was discovered from the wells with the depth up to 3,000-3,500 m drilled for oil and gas. In the north-eastern part of the Greater Caucasus, the thermal water with the temperature of $80^0$C was disclosed from the exploration wells specially drilled for obtaining thermal water.

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# THE INFLUENCE OF COMBINED DRAINAGE ON THE STABILITY OF AGRICULTURAL PRODUCTION IN CONDITION OF CLIMATE CHANGE

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**Abstract**

*Climate change and consequent appearance of natural hazards (floods, droughts, soil erosion, landslides) is major problem globally, and a subject of many scientific, expert and politics meetings and therefore solutions are being sought to mitigate its consequences. Because of climate change, agricultural production is very uncertain during unfavourable hydrological years, in which vegetation deficit or surplus precipitation appears, causing deficit or surplus moisture in rootzone with negative impact on growing and development of plants. To achieve safe agricultural production, hydrotechnical structures are often utilized: flood protection systems, ameliorative drainage systems, as well as irrigation systems. If hydro-ameliorative systems already exist, they often require reconstruction (adaptation) in addition to maintenance.*

**Keywords**: combined drainage, agricultural production, climate change

## I. Introduction

The amount of precipitation, its duration, intensity and frequency of occurrence are factors that directly affect agricultural activities, since surplus or deficit of precipitation restricts agricultural production and requires amelioration measures of drainage and/or irrigation [1]. The main consequence of climate change is the appearance of extreme weather events such as increasing occurrence of droughts and floods, which adversely affects the reduction of water supplies, reduced yields and biodiversity, occurrences of erosions and landslides, water pollution, i.e., changes in surface and groundwater quality [2]. Potential impacts of global climate changes may include the change in hydrologic processes and watershed response, including timing and magnitude of surface runoff, stream discharge, evapotranspiration, and flooding, all of which would influence other environmental variables [3]. More frequent and severe extreme weather events are anticipated to cause serious damage to ecosystems and agricultural systems [4, 5].

In the period from the 1970s to the 1990s, hydrotechnical structures and ameliorative drainage structures were intensively built in Croatia for the purpose of flood protection and drainage of excess soil water, with the largest interventions being carried out in the central part of the Sava River valley (Figure 1), aiming to increase of agricultural areas suitable for growing crops typically for this area, such as corn, wheat, soybeans, clover–grass mixtures. The middle course of the Sava River (pertaining to Lonjsko polje) is located at average altitude of 96 m a.s.l, which is characterized by low surface water runoff and low flow velocity in watercourses flowing through the basin into the Sava River. The area is dominated by hydromorphic soils heavier textures and very small permeability (Figure 1). In order to better monitor the functionality of the combined drainage system and the yields of cultivated crops in the area of Lonjsko polje, an hydroamelioration experimental field was set up in the early 1990s (Figures 2 and 3).

## II. Materials and Methods

Investigations were conducted in the period 1996–2015 at the experimental hydroamelioration field (45°34'46'' N, 23° 51'30''E, Figure 1) at the altitude of 96 m a.s.l., on soil type defined as hydroameliorated Gleyic Podzoluvisol. The trial involved four different drainpipe spacing variants (15 m, 20 m, 25 m and 30 m), set up in four replications. All variants were combined with gravel as the contact material in the drainage ditch above the pipe up to plough layer. Drainpipes are 95 m in length, diameter 65 mm, slope 0.3% and average depth 1 m, which discharged directly into an open detailed canals. Water from details canals inflows into higher order canals and flows towards the pumping station which pumps the water into the river Lonja (recipient), Sava River's tributary. Variants covered areas of 1425 $m^2$, 1900 $m^2$, 2375 $m^2$ and 2850 $m^2$.

In order to obtain the better insight into climate conditions during the period 1996–2015 the official meteorological data from the main meteorological station Sisak were used. The mentioned station Sisak belongs to Meteorological Station Network of Croatian Meteorological and Hydrological Service located in the town of Sisak. The climate conditions are described by Lang's rain factor ($R_f$), which is conducted according Gračanin climate classification [6].

Maize, winter wheat, soybean and rapeseed were grown as the trial crops and the same standard agro–technical measures were applied in all variants for each crop in trial years. After the harvest of crops on each parcel of variant, the yield was determined and kernel samples were taken in order to determine water content in kernel. Real yield was calculated on content of moisture in kernel from 13 %.

Statistical analysis of the yield for both plant species was conducted by means of Duncan's multiple range test [7].


**Figure 1:** *Location of the experimental hydroamelioration (drainage) field*

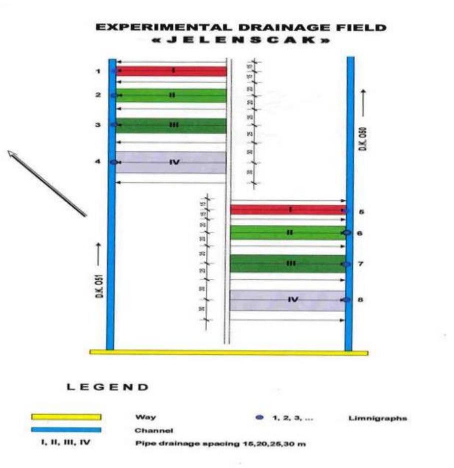


Figure 2: *Design of the experimental field*

Figure 3: *Drainage water collected from wider ameliorated area in the main canal and pump's wet well*

## III. Results and discussion

### 2.1. Features of climate in central part of Sava River valley

All meteorological elements are important to growth and development of plants, but the success of agricultural production is mostly dependents on precipitation amount and air temperature.

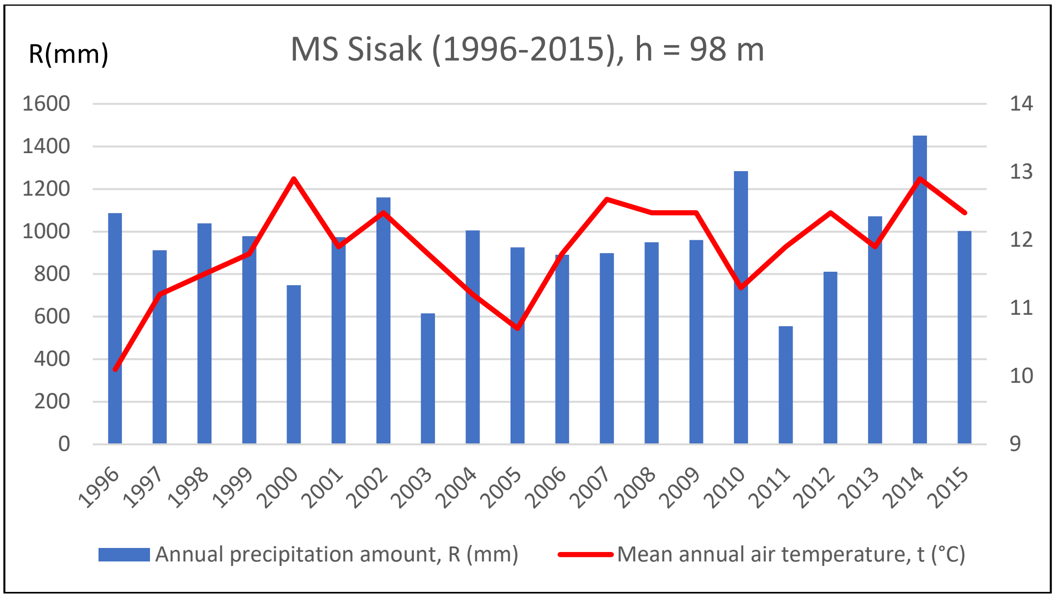


**Figure 4:** *Annual precipitation amount (mm) and mean annual air temperature (°C), MS Sisak*

As shown in Figure 4, annual precipitation amounts in the Sisak region ranged from 554.9 mm (2011) to 1,450.8 mm (2014), while multi–annual mean of annual precipitation amounts was 954.3 mm. In the twenty–year period (1996-2015) the difference between the maximum and the minimum value of annual precipitation amount was 895.9 mm. The precipitation regime is one of the most variable climate characteristics of some area, both spatially and temporally [8]. Monthly precipitation amounts can vary from year to year (Figure 5).

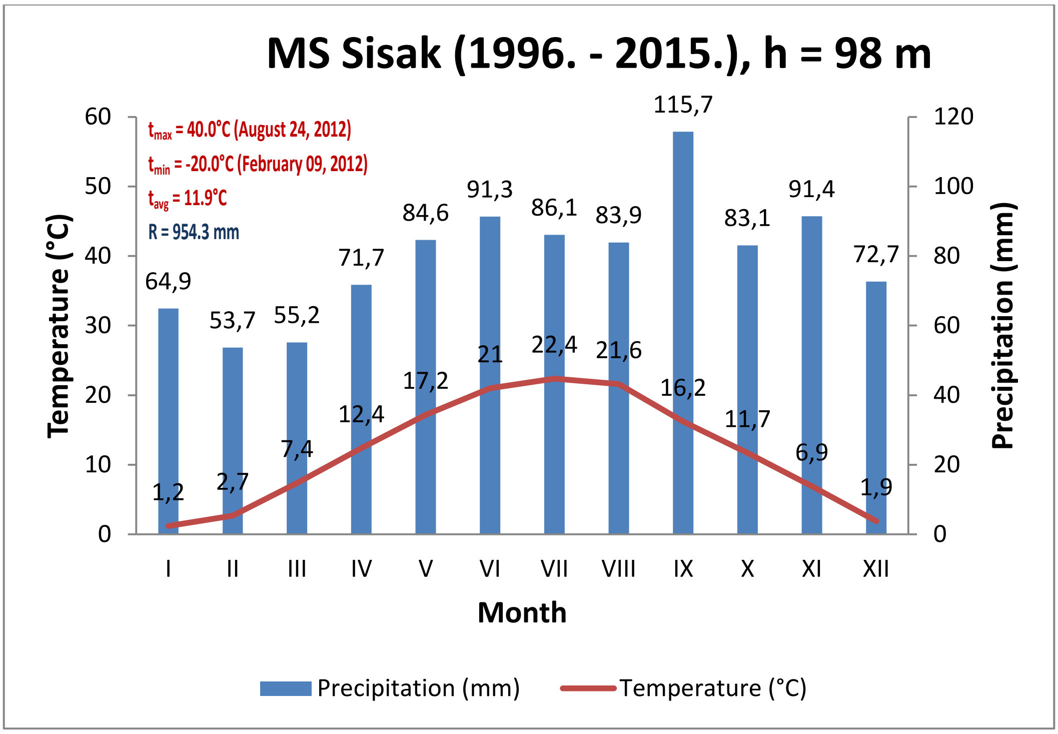


**Figure 5:** *The multi–annual mean of monthly precipitation amounts and multi–annual mean of monthly air temperatures (°C)*

The variability of monthly precipitation amounts is expressed by coefficient of variation and its maximum is in August (cv = 0.63) and minimum in November (cv = 0.41). A comparison of multiannual mean of monthly precipitation amounts reveals that maximum value occurred during the vegetation period. During the growing season (April-September) the Sisak area receives on average 533.3 mm of precipitation or 55.9%, what is characteristic of the continental precipitation regime. The annual course of monthly precipitation amounts in Croatia can be divided into two types, depending on the time of the year when the month with the lowest precipitation amount occur–the continental annual course of monthly precipitation amounts, with the lowest precipitation amount occurring during the cold half of the year [8].

During the analysed period, mean annual air temperatures ranged from 10.1°C (1996) to 12.9°C (2000 and 2014), while the multi–annual mean air temperature was 11.9°C (Figure 5). Based on multi–annual mean of precipitation amounts and multi–annual mean air temperature, the central part of Sava River valley is on the border between semi–humid and humid climate (Rf=80.2) and moderately warm climate (t=11.9°C). The values of multiannual mean of monthly precipitation amounts, precipitation regime as well as the multiannual mean of air temperature lead us to the conclusion that mentioned climate conditions are favourable for agricultural production. The negative impact on yields have extreme weather events such as a lack of precipitation (occurrence of drought) or surplus of precipitation due to heavy rain in a short period (flash floods, occurrence of the stagnant water on the surface of soil during a longer time period, etc.).

### 2.2. Yield of crops in central part of Sava River valley

As can be seen from Table 1, maize participate in the crop rotation in three years, winter wheat and soybean in two years and rapeseed only once.

**Table 1:** *Yield of crops in multi years period*

| Drainpipe spacing (m) | Dry grain yield (t.ha$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Maize | Maize | Wheat | Maize | Soybean | Rapeseed | Soybean | Wheat |
| | 1996 | 1999 | 2000/2001 | 2002 | 2008 | 2009/2010 | 2011 | 2011/2012 |
| 15 | 5.82 a | 6.23 a | 5.70 a | 6.62 a | 3.23 a | 3.30 a | 2.32 a | 6.70 a |
| 20 | 5.34 b | 6.16 a | 5.74 a | 6.44 a | 3.14 a | 3.03 b | 2.40 a | 6.64 a |
| 25 | 4.92 c | 5.77 b | 5.75 a | 6.12 b | 2.90 b | 2.69 c | 2.39 a | 6.52 b |
| 30 | 4.35 d | 5.62 b | 5.35 b | 5.87 b | 2.76 b | 2.38 d | 2.29 a | 6.51 b |

**Legend:** Values marked by the same letter are not significantly different (p>0.05)

Yields of the same crops differed both in different trial years and between variants due to various factors, such as different precipitation amount during growing season (Figure 4), influence of different drain pipe spacing on drainage surplus of soil water, content of soil moisture, drilling time, harvest time, etc. The highest yields on all variants were achieved in years when precipitation amount was around average value and its favourable distribution. In the most humid years (1996, 2009/2010), the highest yields were achieved in drainpipe spacing variant of 15 m. In the less humid years (1999, 2002, 2008), the highest yields were achieved in drainpipe spacing variants of 15 m and 20 m, and the lowest always in drainpipe spacing of 30 m. According to the investigations conducted by [9,10,11,12], shorter pipe spacing is more efficient for drainage surplus water from drained soils, since larger water amounts are drained in a shorter period of time and better water–air ratio in soil are created faster, which is a prerequisite for timely application of agricultural management practices on hydro ameliorated areas. It is very important to remove the excess of water, which forms in the fields during summer season after abundant precipitation (13). In drought year (2011) yield of soybean was on all variants almost the same, but enough lower than in favourable year 2008. According [14] yields of crops in some region in Croatia can be reduced up to 90% due to the drought. Analysis of variance, done separately for each trial year, reveal significant differences (p >0.05) between yields of particular crops in dependence on drainpipe spacing in seven years, while in 2011 differences between yields, depending on the drainpipe spacing, were not significant.

Accordingly, satisfactory yields can be achieved in the agroecological conditions in central part of Sava River valley with the drainpipe spacing of 15 m and 20 m, but only if the drainage system is adequately maintained. In order to have the less risky agricultural production the build of irrigation system is of high importance.

## IV. Conclusion

Based on twenty–year research results, one could conclude the following:

1. In the central part of the Sava River valley combined detailed drainage has influence on yield of growing crops, especially in more humidity years.
2. The highest yields are achieved for drain pipe spacing of 15 m and 20 m.
3. Reliable agricultural production requires construction of the irrigation system.

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# TECHNOLOGICAL SAFETY OF THE OIL AND GAS INDUSTRY

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**Abstract**

*The current trend continues in almost all areas of oil and gas production. The reason is trivial: the lack of interest among the users of natural resources themselves and, as a consequence, the lack of sufficient material resources necessary for the restoration of resource-developed territories. At the present stage, this problem is becoming more and more acute for companies, but the main reason is not in the consciousness of enterprises, but in the tightening of requirements at the legislative level and the deterioration of the profitability of the extracted raw materials. That is, environmental problems continue to grow, but it becomes more and more difficult to regulate them due to their colossal neglect [3]. A decrease in the profitability of deposits, wear and tear of technological equipment and assets lead to a deterioration in the quality of raw materials and a decrease in the efficiency of the work performed, which, together with social problems, only entails an aggravation of the ecological situation. These aspects have a significant impact on the productivity of companies in general - especially in the environmental sense - that are undercapitalized.*

**Keywords:** natural resources, significant impact, environmental sense, material resources, ecological situation.

## I. Introduction

The principles of regulating unfair attitude to resource consumption being introduced by the legislation today is considered to be the introduction of penalties, but this, by and large, is not comparable with the damage to the natural environment and does not interest nature users in the modernization of existing production technologies. It is more profitable for companies to pay a fine than to restructure fixed assets and production. The modern penal system is ineffective, since it has not a direct, but an indirect impact on the economic efficiency of oil and gas companies. An illustrative example is the stimulation of the rational use of associated petroleum gas (APG) [5], that is, the introduction of penalties with increasing coefficients for over-limit flaring of APG together with the likelihood of accounting for investments in the gas program for the implementation of APG utilization projects as a share of these payments. Relatively recently, Russia was one of the leaders among the countries with the largest share of APG flaring, but only before the entry into force of the government decree "On the specifics of calculating fees for pollutant emissions" [6]. The existing situation in the oil and gas industry with regard to environmental problems requires a fundamental revision and implementation of the project, the basis of which should be sufficient material and financial supply of the relevant measures. Oil and gas producing enterprises are forced to reduce funding for environmental protection activities. This fact indicates a lack of desire to contribute to a way out of a negative environmental situation.

To establish the sufficiency of material and financial support, an assessment of the environmental damage to the environment is made. At the legislative level, there are many different methods and techniques for assessing the impact of nature users on the environment [7]. But all these methods are scattered and give narrowly targeted indications, which ultimately complicates the assessment of the state of the environment as a whole. To ensure environmental protection measures at a sufficient level, it is necessary to move away from the assessment in the form of direct damage to the environment, and go to the assessment of environmental risks with mandatory introduction at the legislative level. Environmental risk means the likelihood of direct or remote negative changes in the environment as a result of negative impact on it, in this case, technogenic [8]. That is, when assessing environmental risk, not only damage is assessed, as is done everywhere, but also the likelihood of its occurrence. The basis for the environmental risk assessment procedure is the ISO 14000 series standards and numerous regulations, one of which is GOST R 14.09-2005 “Environmental management. Guidelines for Risk Assessment in Environmental Management". But again, the methodology for assessing environmental risks should contain a set of indicators, on the basis of which the appropriate level of environmental risk should be established. And depending on the final value of the risk level, the natural resource user is obliged to allocate an appropriate share of the profit to compensate for environmental damage in a sufficient volume. The purpose of this work is to develop a comprehensive methodology for assessing environmental risks using the example of oil and gas production facilities.

## II. Methods

The mechanism for managing the economic security of an oil enterprise is a system that consists of a subject and a management object that use a variety of methods, levers, means, resources to solve a set of tasks in order to protect, maintain and improve economic activity in the face of constant changes in the external environment.

To characterize the safety system of an oil enterprise, the following methodological provisions are important:

- the security system of the enterprise is complex, consisting of a number of security elements (scientific and technical, information, fire and others);
- the security system of the enterprise is unique at each enterprise, as it depends, on the region, the level of technical equipment, personnel qualifications, production relations of the enterprise and the competitive environment;
- the creation of an enterprise security system and the organization of its successful functioning should be based on the methodological foundations of the scientific theory of security and the theory of social management.

Initially, it is necessary to establish which elements of the environment are negatively affected by oil and gas production facilities. Environmental pollution occurs from the initial stage - exploration of the field, that is, during exploratory drilling followed by the construction of a well. During this period, pollution occurs as a result of emissions into the air of exhaust gases from the operation of diesel engines and drilling rigs, drilling degassers, containers with dusty materials, sludge pits with drilling waste. Very often, during this period, environmental protection measures are not carried out at the drilling site, due to which fertile soils and water resources are polluted with oil products and toxic components of the drilling mud. The aggravation of the negative impact occurs as a result of washing away by melt and storm water. As a result, under such an impact, in a zone about 100 m from the borehole, complete destruction of vegetation occurs, and at a distance of about 500–800 m, 70–80% of the flora are degraded.

As a result of drilling operations, drilling waste is generated, which accumulate on special land structures - sludge storage facilities. An important aspect in this case is the initial correct organization and preparation of the territory for the sludge storage in order to avoid the likelihood of contamination of groundwater by toxic waste [9]. In addition to the oil products themselves, the drilling mud itself is a strong contaminant, containing a significant amount of various chemical constituents. The period of well construction with the accumulation of drilling waste is characterized by the territorial dispersion of drilling facilities, the heterogeneity of the generated waste itself and temporary changes in their indicators. During the operation of the drilling rig, significant areas of fertile soils are alienated. In a number of cases, companies use outdated models of machinery and equipment, technological processes aimed at obtaining maximum benefits without taking into account environmental consequences, exacerbate the already deplorable environmental situation. When carrying out repair work as a result of a violation of the technology for flushing downhole equipment, the site area may be contaminated with significant concentrations of oil products that require disposal. This can become one of the causes of fire on the territory of the drilling rig [10, 11].

## III. Results

In the course of assessing environmental risks, we used information that includes a description of the conduct of technological processes and the natural and climatic conditions of the objects of study, the results of an environmental impact assessment, data from periodic monitoring and control of the state of the environment, the results of environmental audits and examinations, reporting documents and independent direct measurements. and research on the territories of the objects. In connection with the differences in the annual volume of minerals production for each of the objects under consideration, for comparing indicators with each other, the final value of the complex indicator of environmental risk is expressed as a ratio to 1000 m3 of extracted raw materials. Based on the results of the assessment, it was found that, in general, for all the studied objects, the level of risk corresponds to the average level, but the highest value of the integrated indicator of environmental risk was found at the Yarakta field. The next stage of risk assessment should be a risk management procedure, the meaning of which is in establishing the best ways out of the current negative situation and monitoring its development, assessing the effectiveness and correcting environmental protection measures. The risk management procedure itself is based on the unity of economic, social, political structures, potential costs for the implementation of technological solutions to improve the current environmental situation, various management decisions and measures.

Energy Strategy 2035 does not mention technological safety. Its focus is timely response to challenges and threats to energy security and creation for this a risk management system in the field of energy security, the main tasks of which are: monitoring, assessment and forecasting, including in the long term, the state of energy security; determination of the resources necessary and sufficient to prevent threats to energy security, reduce the likelihood of their implementation, as well as to minimize the consequences of their implementation; defining the tasks of the subjects of energy security and planning measures to ensure it; control over the implementation of measures to ensure energy security and assessment of their effectiveness.

## IV. Discussion

The considered complex methodology will allow comparing environmental risks of various oil and gas companies. Also, the application of the technique gives a clear visio to the management staff of enterprises about the components of the environment most susceptible to negative effects. But the technique, unfortunately, has a number of disadvantages, such as the need to process and compare huge amounts of data for the assessment and the lack of accounting for the impacts as a result of emergency situations in the form of man-made accidents. With the further development of the methodology, these aspects will be taken into account, which will make it possible to apply a similar methodology in any of the oil and gas producing enterprises and bring them one step closer to the status of innovative. An innovative oil and gas production company needs to specialize in the full implementation of the best available technologies and equipment. One of the priority areas of its activity should be the constant reduction of harmful effects on the natural environment, an increase in the level of industrial safety, the organization of healthy and safe working conditions for employees. The advanced nature of the projects being implemented serves as an effective alternative to existing methods of oil and gas field development, which require large investments. The introduction of the best available technologies and the modernization of fixed assets increase the level of production reliability and environmental safety from the consequences of oil and gas production, make it possible to implement efficient and safe field development and reduce the negative impact on the natural environment as a whole.

The level of technological safety is closely related to the innovative potential of the industry. And here, the global oil and gas industry has not been doing well lately. A recent study by the Boston Consulting Group shows that of the world's 50 most innovative companies, the oil and gas sector is represented by only one company, Royal Dutch Shell, which has moved from 30th to 40th place in a year. It is possible to relate differently to this analysis and the places occupied by individual companies, but one cannot fail to notice the general trend - the oil and gas industry is no longer a technological locomotive of the world economy. The solution could be a higher level of integration with high-tech industries, including in the development of new business models. In this regard, it can be mentioned that the rapid development of shale production in the United States was the result of not only a technological breakthrough and extremely favorable financing conditions, but also the use of the principles of a networked business model instead of the traditional vertical hierarchical model for the industry. The search for new optimal business models is important for the industry, since the need for them dictates a change in the general paradigm of the development of the world economy. The sharp rise in the price of oil in the early 2000s, associated with the growth of the Chinese economy, created the idea of an imminent and imminent oil shortage. The consequence was the dominance of national oil companies. By 2007, these (including those privatized shortly before that) were 14 of the world's 20 largest energy producers.

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# SCORE PETROCHEMICAL POLLUTION TERRITORY COMPLEX OF THE CHECHEN REPUBLIC

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**Abstract**

*In the article the results of research of the ecological status of water bodies of the Chechen Republic podvergshie petrochemical pollution of long-period. In this period as a whole in the water bodies of the Chechen Republic is folded the tense ecological situation caused by natural pollution Wednesday, and especially petroleum, biogenic organic and other substances. One of the main sources of water pollution in the basin of the Terek are surface watercourses in the Chechen Republic, pollution made with objects extraction, refining and transportation of oil, sludge, many of which have been destroyed or subjected to destruction presently. Map of petrochemical pollution scheme, is a table of content of petroleum hydrocarbons in soil samples collected in rivers Terek and Sunzha rivers, Neftjanka. Which shows that water resources are in a State of medium and high degree of pollution and in urgent need of organizing activities to optimize their management. The data obtained suggest that there is a gradual decrease in sediment contamination r. Terek and Sunzha r. oil hydrocarbons. The results of the last 5 years show that the largest number of well falls on 2012 year-more than 567 mg/kg.*

**Keywords:** Chechen Republic, petrochemical pollution, air, water resources, environmental condition.

## I. Introduction

The Chechen Republic among the subjects of the Russian Federation in terms of the degree of technogenic impact, including military impact, on the environment is among the heavily polluted areas. Atmospheric air, soil, groundwater and surface water are particularly heavily polluted by enterprises of oil production and transportation, energy and agriculture [1].

## II. Materials and Methods

The main sources of atmospheric pollution are natural, industrial and household processes. They are grouped into the following groups: - pollutants of natural origin (mineral, plant and microbiological); - pollutants formed during the combustion of fuel for the needs of industry, heating of homes, during the operation of transport; - pollutants formed during the combustion and processing of household and industrial waste. This indicates that water resources are in a state of medium and high pollution and are in urgent need of organizing measures to optimize their management. The data obtained indicate a gradual decrease in pollution of the sediments of the Terek River and the Sunzha River with petroleum hydrocarbons. Enterprises of petrochemical and fuel and energy complexes, production of building materials, motor transport and others are significant sources of air pollution of the Chechen Republic, a specific feature of these industries is a large set of ingredients, including inorganic and organic compounds (salts, acids, oxides) a number of the emission ingredients are potent substances. The bottom sediments selected from the Sunzha and Terek rivers were used for the study. Sampling stations are shown in Table 1.

The analysis was carried out by the fluorometric method on the analyzer "Fluorat-02-2M" according to a metrologically certified method. According to the data obtained, the most polluted petroleum hydrocarbons are the soils of the Nefyanka river in the alignment, the Grozny - Chervlennaya - 14.7 mg/kg, the Terek river in the area of the Chervlennaya station - 14.4 mg/kg and the Sunzha river in the area of Grozny (Zhukovsky Street bridge) - 10.2 mg/kg. Soil pollution is uneven in nature. So, other samples taken in the Sunzha river in the area of art.

Petropavlovsk, already contained 4.2 mg/kg of petroleum hydrocarbons. The Terek soils taken at the site of the Kargalinsky hydroelectric complex, as well as in the Sunzha River near the village of Braguna, were characterized by relatively low concentrations of NU - 2.5 and 2.9 mg/kg, respectively (Table 1).

**Table 1:** *Content of NU in soil samples in the rivers Terek, Sunzha and Neftyanka*

| № site | River | Sampling site | Petroleum products mg/kg |
|---|---|---|---|
| 2 | Terek river | st. Chervlennaya | 14,4 |
| 3 | -*- | st. Grebenskaya | 6,4 |
| 4 | -*- | Kargaly hydroelectric complex | 2,5 |
| 6 | Sunzha River | Alkhan-Kala | 1,8 |
| 2 | -*- | Grozny, Zhukovsky str. | 10,2 |
| 10 | -*- | Grozny, Sheripova str. | 3,8 |
| 15 | -*- | s.Braguni | 2,9 |
| 14 | -*- | st. Petropavlovskaya | 4,2 |
| 50 | Neftyanka river | Route Grozny-Chervlennaya | 14,7 |

## III. Results and discussions

In recent years, there has been a clear downward trend in hydrocarbon pollution, and in 2017 the average annual concentration of petroleum carbons was about 50 mg / kg. Thus, it can be assumed that both water and bottom sediments are gradually cleared of oil pollution (Fig. 1). As a result of economic activity, industrial and motor transport enterprises of the Chechen Republic in 2017, 643 thousand tons of harmful substances were emitted into the atmosphere, including 511 thousand tons in Grozny.

The main air pollutants in the territory of the Chechen Republic are still enterprises of the oil and petrochemical industries, road transport, a cement plant and artisanal oil refining. Of all emissions of 84% of harmful substances into the atmosphere by industry (504 thousand tons / year) accounted for enterprises of petrochemistry, oil refining, energy, building materials. The main reasons for the high level of air pollution include: - unsatisfactory implementation of the state plan for environmental protection - weak departmental control over the state of atmospheric pollution and the efficiency of treatment facilities [1; 2].

With the beginning of hostilities, the level of emissions of harmful substances into the atmosphere increased sharply, due to their receipt from burning torches. According to our calculations, more than 500 thousand tons of harmful substances are emitted into the atmosphere per year.

If until 1994 the unfavorable situation for the emission of harmful substances into the atmosphere developed in Grozny, chiri-Yurt settlement, then since 1996 artisanal production of petroleum products has led to the fact that in some settlements of the republic - Tsotsan-Yurt, Mesker-Yurt, Kurchaloi, Mayrtup and others, sanitary standards have been exceeded tenfold.

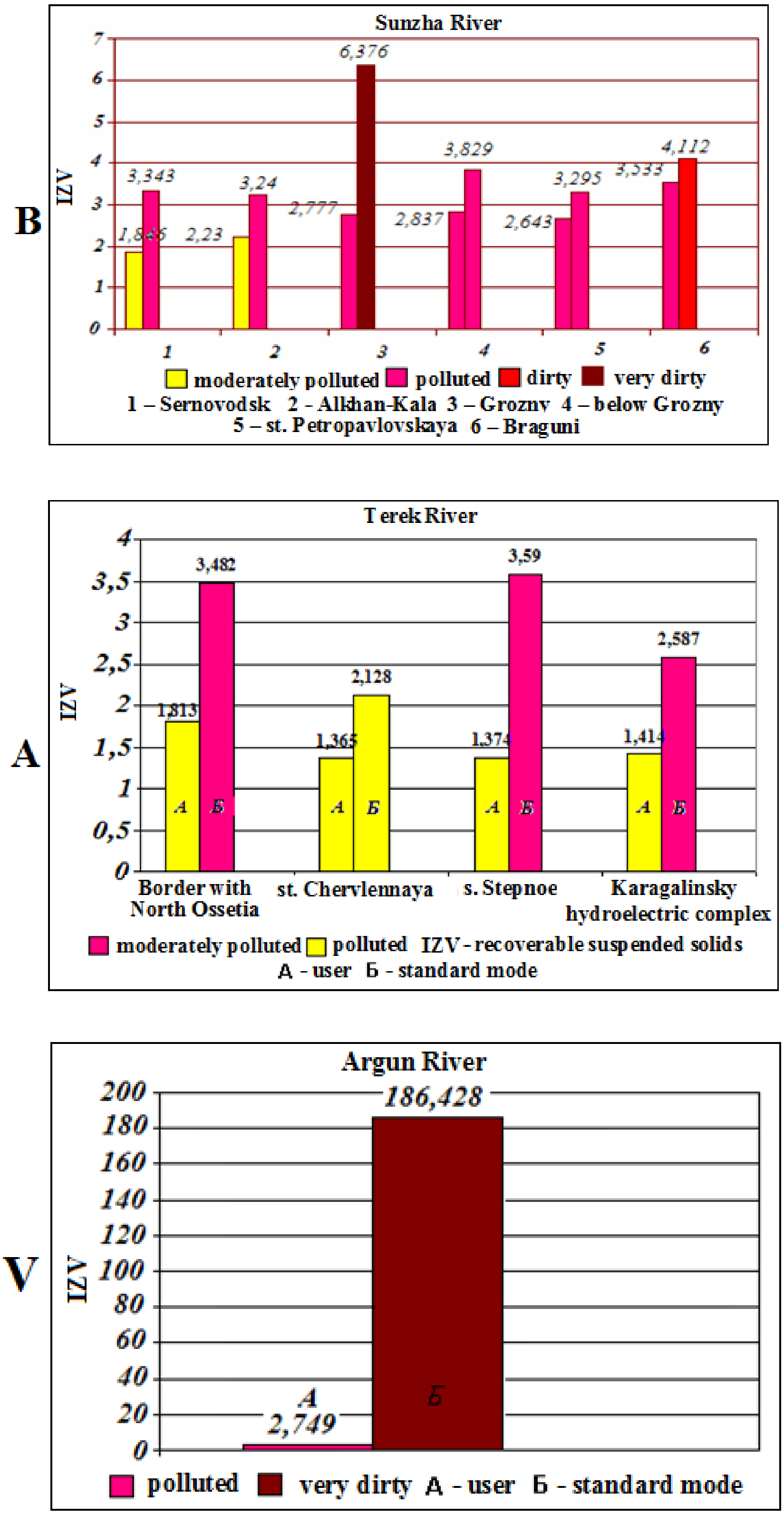
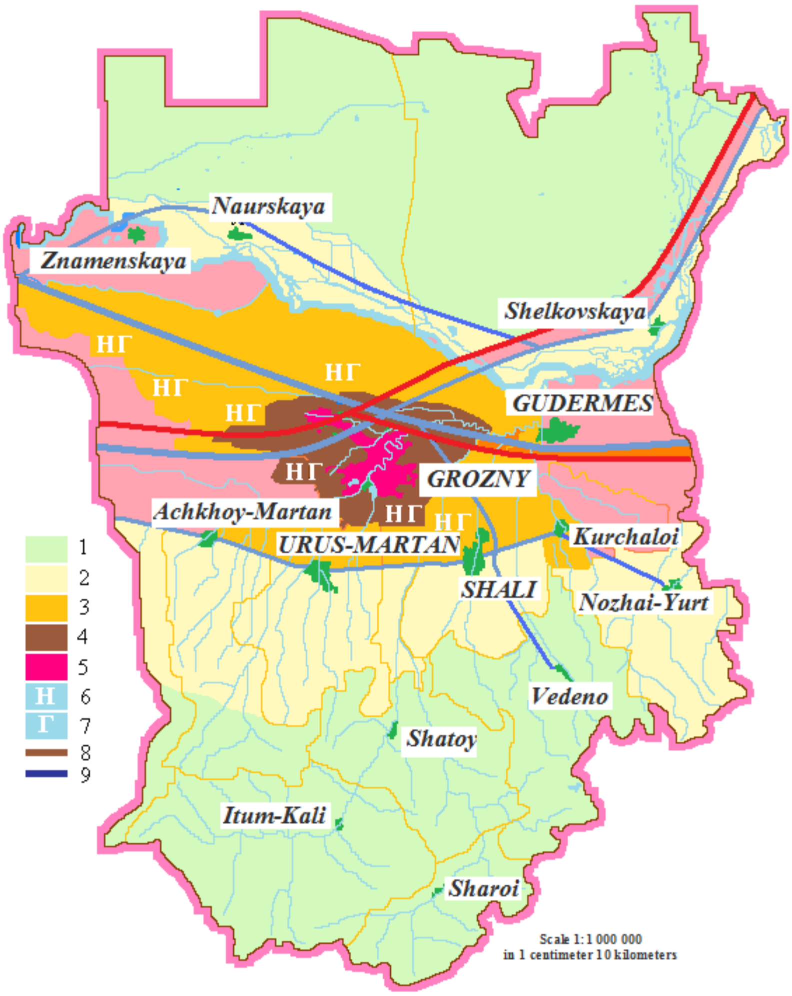



**Figure 1**. (**A, B, V**). *Assessment of water quality of rivers of the Chechen Republic (**A** - Terek, **B** - Sunzha, **V** - Argun) according to **IZV** in the standard mode (taking into account high concentrations of metals)*

This has a very serious impact on the health of the population. Especially high percentage of childhood and oncological diseases (Fig.2) [3,4].




Legend to the map.Conditional Symbol: 1-no pollution; 2 – moderately polluted; 3 – contaminated; 4 – dirty; 5 – very dirty; 6 – oil production; 7 – gas production; 8 – oil pipelines; 9 – gas pipelines.

**Figure 2.** *Zoning of the territory of the Chechen Republic on petrochemical pollution The main pollutants are: 1-hydrocarbons (50%), 2-carbon monoxide (32.8%), 3-sulfur dioxide (8.7%), 4-oxides ofn nitrogen (4.3%); 5 - other pollutants.*

## VI. Conclusion

Studies have shown that the territory of the Chechen Republic is experiencing, although the levels of the Chechen Republic have decreased slightly in recent years, petrochemical pollution. Water bodies have been subjected to particularly severe impact of oil pollution, where unsweetened untreated industrial effluents have been discharged for many years. The above graphic and cartographic material shows that an even greater part of the territory of the Chechen Republic is under the influence of petrochemical pollution.

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# METHODS FOR MEETING REQUIREMENTS IN THE FIELD OF ENGINEERING PRODUCTS SAFETY

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**Abstract**

*The article is devoted to the issues of compliance with the requirements in the field of engineering products safety. In particular, the technical regulations "On the safety of machinery and equipment". The purpose of the work is to develop a management system to ensure the production of safe products. The author proposes a product safety management system. The system is based on the principle of a process approach. The system can be used independently or as a part of an integrated management system. The author proposes a method for evaluating the level of improvement of the organization's processes, including those related to safety.*

**Keywords**: engineering, system, safety, risk

## I. Introduction

In modern conditions of development of technical regulation systems, the issue of integrating the requirements of technical regulations into the organization's management system is of particular relevance. The legislation of the Russian Federation on technical regulation consists of Federal law No. 184 "On technical regulation" [12] and Federal laws and other regulatory legal acts of the Russian Federation adopted in accordance with it. In accordance with Federal law No. 184, a lot of technical regulations have been adopted at present, including:

1. On the safety of high- speed rail transport.
2. On the safety of equipment for working in explosive environments.
3. On the safety of devices running on gaseous fuel.
4. On the safety of pyrotechnic compositions and products containing them.
5. On the safety of lifts.
6. On the safety of machinery and equipment.
7. On the safety of wheeled vehicles.

Technical regulations are a document adopted by an International Treaty of the Russian Federation, ratified in accordance with the legislation of the Russian Federation, or an intergovernmental agreement concluded in accordance with the legislation of the Russian Federation, or a Federal law, or a decree of the President of the Russian Federation, or a resolution of the Government of the Russian Federation and establishes mandatory requirements for the application and execution of technical regulation objects (products, including buildings, constructions and structures or processes related to product requirements for design (including survey), production, construction, installation, adjustment, operation, storage, transportation, sale and utilization) [1-28].

Technical regulations are adopted in order to [12]:

1) protect the life or health of citizens, property of individuals or legal entities, state or municipal property;

2) protect the environment, life or health of animals and plants;

3) warn of actions that mislead buyers.

Technical regulations are adopted to establish measures to ensure safety requirements. In particular, the technical regulation "On safety of machines and equipment" establishes minimum necessary requirements to safety of machines and equipment when designing, manufacturing, installing, adjusting, operating, storing, transporting, realizing and utilizing to protect the life or health of citizens, the property of individuals or legal entities, state or municipal property, environment, the life and health of animals and plants, as well as the prevention of actions misleading purchasers [12]. Article 39 of the technical regulations states that machines and (or) equipment that are put into circulation for the first time on the territory of the Russian Federation are subject to mandatory conformity assessment.

## II. Methodology

The application of “the process approach" when developing, implementing and improving the effectiveness of the quality management system (or any other management system of the organization) is aimed at increasing the satisfaction of customers by meeting their requirements. Understanding and managing the interrelated processes as a system contributes to the effectiveness and efficiency of the organization in achieving the intended results. This approach allows the organization to manage the relationships and interdependencies between the system processes, so that the overall performance of the organization can be improved.

The process approach involves the systematic identification and management of processes and their interaction in such a way as to achieve the intended results in accordance with the quality policy and strategic direction of the organization. Management of processes and systems as a whole can be achieved by using the PDCA cycle paying special attention to risk-based thinking, aimed at using opportunities and preventing undesirable results.

The application of the process approach in the system makes it possible to:

– understand and constantly to fulfill the requirements;
– consider the process from the viewpoint of adding their values:
– achieve effective functioning of processes;
– improve processes based on evaluating data and information.

## III. Results

In organizations, in addition to the traditional management system, such systems as the quality management system (for certification of the organization) and the occupational safety system (to meet the requirements in the field of occupational safety) are being implemented. In this situation, it is logical to develop a Product Safety Management System (PSMS) to meet the requirements of technical regulations, and integrate it into the organization's management system. As an analog, the standard ISO 22000:2018 can be used, which contains the requirements for the organizations involved in food production [3]. The industrial development leads to the fact that it is advisable to develop a single integrated management system at the enterprise, rather than several separate systems aimed at meeting individual, local requirements.

As a part of the creation of the PSMS, it is proposed to develop an organization standard (OS) containing the main requirements for the product safety management system. Due to the fact that quality management systems based on the application of ISO 9000 series standards have become widespread, it is proposed to structurally bring the OS closer to ISO 9001.

The standard contents of the OS "Product safety management system. The requirements”.

1. Application.
2. Normative references.
3. Terms and definitions.
4. Product safety management system.
4.1. General requirements.
4.2. Documentation requirements.
5. Management responsibility.
5.1. Management responsibility.
5.2. Policy in the field of products safety.
5.3. Planning of the product safety management system.
5.3.1 Hazard identification, risk assessment and identification of management measures.
5.3.2 Legislative requirements.
5.4. Responsibility, authority, and information interchange.
5.5. Analysis on the management part.
6. Resource management.
6.1. Providing resources.
6.2. Human resources.
6.3. Infrastructure.
6.4. Production environment.
7. Planning and production of safe products.
7.1. Generalities.
7.2. Program of mandatory preliminary events.
7.3. Hazard analysis.
7.4. Risk-management.
7.5. Verification and validation.
7.6. Tracking system.
7.7. Management of non-conformities.
8. Measurement, analysis, improvement.
8.1. Generalities.
8.2. Monitoring and measurement.
8.3. Continuous improvement.

The proposed PSMS is intended to be used in conjunction with the organization's QMS. Additional documented procedures must be implemented to meet the safety requirements:

1. Risk-management.
2. Hazard analysis.
3. Evaluating the level of process improvement.

In accordance with one of the eight principles of quality management (the process approach) for the implementation of the PSMS, a register of processes was developed. This register is presented in Table 1.

Special attention should be paid to the development and verification of design and technological documentation. At the stages of design and technological preparation of production, it is recommended to use the FMEA analysis methodology or other methods for evaluating the potential risk of defects and (or) product failures that may lead to the violation of the requirements of technical regulations.

Since the requirements of technical regulations, in particular "On the safety of machinery and equipment", are applied to all stages of the product life cycle, including operation by the consumer, the issues related to the rules and technical conditions of operation of the object must be noted in the in-line documentation for the product.

**Table 1:** *Register of the processes of the product safety management system*

| № | Name of the process |
|---|---|
| *1* | ***Management activities in the PSMS*** |
| 1.1 | Strategy, policy and objectives in the field of products safety |
| 1.2 | Planning and development of an FSMS |
| 1.3 | Allocation of responsibilities and privileges* |
| 1.4 | Analysis of the PSMS on the management part |
| 1.5 | Informing the public* |
| 1.6 | Funding the PSMS |
| 2 | ***Main processes of the PSMS*** |
| 2.1 | Mandatory pre- production activities |
| 2.2 | Hazard analysis |
| 2.3 | Risk-management |
| 2.4 | Checking the design documentation |
| 2.5 | Checking the technological documentation |
| *3* | ***Auxiliary processes**** |
| 3.1 | Human resources management |
| *3.1.1* | *Definition of the staff requirements* |
| *3.1.2* | *Staff development and training* |
| *3.1.3* | *Development of a staff social support system* |
| 3.2 | Infrastructure control |
| 3.3 | Material resources control |
| 3.4 | Production environment control |
| *4* | ***Measurement, analysis, improvement**** |
| 4.1 | Process monitoring, measurement and analysis |
| 4.2 | Process control |
| 4.3 | Non- conformities control |
| *Note. For the processes marked with *, it is possible to make changes and additions to the diagram of the existing QMS processes .* | |

PSMS, like any other system, needs constant improvement. However, a number of large companies suffer significant losses, despite major improvements in their processes. This is the so-called "process paradox", which is typical for many domestic organizations [4-15]. In this regard, a three-level system for evaluating process improvement is proposed. This system can be used both for the PSMS and for the QMS of the organization as a whole.

Each level of improvement is divided into two sub-levels, depending on the degree of implementation of the requirements for the process. Each next level includes the requirements of the previous one.

Level I - Certainty. It is characterized by setting goals and objectives of the process. The activity concerning the process description is completed. Outputs, inputs, control actions and process resources are defined. It should be noted that resources alone, taken separately, do not determine the results of the activities in advance. The quality of performance depends on two components: the quality of goals and the quality of execution.

**Table 2:** *Criteria for evaluating the levels of improvement of the PSMS processes*

| № | Criterion name | Weight |
|---|---|---|

| | | |
|---|---|---|
| **Criterion 1. Leading role of management** | | |
| 1.1 | Personal involvement of management in the formation and development of the mission, vision, core values, policies, main goals and objectives in the field of product safety. | 0,35 |
| 1.2 | Personal involvement of management in ensuring the development , implementation and continuous improvement of the product safety management system. | 0,35 |
| 1.3 | Personal involvement of management in providing feedback to the staff to improve their performance. | 0,30 |
| **Criterion 2. Policy and strategy** | | |
| 2.1 | Development and improvement of policies and strategies and the degree of participation of the interested parties in these processes. | 0,25 |
| 2.2 | Mechanisms for collecting and analyzing comprehensive information about the effectiveness and efficiency of the company's operation when forming policies and strategies | 0,25 |
| 2.3 | Mechanisms for projecting policy and strategy implementation to all levels of management, structural divisions, and key processes | 0,25 |
| 2.4 | Mechanisms for informing the staff and consumers about the policy and strategy | 0,25 |
| **Criterion 3. Process management** | | |
| 3.1 | Activities for the development , implementation and improvement of the SMBP | 0,20 |
| *3.1.1* | *Documentation control* | *equally* |
| *3.1.2* | *Records control* | |
| *3.1.3* | *Planning and building the organizational structure of the PSMS, distribution of responsibilities and priveleges* | |
| *3.1.4* | *Building, maintaining and developing a system for measuring and monitoring the PSMS processes* | |
| *3.1.5* | *Planning the processes of the PSMS* | |
| 3.2 | Main processes of the PSMS | 0,60 |
| *3.2.1* | *Mandatory pre- production activities* | *equally* |
| *3.2.2* | *Hazard analysis* | |
| *3.2.3* | *Risk-management* | |
| *3.2.4* | *Checking the engineering documentation* | |
| *3.2.5* | *Checking the technological documentation* | |
| 3.3 | Auxiliary processes | 0,20 |
| *3.3.1* | *Infrastructure and production environment control* | *equally* |
| *3.3.2.* | *Control of auxiliary processes* | |
| **Criterion 4. Results of activity** | | |
| 4.1 | Mechanisms for collecting and analyzing information on the results of the PSMS activities | 0,30 |
| 4.2 | Financial results of the PSMS | 0,35 |
| 4.3 | Other non-financial results of the PSMS activities | 0,35 |

Level II – Performance. Performance is the degree of implementation of planned activities and achievement of planned results. Based on this definition, it is necessary to allocate a criterion for rating a process to the sublevels of the performance level. The organization's processes are fully described in a formalized form.

Level II – Efficiency. Efficiency is the relationship between the result achieved and the resources used. The main activity of the organization is aimed at identifying and minimizing activities that do not add value to consumers (including internal ones). The organization should develop evaluation criteria. This is a necessary condition for the organization to "get" to sublevel 2 of level I. It is proposed to use the criteria listed in table 2 to evaluate the PSMS.

These criteria may change (new ones may be added or removed) due to the specific character of a particular product or production. Accordingly, the expert method can change the weight coefficients of the criteria. The reasons for applying certain weight coefficients must be recorded in the appropriate type of records [11, 17, 21].

The evaluation of the levels of excellence of various components of the model is based on the following six "dimensions" that correspond to the basic principles of TQM:

1. The degree of focus on consumers and other interested parties (from minimum satisfaction to full consideration of the interests of all interested parties).

2. The degree of consistency of the applied approach (from short-term episodic measures to long-term policy and strategy planning).

3. The extent to which the approach is applied across management levels, departments and processes.

4. The degree of staff involvement in the relevant processes.

5. The degree to which the process procedures are documented (from informal execution to fully documented processes).

The degree of focus is on preventing inconsistencies and continuous improving, rather than fixing problems that arise.

The PSMS self-evaluating system includes 4 criteria for evaluating the levels of process improvement (leading role of management, policy and strategy, process management, performance). Each criterion has three levels of improvement. Each level of improvement has two evaluation options, depending on the level of development. To evaluate all the subcriteria and components of the model group, special qualimetric scales are used that verbally describe three ordered "levels of excellence" or stages of development of the subcriteria and components. These three levels of excellence correspond to a 6-point numerical scale (from 1 to 6 points). This allows us to move from a qualitative evaluation of the relevant subcriteria and components (activities, works) to their quantitative evaluation. The methodology for calculating the values of the" improvement levels "of criteria is developed taking into account the "importance" of each of the indicators in the overall process.

Calculation the score in subcriteria points (for criterion 3). To do this, use the weighted average formula.

$$Q_i=\sum q_k \times b_k \quad (1)$$

where $q_K$ is the weight of the k-th component of the i-th criterion; n is the number of components in the subcriterion; $Q_i$ is the evaluation of the i-th subcriterion in points.To calculate the score in criteria points we use the following formula.

$$Q_m=\sum q_n \times Q_i \quad (2)$$

where $q_n$ is the weight of the i-th subcriterion;$Q_i$ is the evaluation of the i-th subcriterion in points;.k is the number of criterion components; $Q_m$ is the score in points of the m-th criterion.

The calculation of the overall evaluation of the organization.

$$Q=\sum q_m \times Q_m \quad (3)$$

where $q_m$ is the weight of the m-th criterion;Q is the overall rating in points.

To "balance" the influence of different criteria, the criteria weights ($q_k$) are applied. When grouping processes according to the activity (for example, human resources management processes or basic production processes), process weights ($q_n$) are used. When evaluating the level of improvement of the organization, the process group weights ($q_m$) are used. Formula 1-3 are used for calculation and the results can be presented in the form of a leaf-type diagram (Fig.1).

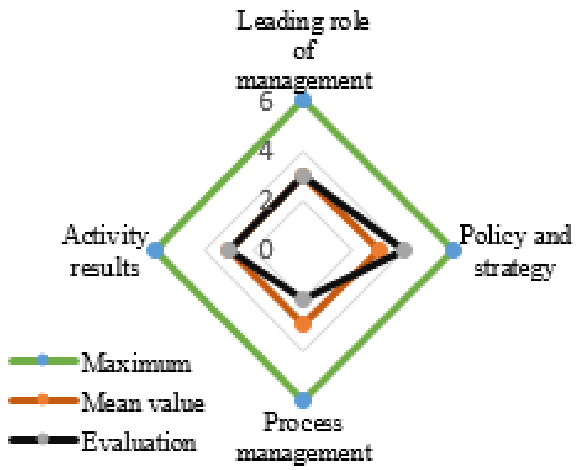


**Figure 1:** ***Leaf-type diagram***

## IV. Discussion

The government of the Russian Federation intends to increase the amount of fines for violations of technical regulations by 20 times. The corresponding bill has been submitted to the state Duma and is being prepared by deputies for consideration. If the document is adopted, the business will receive confiscation of the goods and a fine of one million rubles for non- compliance with the mandatory requirements of technical regulations.

## V. Conclusions

The compliance with the requirements of technical regulations is mandatory for all territories of the Russian Federation. However, due to the fact that they have been adopted quite recently, a unified approach to the methods of fulfilling the requirements has not yet been formed. As a result of the research, the author came to the conclusion about the high relevance of this problem. The article proposes an approach to meet the requirements of technical regulations, based on the construction of a product safety management system. The proposed system can be independent or used as a part of an integrated management system. The developed methodology for evaluating the levels of process improvement based on ISO 9000 series standards is applicable for choosing the optimal direction of development of the organization's processes, which entails obtaining strategic benefits, including material profit.

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# PORT TRANSPORTATION CRITICAL INFRASTRUCTURE SAFETY AND OPERATION COST JOINT OPTIMIZATION

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**Abstract**

*To analyze jointly the system safety and its operation cost optimization, we propose the procedure of determining the optimal values of limit transient probabilities of the system operation process at the particular operation states that allows to find maximal system safety indicators, through applying the system safety model and linear programing. Next, to find the system conditional operation total cost during the fixed operation time, corresponding to this system maximal safety indicators, we replace the limit transient probabilities, existing in the formula for the system operation total cost during the fixed operation time, by their optimal values existing in the formulae for the coordinates of the system safety function after maximization. The proposed procedure is applied to the port oil terminal critical infrastructure and to fulfill in practice the obtained terminal optimal safety and operation cost results, the modification of its operation process is proposed.*

**Keywords**: safety, operation cost, optimization, port oil terminal, piping transport

## I. Introduction

To tie the investigation of the complex technical system safety together with the investigation of its operation cost, the semi-Markov process model [6], [8], [10], [24], [26], [28], can be used to describe this system operation process [16], [19]. The system operation process model, under the assumption on the system safety multistate model [30], can be used to construct the general safety model of the complex multistate system changing its safety structure and its components safety parameters during variable operation conditions [12], [15], [19]. Further, using this general model, it is possible to define the complex system main safety characteristics such as the system safety function, the mean values and standard deviations of the system lifetimes in the system safety state subsets and in the system particular safety states [2], [13]-[14], [19] and other system safety indicators can be introduced as well [9], [21]-[23], [27]. Using the system general safety model, it is possible to change the system operation process through applying the linear programming [11] for maximizing the system safety function [19] and finding the optimal values of the system limit transient probabilities at the particular operation states. Having the system operation process characteristics and the system conditional instantaneous operation costs at the operation states, it is also possible to create the system general operation total cost model during the fixed operation time [16], [18]. To analyze jointly the system safety and its operation cost optimization, in the case we prefer more the system safety maximization than the system operation cost minimization, we first apply the procedure of determining the optimal values of limit transient probabilities of the system operation process at the particular operation states that maximize the system safety. Next, to find the system conditional operation total cost during the fixed operation time, corresponding to this system maximal safety, we replace the limit transient probabilities at particular operation states, existing in the formula for the operation total cost, by their optimal values existing in the formula for the system maximal safety function coordinates. Whereas, in the case we prefer more the system operation cost minimization than the system safety maximization, then to analyze jointly the system safety and operation cost optimization, we first apply the procedure of determining the optimal values of limit transient probabilities of the system operation process at the particular operation states that minimize the system operation total cost during the fixed operation time and next we find the system conditional safety indicators, corresponding to this system minimal total operation cost.

## II. Port oil terminal critical infrastructure operation and safety

### 2.1. Terminal description

The port oil terminal placed at the Baltic seaside is designated for receiving oil products from ships, storage and sending them by carriages or trucks to inland and in reverse way as well [22]. The considered terminal is composed of three parts *A*, *B* and *C*, linked by the piping transportation system with the pier. The main technical assets (components) of the port oil terminal critical infrastructure are: $A_1$ – port oil piping transportation system, $A_2$ – internal pipeline technological system, $A_3$ – supporting pump station, $A_4$ – internal pump system, $A_5$ – port oil tanker shipment terminal, $A_6$ – loading railway carriage station, $A_7$ – loading road carriage station, $A_8$ – unloading railway carriage station, $A_9$ – oil storage reservoir system.

The asset $A_1$, the port oil piping transportation system operating at the port oil terminal critical infrastructure consists of three subsystems:

- the subsystem $S_1$ composed of two pipelines, each composed of 176 pipe segments and 2 valves,
- the subsystem $S_2$ composed of two pipelines, each composed of 717 pipe segments and 2 valves,
- the subsystem $S_3$ composed of three pipelines, each composed of 360 pipe segments and 2 valves.

The asset $A_1$ operation is the main activity of the port oil terminal involving the remaining assets $A_2$ – $A_9$. The port oil transportation system is a series system composed of two series-parallel subsystems $S_1$, $S_2$, each containing two pipelines and one series-"2 out of 3" subsystem $S_3$ containing 3 pipelines. The subsystems $S_1$, $S_2$ and $S_3$ are forming a general series port oil transportation system safety structure presented in Figure 1.

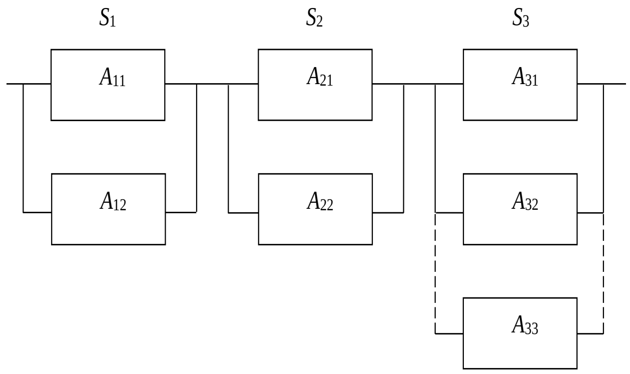


**Figure 1:** *The port oil piping transportation system safety structure*

### 2.2. Operation process

On the basis of the statistical data and expert opinions [7], it is possible to fix the port oil terminal critical infrastructure operation process number of operation states $\nu = 7$ and to define the following operation states [16]:

- the operation state $z_1$ – transport of one kind of medium from the terminal part B to part C using two out of three pipelines of the subsystem $S_3$ of the asset $A_1$ and assets $A_2$, $A_4$, $A_6$, $A_7$, $A_9$;
- the operation state $z_2$ – transport of one kind of medium from the terminal part C to part B using one out of three pipelines of the subsystem $S_3$ of the asset $A_1$ and assets $A_2$, $A_4$, $A_8$, $A_9$;
- the operation state $z_3$ – transport of one kind of medium from the terminal part B through part A to pier using one out of two pipelines of the subsystem $S_1$ and one out of two pipelines of the subsystem $S_2$ of the asset $A_1$ and assets $A_2$, $A_4$, $A_5$, $A_9$;
- the operation state $z_4$ – transport of one kind of medium from the pier through parts A and B to part C using one out of two pipelines of the subsystem $S_1$, one out of two pipelines in subsystem $S_2$ and two out of three pipelines of the subsystem $S_3$ of the asset $A_1$ and assets $A_2$, $A_3$, $A_4$, $A_5$, $A_6$, $A_7$, $A_9$;
- the operation state $z_5$ – transport of one kind of medium from the pier through part A to B using one out of two pipelines of the subsystem $S_1$ and one out of two pipelines of the subsystem $S_2$ of the asset $A_1$ and assets $A_2$, $A_3$, $A_4$, $A_5$, $A_9$;
- the operation state $z_6$ – transport of one kind of medium from the terminal part B to C using two out of three pipelines of the subsystem $S_3$, and simultaneously transport one kind of medium from the pier through part A to B using one out of two pipelines of the subsystem $S_1$ and one out of two pipelines of the subsystem $S_2$ of the asset $A_1$ and assets $A_2$, $A_3$, $A_4$, $A_5$, $A_6$, $A_7$, $A_9$;
- the operation state $z_7$ – transport of one kind of medium from the terminal part B to C using one out of three pipelines of the subsystem $S_3$, and simultaneously transport second kind of medium from the terminal part C to B using one out of three pipelines of the subsystem $S_3$ of the asset $A_1$ and assets $A_2$, $A_4$, $A_6$, $A_7$, $A_8$, $A_9$.

On the basis of the suitable statistical data coming from [7], it is possible to estimate the port oil terminal operation process characteristics [19]:

- the values of limit transient probabilities $p_b$, $b = 1,2,\ldots,7$, at the particular operation states $z_b$, $b = 1,2,\ldots,7$:

$$p_1 = 0.395,\ p_2 = 0.060,\ p_3 = 0.003,\ p_4 = 0.002,\ p_5 = 0.200,\ p_6 = 0.058,\ p_7 = 0.282; \tag{1}$$

- the expected values of the total sojourn times at the particular operation states $z_b$, $b = 1,2,\ldots,7$, during the fixed operation time $\theta = 1$ year, expressed in days:

$$\hat{M}_1 = 144.175,\ \hat{M}_2 = 21.9,\ \hat{M}_3 = 1.095,\ \hat{M}_4 = 0.73,\ \hat{M}_5\hat{M}_5 = 73, \hat{M}_6 = 21.17,\ \hat{M}_7\ \hat{M}_7 = 102.93. \tag{2}$$

**Safety**

We distinguish the following three safety states of the terminal and its components [16]:

- a safety state 2 – the components and the port oil terminal are fully safe,
- a safety state 1 – the components and the port oil terminal are less safe and more dangerous because of the possibility of environment pollution,
- a safety state 0 – the components and the port oil terminal are destroyed,

and we assume that there are possible the transitions between the components safety states only from better to worse ones.

After applying the procedure of the system safety maximization, we can get the optimal limit transient probabilities of the port oil terminal at the particular operation states [25]:

$$\dot{p}_1 = 0.46,\ \dot{p}_2 = 0.08,\ \dot{p}_3 = 0.002,\ \dot{p}_4 = 0.001,\ \dot{p}_5 = 0.15,\ \dot{p}_6 = 0.04,\ \dot{p}_7 = 0.267, \tag{3}$$

and the corresponding optimal safety function coordinates of the port oil terminal:

$$\dot{S}(t,1) = 0.46\exp[-0.12371t] + 0.08\exp[-0.12246t] + 0.002\exp[-0.131548t] + 0.001\exp[-0.146885t] + 0.15\exp[-0.131548t] + 0.04\exp[-0.146885t] + 0.267\exp[-0.12496t],\ t \ge 0, \quad (4)$$

$$\dot{S}(t,2) = 0.46\exp[-0.193913t] + 0.08\exp[-0.191913t] + 0.002\exp[-0.206087t] + 0.001\exp[-0.230261t] + 0.15\exp[-0.206087t] + 0.04\exp[-0.230261t] + 0.267\exp[-0.195913t],\ t \ge 0. \quad (5)$$

## 1. Port oil terminal critical infrastructure operation cost

The port oil terminal mean operation total cost during the operation time $\theta$ = 1 year is given by [16], [25]

$$\hat{\boldsymbol{C}}(\theta) \cong 0.395 \cdot 1553110.88 + 0.06 \cdot 268320.64 + 0.003 \cdot 58858.528 + 0.002 \cdot 90183.04 + 0.2 \cdot 130735.2 + 0.058 \cdot 655308.16 + 0.282 \cdot 1133107.008 \cong 1013630. \quad (6)$$

# III. Joint system safety optimization and operation cost analysis

### 3.1. Port oil terminal operation cost corresponding to its maximal safety

To find, the system conditional operation total cost during the fixed operation time of one year, corresponding to the system maximal safety coordinates, we replace $p_b$, $b$ = 1,2,…,7, given by (1) and existing in the formula (6) for the the system total operation cost, by $\dot{p}_b$, $b$ = 1,2,…,7, given by (3) and existing in (4)-(5). This way, we get the port oil terminal conditional operation total cost during the fixed operation time of one year, corresponding to the system maximal safety coordinates, given by

$$\hat{C}(\theta)\ \hat{C}(\theta) \cong 0.46 \cdot 1503110.88 + 0.08 \cdot 268320.64 + 0.002 \cdot 58858.528 + 0.001 \cdot 90183.04 + 0.15 \cdot 130735.2 + 0.04 \cdot 655308.16 + 0.267 \cdot 1133107.008 \cong 1084467. \quad (7)$$

### 3.2. Discussion of results

Thus, if we prefer the high safety of the port oil terminal more than ensuring the terminal lower operation total cost, we can modify this system operation process through replacing approximately the limit transient probabilities at the operation states $p_b$, $b$ = 1,2,…,7, at the particular operation states before the system safety maximization given by (1) by the values convergent to their optimal values $\dot{p}_b$, $b$ = 1,2,…,7, after the terminal safety maximization given by (3). In practice, it is easier to modify the considered terminal operation process through replacing approximately the terminal total operation time mean values at the particular operation states during the fixed operation time of $\theta$ = 1 year, determined by (2) by their optimal values after the terminal safety maximization, determined according to the approximate formula from [17], after considering (3), given in days by:

$$\dot{\hat{M}}_1 = 167.9,\ \dot{\hat{M}}_2 = 29.2,\ \dot{\hat{M}}_3 = 0.73,\ \dot{\hat{M}}_4 = 0.365,\ \dot{\hat{M}}_5 = 54.75, \dot{\hat{M}}_6 = 14.6,\ \dot{\hat{M}}_7 = 97.455. \quad (8)$$

The procedure of the terminal operation process modification can be performed for other than the above fixed operation time of 1 year, dependently to the system operator comfort in the achievement of the best results of the system operation total times at the particular operation states convergence to their optimal values resulting from the performed system safety maximization.

# IV. Conclusion

The proposed system safety and system operation cost optimization procedures can be used in safety and operation cost optimization of various real complex systems and critical infrastructures [9], [17], [23], [25]. Further research can be related to considering other impacts on the system safety and its operation cost, for instance a very important impact related to climate-weather factors [15], [20], [29] and resolving the issues of critical infrastructure [23] safety and operation cost optimization and discovering optimal values of safety, operation cost and resilience indicators of system impacted by the operation and climate-weather conditions [20]. These developments can also benefit the mitigation of critical infrastructure accident consequences [1], [3]-[5] and inside and outside dependences [14] and to minimize the system operation cost and to improve critical infrastructure resilience to operation and climate-weather conditions [15], [20], [29]. The proposed optimization procedures and perspective of future research can give practically important possibility of real systems effectiveness improvement through their new operation strategy application.

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# GROUNDWATER OF GANIKH-AYRICHAY FOOTHILLS ON THE PROSPECTS OF USE

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**Abstract**

*At last years, the demand for drinking and irrigation water increased sharply of our republic. The main water resources Kura and Araz rivers before get to our country, they were polluted with various chemical elements and compounds, organic substances, and the water level of the rivers decreased by 30%. The geological and hydrogeological conditions of the area have been thoroughly studied in order to select a sustainable water source in order to improve the drinking water supply of Baku and the Absheron Peninsula, as well as the city of Balakan. The object of study is the Ganikh-Ayrichay (Alazan) foothill plain, located on the southern slopes of the Main Caucasus Range, 210 km long and up to 30 km wide in Azerbaijan. Geophysical electrical exploration (GEZ) was conducted in the area with the ERA-MAX device and interpreted with the help of special computer programs. It was determined that the total mineralization rate (GMP) of plain ground and pressurized waters does not exceed 0.5-0.7g/l. These waters are mainly hydrocarbonate and mixed cations.*

**Keywords**: Ganikh-Ayrichay foothill plain, water supply, aquifer, ground and pressurized waters, percent of mineralization

## I. Introduction

Compared to neighboring republics, Azerbaijan's drinking water resources are unevenly distributed and limited in the South Caucasus. At the same time, 70% of the water resources formed outside of country. The main water resources Kura and Araz rivers before get to our country, they were polluted with various chemical elements and compounds, organic substances. Measures are being to take gradually replace the water of the Kura River, which is currently used in the water supply of Baku with quality groundwater resources.

Given the problems of protection and preservation of the environment, groundwater and surface water resources, forest massifs, especially the consequences of global climate change, it is impossible completely to solve them by individual states in this time. Consequently, all countries of the world or neighboring countries should resolve these issues globally. It is necessary to implement the conventions adopted by the UN [1-3].

Azerbaijan begins from the top of Tinov Rosso (3374 m), the border of the Main Caucasus Range in Azerbaijan, which represents most of the Greater Caucasus, providing the formation of the largest groundwater and surface water bodies. In many parts of the range, the height is more than 3,000 m, and in the central part it is more than 4,000 m. Absolute values of this range are gradually decreasing and expanding in the south-east of Bazarduzu-4466 m, Tufandag-4191m, Bazaryurd-4126 m, Babadag-3629m peaks. The length of the Ganikh-Ayrichay foothill plain in Azerbaijan is 210 km, and its width is up to 30 km.

The main rivers flowing from the southern slope of the Greater Caucasus Mountains flow perpendicular to the direction of elongation of Grade I tectonic rocks. Therefore, they intersect structures of different neotectonic regimes in the direction of their currents. Many of their tributaries extend perpendicular to the main river on tectonic faults.

Mountain rivers of the north-eastern slope of the Greater Caucasus (Samur, Gusarchay, Gudialchay, Garachay, Valvalachay, Shabranchay, Atachay) and rivers of the southern slope (Ganikhchay, Balakanchay, Ayrichay, Mukhakhchay, Katehchay, Kaychaychay, Talachay, Mazimchay) derives its sources from mountain ranges at an altitude of 2000-4000 m above sea level. These rivers form riverbeds and waterfalls in their streams, and when they reach the plains, they form strong ravines and divide into many tributaries, forming natural outflows (springs) of groundwater.

Orographically, the study area characterized by a very complex geological structure, as a typical mountainous area with sharply fragmented southern slopes of the Main Caucasus Range. The geological structure of the area includes complex complexes of various sediments formed in different paleogeographic and geodynamic conditions of the Meso-Cenozoic.

The history of geological development of the area played an important role in the formation of the Greater Caucasus rivers, their tributaries and groundwater complexes, in the formation of classical hydrogeological conditions as a whole, especially in the collection of sediments of the Fourth Period (QIV). The Ganikh-Ayrichay valley consists of the Fourth Period and the Pliocene large riverbed. The thickness of Upper Pliocene and Quaternary sediments is in the range of 1000 m. Mesozoic sediments were collected in the eastern part, and Mesozoic and Paleogene sediments in the west.

The relevance of the article is that the groundwater resources of the basin are estimated at 23-25 $m^3/s$, and the huge Ganikh-Ayrichay foothills begin in the north of Balakan region and in the south it includes the administrative districts of Zagatala, Gakh, Sheki, Oguz, Gabala, Goychay and Ismayilli regions area included. From 2010, high-quality drinking water for 5 $m^3/s$ is supplied to Baku via the main water pipeline from the Oguz-Gabala section of this basin, and in the coming years, it is planned to build 2-3 new water pipelines from this field to Baku. Proceeding from this, taking into account of the Samur-Valvalachay and Ganikh-Ayrichay foothills on the north-eastern and southern slopes of the Greater Caucasus in the next 10 years, the protection, conservation and efficient use of both reservoirs is one of the most important issues.

The annual operational reserves of the republic's usable waters are concentrated in the Samur-Shabran, Ganikh-Ayrichay, Ganja-Gazakh, Mil-Garabagh, Jabrayil and Nakhchivan foothills. Only in the geological section of the Samur-Shabran and Ganikh-Ayrichay foothills is prevalent large river rocks, gravel and sandy rocks. The good development of the river network, the thickness and size of the aquifers and river cones, provided very important hydrogeological conditions for the Quaternary sediments at the intersection of these areas (Figure 1.).

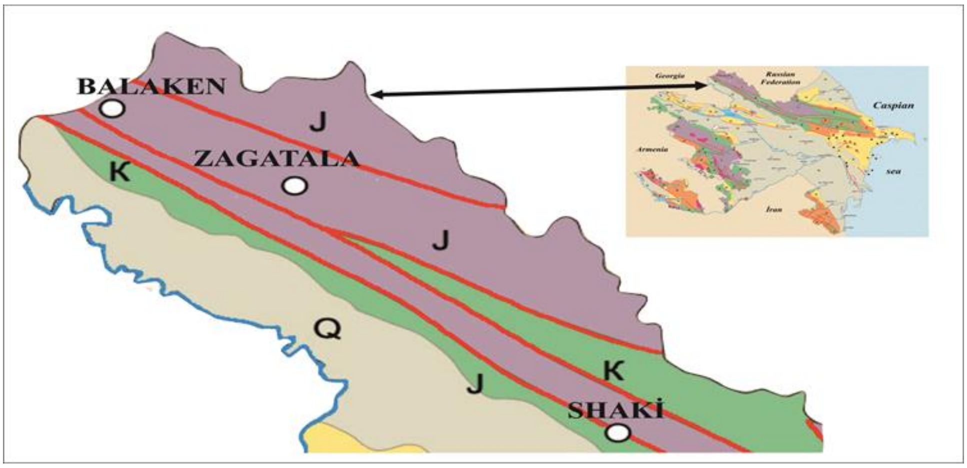

**Figure 1:** *Overview map of Azerbaijan*

Considering all this, the foothills of Samur-Shabran and Ganikh-Ayrichay have proven reserves of high categories (A, B, C1, C2) based on existing wells, and each of the two giant reservoirs should be used mainly for water supply to Baku and the Absheron Peninsula.

The foothill plain of Ganikh-Ayrichay, like the huge artesian basin in Azerbaijan, is characterized by the presence of large surface watercourses filled with coarse-grained alluvial and proluvial-diluvial deposits, and by the presence of intense atmospheric precipitation. The groundwater runoff from Quaternary sediments, which have a large thickness in this area, form due to the recharge of groundwater from the north of the Balakan-Zagatala zone, surface water and atmospheric precipitation, as well as water under pressure from the depth [4].

In accordance with the agreement signed between "Azersu" OJSC “Su kanal” Research and Design Institute and "Hydro Geo Environment Group" LLC in 2020, as a result of the work carried out on the selection of sustainable water sources to improve drinking water supply of Balakan city, Ganikh-Ayrichay confirms the great role of the plain in sustainable water supply.

During the research, hydrogeological conditions were assessed, comprehensive geophysical studies have once again confirmed the conditions of occurrence, depth and thickness of the aquifers. Monitoring of existing water intake wells, static and dynamic well levels, flow and determined the chemical composition of the water (Table 1) [5, 6].

**Table 1:** *Results of water samples analysis (2021)*

| № | **Wells** | **E-1** | **E.-2** | **W-3** | **W-7** | **W-11** | **W-12** | **W-24** | **W-25** |
|---|---|---|---|---|---|---|---|---|---|
| 1 | pH | 7,24 | 7,27 | 6,98 | 7,3 | 7,01 | 6,76 | 7,46 | 7,36 |
| 2 | Mineralization | 387,6 | 557,7 | 204,5 | 201,7 | 193,8 | 200,9 | 658,3 | 377,6 |
| 3 | Hydrocarbonate- $HCO_3$ | 231,8 | 396,5 | 85,4 | 85,4 | 79,3 | 85,4 | 427 | 231,8 |
| 4 | Sulfates ($SO_4^{2-}$) | 22 | 8 | 59 | 58 | 60 | 59 | 8 | 15 |
| 5 | Chlorides ($Cl^-$) | 26,6 | 9,6 | 4,6 | 2,8 | 1,4 | 2,8 | 51,8 | 22,3 |
| 6 | Calcium ($Ca^{2+}$) | 50, | 76,2 | 36,1 | 36,1 | 36,1 | 36,1 | 76,2 | 56,1 |
| 7 | Magnesium ($Mg^{2+}$) | 13,4 | 21,9 | 9,7 | 8,5 | 8,5 | 8,5 | 30,4 | 14,6 |
| 8 | $Na^++K^+$ | 34 | 32 | 4,8 | 5,5 | 3,2 | 4,8 | 54,7 | 19,8 |
| 9 | Nitrites ($NO_2^-$) | 0,015 | 0,037 | 0,004 | 0,007 | 0,06 | 0,07 | 0,28 | 0,48 |
| 10 | Nitrates ($NO_3^-$) | 0,03 | 0,08 | 0,22 | 0,27 | 0,23 | 0,24 | 0,02 | 0,01 |
| 11 | Ammonium ($NH_4$) | 0,08 | 0,29 | 0,05 | 0,07 | 0,06 | 0,07 | 0,28 | 0,48 |
| 12 | Iron ($Fe^{3+}$) | 0,2 | 0,19 | 0,59 | 0,28 | 0,3 | 0,44 | 0,18 | 0,09 |
| 13 | Copper ($Cu^{2+}$) | - | - | - | - | - | - | - | - |
| 14 | Aluminum ($Al^{3+}$) | 0,015 | 0 | 0,012 | 0,012 | 0 | 0 | 0,288 | 0 |
| 15 | Zinc ($Zn^{2+}$) | 0,03 | 0,08 | 0,22 | 0,27 | 0,23 | 0,24 | 0,02 | 0,01 |

In the northern part of the Ganikh-Ayrichay foothill plain, in the territory of the village of Solban, Balakan region, geophysical studies by 6 points of the SEZ with 1 profile were carried out performed by DC vertical electrical sensing method (DCS) [7]. As a result of research conducted by this method, all the layers involved in the geological section of the area were interpreted by special computer programs to a depth of 230 m and final plans-profiles were compiled (Figure 2).

At the same time on the site drilled two exploration wells and along with the hydrogeological parameters of the area, the lithological features of the geological section, especially their thickness, were clarified. During the experimental-injection water in the exploration wells monitoring operations were carried out in existing wells and interactions were assessed. (Tables 2, 3).

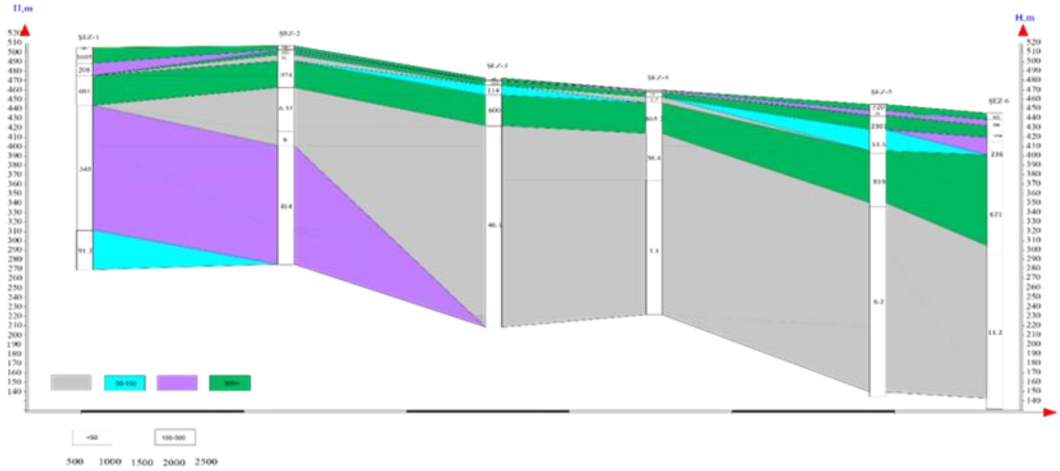

**Figure 2:** *Profile built on 6 GEZ points of Balakan region*

**Table 2:** *Lithological composition of exploration well No. 1 of Balakan region*

| **Balaken district** | | **Exploration well number K-1** | | **Litological composition** | |
|---|---|---|---|---|---|
| Based on rock samples taken from every meter interval | | | | X | 619921.58 |
| | | | | Y | 4620634,00 |
| | | | | Z | 445 |
| S/№ | Name of rock example | How many meters | From meters | To meters | |
| 1 | Land | 1 | 0 | 1 | |
| 2 | Gravel | 77 | 1 | 78 | |
| 3 | Gravel filler clay | 12 | 78 | 90 | |
| 4 | Clay-gravel with clay filler | 3 | 90 | 93 | |
| 5 | Gravel filler clay | 7 | 93 | 100 | |
| 6 | Clay-gravel with clay filler | 6 | 100 | 106 | |
| 7 | Clay | 8 | 106 | 114 | |
| 8 | Clay-gravel with clay filler | 4 | 114 | 118 | |

**Table 3:** ***Lithological composition of exploration well No. 2 of Balakan region***

| **Balaken district** | | **Exploration well number K-2** | | **Litological composition** | |
|---|---|---|---|---|---|
| Based on rock samples taken from every meter interval | | | | X | 621480.25 |
| | | | | Y | 4622477,35 |
| | | | | Z | 522 |
| S/№ | Name of rock example | How many meters | From meters | To meters | |
| 1 | Land | 1 | 0 | 1 | |
| 2 | Gravel | 41 | 1 | 42 | |
| 3 | Gravel with sand filler | 6 | 42 | 48 | |
| 4 | Gravel | 33 | 48 | 81 | |
| 5 | Gravel filler clay | 7 | 81 | 88 | |
| 6 | Sand filler clay | 14 | 88 | 102 | |
| 7 | Gravel filler clay | 8 | 102 | 110 | |

| | | | | |
|---|---|---|---|---|
| 8 | Sand filler clay | 2 | 110 | 112 |
| 9 | Gravel with sand filler | 11 | 112 | 123 |
| 10 | Black clay | 18 | 123 | 141 |

Thus, the Ganikh-Ayrichay foothill plain was identified in previous years, in particular, the stability of the main geological-tectonic and hydrogeological indicators of the sediments of the IV period was confirmed. Centralized water supply to Baku and the Absheron Peninsula at the beginning of 2000 was calculated for a population of about 1.56 million people. At present, this figure is around 3.0 million. As a result of comprehensive measures taken at the state level over the past 10-15 years, the volume of drinking water supplied to Baku has increased from 570 million m3 to 700 million m3.

Taking into account the results of new hydrogeological surveys carried out within the boundaries of the Ganikh-Ayrichay reservoir, at the same time, in the water supply of Baku and the Absheron Peninsula, given the great and long-term importance of this reservoir it is necessary monitoring and expansion of the control and protection regime of the water intake.

## II. Results

1. As a result of recent geophysical surveys (GEZ) in Solban village of Balakan region, a number of well sections and a profile of the area covering 6 wells have been established. The lithological composition, thickness, reservoir characteristics of layers to a depth of 230 m in the study area have been clarified and the chemical composition of groundwater has been studied. The hydrogeological parameters of the reservoir and the groundwater regime were specified from the drilled exploration wells.

2. Lack of fresh water resources in the country, global climate change and rising average temperatures observed in recent years, reduction of water in transboundary rivers and excessive pollution, on the other hand population growth, improving the standard of living, given the sharp increase in demand for irrigation water due to the development of agriculture, the action plan for water supply in Azerbaijan, it should be continued and expanded.

3. Analysis of the collected materials on water supply of Balakan region, Baku city and Absheron peninsula shows that the groundwater resources of Ganikh-Ayrichay water basin should be used comprehensively and efficiently. Along with the protection of the basin, it is considered important to begin construction of the III (Shollar) main water pipeline from the Samur-Gusarchay basin in the coming years. Groundwater resources of the Samur-Gusarchay basin with high categories (A, B, C1, C2) were approved in 1969 by the State Reserve Commission under the USSR Council of Ministers at 9 $m^3/s$. However, the construction of the III (Shollar) main water pipeline has not been completed yet.

4. In recent years, there has been a significant reduction in the water resources of transboundary rivers, and since 1970, the reserves of the Kura, Araz, and Ganikh rivers have decreased by more than 30%. According to various climate forecasts, taking into account the further reduction of water resources in the future, necessary steps should be taken and adaptation measures should be taken at the transboundary level, both within the country and in neighboring countries.

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# GEOECOLOGICAL ASSESSMENT OF THE SOIL COVER OF THE CHECHEN REPUBLIC

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**Abstract**

*Scientific and practical problems facing the "society-nature" system that have developed a new direction in the system of geographical sciences - landscape ecology, which deals with just the problems or rather the consequences of irrational nature management. From these positions, the relevance of the research topic seems relevant and in demand, primarily by the practice of combating desertification processes in the Chechen Republic. The purpose of the study is to study the influence of anthropogenic factors on landscapes and the patterns of their changes depending on the stages of development of degradation processes. Research objectives: to conduct studies of anthropogenic changes in landscape complexes under the influence of desertification processes; to identify natural indicators of the desertification process; to establish regional features of landscape transformation in the semi-desert zone; to develop measures to optimize the natural environment of the semi-desert zone.*

**Keywords:** Chechen Republic, geoecological assessment, soil cover, anthropogenic changes, chernozems, sandy soils.

## I. Introduction

The soil cover of the territory of the Chechen Republic is a poorly studied component of the environment, with the exception of a few descriptive works [1]. Therefore, we were faced with the task of giving soil research a comprehensive character. In its natural state, the plain parts of the Chechen Republic were a tipchak-kovyl steppe, currently they are used as arable agricultural landscapes that have undergone a strong change in the soil and vegetation cover, and cultivated pasture lands. The content of silty fractions is an indicator of the natural fertility of soils, however, open and unpaved sands are devoid of silty inclusions. These soils are poorly provided with mobile forms of nutrients. Very little in them is the gross stock of the following elements nitrogen, potassium and phosphorus.

## II. Materials and Methods

The soil is mountainous-podzolic medium-sized skeletal on the eluvium of clay shales. Genetic horizons are well distinguished in mountain-podzolic soils. Removal of colloids and one and a half oxides from the upper horizons to the lower ones is characteristic of soils of this type. Eluvial horizons, as a rule, in these soils are loosely lumpy, crumbly, structureless, enriched with silica, which in the form of powdery powder covers structural lumps. The illuvial horizon is noticeably compacted, lumpy-nutty, structural, usually colored in red-brown tones. Mountain-podzolic low-power soils are younger compared to medium-sized ones, therefore, podzolic among them is less pronounced. It is noteworthy that all soils have an acidic reaction of the medium (pH = 4.6-5.3), and with depth the pH value approaches neutral (pH = 6.20-6.45). H+ occupies a significant place in the composition of exchange bases (up to 47%). A low amount of exchange bases is typical for these soils. With depth, the absorption capacity drops sharply, the degree of saturation with cations is low. Soils are characterized by high rates of metabolic acidity - 3.5 mg eq and low content of exchangeable Al3+. Humus content (7.6-13.7%). Its amount decreases sharply with depth (up to 1-7.0.6%). A significant decrease in the amount of exchange cations with depth, the total insignificant amount of them in the profile is due to the degree of weathering of primary minerals. A certain variability in the composition of cations is associated with the influence of the soil-forming rock. According to the mechanical composition of the soil, they belong to loamy-stony-cartilaginous. The accumulation of silty particles in the upper horizon is characteristic of mountain–podzolic low-power soils. The removal of particles smaller than 0.001 is not noted. The soil-forming process here has not reached the stage when this movement can be captured analytically.

The soil is brown mountain-forest thick loamy podzolized carbonate-free on the eluvia-deluvia of clay shales.

The morphological profile is divided into eluvial and illuvial horizons. The podzolic horizon of these soils differs from the podzolic soils of the north in pale color, lumpy structure, significant content of silt and one and a half oxides. The process of humification in podzolic soils is weaker, therefore, they are poorer in providing nutrients compared to non-saline brown mountain-forest soils. On carbonate rocks, the ash content is not pronounced. Brown mountain-forest podzolic soils are characterized by high calcium unsaturation, acidic reaction, increased content of metabolic acidity with an insignificant content of mobile Al3+. The composition of exchange cations and the nature of their distribution indicate the development of the podzolic process. In both soils, there is a redistribution of the colloidal fraction (particles less than 0.001). The removal of the silty fraction from the upper horizons into the parent rock reaches 48%, which is an indicator of the intensity of the podzolic process.

## III. Results and discussions

Sandy soils are common in the north of the republic and coincide with the areas of sand occurrence. The distribution area of the sands occupies more than 350 thousand km2. In the east, the boundary of the sand massifs is Sulu-Chubutla and forms a fairly extensive Priterskiy sand massif.

The sands of the Priterskiy sand massif are relatively rich in nutrients necessary for the development of vegetation, and has a favorable hydrological regime.

In the Tersk sands, even at not great depths, significant volumes of fresh water lie. However, in sandy soils, only the upper horizon is expressed with weak humification, the horizons are not differentiated [1, 2].

The fertility of sandy soils is characterized by silty fractions, the content of which is one of the important factors. However, open and unpaved sands are devoid of silty inclusions.

These soils are poorly provided with mobile forms of nutrients. Very little in them is the gross stock of the following elements nitrogen, potassium and phosphorus. It should be noted that sandy soils, despite the poverty of the nutrient content, are the most fertile of the sandy soil differences of the North Chechen Lowland. In agricultural production, sandy soil resources have been used for a long time and are valuable pasture lands, they are also very promising for growing grapes, melons and vegetable crops (Fig.1).

Chestnut soils are available both on the Left Bank and on the Right Bank of the Terek, as well as in the eastern part of the Tersko-Sunzhenskaya upland. These soils are formed in a dry and hot climate [3, 4].

The soil-forming rocks for chestnut soils are yellow-pale carbonate loess-like loams and clays, in the Left Bank they are represented by sandy loams. There are three subtypes of chestnut soils on the territory of the republic: dark chestnut, chestnut and light chestnut.

Light chestnut soil differences have small humus horizons (A + B = 40 centimeters).

According to their mechanical composition, they most often belong to sandy loam and light-loamy varieties. Light chestnut soil differences are poor in humus (in horizon A from 1.5 to 2.5%).

Light chestnut soil differences are not provided with digestible forms of nitrogen and phosphorus, they contain sufficient calcium.

Dark chestnut soils, unlike light chestnut soils, are characterized by the thickness of humus horizons (A + B = 50-60 centimeters), compacted addition, less dispersed structure of the upper horizons. Dark chestnut soils by mechanical composition belong to loamy and clay varieties. In the arable horizon, dark chestnuts contain up to 4% humus, they contain a large number of gross elements: nitrogen, phosphorus and potassium, but there are few mobile forms of these elements, with the exception of mobile potassium.

Chestnut soils are in an intermediate position between light chestnut and dark chestnut [5].

Chernozems are the richest soil varieties in nutrients (nitrogen, phosphorus, potassium), having a well-formed structure and are characterized by high fertility.

Meadow soils have a wide location in the republic, they are found in the Priterskaya part, the Gudermess plane and everywhere in the foothill zone. Meadow soils are formed in conditions of ground and surface waterlogging. The basis of the soil-forming process are rocks of medium and heavy loamy deposits along with carbonate clays and loams.

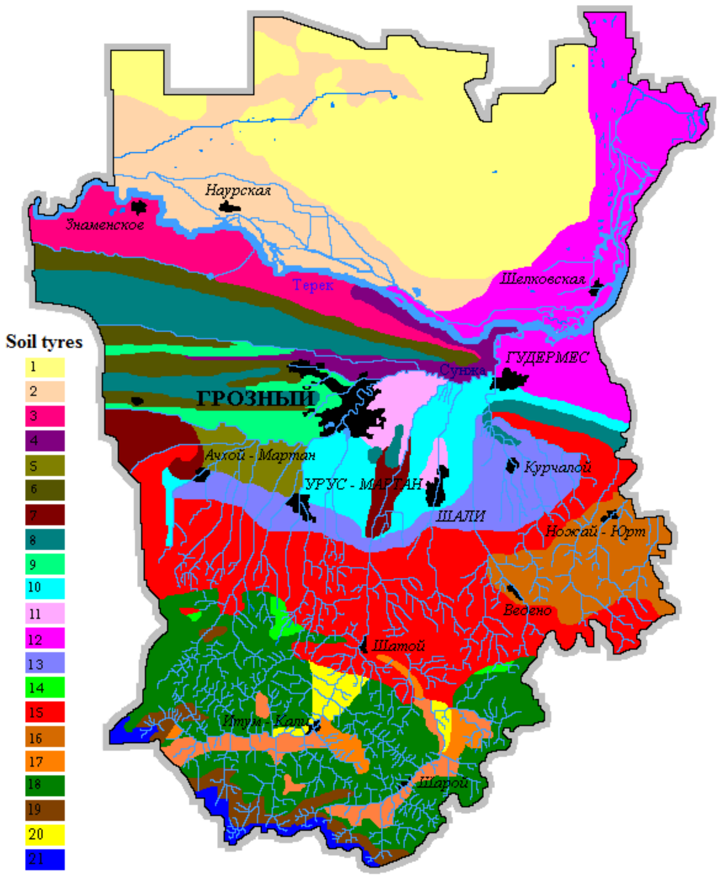


**Figure 1:** *Map of soils of the Chechen Republic [6].*

**SOILS OF PLAINS AND FOOTHILLS:** *1- Sandy soils and sands; 2-Light brown and chestnut carbonate; 3-chestnut with patches of chestnut saline soils and salt; 4- Chestnut and dark chestnut carbonate; 5-Carbonate chernozems less often with reduced boiling, medium-thick; 6-Carbonate chernozems, medium and low-power in combination with saline and washed away chernozems; 7-Chernozems carbonate or slightly leached, medium and low-power, laid with pebbles; 8-leached, medium and low-power chernozems in combination with carbonate and slightly saline; 9- saline, medium and low-power chernozems; 10- Meadow-chernozem, underlain by pebbles; 11- Meadow-*

*chernozem carbonate in combination with meadow carbonate; 12-meadow and alluvial-meadow carbonate, mainly saline and saline; 13- Sod and sod-gley, leached or podzolized often on pebbles, sometimes merged;15-Gray forest podzol;*

***MOUNTAIN SOILS:*** *16—Mountain-forest brown, sometimes podzolized in combination with humus-carbonate and meadow-alluvial; 17- mountain-forest, grayish-brown, swampy, merged; 18- Mountain-forest primitive, slightly podzolized, stony-cartilaginous; 19- Mountain-meadow subalpine powerful and medium-sized multi-humus, weakly skeletonized; 20- Mountain-meadow alpine low-power, medium-humus, skeletonized, often swampy; 21- Mountain-steppe skeletonized, often washed away.*

For meadow soils, it is characteristic, as well as for chernozem soils, a significant variety is distinguished here by carbonate, leached, saline and saline.

The reduction of forests on the Chechen foothill inclined plain and the subsequent characteristic transformations of vegetation cover, as well as changes in the process of moistening, all caused the active process of settling of meadow soils.

The thickness of the humus horizon in meadow soils is 40-60 cm, characterized by a poor structure, which is represented by lumpy individuals. Humus content in meadow soils in the range from 2 to 5%.

Thus, the fertility of soils depends on the age and on the conditions in which they are formed. The total reserves of nitrogen and phosphorus are small, potassium is significant. Meadow soils are well provided with mobile potassium, weakly mobile phosphorus and medium-hydrolyzable nitrogen.

The main unfavorable signs of meadow soils in the north-east and the Gudermess plane are their salinity, salinity and negative water-physical properties.

The elimination of these properties should be the main measures to increase the fertility of meadow soils.

Alluvial soils. These soils have a fairly significant distribution in the foothill zone of the republic. They spread in floodplains and on river terraces. A distinctive feature of their morphological structure is layering. The soil profile is very heterogeneous, as it is composed of river sediments of different mechanical composition and color. The humus horizon of alluvial soils has a small capacity and it depends on how the uppermost humus horizon is developed.

The lower layers are composed of slightly affected by soil formation alluvial deposits with traces of partial waterlogging. The humusized upper horizon has a gray-brown or gray color and contains a small amount of organic matter (2-5%).

## V. Conclusion

In order to conduct a serious and successful struggle against the processes of soil degradation, it is necessary first to assess the natural resource potential of the Chechen Republic, which will make it possible to characterize the current state of the landscape complex, to determine the degree of destruction of land resources and soils.

The soil cover, the main source of food for the population, is under the influence of a number of degradation processes: salinization, chemical pollution, catastrophic decline in fertility, which, naturally, provoked the processes of desertification. Unfortunately, the territory of the Chechen Republic has not escaped those environmental problems that take on a threatening character and the most extensive of them is the process of desertification, which covers more than 350 thousand hectares of land in semi-desert and dry-steppe zones. Naturally, studies of the active desertification process, as already noted, have covered large territories, the search for optimal measures from the standpoint of rational land use, based on serious scientific research that could be used as the basis for these activities.

Our research has shown that further use of the soils of the Chechen plain without the organization of reclamation measures to optimize their condition and especially increase their fertility, can provoke degradation processes: compaction, salinization, drop in organic matter content, waterlogging.

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# LANDSCAPE ANALYSIS OF EXOGENIC PROCESSES DISTRIBUTION IN MOUNTAIN REGIONS OF THE CHECHEN REPUBLIC

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**Abstract**

*The landscape structure is an important basis for analyzing the distribution of exogenous processes. Six types, 11 subtypes and 45 groups of landscapes were identified, for which an analysis was carried out of the occurrence and intensity of distribution of the main exogenous processes in the mountainous territories of the Chechen Republic such as: avalanches, mudflows, landslides, erosion, karst.*

**Keywords:** landscapes, exogenous processes, Chechen Republic.

## I. Introduction

The middle and high mountains of the Chechen Republic (CR) occupy about a quarter of its territory. However, this part of the republic is still undeveloped. The reasons for this are the eviction of Chechens in 1944 and the ban on returning to the settlements of the mountainous zone (only about 300 settlements remain abandoned) at the end of the 1950s. In connection with the changed socio-economic and natural-ecological conditions, the tasks arose for the redevelopment of this territory. In the Chechen Republic, the program "Socio-economic development of mountainous territories (Vedensky, Itum-Kalinsky, Nozhai-Yurtovsky, Shatoisky, Sharoysky municipal regions of the Chechen Republic (for 2017 – 2020 and subsequent years)", was adopted and aimed at improving the socio-economic situation of mountainous municipal regions of Chechnya. In this regard, the issues of effective development of the mountainous part of Chechnya arose, therefore, the priority task is to assess the spread of slope processes to ensure the prospective development of mountainous areas of the Chechen Republic.

## II. Methodology

Landscape research is the basis for a comprehensive analysis of the processes taking place in mountain areas. Landscape mapping tools have proven their effectiveness in assessing the risks of manifestation of exogenous processes. In mountainous regions, characterized by the dynamism and different ages of natural components and natural processes, landscape mapping is an effective way to streamline, establish the hierarchy and boundaries of natural complexes that determine the conditions for the manifestation of exogenous processes [4]. Thus, the landscape binding of the manifestation and dynamics of exogenous processes is the basis that allows the most complete assessment of the risks of a particular process for different types of nature management.

The landscape structure of the mountainous regions of the Eastern Caucasus was studied in the works of A. E. Fedina [8], A. M. Alieva [1], VV Bratkov. [3], Golovleva A. A. [2] and others.

North Caucasian complex expeditions in 2015-2021 made it possible to establish the main high-altitude-zonal regularities of the landscape structure and take the first steps to streamline knowledge about the distribution of slope processes in certain landscapes [5,6,7].

## III. Methods and materials

The main methods of field work were: landscape description, complex physical-geographical profiling and landscape mapping. When processing the data, GIS tools were used, which made it possible to create maps of inclination angles, exposure, and identify potential areas of manifestation of slope processes. In 2016-2021 detailed studies of the mountainous territory of the Chechen Republic were carried out. Based on the results of the expeditions, a database of complex landscape descriptions was compiled, which included about 60 complex descriptions. The database is a table in which the description points are plotted along one axis, and the description characteristics themselves are plotted along the other. First of all, this is the height above sea level, geographical position, names of facies, anthropogenic load, mesorelief, slope exposure, slope steepness, microrelief, rocks, size of clastic material, soil type, description of the presence and distribution of the main exogenous processes: avalanches, mudflows, landslides, erosion, karst, etc.

## IV. The main exogenous processes and their distribution

The research area covers the middle and high mountains of the Chechen Republic from about 500 to 4 493 m above sea level (city of Tebulosmta). The conditions for the formation, distribution and activity of exogenous processes are closely related to the landscape structure of the study area, which is represented by 6 types and 11 subtypes of landscapes, as well as 45 groups of landscapes.

The following types of landscapes have been identified: nival-glacial (above 3000-3500 m above sea level); mountain meadow (the lower border varies from 2000 to 2500 m, and the upper one coincides with the upper border of nival-glacial landscapes; mountain-forest, extending to an altitude of 2000 m (along some parts of the southern slopes, forests extend to an altitude of 2600 m above sea level) ); mountain-steppe (up to 1800-2400) .The mountain-forest-meadow type of landscapes, which is an anthropogenic transformation of the mountain-forest zone (2000-2600), and mountain-forest-meadow-steppe, transitional from mountain steppes to mountain forests (up to 1800- 2400).

The nival-glacial type of landscapes is divided into glacial and nival-rocky subtypes. Mountain meadow landscapes are divided into subnival-alpine, subalpine and subalpine steppe. Mountain-forest landscapes are divided into small-leaved-coniferous alpine and broad-leaved-small-leaved (up to an altitude of 1600-1800 m). Mountain-forest-meadow landscapes are represented by the pasture subtype. Mountain-forest-meadow-steppe – cultivated subtype of the same type. Mountain-steppe landscapes are divided into bush and mountain-meadow-cultivated landscapes.

If the ratio of heat and moisture plays a leading role in the identification of high-altitude-zonal types and subtypes of landscapes, then the identification of groups of landscapes is associated with geological and geomorphological features. Within the region, several types of rocks are distinguished, which have different resistance to the development of exogenous processes: Maikop clays, calcareous rocks of the Cretaceous-Jurassic, siltstones and sandstones of the Jurassic, mudstones and sandstones of the Jurassic. The southern part of the territory is dominated by Lower Jurassic mudstones. They are represented by clays, often serving as aquicludes, as a result of which the steep relief is combined with landslide processes. Further, a narrow strip is the Middle Jurassic siltstones, more silty, sandy. They serve as a fertile substrate for soils, in particular, in the Galanchozhbasin depression, which is considered the historical core of the settlement of Chechens, as well as in the Itumkala and Sharo-Argun basins. Upper Jurassic-Lower Cretaceous and Cretaceous rocks are represented in the very north. They make up the Pasture Ridge. In these areas, there are developed calcareous soils, karst, and partly also gypsum karst. The distribution of the main exogenous processes in the types of landscapes of the study area is given in Table 1.

**Table 1:** *Distribution of the main exogenous processes in the types of landscapes of the mountainous part of the Czech Republic: ++ - often, + - sporadically*

| Landscape types | Main exogenous processes | | | | |
|---|---|---|---|---|---|
| | Avalanches | Mudflows | Landslides | Erosion | Karst |
| Nival-glacial | ++ | | | | |
| Mountain meadow | ++ | | | + | |
| Mountain-forest meadow | + | | + | ++ | + |
| Mountain forest | + | + | ++ | + | + |
| Mountain-forest-meadow-steppe | | + | + | + | + |
| Mountain-steppe | | + | + | ++ | + |

In the mountain-meadow and nival-glacial zones, the steepness and dissection of slopes play an important differentiating role in the formation of various groups of landscapes and the confinement of certain slope processes. Typical groups of landscapes, in which avalanches appear, are confined to the slopes of the northern exposure. A decrease in snowiness in high-mountainous landscapes is manifested by the disappearance of glaciers.

In the mountain-forest-meadow zone, the main groups of landscapes, where erosion and landslide processes are widespread, are slopes composed of flysch deposits of siltstones and mudstones, with meadows degraded in the course of long-term grazing.

Below 1800-1600 meters above sea level, broad-leaved and mixed forests have formed on calcareous rocks. Gorges cut by the river in calcareous rocks often represent a complex combination of precipices, caves and slopes of different steepness and exposures with hornbeams with an admixture of oak on calcareous and skeletal soils. The close bedding of calcareous rocks leads to fragmentation of the forest cover into groves of birch with an admixture of hornbeam and oak on loamy-gravelly skeletal soils in places. Typical broad-leaved forests with hornbeam and beech forests formed on the northern exposure slopes, composed of Maikop clays. Landslide processes here have intensified due to intense precipitation in the early summer period. Quite often their activation is associated with the construction of roads. However, there are also hard-to-reach areas, in which fresh landslides descended in 2016, destroying century-old beech forests.

Mountain-forest-meadow-steppe landscapes were formed under the influence of anthropogenic activity under conditions of moisture deficit. Human activities leading to deforestation have stimulated processes leading to the spread of erosion and landslides.

## V. Conclusion

It was revealed that slope processes have different activity and distribution in different landscapes. This is primarily due to the heterogeneous nature of the lithogenic base, climate features, and the degree of development of the vegetation cover. The distribution of many slope processes is subject to altitudinal zoning. Karst processes are confined to landscapes formed on calcareous rocks. There are sinkholes and caves can be found in the research area.. Landslides are common in landscapes on flysch rocks, especially with a predominance of mudstones, which usually play the role of an aquiclude. To a greater extent, they are observed in mountain-forest-meadow and partly mountain-steppe types of landscapes. The development of landslides here is often stimulated by pasture digression.

Avalanches are confined to the high chains of the Lateral Ridge. The avalanche activity mainly affected the nival-glacial, mountain-meadow and, in part, mountain-forest landscapes adjacent to the mountain-meadow. Mudflow manifestations are more typical for mountain-steppe landscapes, where the slopes are subject to pasture digression and the soil and vegetation cover is disturbed.

As a rule, the manifestation of erosion is correlated with pasture digression, in particular, with the spread of the so-called "goat" trails. In some cases, erosion is stimulated by road construction. The compiled maps of the distribution of the main exogenous processes in landscapes can be used as the basis for developing a strategy for the development of mountainous territories in the Chechen Republic, taking into account modern trends: population growth in the Chechen Republic and the gradual settlement of mountain and high-mountain villages abandoned in the middle of the 20th century. On the other hand, it is necessary to take into account the changed natural and economic conditions in the mountains: climate variability, lack of roads and exposure of landscapes to dangerous natural phenomena.

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# COVID-19: Human Crisis and Challenge

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**Abstract**

*Today, humanity faces the millennium challenge. Those challenges always require the development of new agenda and solutions. The same time, different states and society are making the certain programs. States usually undertake to develop problem-solving plans, as well as to lead the implementation of the effective measures. While the states often consider each other as partners, sometimes the contradictions between them raise. It depends on various political and economic factors. Currently, the case is different. The whole world, and not any certain regime, whether democratic or totalitarian/authoritarian, has to solve a common problem. There was a strangeness at the beginning of the pandemic that neither the whole world was together nor separately. Everyone seemed to be withdrawn into oneself and was trying to solve 'their' problem themselves. There was and, you could say, it is now an alienation between the nations. The solution of the problem needs the understanding and vision, determination of the perspectives. The strangeness continues with the fact that nowadays neither the definition nor the real plan is fully given. And it's about the human lives. Since this threat is all-encompassing, the strangeness of this crisis is in the fact that, as it was already said, the world does not still hold together. And this danger/crisis is named after COVID-19. The paradox chain continues: today we, the humanity, do not know* ***when*** *will this crisis end. We also do not know* ***how*** *it will end; in the ling-term perspective, we also do not know with* ***what*** *and* ***which*** *political and economic results will it end.* ***What*** *and* ***which is*** *very important because it wouldn't be a little hard, and it is necessary to define* ***what*** *will it look like, since we will proceed from this '****what****' in the long-term operational and decisional perspective.*

**Keywords:** pandemic, COVID-19, uncertainty, unsustainability

## I. Introduction

All crisis periods are characterized by uncertainty and unsustainability. The contradiction is that as much as millions of people are infected with this virus, so much the world community is obsessed with uncertainty and a sense of fragility that will have more negative consequences than this virus. In all times of crisis, and not only after the crisis, the opinion must be expressed in order, to get out of this situation, on the one side, and to adequately analyze it further, to understand its lessons in future better. This, unfortunately, in most cases, does not happen for the simple reason that the state and society are satisfied by self-sufficiency and uses every crisis overcame to prove its strength and to prove its impact on others. And this provision is now deprecated.

Since this crisis is different from others, we still have the opportunity for its preliminary analysis. In this case, one can especially highlight a few major issues.

**a) Role and designation of the state.** During the economic crises of various years, the attitude of citizens and civil society to the state was different. During the financial crisis 2008-2009, many specialists believed that faith in the government of the state would grow, but finally, this did not happen. The views of increasing faith in the state were confirmed by the Great Economic Depression Facts 1929, when the civil society demanded from the state strong, decisive steps to save the market economy (consumer and industrial market) through the big governmental economic interventions.

During the pandemic, the society demands and expects total intervention from the state to manage this crisis and asks it to give it not only the perfect protection from the given situation, but also to save the entire economy (both industry and agriculture).

It can be mentioned that the paradox 2008-2009 was that distrust in the market economy did not lead to further encouragement of economic interventions from the most of states. It had its own explanation because the states differ from each other in their structure/arrangement/constitution. This difference is not only observed among the democratic and totalitarian/authoritarian states, but also among the democratic states. One of the main factors is what their attitude to the market economy is. The market economy, without any regulations or restrictions, is an unbreakable postulate of the existence of a free society for the liberal democratic or neoliberal states. In fact, without certain social "limitations", a market economy can become the best opportunity for the labor exploitation, in which case the principle of the distributed equality is completely violated and not equal recognition of each other from people is carried out. In contrast, a democratic state is indeed a guarantor of the freedom when it is constitutional and social, when equal and fair principles of redistribution of goods are carried out for all citizens: e.g. such as an equal availability of the education and medical insurance for health for all citizens. Therefore, this crisis in the unrestricted absolute/total market economy truth can cause or has probably already caused serious doubts. For the totalitarian/authoritarian states and for the right-wing populist governments existing in the democratic space, this challenge can cause a destroy of their foundation, because the faith in authority, totality is shaken when the authority is no longer able to solve problems for the masses. Right now, while overcoming this crisis, a forceful government seems as helpless as, a liberal democratic society.

The above is important to consider because during this crisis in the nearest future all governments can face a terrible dilemma: either to carry out fast and maximum localization of the epidemic as soon as possible, which can lead to the collapse of the economy, or to pay a big price and to sacrifice the lives of people for the development of the economy. However, it is probably early and difficult to talk about the consequences of the epidemic. Anyway, whatever decisions they make, this should come in full agreement with the interest of the civil society and individual/individuals and individual public groups should not place make decisions, which will aggravate this crisis situation.

**b) A turn toward the idea of nationalism or a national state**. It is particularly important that this problem, which has created as a result of the pandemic, is taking place not in the world in general but within the EU. Even those types of countries, for which the internationalism and interstate solidarity is a cornerstone of core values and foreign policy, took a step back in favor of national states. Maybe it is a manifestation of a temporary defensive instinct? Anyway, after the states within the EU closed their borders in order to protect against the epidemic, it seems that in the process of overcoming the danger and getting out of this hard situation with as little loss as possible, the world and the EU have chosen to strengthen the role of the national states.

Indeed, in these circumstances, from today's point of view, it seems that each state is only concentrated on its citizens, and the intergenerational principle of solidarity is not completely lost but it has been moved back. However, moving to the front of the national states' role should not cause (and probably will not cause) the economic, social, cultural and academic disintegration of the world, which, in turn, can cause even more and more severe crises in future, as long as there is a little step from the national states to nationalist and chauvinistic states if the balance of nationality, internationality and solidarity is not kept.

The real fact is that the European states in the relatively better position noticed the above risks in timely manner and, after the first shock caused by the pandemic, effective mechanisms for expressing solidarity with those in a more serious situation were engaged again actively (e.g. the treatment of Italian and French/Elsassian patients in the clinics in Germany and Switzerland, support with doctors, medical equipment, huge financial resources prepared to ensure economic stability in the post-crisis period, announced by EU, etc.)

At the same time, catches the eye that the leaders of few EU member states, in fact try to practice their authoritarian inclination and to strengthen it by bringing the idea of a national state to the front, which requires attention and a corresponding reaction to it.

Since the current epicenter of the corona-crisis is in Europe, we might also express a cautious assumption that this crisis may not only be a catalyst for strengthening centripetal processes from Brussels, but also a specific unified EU policies (e.g. such as financial, military and military/political), which may be in the interests of all EU countries. Historically, such was large crises of similar scale allowed to make a large jump, which, in the common case, remained an unachievable goal.

**c) Globalization/anti-globalization.** The coronavirus crisis has also put the problem of globalization/anti-globalization on the agenda. The anti-globalists may today, at first glance, have the truth on their side when they present closed borders, airports, sea ports and various means of land traffic as a means of saving the nations during this period. But, if the anti-globalists' truth is based on the correctness of the temporary measures taken at this stage, they still do not have the substantive visions/ways to solve the problem. What is or what was understood under the globalization? How can we talk about the globalization, when the world is divided into three or four parts opposing each other, independent of each other? If that's the case, so what is the basis that allows us to talk about the globalization? May be in fact the globalization is an attempt of the world's ruling camps to impose their ideology and economic models on the countries that are under their influence? And to increase their spheres of influence further? Will this escalate the confrontation in the future, which, in its essence, is against the globalization? In our view, it won't be so if the positive connotation of the globalization will be based on the idea of equal redistribution of intergenerational equality, recognition and kindness. It must be mentioned that the main ideologists of the opposing camps of the world 'globalization' have been withdrawn from this process during the corona-crisis and locked themselves. It should also be taken into consideration that despite these ideological controversies, for their economic benefit, these camps not only cooperate, but actually (implicitly and latently, at least) strengthen each other in the fight for strengthening and expanding spheres of influence. It turns out that this problem should be considered completely newly (especially for small states, which mostly have to fight these and other crises with their limited powers). Since we all live in one world, on the Earth, separation from each other, long-term closure of borders to each other, can't stop the spread of the virus because the virus is also part of the unified ecosystem.

d) It is important not which, but what kind of states have found themselves resistant to the virus. From today's point of view, it is obvious that those on the basis of which are social equality and whose industry and agriculture are properly developed; those whose social security systems are more or less highly represented, which also belong to the medical system of health insurance. Therefore, it is important for all countries to determine their socio-economic development priorities for future correctly.

**e) Trust in professional experts and professionals**. Coronavirus has put another issue on the agenda: hope, faith and demand for scientists-scholars have increased not in one certain country but in the world society. If the opinions of the scientific experts during the previous economic and refugee crises caused resentment in large or certain parts of the population based on the propaganda of right-wing populists, and now the situation is different, because the humanity expects help from the scientific experts. This is directly related to the definition of the scientific-research and educational priorities, which is primarily carried out in the academic space. The academic space, like never before, has become in demand. The case here is not only about the medical field, but also the fields that play a direct role in overcoming of the crisis. These include the agrarian, engineering-technological, fundamental natural sciences, but at the same time, since the corona virus epidemic is a common human problem, and humanity is an organism of moral communication with each other, it is in demand or there should be a social and humanitarian sciences that are engaged in the research of justice and morality. Engineering technological and natural sciences have been in demand at different times with more or less intensity. But, after the World War II, it became clear that their popularity was determined only by the benefits and increased financial gain caused by the technological development, which, often, was not only in connection, but also in complete confrontation with the basis for the existence of humanity – morality. Anyway, academic professionalism still "comes into fashion," which requires new definitions of the education system and in this case, the functioning of the higher education system and the right priorities. But the **education must be educational and therefore it must be humanistic, and not only available for**

**the individual social groups, but also available for everyone**, so that these and similar problems end in timely manner and with the correct humanistic results.

## II. Georgia and Corona Virus

How has Georgia met the coronavirus and what priorities have the country defined for the solid and long-term development in order to meet the future challenges of the world/humanity more prepared? As for the current problem, the management of the crisis both at the beginning of the crisis and in the present day, in this regard, the actions of the government of Georgia are adequate and the same time goals are defined correctly. Every step the government took after the world-delayed response in general was well thought out, organized and timely. In this regard, it will be difficult even for an opposing side to make a complaint within the reasonable limits. Medical and political leadership works professionally and efficiently, but despite the difference between the social and political systems, all countries of the world struggle against this challenge with the same methods, however, with the different indicators of the efficiency and timeliness. It is more important that both the government and the society begin to think seriously, and moreover, to develop for the country development in the post-crisis period, in which case the number of mistakes that can hamper the country's possible rapid progress in the event of a continuing crisis and after its completion. The first and most important thing is to develop a strategic plan for the development of industry and agriculture, and the country should be able to have self-sufficient existence not only during the global and local crises, but also during the normal condition. In this regard, it is very notable and hopeful that the Georgian government has already started to formulate and implement relevant plan.

It should be taken into account that such strategic plans require a deep scientific research analysis, and therefore high-ranking scholar-experts from the academic space should be involved in its development, as far as, as we mentioned above, the crisis has caused demand for them worldwide.

In addition, the improvement of the legal and political system should facilitate the effective implementation of measures necessary for the rapid development of the industry and agriculture. The current crisis has directly or indirectly raised the demand for rapid and reasonable development and reform of education and especially higher education (which includes research) all over the world and especially in our country. Instead of the marginal destinations which, according to the time requirement, were at the forefront as a result of populist propaganda, such as, for example, the sectoral direction of tourism, or business administration. It should quickly turn the academic spectrum towards the development of such fields that are not only crucial and important for the crisis period, but also for the long-term and sustainable development of the country in general, such as engineering technological directions, agricultural sciences, medical direction and all the fields that are the basis for the creation of the country's economic and social space. This does not mean that a number of academic fields are affected by this, but the priorities should be defined clearly. And also, the priority directions should be accurately determined not only according to the temporary need, but also from a fundamental point of view. Also, the structure and legal status of public and private high schools will be determined, which will support the proper operation of this field.

**This crisis has once again clearly showed the world that the economic and social development of the country is possible only on the basis of knowledge**. Therefore, the industry, agriculture or other directions that are necessary for the development of the country and for in long term proper existence should be discussed in constant link with the academic space of education and research.

# THE ROLE OF STUDYING TECTONIC FACTORS IN REDUCING THE RISKS OF EXPLORATION

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**Abstract**

*A comprehensive study of geophysical, geological, tectonic, lithofacies, petrophysical and a number of other factors of oil and gas content and their changes in space over time make it possible to develop the foundations of the main criteria for predicting the distribution of oil and gas territories and the development of hydrocarbon deposits. In order to assess the prospects for prospecting for oil and gas accumulations and reduce the risks of ineffectiveness of exploration and further development and drilling operations in the lower section of the Productive Strata (PS) of the western side of the South Caspian Basin (SKV), based on the available material and taking into account the large number of published works, We considered the tectonic criteria and conditions for the preservation of the formed accumulations of hydrocarbons in the South Absheron archipelago, in the example of the Gum-Deniz and Bahar areas. By specifying the development of uplifts, tectonic faults and the lithofacies composition of more ancient sediments, paleostructural analysis can provide significant assistance in identifying promising areas for prospecting and exploration, and ultimately thereby significantly reduce the risks of inefficiency in drilling operations.*

**Keywords:** structure, rock, stratum, horizon, prospects

As is known, among all the factors that control the development of the formation of oil and gas bearing territories, the main role belongs to the structural and paleostructural factors. The South Caspian Basin (SCB) is a large sub-latitudinal structure that was fully formed in the Lower Pliocene. The tectonic boundaries of the SCB are: in the northwest, the subsidence of the southeastern part of the meganticlinorium of the Great Caucasus, in the northeast of the Absheron-Balkhan zone of uplifts, in the west of the Talysh-Vandam gravity maximum, in the east of the Aladag-Messerian step and in the south of the folded structures of the Elburz. In the depression, the outer near-rim framing and the inner region are distinguished [1, 3, 4, 8].

The inner area includes the shelf areas adjacent to the land and the deep-water part of the Caspian Sea, experiencing the greatest subsidence. Large geostructural elements are widespread within the boundary framing, favorable for the formation of oil and gas regions developed in the Eastern part of the Transcaucasian oil and gas province. These include the Kura intermontane depression, as well as the structural elements of folding of the southeastern subsidence of the mega anticlinorium of the Greater Caucasus. The inner region of the South Caspian Basin is a depression of maximum bending and differs in tectonics from the near-edge regions.

In the study area, more precisely, in the southern part of the Absheron archipelago, numerous anticlinal belts are developed. The structures developed in these belts are associated with oil and gas accumulation zones, and with local uplifts of anticlinal belts - oil and gas accumulation locations. The structures with which the sites of accumulation are associated developed consedimentally, and their formation occurred before the migration of hydrocarbons from the generating area. The emerging local structures did not lose their isolation in the subsequent development. Our research is based on a wide range of geological surveys, geophysical studies, mapping, structural prospecting and deep drilling. It should be noted that the Gum-Deniz and Bahar areas studied by us (Figure 1) formed in the southern part of the Absheron archipelago belong to the Fatmai-Zykh-Bahar anticlinal belt, which is part of the oil and gas bearing area of the same name [1, 3, 7, 8].


**Figure 1:** *Overview map of the Absheron archipelago.*
*Location of structures Gum-deniz and Bahar [2].*

For the effective conduct of prospecting and exploration work, it is of great importance to clarify the history of the geological development of individual local structures in time and space. It is in this regard that the widely used paleostructural analysis can be of significant assistance in the discovery of both ancient uplifts, which can represent promising areas for exploration, and lithofacies skills along the section of the study area. The study of older deposits in this way and the refinement of the development of tectonic disturbances ultimately significantly reduce the risks of inefficiency both in prospecting and drilling operations.

The analysis of the capacities when obtaining the construction of the corresponding maps makes it possible to clarify the formation and destruction of oil and gas deposits, since it is by this method that it is possible to identify and explain the regularity of the distribution of hydrocarbon accumulations in different horizons of individual areas. As you know, identifying and clarifying the distribution of hydrocarbon accumulations in various areas significantly reduces the risks of unnecessary and unnecessary costs when drilling production wells. We carried out paleotectonic analysis for the structures of Gum-Deniz and Bahar [2].

To trace the history of the development of the Gum-Deniz and Bahar structures, we selected the following as reference surfaces and analyzed the following graphical results: - Under Qirmeki (UQ) and Qirmeki retinue (QR) (layer qroup); - On the Qirmeki Clay (OQC) and On the Qirmeki Sandy (OQS) retinue; - Fasile retinue, X, IX horizons of the Balakhani retinue; -VIII + VII + VI + V horizons of the Balakhani retinue and the clay section between the VIII horizon and IVb horizon of the Sabunchy retinue; - Sabunchy retinue; - Surakhani retinue [4].

Studies have shown that the Qala retinue (QaR) is absent in the submerged direction in the Bahar area and adjacent territories, and the deposits of the Podkirmakinskaya suite directly overlap the Miocene. As can be seen from paleotectonic maps, the structure of Gum-Deniz and Bahar has a more ancient origin. By the end of the QR century, three uplifts were formed on the Bahar square: northern, central and southeastern. The northern rise along the isolines of 400 m, having a height of 10-15 m, is characterized by a length of 1.7, and a width of 0.7 km. The uplift is located in the area of wells 74, 46 and 19, and extends in the meridional direction (Figure 2) [5, 7].

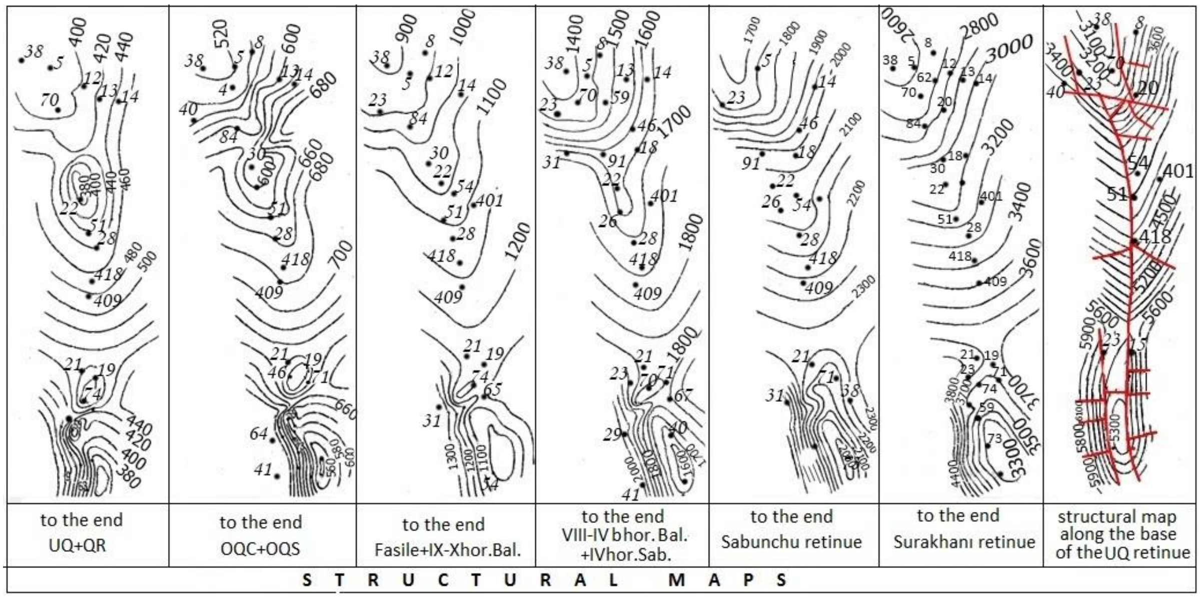


**Figure 2:** *Paleostructural and area structures*
*Bahar and Gum-deniz along the sole of the UQ retinue*

The central uplift also extends in the meridional direction. This uplift has an asymmetric structure, because the west wing is steeper than the east. Its height along the 400 m isoline is 45 m, and its dimensions are 1.5x0.8 km. The southeastern uplift is located in the area of wells 12 and 50. Its northern pericline is directed to the northwest. Measuring 1.8x0.6 km along the 400 m isoline, the fold has a height of 60-70 m.

The buried Gum-Deniz uplift finds its expression on the same surface. This uplift is located in the area of wells 30, 22, 26, 54 and has a meridional orientation. The Gum Deniz structure is outlined by isohypses of 380 m, 400 m and 420 m. The dimensions of the closed vaulted part of the structure are 4x1.8 km, and the height is 30 m. The Gum Deniz structure is complicated by a mud volcano, as a result of which longitudinal and transverse tectonic faults of various directions. The fold is 17 km long and 6.5 km wide. In the south of Gum Deniz, geophysical surveys have discovered the buried structure of Janubi Gum Deniz. It is assumed that the uplift is a reflection of the ancient structural plan of the lower PS and underlying sediments [7, 8].

The Bahar and Gum Deniz uplifts (Figure 3) are complicated by longitudinal and transverse faults. As can be seen from the structural surface, by the end of the UQ and the beginning of the OQC centuries, the base of the Bahar square was beginning to form. This is also indicated by the sediments of the formation. The uplift appeared in the form of folds: the central uplift developed in the form of a structural nose, while the northern one retains its configuration [2, 5].

This map clearly shows the almost unchanged Southeast Uplift. The Gum Deniz Rise has retained its previous configuration. The thickening of isopachs between individual wells indicates a significant activation of movements along tectonic faults. The anticlinal fold along the base of the UQ retinue by the end of the formation of the Fasile retinue, horizons X and IX of the Balakhani retinue underwent significant changes. On the Bahar square, the southeastern uplift, uniting with the central one, expands its boundaries. The dimensions of the fold along the 1100 m isoline are 5x2.5 km, and the height reaches 100 m.

It should be noted that the northern uplift has also undergone a change. The arch of the structure gradually moves to the southwest, to the area of wells 13, 62 and 74. The fold height is 20 m, and the dimensions along the 1100 m isoline are 1.7x0.6 km.

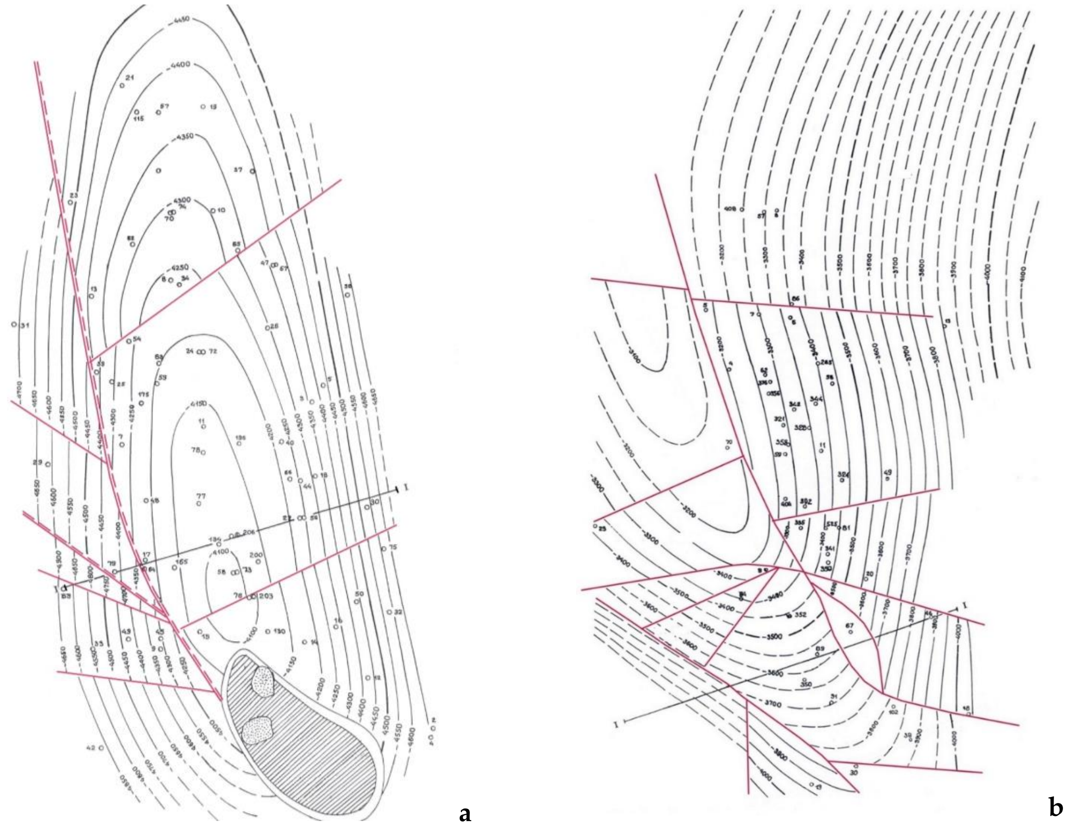

**Figure 3:** *Deposits Bahar (a) and Gum-Deniz (b).*
*Structural map of the 2nd horizon QaR [2].*

The buried Gum-Deniz uplift acquires the shape of a structural nose by the end of the accumulation time of horizon VIII of the Balakhani retinue. As can be seen from the isolines, the northeastern limb of this structure is flatter than the southwestern one. It should be noted that by the end of the 4th century sediments of the horizon of the Sabunchu age, the structures of Gum-Deniz and Bahar had hardly undergone significant changes. But a detailed study showed that it was at this time that the Gum-Deniz structure joined the Karachukhur uplift, forming its southern pericline.

By the end of the Sabunchu century, only the southeastern uplift looms along the Bahar fold, and a structural nose can be traced in the place of the northern one. As can be seen on the map, the structure of Bahar, starting from this century, gradually acquires its modern shape. By the end of the formation of the Surakhani retinue, the Gum-Deniz uplift did not undergo any changes. The structural nose in the area of wells 22, 54, 26, 78 and 51 remains unchanged. By the beginning of the accumulation of sediments from the top of the PS, the roof of the Bahar uplift moves to the southwest, and it acquires a shape close to the modern one. By this time, the base of the PK formation lay at a depth of 3650-4050 m. The Bahar structure has an asymmetric shape, more precisely, the southwestern wing of the fold is more steep than the northeastern one. The Gum-Deniz uplift at this time remains practically unchanged with the difference that the isoline between wells 91 and 18, 7 and 12 is thickened. This indicates the intensive development of tectonic disturbance. In modern terms, the Bahar uplift along the base of the UQ retinue is an anticline stretching from northwest to southeast. It should be noted that a mud volcano located on the southern pericline complicates the structure with numerous faults of various scales, amplitudes and directions. The base of the UQ retinue lies at a depth of 5300-6100 m. The structure is complicated by a series of faults, two of which extend almost parallel to the fold axis and complicate its arch part. Structurally, the Gum-Deniz area is the southeastern pericline of the Karachukhur-Zykh anticline. Thus, the performed paleostructural analysis shows that the Gum-Deniz and Bahar uplifts are elements of early origin; their development in the PS age took place under conditions of stable subsidence of the basin bottom and intensive accumulation of sediments.

Investigations of the territory of the formed structures Gum-Deniz and Bahar showed a more intensive bowing of the basin bottom in the PS century, more precisely, the southern part of the western side of the South-Caspian depression sank more intensively than its northern part. The studies make it possible to assert that an increase in thickness is observed in the direction from the coastlines of the basins of the formations of the lower section of the PS towards the subsidence of the bottom, at a different rate for individual formations. In the uplifts, an increase in thickness is observed from the arched parts to the wings, and this indicates their consedimentary development. Within the Bahar uplift, QaR falls out of the section, which indicates an intensive increase in the uplift and erosion during these deposits.

## Conclusions

1. The considered structures are characterized by different initiation times and changes in the intensity of their development in different periods of geological time.
2. Within the Gum-Deniz structure, areas of minimum thickness of the lower support surfaces are observed, indicating the presence of a buried uplift in the underlying productive strata of sediments.
3. Most of the longitudinal and some lateral faults are consedimentary, and their occurrence occurred at different times.
4. Longitudinal consedimentary fractures of early occurrence served as a screen on the path of hydrocarbons from the areas of their generation to the formations of the lower part of the PS. Post-depositional ruptures have contributed to the destruction of previously formed oil and gas deposits, and this increases the risks of ineffective work.

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# RISK AND INDUSTRIAL SAFETY

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**Abstract**

*Developments in science, technologies, complexity of industrial infrastructure facilities sustaining life necessary systems are associated with an increased dangers of their functioning at all stages of the life cycle. These dangers are characterized by man-made risks that determine the likelihood of hazardous processes and damage from them. Industry-related risks together with natural and anthropogenic risks are integral risks. The tasks of ensuring safety are coming down to the achievement through calculations and experiments of an acceptable level of risks with the necessary estimated economic costs. Approbation of the described approach is carried out on the example of nuclear power plants.*

**Keywords:** safety, risk, durability, accident, disaster, technosphere

## I. Introduction

For centuries people, society, states and humankind in general have developed in rough conditions that were intertwined with dangers from natural, industry related and anthropogenic causes. At the same time problems of human life activities and their systems had to be resolved, factoring in endless increase with time τ of the risks spectrum R(τ). Risks spectrum included risk of large numbers *N* of casualties and loss of health $R_N(\tau)$, risk of damage and loss of number of industry related facilities $R_T(\tau)$ and risk for environment $R_S(\tau)$. In the context of the contemporary comprehensive safety S(τ) and risks R(τ) theory functional relation between integrated safety S(τ) and integral risks R(τ) and their components $R_N(\tau)$, $R_T(\tau)$ and $R_S(\tau)$ must be considered as generally accepted. Its analysis was carried out in a multivolume edition [1].

$$S(\tau) = F_S\left\{R(\tau)\right\} = F_S\left\{R_N(\tau), R_T(\tau), R_S(\tau)\right\} \tag{1}$$

In turn, the risks included in formula (1) for the analyzed time τ can be quantitatively assessed through the probabilities P(τ) of the occurrence of hazardous processes, phenomena and events and the accompanying degrees of damage U(τ) to humans, the natural environment and the technosphere

$$R(\tau) = F_R\left\{P(\tau), U(\tau)\right\} \approx P(\tau)\cdot U(\tau) \tag{2}$$

As the generalization of a large number of social hazards, natural disasters and man-made accidents shows that between P(τ) and U(τ) there is a power-law dependence

$$U(\tau) = C_u \cdot P(\tau)^{m_p} \tag{3}$$

Where $C_u$, $m_p$ – hazard type parameters ($m_p$>1).

If time τ is measured in years, then values P(τ) evaluate through [1/year]. If U(τ) is put through ratio of $N_n$ damaged or destroyed objects at a given time (year) to the total *N* of analyzed objects in a given territory, then $U(\tau) = N_n/N$ and then dimension R(τ) will be [1/year].

Tens and hundreds of thousands of people died in natural disasters (floods, tsunamis, earthquakes), in man-made disasters - up to 30 thousand people, in social upheavals (wars, military conflicts, pandemics) - millions and tens of millions of people.

For the social, natural and technogenic spheres, an assessment of economic damage is carried out, measured, for example, in [USD], then the dimension of risks R(τ) will be in [USD./year]. In this case, to determine the integral risks at the moment τ, it is possible to summarize the risks *R* in the expression (1)

$$R(\tau) = R_N(\tau) + R_T(\tau) + R_S(\tau) \quad (4)$$

Risks R(τ) in expressions (1) – (4) of the most dangerous processes and phenomena observed and analyzed over long intervals of time Δτ ($10^0 \leq \Delta\tau \leq 10^2$ years), could be considered as unacceptable (critical) $R_c(\tau)$. The tasks of modern risk theory, science and technology are pivoted to reduction of risks $R_c(\tau)$ to an acceptable level

$$R(\tau) \leq \left[R(\tau)\right] = R_c(\tau) / n_R, \quad (5)$$

where $n_R$ – risk margin ($2 \leq n_R \leq 5$).

Then safety S(τ) can be quantitatively assessed by expression (1) and risk parameters in expression (5)

$$S(\tau) = \left[R(\tau)\right] - R(\tau) \quad (6)$$

Safety is considered secured if S(τ)≥0 and vice versa. If safety is not ensured for a facility at a given stage of the life cycle τ, then it is necessary to carry out comprehensive measures of a scientific, technological, supervisory, personnel nature with the costs $Z_R(\tau)$ of reducing risks R(τ) to an acceptable level [R(τ)]

$$Z_R(\tau) = \frac{1}{m_z}\left\{\left[R(\tau)\right] - R(\tau)\right\}, \quad (7)$$

Where $m_z$ - economic cost efficiency ratio ($1 \leq m_z \leq 10$).

## II. Methodology for the analysis of industrial safety by risk criteria

For the modern technosphere of life sustenance, which is one of the most changing in comparison with the natural and social components, over the past decades of the XX – XXI centuries, was carried out [1, 2] a statistical analysis of the parameters P(τ) and U(τ) of man-made failures, accidents and severe disasters at facilities of various potential hazards in the civil and defense complexes of Russia and other countries was carried out [1, 2] (Fig. 1).

The analyzed facilities and industrial sectors included:

- energy: large nuclear – 1 and hydraulic – 2 power plants, liquefied gas factories – 3, trunk pipelines – 4
- defense facilities: rocket and space complex – 5, nuclear submarines – 6;
- transport complex: railway and aviation – 7
- petrochemical complex – 8;
- unique buildings and structures – 9;
- offshore development facilities: offshore platforms – 10.

Shown in fig. 1, the data refer to industry related accidents and disasters associated with the dangerous manifestation of anthropogenic (*N*), natural (*S*) and man-made (*T*) factors that create risks R(τ) according to expression (4).

Based on the results of the analysis, taking into account the damage U(τ), a classification (1 – 7 classes) of accidents and catastrophes was carried out: 1 – areal for the elements of the facility, 2 – on site with damage to the facility; 3 – local with damage to the industrial site; 4 – regional with municipal damages; 5 – national with damage to the country; 6 – global with damages for neighboring countries; 7 – planetary with damage to continents or the planet as a whole.

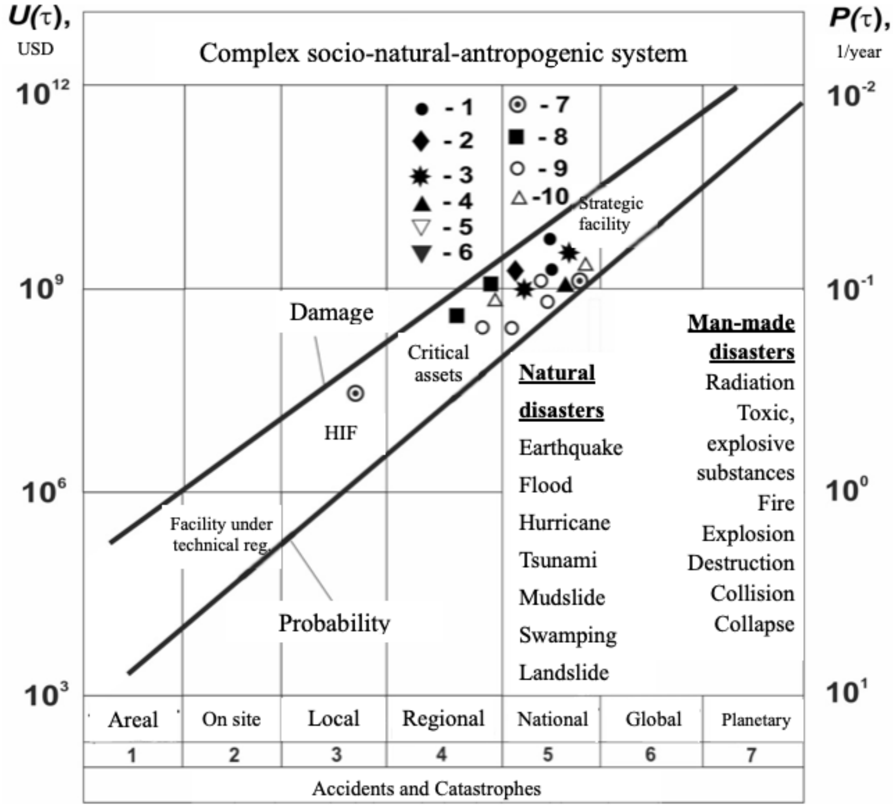


**Figure 1:** *Schematic diagram for determining risk parameters, classifying hazardous situations and categorizing facilities*

Taking into account U(τ) and P(τ) industrial facilities were categorized by risk levels: facilities under technical regulation - mass or large-scale facilities with *N* up to$10^6 \div 10^7$; hazardous industrial facilities (HIF) – serial facilities with *N* up to $5 \cdot 10^4 \div 10^5$; critical assets with *N* up to $10^3$-$5 \cdot 10^3$; strategic facilities with *N* up to $10^2 \div 5 \cdot 10^2$. The corresponding dots in Fig. 1 shows data for critical assets and strategic facilities.

Using expression (2) and values P(τ) and U(τ), according to the scales in Fig. 1, it is possible to determine the critical industry-related risks $R_c(\tau)$ included in expression (5). Justifying and assigning the values of margins $n_R$, according to this expression, it is possible to establish acceptable economic risks [R(τ)] for the analyzed facilities. Having determined the state of facilities through the methods of technical diagnostics and monitoring, according to (2) it is possible to assess the formed risks R(τ). This makes it possible to assess industrial safety S(τ) according to (1) and (6) and the necessary costs $Z_R(\tau)$ for its achievement according to (7).

## III. Analysis results

Of key importance for the substantiation of industrial safety S(τ) according to (1) and (6) is the computational and experimental determination of the risks R(τ) of hazardous and safe states of the analyzed facility for a given stage of its life cycle. This definition is linked to the solution of criterion issues of strength, resource, reliability and integrity of critical elements of the object at the most dangerous points in the most dangerous situations – design, beyond design and hypothetical [1 – 3]. In this case, one can proceed from the assumption that accidents and disasters are ultimately caused by damage and destruction of critical elements of the facility.

Damage and destruction according to the above criteria are assessed taking into account:

- spectrum of hazardous impacts Q(τ), consisting of operational technological $Q_T(\tau)$, natural $Q_S(\tau)$ and anthropogenic $Q_N(\tau)$ impacts;
- emerging reactions of load-bearing elements to these impacts, expressed in terms of maximum stress $\sigma_{max}(\tau)$ and deformation $e_{max}(\tau)$ at critical points;
- resistance to damage and destruction, expressed through the critical values of stresses $\sigma_k$ and strains $e_k$, depending on temperatures $t^S$, time $\tau^s$, environment $s$, number of cycles $N^s$, formation and development of cracks $\ell^s$. When destroyed, these figures reach critical values. For this purpose, based on the results of calculations and experiments, three-dimensional surfaces of limiting and permissible states are constructed (Fig. 2):
- by the initial damage with the formation of cracks $\ell_0$;
- by the final failure with the formation of critical cracks $\ell_c$;
- according to the current state at the moment τ at $n$(τ ) and $t$(τ ) with a crack $\ell$.

These states comply with the corresponding loads Q(τ), stresses $\sigma_{max}$, $\sigma_o$, $\sigma_c$, deformations $e_{max}$, $e_o$, $e_c$, characterized by the position of point $A$(τ) in three-dimensional space with coordinates $\ell$(τ ), { $\sigma_{max}(\tau)$, $e_{max}(\tau)$}, {τ, $n$(τ), $t$(τ )}.

For this point, using an expression similar to (5), one can determine the position of the surface of admissible states

$$\left\{[\sigma],[e]\right\} = \left\{\frac{\sigma_c}{n_\sigma},\frac{e_c}{n_e}\right\};\ [e] = \frac{\ell_c}{n_\ell};\ \left\{[\tau],[N],[t]\right\} = \left\{\frac{\tau_c}{n_\tau},\frac{n_c}{n_N},\frac{t_c}{n_t}\right\} \quad (8)$$

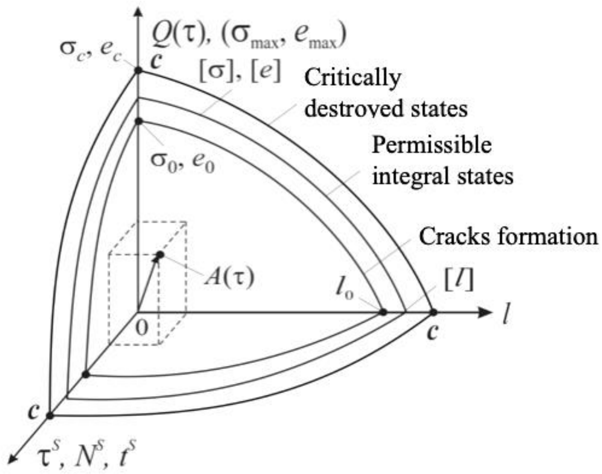


**Figure 2:** *3D surfaces of the load-bearing elements' states*

All parameters of operational influences Q(τ), reactions to them {$\sigma_{max}(\tau)$, $e_{max}(\tau)$}, levels of defectiveness $\ell$ and operational loading {$\tau^s$, $N^s$, $t^s$}, as well as critical values {$\sigma_c$, $e_c$ } , $\ell_c$, {$\tau^s$, $N^s$, $t^s$} are stochastic, which determines the probabilistic nature of the surfaces of limiting and permissible states according to Fig. 2.

The probabilistic position of point $A$(τ) relative to the zero point "0" determines the probabilistic vector «0-$A$(τ)» characterizing $P$(τ) in expression (2). If this vector does not go beyond the surface of permissible states, then, taking into account (8), the integrity of the facility and its technogenic safety $S$(τ) according to (6) are ensured and vice versa.

In the latter case, it is necessary to carry out measures to fulfill conditions (5), (6) with economic costs according to (7).

# IV. Debate

The above methodology was tested for nuclear power plants with pressurized water reactors [1 – 5] with a capacity of 1000 MW.

Fig. 3 shows the relation between the probability $P(\tau)$ and damage $U(\tau)$ for critical $P_c(\tau)$ and $U_c(\tau)$ and admissible $[P(\tau)]$ and $[U(\tau)]$ states.

In this case, we used data on real disasters and accidents at nuclear power plants (see Fig. 1, points 1), as well as on current damage to steam generators and turbine generators. Considering the extremely high danger of nuclear disasters belonging to classes 4 – 5 in Fig. 1, the margin in expression (5) was taken to be increased ($n_R \geq 10$).

Achievement of negligible risks at the stage of cracking $\ell_0$ according to Fig. 2 is practically impossible (complex equipment of nuclear power plants has non-zero initial technological defects $\ell_0 \neq 0$).

For severe disasters at nuclear power plants (such as Three Mile Island, USA; Chernobyl, USSR; Fukushima-1, Japan), social and environmental damages can significantly (by 1 – 2 orders of magnitude) exceed the direct ones indicated in Fig. 3. This leads to a large necessary additional calculated costs $Z_R(\tau)$ according to expression (7) to reduce risks $R(\tau)$ to an acceptable level $[R(\tau)]$. According to Fig. 2 and 3, they turn out to be in the range of $(5 \div 10) \cdot 10^6$ USD/year for one nuclear power plant.

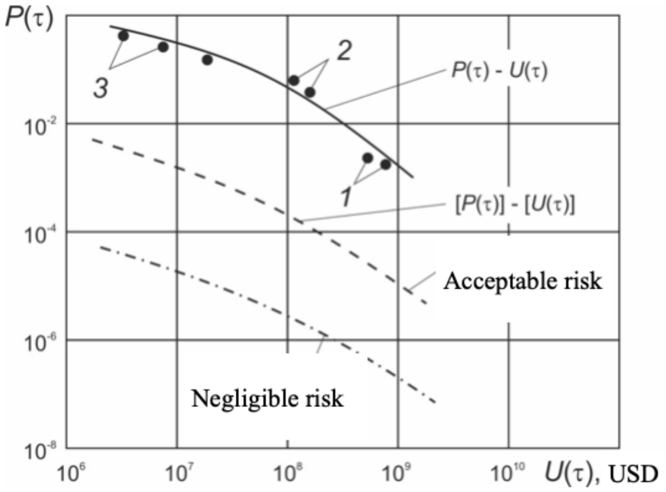


**Figure 3:** *Probabilities and direct man-made damages from accidents and disasters at nuclear power facilities: NPP – 1, steam generators – 2, turbine generators – 3*

The implementation of the outlined risk-oriented approach requires a phased realization of fundamental research and applied developments in mathematics, mechanics, physics, chemistry, biology, sociology, economics, ecology of crises, accidents and disasters in a scientific interconnected system that includes technogenic, natural and social spheres with their own risks.

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# ENVIRONMENTAL SAFETY IN COMPLEX CONSTRUCTION ON THE TERRITORY WITH DISTURBED EXOGENOUS PROCESSES

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**Abstract**

*Environmental support of construction projects considers and solves environmental problems from the development of a concept for construction, preparation of a pre-design documentation in the pre-investment period, preparation of data for design, development of project documentation, etc. and until the destruction of the existing building after the expired period of its operation. Thus, environmental support is carried out throughout the entire life cycle of the functioning of buildings or structures. Environmental support for construction projects implies a set of works on instrumental measurements of parameters, performing calculations, developing environmental protection measures in order to ensure and create environmentally friendly solutions.*

**Keywords**: erosion processes, complex construction, erosion resistance, construction of facilities, acceleration of convergence, geocomposition systems.

## I. Introduction

At present, there is an acute issue of creating a safe and comfortable living environment in the conditions of the city; high density of development due to the lack of territory, negative changes in the environment due to the impact of transport and vital facilities of the city infrastructure - all this does not contribute to the formation of favorable conditions for living and working for 1, 2 days. One of the reasons for this situation is believed to be the development of hazardous exogenous processes, including erosion in the developed territories [3]. The development of negative exogenous processes in its turn has an impact on ensuring the ecological safety of the built-up areas. The problem of soil erosion is not new, however, the use of various types of protection against soil erosion is based, as a rule, on experience and does not presuppose additional preliminary study and calculation of the solutions adopted. This article discusses a mathematical description of the erosion process and the relationship of the decisions made with the use of additional measures to protect the slopes from erosion.

For a mathematical description, the pro-ecological safety of construction and urban economy, the erosion (erosion) must be presented as the action of forces that promote and hinder it. The forces that hinder the process of development are: first, the force of gravity; secondly, the power of cohesion, which plays an important role in the processes of development. The forces contributing to the wash-out process include the pulsation action of bottom velocities, or even a bending moment tending to tear off the structural part [4].The problem of soil erosion is not new, however, the use of various types of protection against soil erosion is based, as a rule, on experience and does not presuppose additional preliminary study and calculation of the solutions adopted.

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The tasks of engineering and environmental surveys are determined by the peculiarities of the natural environment, the nature of existing and planned anthropogenic impacts. The need for the development of environmental engineering surveys is determined by Article 47 (part 5) of the Urban Planning Code of the Russian Federation: The need to carry out certain types of engineering surveys, the composition, scope and method of their implementation is established taking into account the requirements of technical regulations by an engineering survey program developed on the basis of an assignment from a developer or a technical the customer, depending on the type and purpose of capital construction projects, their design features, technical complexity and potential danger, the stage of architectural and construction design, as well as the complexity of the topographic, geotechnical, environmental, hydrological, meteorological and climatic conditions of the territory where the to carry out construction, reconstruction of capital construction objects, the degree of knowledge of these conditions. The results of engineering and environmental surveys are a document on the completed engineering surveys, containing materials in text form and in the form of maps (diagrams) and reflecting information about the tasks of engineering surveys, about the location of the territory on which it is planned to carry out construction, reconstruction of a capital construction object, about the types , on the volume, on the methods and on the timing of work on the implementation of engineering surveys in accordance with the engineering survey program, on the results of a comprehensive study of the natural and man-made conditions of the specified territory, including the results of the study, assessment and forecast of possible changes in the natural and man-made conditions of the specified territories in relation to a capital construction object during the construction, reconstruction of such an object and after their completion.

Expertise of engineering and environmental surveys is determined by the Urban Planning Code of the Russian Federation. Environmental support of construction projects involves the implementation of a set of regulated procedures aimed at ensuring environmental safety in the area of creation (construction) of an enterprise that has an impact on the environment, and related to the development and implementation of measures aimed at protecting nature and public health from the harmful effects of this facility at all stages of its life cycle. The preparation of project documentation begins with an analysis of the initial permitting documentation and the results of engineering and environmental surveys. In all design sections and adopted architectural, structural and technical solutions, environmental safety issues are reflected to one degree or another. The section "List of measures for environmental protection" (PM EP) as part of the project documentation is developed in accordance with the Urban Planning Code of the Russian Federation and the Decree of the Government of the Russian Federation dated February 16, 2008 No. 87 "On the composition of sections of project documentation and requirements for their content." The PM EP section deals with environmental safety issues in connection with the planned economic activities. It will hold back design developments for environmental protection with elements of environmental regulation (MPE projects, VAT, PNOOLR, SPZ), which must be taken into account in the design, implementation and control of planned economic activities.

Environmental support of project documentation is an integrated approach at the design stage of an object, where the foundations of rational environmental management are laid.

## II. Conclusions

Environmental support for construction and installation work consists in following the organization of construction in terms of the section of the project documentation "List of measures for environmental protection". All construction organizations are required to carry out a whole range of measures, including laboratory research and instrumental measurements, to ensure environmental control at the work site and adjacent territories. This complex can be carried out with the involvement of third-party specialized organizations and is of a regular nature. The most important point in the process of environmental support for construction, in addition to administering payments, is environmental monitoring and industrial environmental control. The main tasks of environmental support of operation are mainly in the development and coordination of environmental standards with the environmental protection authorities and in the subsequent enforcement of these standards. The duty to control the state of the environment is imposed on all entities carrying out activities that can cause harmful effects on the environment (OS) and is enshrined in the laws on environmental protection, on production and consumption waste, in land, water and forestry legislation and other regulations. ... Monitoring is carried out for the implementation in the process of economic and other activities of measures for environmental protection, rational use and restoration of natural resources, as well as in order to comply with the requirements in the field of environmental protection established by legislation in the field of environmental protection. An important part of the process of environmental support of the economic activities of natural resource users is the calculation of the fee for negative impact (NVOS) and its correct payment not only on time, but also in the corresponding subdivision of the budget system. The stage of liquidation of the facility should also begin with pre-design and design study and environmental justification of the proposed solutions, followed by ensuring their implementation in cases where the facility is classified as hazardous and the process of its liquidation may be accompanied by a significant negative impact on the environment. The overall goal of environmental management is to prevent deterioration of the quality of the environment. Guaranteed by Article 42 of the Constitution of the Russian Federation, everyone's right to a favorable environment, reliable information about its condition and to compensation for damage caused to his health or property by an environmental offense, as well as the implementation of the provisions provided for in Part 1 of Article 9, Part 2 of Article 36, Article 58 of the Constitution Of the Russian Federation, is ensured, among other things, through the correct application of the legislation on liability for violations in the field of environmental protection and nature management.

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# RESULTS COMPARISON OF ANALYTICAL AND SIMULATION MODELLING OF OIL SPILL DOMAIN MOVEMENT AT PORT WATER AREA

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**Abstract**

*A theoretical background of process of changing hydro-meteorological conditions impact on oil spill trajectory is presented. Probabilistic procedures, analytical and simulation, to oil spill domain movement modelling are proposed considering the impact of hydro-meteorological conditions. The procedures are practically applied to prediction of oil spill domain movement at Karlskrona seaport water area. The discussion and comparison of results are also presented.*

**Keywords:** oil spill, stochastic modelling, Monte Carlo prediction, Karlskrona seaport

## I. Introduction

Closed sea areas are more vulnerable to various types of pollution [2], [5]. The Baltic Sea is one of the smallest seas through which pass the busiest communication routes in the world. Over the years, an increase in ship traffic has been observed, including the transfer of gas carriers, oil tankers, container ships and transit traffic [11]. Hazardous materials, for instance crude oil, constitute a very high percentage of the shipping transport. The Baltic Sea was recognized as a particularly sensitive sea area by the International Maritime Organization in 2005 [10]. This status is intended to help more effectively protect areas contaminated by ships. The threats mainly come from the damaged tankers or offshore, polluting large water areas and coasts [5]. Collision between ships carrying dangerous materials may also cause pollution of the marine environment.

There are several ways to protect the marine environment and improve shipping safety. One is to predict the behavior of oil spill trajectory and domain at the water area. The movement of this domain can be predicted based on statistical data from sea experiments. Based on the models given in [3]-[4], one of the accurate and effective methods to determine the spill area and its movement may be a stochastic method supplemented by considering and applying the Monte Carlo simulation approach to solve this problem. Those methods proposed in this paper are applied to the movement prediction of the oil spill domain movement at Karlskrona harbour in order to minimize the potential environmental consequences.

## II. Theoretical background

### I. Process of changing hydro-meteorological conditions

We denote by $A(t)$ the process of varying hydro-meteorological conditions in the sea water area where the oil spill happened. Then, we assume that $A = \{1,2,...,m\}$ is the set of all possible states of $A(t)$ in which it may stay at the moment $t$, $t \in <0,T>$, $T > 0$. Further, we assume a semi-

Markov model [7]-[8] of the process $A(t)$ and denote by $\theta_{ij}$ its conditional sojourn time in state $i$ while its next transition will be done to state $j$, where $i, j \in \{1,2,...,m\}$, $i \neq j$. The process $A(t)$ is described by the following parameters [3]-[4], [7]-[8]:

- the vector $[p(0)]_{1\times m}$ of probabilities $p_i(0)$ of the process' initial states at $t = 0$;
- the matrix $[p_{ij}]_{m\times m}$ of transitions' probabilities $p_{ij}$ between the particular states, where $\forall\, i = 1,2,...,m$, $p_{ii} = 0$;
- the matrix $[W_{ij}(t)]_{m\times m}$ of distribution functions $W_{ij}(t)$ of $\theta_{ij}$ at the particular states;
- the expected values $M_{ij} = E[\theta_{ij}]$ of its conditional sojourn times $\theta_{ij}$ at the particular states

## III. Modelling oil spill trajectory

Let $T$ be time of experiment and $k$ be the hydro-meteorological process state, $k = 1,2,\ldots,m$. We suppose that the central point $(m^k_X(t), m^k_Y(t))$ of oil spill domain is placed in the oil spill domain $D^k(t)$, $t \in <0,T>$, $T > 0$, with a fixed probability $p$. From [3], we have

$$P\Big((X^k(t),Y^k(t)) \in D^k(t)\Big) = \iint\limits_{D^k(t)} \varphi_t^k(x,y)dxdy = p,\ \ t \in <0,T>,\ k = 1,2,\ldots,m, \tag{1}$$

where

$$D^k(t) = \{(x,y): \frac{1}{1-(\rho^k_{XY}(t))^2}[\frac{(x-m^k_X(t))^2}{(\sigma^k_X(t))^2} - 2\rho^k_{XY}(t)\frac{(x-m^k_X(t))(y-m^k_Y(t))}{\sigma^k_X(t)\sigma^k_Y(t)} + \frac{(y-m^k_Y(t))^2}{(\sigma^k_Y(t))^2}] \le c\}$$

is the domain bounded by an ellipse being the projection on the plane $0xy$ of the curve resulting from the intersection (Figure 3 in [3]) of the density function surface $\pi_1^k$ and the plane $\pi_2^k$, for $t \in <0,T>$, $k = 1,2,\ldots,m$:

$$\pi_1^k = \{(x,y,z): z = \varphi_t^k(x,y), (x,y) \in R^2\}, \tag{2}$$

$$\pi_2^k = \{(x,y,z):\ z = \frac{1}{2\pi\sigma^k_X(t)\sigma^k_Y(t)\sqrt{1-(\rho^k_{XY}(t))^2}}(1-p)\exp[c^2]], (x,y) \in R^2\}. \tag{3}$$

Considering the varying hydro-meteorological conditions, for a fixed time-step $\Delta t$, we assume that $s_i$ is a number of steps corresponding to the successive hydro-meteorological process' states $k_1, k_2, ..., k_{n+1}$, such that

$$(s_i - 1)\Delta t < \sum_{j=1}^{i} E[\theta_{k_j k_{j+1}}] \le s_i\Delta t,\ i = 1,2,...,n,\ \ s_n\Delta t \le T. \tag{4}$$

Therefore, assuming parametric form of oil spill central point drift trend curve

$$K^{k_i}: \begin{cases} x^{k_i} = x^{k_i}(t) \\ y^{k_i} = y^{k_i}(t), \end{cases} \quad t \in \langle 0,T\rangle,\ i = 1,2,...,n,$$

at each hydro-meteorological process' state $k_i$, we obtain the sequences of oil spill domains

$$\overline{D}^{k_i}((s_{i-1}+1)\Delta t), \overline{D}^{k_i}((s_{i-1}+2)\Delta t), \ldots, \overline{D}^{k_i}(s_i\Delta t), \tag{5}$$

where $\overline{D}^{k_i}(t)$, for $t$ equal to $(s_{i-1}+1)\Delta t$, $(s_{i-1}+2)\Delta t$, ..., $s_i\Delta t$, are defined by (1) with expected values, standard deviations and radiuses as follows:

$$m_X^{k_i}(t) := m_X^{k_{i-1}}(s_{i-1}\Delta t) + m_X^{k_i}(a_i\Delta t),\ m_Y^{k_i}(t) := m_Y^{k_{i-1}}(s_{i-1}\Delta t) + m_Y^{k_i}(a_i\Delta t),$$

$$\bar{\sigma}_X^{k_i}(t) := \sigma_X^{k_i}((s_{i-1}+a_i)\Delta t) + \sum_{j=1}^{i} r^{k_j}(b_j\Delta t),\ \bar{\sigma}_Y^{k_i}(t) := \sigma_Y^{k_i}((s_{i-1}+a_i)\Delta t) + \sum_{j=1}^{i} r^{k_j}(b_j\Delta t),\ r^{k_j}(t) := r^{k_j}(b_j\Delta t),$$

for $a_i = 1,2,...,b_i$, $b_i = 1,2,...,s_i - s_{i-1}$, $i = 1,2,...,n$, $j = 1,2,...,i$.

The oil spill domain in the experiment is described by the sum of domains (5).

## IV. Modelling oil spill domain analytical and simulation prediction procedures

The general stochastic (analytical and simulation) prediction procedures of the oil spill trajectory and its domain movement at varying hydro-meteorological conditions, based on the models from [3]-[4] and described shortly in Section II, are given in the scheme presented below. Generally, the simulation procedure consists of the following steps:

- we input data described in Section II;
- we select the initial state at the moment $t = 0$, by generating realizations from the distribution defined in Section I by the vector $[p(0)]_{1\times m}$ of probabilities of the process' initial states, using formula $k_i := k_i(q)$, $i \in \{1,2,...,m\}$, where $q$ is a randomly generated number from the uniform distribution on the interval $\langle 0,1)$;
- we can fix the next operation state of the process of changing hydro-meteorological conditions at oil spill area and denote by $k_{i+1} = k_{i+1}(g)$, $i \in \{1,2,...,m\}$, $i \neq i+1$, the sequence of the realizations of the operation process' consecutive states generated from the distribution defined in Section I by the matrix $[p_{ij}]_{m\times m}$ of transitions' probabilities $p_{ij}$, where $g$ is a randomly generated number from the uniform distribution on the interval $\langle 0,1)$;
- we can use several methods generating draws from a given probability distribution from the given in Section I matrix $[W_{ij}(t)]_{m\times m}$ of distribution functions $W_{ij}(t)$ of $\theta_{ij}$, e.g. an *inverse transform method*, a *Box-Muller transform method*, *Marsaglia and Tsang's* rejection sampling; using the inverse transform method, the realization is generated from $t_{k_i k_{i+1}}^{(i)}(h) := W_{k_i k_{i+1}}^{-1}(h)$;
- we put some values equal to zero for the conveniece to start the procedure;
- we generate the inital state, next state and realisation $t_{k_i k_{i+1}}^{(i)}(h)$ of the conditional sojourn time, then substitute $i := j$ and repeat drawing another randomly generated numbers $g$ and $h$ (selecting the states $k_{i+1}$ and generating realizations $t_{k_i k_{i+1}}^{(i)}(h)$), until the sum $\sum_{j=1}^{i} t_{k_j k_{j+1}}$ of all generated realisations reach a fixed experiment time $T$;
- we calculate the necessary parameters and get (5);
- we obtain the sequences of oil spill domains for varying hydro-meteorological conditions.

The analytical approach has the same input data, but the approach is different in a following way:

- we can either fix the states $k_i$ and $k_{i+1}$, or take the generated states;
- we select $M_{k_j k_{j+1}}$, check the condition $(s_i - 1)\Delta t < \sum_{j=1}^{i} M_{k_j k_{j+1}} \leq s_i\Delta t$, and find new $M_{k_j k_{j+1}}$;
- the output data are the sequences of domains for varying hydro-meteorological conditions.

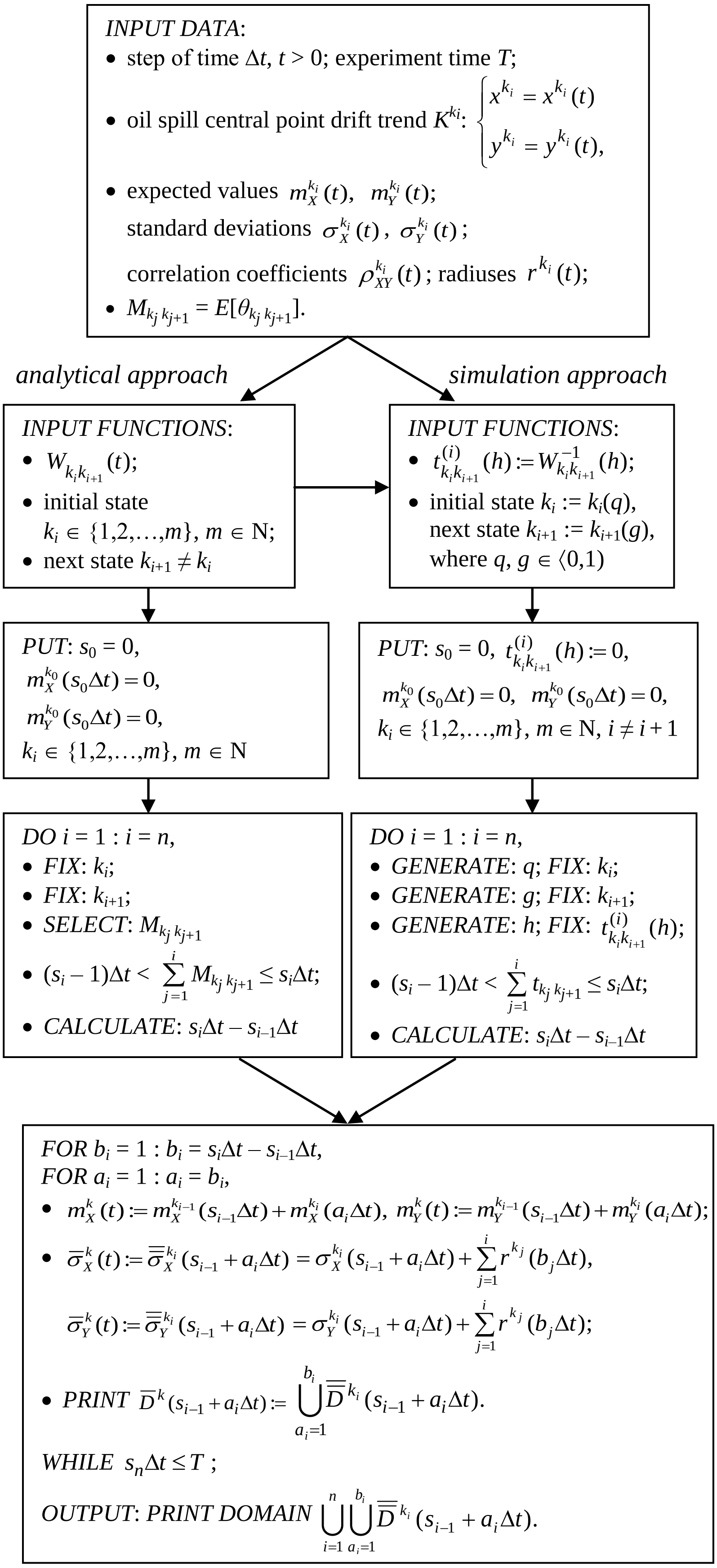


**Figure 1:** *Oil spill trajectory and domain movement analytical and simulation prediction procedures*

# V. Application

**I. Process of changing hydro-meteorological conditions at Karlskrona seaport area**

After discussion with experts, we assume the selected hydro-meteorological factors having crucial influence on the oil spill trajectory in port areas [6]:

- wind speed,
- wind direction,
- sea level height,
- direction of currents,
- visibility difficulties (e.g. fog, icing).

The statistical data were collected in Marches [9] for six years of the experiment. March is the month, where the weather in Sweden is changing rapidly, from the noticeable strong wind and storm to calm breeze, that is why, this factor is the major one in the investigation. The strongest winds (>33 m/s) did not occur in the considered area. Second notable parameter that the experts suggested to include is the wave height. Considering the above, there were distinguished $m$ = 6 states of the process $A(t)$, $t \in <0,T>$, $T > 0$, i.e.

- $k$ = 1 – the wave height from 0 up to 2 m and the wind speed from 0 m/s up to 17 m/s;
- $k$ = 2 – the wave height from 2 m up to 5 m and the wind speed from 0 m/s up to 17 m/s;
- $k$ = 3 – the wave height from 5 m up to 14 m and the wind speed from 0 m/s up to 17 m/s;
- $k$ = 4 – the wave height from 0 up to 2 m and the wind speed from 17 m/s up to 33 m/s;
- $k$ = 5 – the wave height from 2 m up to 5 m and the wind speed from 17 m/s up to 33 m/s;
- $k$ = 6 – the wave height from 5 m up to 14 m and the wind speed from 17 m/s up to 33 m/s.

On the basis of the statistical data [6], it was possible to evaluate the following unknown basic parameters of the semi-Markov model of the process of changing hydro-meteorological conditions at the considered area, where the oil spill happened, according to Section I and [1]:

- the initial probabilities:

$$p_1(0) = 0.324,\ p_2(0) = 0.018,\ p_3(0) = 0.447,\ p_4(0) = 0.029,\ p_5(0) = 0.182,\ p_6(0) = 0; \quad (6)$$

- the probabilities of transitions from the state $i$ into the state $j$:

$$\begin{gathered} p_{12} = 0.12,\ p_{13} = p_{63} = 0.67,\ p_{14} = p_{42} = 0.03,\ p_{15} = 0.18,\ p_{21} = 0.25,\ p_{23} = 0.11,\ p_{24} = 0.64,\ p_{31} = 0.6, \\ p_{32} = p_{36} = p_{46} = 0.01,\ p_{34} = 0.15,\ p_{35} = 0.23,\ p_{41} = 0.01,\ p_{43} = 0.95,\ p_{51} = 0.37,\ p_{53} = 0.63,\ p_{65} = 0.33, \end{gathered} \quad (7)$$

where the rest probabilities are equal to 0.

The hypotheses on the distributions of this process' conditional sojourn times at the particular states were verified for the sets containing at least 30 realizations coming from the experiment (Table 1). The random samples that were not sufficiently large have the empirical CDF-s. The remaining distribution functions could not be evaluated because the corresponding states have not happened during the experiment.

**Table 1:** *The distribution functions of the verified sojourn times*

| Distribution | Sojourn times | Expected values |
|---|---|---|
| Exponential | $\theta_{12}$, $\theta_{15}$ | 31.55, 36.1 |
| Chimney | $\theta_{13}$, $\theta_{31}$, $\theta_{43}$ | 39.49, 35.86, 15.77 |
| Gamma | $\theta_{34}$, $\theta_{35}$, $\theta_{51}$, $\theta_{53}$ | 17.56, 26.75, 43.45, 20.45 |
| empirical CDF | $\theta_{14}$, $\theta_{21}$, $\theta_{23}$, $\theta_{32}$, $\theta_{36}$, $\theta_{41}$, $\theta_{42}$, $\theta_{46}$, $\theta_{63}$, $\theta_{65}$ | 7.12, 7.29, 5, 15, 77.5, 3, 3, 3, 4.5, 6 |

**II. Oil spill domain in varying hydro-meteorological conditions at Karlskrona seaport water area**

We arbitrarily assume, that $T = 48\,h$ and after discussion with experts, the points $(m_X^{k_i}(t), m_Y^{k_i}(t))$, $t \in \langle 0,48 \rangle$ for each hydro-meteorological state $k_i$, create a curve

$$K^{k_i}: \begin{cases} x^{k_i} = t^2 \\ y^{k_i} = k_i \cdot t, \end{cases} \quad t \in \langle 0, 48 \rangle,\ k_i \in \{1,2,\ldots,6\}, i = 1,2,\ldots,n. \tag{8}$$

Moreover, after assuming arbitrarily the remaining parameters, we have

$$\overline{D}^{k_i}(t) = \{(x,y): \frac{1}{1-0.8^2}[\frac{(x-t^2)^2}{(\overline{\sigma}_X^{k_i}(t))^2} - 1.6\frac{(x-t^2)(y-k_i \cdot t)}{\overline{\sigma}_X^{k_i}(t)\overline{\sigma}_Y^{k_i}(t)} + \frac{(y-k_i \cdot t)^2}{(\overline{\sigma}_Y^{k_i}(t))^2}] \le 5.99\}, \tag{9}$$

where $\overline{\sigma}^{k_i}(t)$, $t \in \langle 0,48 \rangle$, are defined in Section II, substituting

$$\sigma^{k_i}(t) = 0.1 + 0.2t,\ r^{k_i}(t) = 0.5 + 0.5t,\ t \in \langle 0,48 \rangle, k_i \in \{1,2,\ldots,6\}, i = 1,2,\ldots,n. \tag{10}$$

Having all the parameters determined, we select the initial state at the moment $t = 0$, by generating realizations from the distribution defined by (6) using formula $k_i := k_i(q)$, $i \in \{1,2,\ldots,m\}$, i.e.

$$k_1(q) = \begin{cases} 1, & 0 \le q < 0.324 \\ 2, & 0.324 \le q < 0.342 \\ 3, & 0.342 \le q < 0.789 \\ 4, & 0.789 \le q < 0.818 \\ 5, & 0.818 \le q < 1; \end{cases}$$

where $q$ is a randomly generated number from the uniform distribution on the interval $\langle 0,1)$. Then, we can fix the next operation state of the process of changing hydro-meteorological conditions at oil spill area and denote by $k_{i+1} = k_{i+1}(g)$, $i \in \{1,2,\ldots,m\}$, $i \ne i+1$, the sequence of the realizations of the operation process' consecutive states generated from the distribution defined by (7), where $g$ is a randomly generated number from the uniform distribution on the interval $\langle 0,1)$, i.e.

$$k_2(g) = \begin{cases} 2, & 0 \le g < 0.12 \\ 3, & 0.12 \le g < 0.79 \\ 4, & 0.79 \le g < 0.82 \\ 5, & 0.82 \le g < 1, \end{cases} \text{ if } k_1(q) = 1;$$

$$k_2(g) = \begin{cases} 1, & 0 \le g < 0.25 \\ 3, & 0.25 \le g < 0.36 \\ 4, & 0.36 \le g < 1, \end{cases} \text{ if } k_1(q) = 2;$$

$$k_2(g) = \begin{cases} 1, & 0 \le g < 0.6 \\ 2, & 0.6 \le g < 0.61 \\ 4, & 0.61 \le g < 0.76 \\ 5, & 0.76 \le g < 0.99 \\ 6, & 0.99 \le g < 1, \end{cases} \text{ if } k_1(q) = 3;$$

$$k_2(g) = \begin{cases} 1, & 0 \le g < 0.01 \\ 2, & 0.01 \le g < 0.04 \\ 3, & 0.04 \le g < 0.99 \\ 6, & 0.99 \le g < 1, \end{cases} \text{ if } k_1(q) = 4;$$

$$k_2(g) = \begin{cases} 1, & 0 \le g < 0.37 \\ 3, & 0.37 \le g < 1, \end{cases} \text{ if } k_1(q) = 5;$$

$$k_2(g) = \begin{cases} 3, & 0 \le g < 0.67 \\ 5, & 0.67 \le g < 1, \end{cases} \text{ if } k_1(q) = 6;$$

and so on. For the analytical approach, we assume that the process of changing hydro-meteorological conditions $A(t)$ in succession takes these simulated states. Thus, we proceed with procedures from Section II, taking the input data from this section. We get:

- for $i = 1$, we generate $g \cong 0.456$, $q \cong 0.88$ and select $k_1(0.456) = 3$, $k_2(0.88) = 5$:

*analytical approach*

- we select the conditional mean value $M_{35} = 26.75$ of the sojourn time $\theta_{35}$;
- we check the condition $(s_1 - 1) = s_0 = 0 < M_{35} = 26.75 \le s_1$;
- hence, $s_1 = 27$ and $s_1 - s_0 = s_1 - 0 = 27$;
- consequently, we draw 1,2,...,27 ellipses;
- we compare $s_1$ with the experiment time: $s_1 = 27 < 48 = T$;
- we draw the sequence of the oil spill domains for $a_1 = 1,2,\ldots,b_1$, $b_1 = 1,2,\ldots,27$, (Figure 2);

*simulation approach*

- we generate $h_1 = 0.7$, $h_2 = 0.9$ and select the realisation $t^{(1)}_{k_1k_2} = t^{(1)}_{35} = 5.593$ of the sojourn time $\theta_{35}$;
- we check the condition $(s_1 - 1) = s_0 = 0 < t^{(1)}_{35} = 5.593 \le s_1$;
- hence, $s_1 = 6$ and $s_1 - s_0 = s_1 - 0 = 6$;
- consequently, we draw 1,2,...,6 ellipses;
- we compare $s_1$ with the experiment time: $s_1 = 6 < 48 = T$;
- we draw the sequence of the oil spill domains for $a_1 = 1,2,\ldots,b_1$, $b_1 = 1,2,\ldots,6$, (Figure 4);

- for $i = 2$, $k_2 = 5$ and we generate $q \cong 0.217$ to select $k_3(0.217) = 1$:

*analytical approach*

- we select the conditional mean value $M_{51} = 43.45$ of the sojourn time $\theta_{51}$;
- we check the condition $(s_2 - 1) = s_1 = 27 < M_{35} + M_{51} = 26.75 + 43.45 \le s_1$;
- hence, $s_2 = 70.2$ and $70.2 > 48 = T$, thus $s_2 = 48$ and $s_2 - s_1 = 48 - 27 = 21$;
- consequently, we draw 1,2,...,21 ellipses;
- we draw the sequence of the oil spill domains for $a_2 = 1,2,\ldots,b_2$, $b_2 = 1,2,\ldots,21$, (Figure 2);

*simulation approach*

- we generate $h_1 = 0.2$, $h_2 = 0.6$ and select the realisation $t^{(2)}_{k_2k_3} = t^{(2)}_{51} = 11.928$ of the sojourn time $\theta_{51}$;
- $t^{(1)}_{k_1k_2} + t^{(2)}_{k_2k_3} = t^{(1)}_{35} + t^{(2)}_{51} = 5.593 + 11.928 = 17.521$;
- we check the condition $(s_2 - 1) < 17.521 \le s_2$;
- hence, $s_2 = 18$ and $s_2 - s_1 = 18 - 6 = 12$;
- consequently, we draw 1,2,...,12 ellipses;
- we compare $s_2$ with the experiment time: $s_2 = 18 < 48 = T$;
- we draw the sequence of the oil spill domains for $a_2 = 1,2,\ldots,b_2$, $b_2 = 1,2,\ldots,12$, (Figure 4);

- for $i = 3$, $k_3 = 1$ and we generate $q \cong 0.469$ to select $k_4(0.469) = 3$:

*simulation approach*

- we generate $h = 0.3$ and select the realisation $t^{(3)}_{k_3k_4} = t^{(3)}_{13} = 10.587$ of the sojourn time $\theta_{13}$;
- $t^{(1)}_{k_1k_2} + t^{(2)}_{k_2k_3} + t^{(3)}_{k_3k_4} = t^{(1)}_{35} + t^{(2)}_{51} + t^{(3)}_{13} = 5.593 + 11.928 + 10.587 = 28.108$;
- we check the condition $(s_3 - 1) < 28.108 \le s_3$;
- hence, $s_3 = 29$ and $s_3 - s_2 = 29 - 18 = 11$;
- consequently, we draw 1,2,...,11 ellipses;
- we compare $s_3$ with the experiment time: $s_3 = 29 < 48 = T$;
- we draw the sequence of the oil spill domains for $a_3 = 1,2,\ldots,b_3$, $b_3 = 1,2,\ldots,11$, (Figure 4);

- for $i = 4$, $k_4 = 3$ and we generate $q \cong 0.758$ to select $k_5(0.758) = 1$:

*simulation approach*

- we generate $h = 0.45$ and select the realisation $t^{(4)}_{k_4k_5} = t^{(4)}_{31} = 19.367$ of the sojourn time $\theta_{31}$;
- $t^{(1)}_{k_1k_2} + t^{(2)}_{k_2k_3} + t^{(3)}_{k_3k_4} + t^{(4)}_{k_4k_5} = t^{(1)}_{35} + t^{(2)}_{51} + t^{(3)}_{13} + t^{(4)}_{31} = 5.593 + 11.928 + 10.587 + 19.367 = 47.475$;
- we check the condition $(s_4 - 1) < 47.475 \le s_4$;
- hence, $s_4 = 48$ and $s_4 - s_3 = 48 - 29 = 19$;
- consequently, we draw 1,2,...,19 ellipses;

- we compare $s_4$ with the experiment time: $s_4 = 48 = T$;
- we draw the sequence of the oil spill domains for $a_4 = 1,2,\ldots,b_4$, $b_4 = 1,2,\ldots,19$, (Figure 4).

The results for the analytical approach – an oil spill trajectory and sequence of domains for $t = 27$ *h* and 47 *h* and the results for the simulation approach – an oil spill trajectory and sequence of domains for $t = 6$ *h*, $t = 18$ *h*, $t = 29$ *h* and 47 *h* are presented below. To clearly indicate the changing in time hydro-meteorological conditions, there were omitted the starting states in the Figures 2 and 3. The oil spill domain movement at the moment $t = 48h$ is illustrated in Figures 3 and 5.

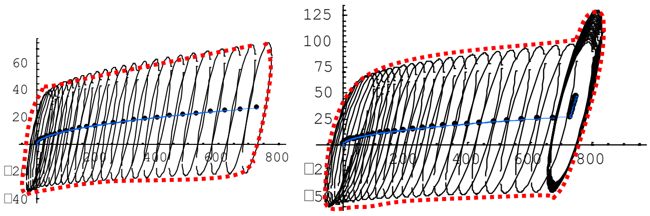


**Figure 2:** *Oil spill trajectory and sequence of domains for t = 27 h and 47 h (analytical approach).*

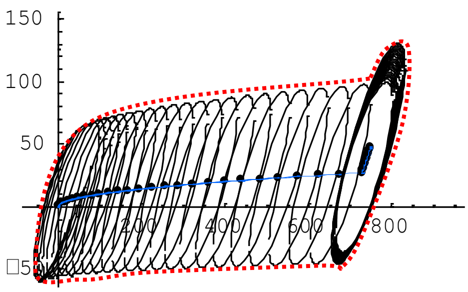


**Figure 3:** *The final oil spill domain at the moment t = 48 h (analytical approach).*

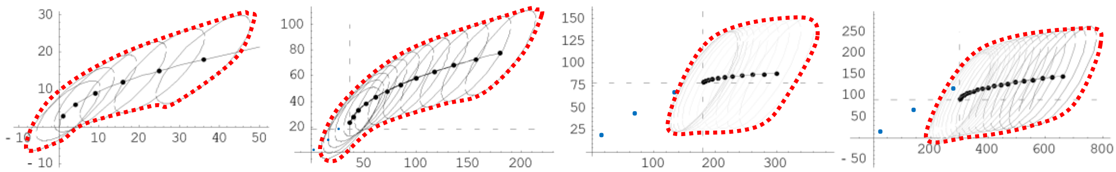


**Figure 4:** *Oil spill trajectory and sequence of domains for t = 6 h, t = 18 h, t = 29 h and 47 h (simulation approach).*

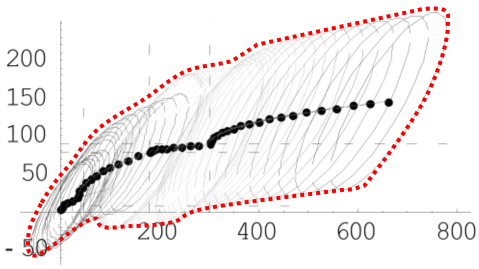


**Figure 5:** *The final oil spill domain at the moment t = 48 h (simulation approach).*

## VI. Discussion

We can notice that the oil spill domains illustrated in Figures 3 and 5 are slightly different. The results obtained for the analytical approach could be improved to better reflect the real oil spill domain impacted by the hydro-meteorological process' changes. These two methods are the aproximate methods, thus, to improve the results of the analytial approach, we can change the hydro-meteorological state, e.g. at the moment $t = 18\ h$ and then start the procedure from Section II from the beginning. Moreover, during the experiments and in real-life situations, the real hydro-meteorological data can be identified as a result of the conducted experiment or as data collected on an ongoing basis (real-time data). The improvement of the methods of the oil spill domains determination gives the possibility of identifying the pollution size and the reduction of time of its consequences elimination.

## VII. Conclusion

The paper presents the comparison of the methods of stochastic prediction of oil spill domain movement prediction impacted by changing hydro-meteorological conditions: analytical approach and Monte Carlo simulation approach, applied at Karlskrona seaport water area. The following two significant parameters were considered: the wave height and the wind speed. There were obtained the oil spill trajectory and sequences of oil spill domains for varying hydro-meteorological conditions.

Author's current research is related to the further development of the simulation procedures to take into account more relevant factors, e.g. the density (thickness) of different chemicals. The final effect of the research should be a model for rapid simulation of the situation at sea during a disaster. Then, the searched domain can be easily found for rescue action organizing.

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# MULTIVARİATE CHARTS OF STATISTICAL CONTROL OF THE DYNAMIC PROCESS OF OIL FIELD DEVELOPMENT MANAGEMENT

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**Abstract**

*The properties of the procedure for constructing multidimensional Hotelling maps are investigated for the case of individual observations of a dynamic process. The features of the behavior of such maps are noted in comparison with multivariate statistical control of controllability and stability, using sample observations at a certain fixed point in time or in a short period of time. At the same time, detrending of non-stationary time series, describing the dynamics of each feature separately, as well as the transformation of the multidimensional sample distribution of observations to a joint multivariate normal distribution is used.*

**Keywords:** optimal oil recovery, multivariate dynamic Hotelling charts, process detrending, multivariate normal distribution, statistically controlled process

## I. Introduction

Development of oil fields is a complex process that depends on many geological and technological factors and must meet the requirements of the most optimal oil recovery [1,2]. In order to maintain the optimal mode of oil production, the task is to stabilize the development process based on the application of the concept of a statistically controlled process using Hotelling's multivariate control charts [3-5].

Typically, control charts (CC) are used to control the quality of some large volume of single-item products that are divided into subgroups (lots, lots) of the same volume n. At the same time, checks (observations) of the quality of each unit of production can be carried out according to one indicator (onevariate CC) or several indicators (multivariate CC) at the same moment in time with a random selection of the unit of the tested product. For $n = 1$, these observations are called individual.

When using CC to check the statistical controllability of dynamic processes (in particular, the process of developing an oil field), the following features should be taken into account.

For a multidimensional dynamic process defined by time series of discrete values of indicators in a sequence of time values t, each of these series describes a one-dimensional non-stationary random process with mathematical expectation, which is generally a function of time (process trend) and only for a stationary process its first moment (expectation) and the second moment (covariance) do not depend on time [6].

Therefore, to construct CC, the first differences of the initial time series are usually used, as is done in the "STATISTIKA" package. In this case, it is assumed that such a procedure leads to a stationary random process. However, only after taking the second time difference, the obtained time series can be approximately considered stationary [7, 8]. In this regard, it is advisable to construct a multidimensional dynamic CC to use for each indicator not the initial time series, but the corresponding detrended time series obtained by detecting and rejecting a trend, which is obviously stationary with a high accuracy of the calculated trend.

## II. Statistical process control using control charts.

When constructing CC, two different phases are distinguished [3,4]. Phase I, carried out with a hindsight analysis, involves testing the statistical control of the process based on original or subgrouped observational data. This phase is commonly referred to as the start-up-stage of the process, in which a set of data (training sample) is obtained from which control limits are set for monitoring the process. The purpose of this phase is to identify statistical controllability and find the upper control limit (UCL) and lower control limit (LCL). In the second phase, on the basis of the obtained control limits, corrective control is carried out, including the detection of points of instability (outliers) of the process and subsequent regulation of the process with maintaining its statistical stability.

In this paper, we consider phase I of a multivariate statistical control with individual observations representing the values $x_{ij}$ of several indicators xj, given in a certain sequence of times $t_i$, $i = 1,\ldots, m$. With regard to the process of developing an oil field $x_{ij}$ - oil production indicators by years $t_i$, $i = 1,\ldots, m$.

## III. Multivariate charts of statistical control at the start-up stage for individual observations.

Suppose that we are dealing with individual observations, that is, the sample of observations consists of m subgroups of observations with the same volume of observations n = 1. Let $\boldsymbol{x} = \left(x_1,\ldots,x_j,\ldots,x_p\right)$ there be a vector of p variables (indicators of the process under study) $x_1,\ldots, x_j,\ldots, x_p$ and $x_{ij}$ - the value of the variable $x_j$ in the $i$-th ($i = 1,\ldots, m$) observations. Let's introduce the notation:

$$\boldsymbol{X} = \left(\boldsymbol{X}_1,\ldots,\boldsymbol{X}_i,\ldots,\boldsymbol{X}_m\right)^T ;$$

$$\boldsymbol{X}_i = \left(x_{i1},\ldots,x_{ip}\right)^T \; \left(i = 1,\ldots,m\right)$$

$$\bar{\boldsymbol{X}}_m = \left(\bar{x}_1,\ldots,\bar{x}_j,\ldots,\bar{x}_p\right) ,$$

$$\bar{x}_j = \frac{1}{m}\sum_{i=1}^{m} x_{ij}$$

$$\boldsymbol{S}_m = \frac{1}{m-1}\sum_{i=1}^{m}\left(\boldsymbol{X}_i - \bar{\boldsymbol{X}}_m\right)\left(\boldsymbol{X}_i - \bar{\boldsymbol{X}}_m\right)^T$$

where $\bar{\boldsymbol{X}}_m$ and $\boldsymbol{S}_m$ - sample mean vector and covariance matrix; $T$ is the transposition sign.

To construct a multivariate CC based on Hotelling's $T^2$-statistic, it is assumed [9] that observations are independent and identically distributed (i.i.d.) random variables satisfying a $p$-dimensional normal distribution $\boldsymbol{N_p}\left(\boldsymbol{\mu},\boldsymbol{\Sigma}\right)$ with a mean vector $\boldsymbol{\mu} = \left(\mu_1,\ldots,\mu_p\right)^T$ and a covariance matrix

$$\Sigma = \left(\boldsymbol{X} - \boldsymbol{\mu}\right)\left(\boldsymbol{X} - \boldsymbol{\mu}\right)^T .$$

If the vector $\boldsymbol{X} = \left(\boldsymbol{X}_1,\ldots,\boldsymbol{X}_i,\ldots,\boldsymbol{X}_m\right)$ obeys $d$-variate normal distribution, then the asymmetry indices $b_{1,d}$ and curvatures $b_{2,d}$ satisfy the relations $b_{1,d} = 0$ and $b_{2,d} = d\ (d + 2)$. Sample estimates of these indicators $b_{1,d} = \frac{1}{m}\sum_{h=1}^{m}\sum_{i=1}^{m} g_{hi}^3$ , $b_{2,d} = \frac{1}{m}\sum_{i=1}^{m} g_{ii}^2$ where

$$g_{hi} = \left(\boldsymbol{X}_h - \bar{\boldsymbol{X}}\right)^T \cdot \frac{1}{m}\boldsymbol{Q}_m^{-1}\left(\boldsymbol{X}_i - \bar{\boldsymbol{X}}\right),$$

$$\boldsymbol{Q}_m = (m-1)\boldsymbol{S}_m = \Sigma\left(\boldsymbol{X}_i - \bar{\boldsymbol{X}}\right)\left(\boldsymbol{X}_i - \bar{\boldsymbol{X}}\right)^T,$$

$$\boldsymbol{X}_i = (x_{i1},...,x_{id}) \text{ (i=1,…,m)},$$

$$\bar{\boldsymbol{X}} = \bar{\boldsymbol{X}}_m = \left(\bar{X}_1,...,\bar{X}_d\right),$$

$$\bar{X}_j = \frac{1}{m}\sum_{i=1}^{m} x_{ij}.$$

Mardia [10] showed that if $\boldsymbol{X} \in N_d(\boldsymbol{\mu},\boldsymbol{\Sigma})$, then for $d$> 2 and $m$> 50

$$A = \frac{1}{6} m b_{1,d} \sim \chi_f^2 ,$$

$$f = \frac{1}{b} d(d+1)(d+2)$$

and

$$B = \frac{b_{2,d} - d(d+2)}{\left[8d(d+2)/m\right]^{1/2}} \sim N_1(0,1)$$

where $\chi_f^2$ is the χ²-distribution with $f$ degrees of freedom, $N_1(0,1)$ is the standard one-dimensional normal distribution.

$T_i^2$ - Hotelling statistics corresponding to the observation $\boldsymbol{X}_i$ is written in the form $T_i^2 = \left(\boldsymbol{X}_i - \bar{\boldsymbol{X}}_m\right)^T \boldsymbol{S}_m^{-1}\left(\boldsymbol{X}_i - \bar{\boldsymbol{X}}_m\right)$. Assuming that the estimates $\bar{\boldsymbol{X}}_m$ and $\bar{S}_m$ characterize a sample from a $p$-dimensional normal population (general population) with a mean $\boldsymbol{\mu}$ and a covariance matrix Σ, the statistics $T_i^2$ obey the Pearson χ²-distribution with $p$ degrees of freedom. In this case, at the initial stage, the lower control limit is written as $LCL = \chi^2(1-\alpha/2, p)$ , and the upper limit is written as $UCL = \chi^2(\alpha/2, p)$ where $\chi^2(\alpha, p)$ - $(1-\alpha)$ - percentile $\chi^2$ - distribution with $p$ degrees of freedom; $\alpha$ - a given level of significance.

Assuming that the $i$-th observation $\boldsymbol{X}_i$ does not depend on $\bar{\boldsymbol{X}}_m$ and $\boldsymbol{S}_m$ the statistics $T_i^2$ (for a fixed i) obeys Fisher's $F$-distribution with degrees of freedom $p$ and $m$-$p$ [11]. In this case, the lower control limit has the form

$$LCL = \frac{p(m-1)(m+1)}{m(m-p)} F(1-\alpha/2; p, m-p)$$

and the top one is,

$$UCL = \frac{p(m-1)(m+1)}{m(m-p)} F(\alpha/2; p, m-p)$$

where $F(\alpha; p, m-p)$ is the $(1-\alpha)$ percentile of the $F$-distribution with degrees of freedom $p$ and $m$-$p$.

Checking the mutual independence of random variables can be carried out using the appropriate test [12, p. 612].

If the above assumption about the independence of observation $\boldsymbol{X}_i$ from $\bar{\boldsymbol{X}}_m$ and is not fulfilled, the specified equalities for LCL and UCL may be violated. As shown in [12], statistics $T_i^2$ (for a fixed $i$) has a beta distribution, $T_i^2 \sim \frac{(m-1)^2}{m} B\left(p/2, (m-p-1)/2\right)$ which can be correctly used in the case of individual observations when constructing control limits at the initial stage to check the statistical controllability of the process. In this case, the lower control limit is set as,

$$LCL = \frac{(m-1)^2}{m} B\left(1-\alpha/2; p/2, (m-p-1)/2\right)$$

and the top one is,

$$UCL = \frac{(m-1)^2}{m} B\left(\alpha/2; p/2, (m-p-1)/2\right)$$

where $B\left(\alpha/2; p/2, (m-p-1)/2\right)$ is the $(1-\alpha)$percentile of the beta distribution with the parameters p/2 and (m-p-1)/2.

If the tables for the beta distribution are difficult to access, you can use the following relationship between it and the *F* - Fisher distribution:

$$\frac{\left[p/(m-p-1)\right]\cdot F(\alpha; p, m-p-1)}{1+\left[p/(m-p-1)\right]F(\alpha; p, m-p-1)} = B\left(\alpha; p/2, (m-p-1/2)\right)$$

$$LCL = \frac{(m-1)^2}{m}\cdot\frac{\left[p/(m-p-1)\right]\cdot F(1-\alpha/2; p, m-p-1)}{1+\left[p/(m-p-1)\right]\cdot F(1-\alpha/2; p, m-p-1)} \quad \text{and}$$

$$UCL = \frac{(m-1)^2}{m}\cdot\frac{\left[p/(m-p-1)\right]\cdot F(\alpha/2; p, m-p-1)}{1+\left[p/(m-p-1)\right]\cdot F(\alpha/2; p, m-p-1)}.$$

In many cases, LCL is assumed to be 0 because any shift in the mean results in an increase in the $T^2$ statistic, thus allowing the LCL values to be ignored. However, $T_i^2$ it is sensitive not only to shifts of the mean vector, but also to changes in the covariance matrix of observations. If it strongly depends on the volume of observations, then this can lead to a violation of normality at small values $T_i^2$. To detect such deviations from normality, non-zero LCL values should be used. Statistics $T_i^2$ going beyond the control values UCL or LCL indicates a violation of statistical control at time $t = t_i$. The task of identifying an indicator or several indicators that caused this violation and the subsequent regulation of the process (phase 2) will be considered separately.

**Detrending of the process**. Let be $\{x_k\}, (k = 1,\dots,k_0)$ , $x_k = x(t_k)$ , $t_1 < t_2 < \dots < t_{k_0}$ - the initial time series of some indicator of the investigated dynamic process. We will assume that, $k_0 = s\cdot N_s$ where $s$ and $N_s$ are positive integers. We divide the full time interval of observations $[t_1, t_{k0}]$ into intervals of length *s*. For each $\nu = 1,\dots, \nu_0$, $\nu_0 = N_s$, we construct a polynomial regression $x = \sum_{r=0}^{m_\nu} c_r^{(m_\nu)} t^r$ of order $m (m = 1,\dots, m_o)$. The best value $m_\nu^*$ of the degree of the polynomial of model is obtained by enumerating $m_\upsilon = 1,\dots,m_0$ the minimum sum of squares of residuals SSR (see details of the detrending algorithm in [13]). Then $x_k^{trend} = \sum_{r=0}^{m_\nu^*} c_r^{(m_\nu^*)} t_k^r$

$x_k^{stas.} = x_k - x_k^{trend}$ $k=(\nu-1)s+i$ $i=1,\dots,s$ $\nu=1,\dots,\nu_0$.

## IV. Normalization of a multivariate random variable

To normalize d-dimensional vector of variables $x = \left(x_1,\dots,x_j,\dots,x_d\right)$, it is proposed [14] to use the vector of parameters $\lambda = \left(\lambda_1,\dots,\lambda_j,\dots,\lambda_d\right)$ and the transformed vectors

$$x_j^{(\lambda_j)} = \begin{cases} \dfrac{x^{\lambda_j} - 1}{\lambda_j}, \lambda_j \neq 0, \\ \log x_j, \lambda_j = 0; x_j > 0 \end{cases}$$

corresponding to the variables $x_j$ $(j = 1,...,d)$. Wherein $\lambda_j (j = 1,...,d)$ are chosen so that the vector $x^{(\lambda)} = \left(x^{(\lambda_1)},...,x_j^{(\lambda_d)}\right)$ consists of independent identically distributed random variables satisfying a joint normal distribution $N_d(\mu, \Sigma)$ with a mean vector $\mu$ and a normal matrix $\Sigma$. In this case, the maximum likelihood function is written as $L\frac{1}{2} log|\Sigma| \sum_{i=1}^{d} (\lambda_j - 1) \sum_{i=1}^{m} log\, x_{ij\max}$ , where $x_{ij}$ is the $j$-th element of the vector $\boldsymbol{X}_i = \left(x_{i1},...,x_{id}\right)^T$ ($i$ = 1,...,$n$), and ML is the estimate (maximum likelihood estimate) $\sum$ for the matrix $\boldsymbol{\Sigma}$. The function $(-L_{\max}(\lambda))$ minimum $\lambda$ is determined by the coordinate descent method [13].

## V. Conclusion

The construction of multivariate dynamic control charts for statistical control of the oil field development process has distinctive features in comparison with commonly used (onevariate or multivariate) CC based on quality control of products for its various indicators, but issued at a certain fixed time of control (that is, the task statics). Even a sample of observations, represented by the values of the same indicator of the production process, is a non-stationary time series, the mathematical expectation (trend) of which is generally characterized by a non-linear dependence on time, and only the residual time series obtained by detrending the initial time series is stationary a time series in which both the first moment (mathematical expectation) and the second moment (variance) do not depend on time. So, it is more accurate to investigate the statistical stability of the stationary remainder of the time series, and the variance of this series will characterize the stability band of the square deviation of the stationary remainder from its constant mean, which fundamentally diverges from the analysis using Shewhart's CC. Another feature of multivariate analysis, in comparison with the traditionally used sequence of onevariate control charts, is to take into account the interdependent influence of a set of features on the response of the process. Thus, the synergistic nature of the multivariate control of the dynamic process is revealed, in which various interactions of different signs are manifested.

Thus, the proposed methodological approach to multivariate statistical control of oil field development is of both theoretical and practical significance and can be applied in the statistical control of any dynamic production processes.

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# ENVIRONMENTAL RISK MANAGEMENT SYSTEM IN REGIONAL CONSTRUCTION

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**Abstract**

*Construction is one of the most capital-intensive and organizationally complex sectors of the economy. This leads to a high degree of risk for all participants in the construction services market, who may face not only objectively determined risks associated with the complexity and duration of the production cycle, but also with the dishonesty of contractors and potential partners. in operation are varied and are usually measured in significant amounts. In addition, recently from the side of financial institutions and banks to ensure the protection of the financial resources they provide, requirements have been put forward for compulsory insurance of construction risks, which requires building a system of relationships that takes into account the interests of all participants in the construction process.*

**Keywords:** world economy, environmental risk, natural resource, sustainable development, ecological development.

## I. Introduction

Environmental safety is just as important a component of the country's security, life and health of people, as is economic security, as is the security of the country's borders. If the problems of the country's defense, economic security are solved by specialized structures with a developed management system (the Ministry of Defense, the economy, other departments), then the management of environmental safety, including the environmental safety of construction, is the main technogenic factor of impact on the environment, on the quality of life and human health. , until now it has not been comprehensively decided. Separate studies and practical steps in this direction have been undertaken for a long time, but the accumulated experience and scientific potential are not fully utilized, which is actually felt in everyday life by every person. The issues of environmental safety management in large cities and industrial centers are especially relevant, where the intensity of environmental problems often develops into social and political problems.
Investment activity is a prerequisite for the development and competitiveness of Russian construction enterprises, since construction is the most capital-intensive sector of the economy. It traditionally involves design and engineering organizations, uses expensive technologies and unique equipment, and concludes large supply contracts. It is obvious that the risks inherent in each stage of the project are varied and significant, and the possible losses during its implementation can be measured in huge amounts. Insurance of construction risks as part of the construction investment process at all its stages from the development of a feasibility study to the commissioning of an object allows participants to compensate for unforeseen losses incurred during construction and provides protection for investment in construction.

The construction area in all countries is considered a high-risk area where there is a high probability of unfavorable and unpredictable situations during the implementation of an investment project (an increase in investment costs, a decrease in profits, etc.). In investment and construction activities (ISD), research, identification and identification of risk factors underlies the effective implementation of the economic interests and needs of all stakeholders. The study of risk management problems in the context of political, economic and regulatory transformations of the basic rules of doing business in the construction industry is one of the most difficult economic problems and provides the following main approaches: avoidance, prevention, insurance, transfer and acceptance of risk.

Unfortunately, as world and domestic practice shows, despite significant efforts to reduce risk (introduction of new standards, use of innovative technologies), the developer, when carrying out construction and installation works (CMP), often faces the problem of situations that are difficult to predict and can lead to to an increase in construction time due to damage or loss of building materials, construction equipment, equipment during installation and installation, property of third parties, damage to life and health of people, and there is also a risk of a significant increase in the cost of objects from the initial investment amount.

## II. Methods

A possible solution to ensuring the environmental safety of construction is the creation of an analysis of existing classifications of risks in relation to the investment and construction sector and an attempt to create on the basis of this classification a unified long-term methodology for increasing the efficiency of investment resources of construction organizations remains unrealized. As a rule, these techniques are aimed at solving specific tactical problems. The reasons for the occurrence and the degree of influence on investment activities for each risk is individual.

The most optimal solution in the context of analyzing the objectively evolving situation and taking into account the economic interests of IUD participants is the insurance of construction and installation risks. In this case, there is no need to accumulate funds on the accounts of the reserve fund to cover possible damage and the contractor can use these funds as working capital, in addition, the terms of restoration of the object can be significantly reduced by compensating the insurer for additional costs associated with the urgent delivery of building materials, equipment and overtime.

Construction and installation insurance is a real guarantee of ensuring economic protection of project participants from losses caused as a result of various types of dangerous situations. Unlike other types of property insurance, insurance of construction risks has a specific format of insurance coverage provided, the peculiarity of which is that due to the multiplicity of possible risks of a construction object, the insurance contract for a construction object does not contain a list of them, but, on the contrary, contains a list of cases, the damage from which is not is subject to reimbursement by the insurer.

In international practice, insurance coverage does not cover losses:

- caused by defects and errors arising in the design and manufacture of materials;
- as a result of gross negligence of the policyholder and deliberate damage caused by him or his representative;
- as a result of extraordinary and military events, the arrest of property by a court decision;
- as a result of strikes or mutiny;
- damage caused by exposure to nuclear energy.

Thus, insurance can cover all civil and industrial construction projects, with the exception of those listed in the list.

## III. Results

Environmental risk is the likelihood of an event that has adverse consequences for the life of humans, animals, plants and other living organisms, caused by the negative impact of economic and other activities on the environment [2].

In popular science literature on economic issues (both foreign and domestic), a special place is occupied by a range of issues related to the interaction of the economy and the environment. The central place is occupied by the problem of environmental risk and the possibility of managing this risk through the system of insurance protection. Environmental risks can be divided into risks of technogenic and natural origin [4]. In statistical analysis, the insurer takes into account the following patterns: risks of a man-made nature in practice are much more common, but the damage from natural disasters is much greater in monetary terms, and in this case, a large number of people and areas of territories are involved. Insurance is one of the main recognized methods of risk management, but by no means the only one. All methods of risk management can be conditionally subdivided into economic and non-economic.

Environmental risk assessment is a complex and ongoing scientific and technological process that includes the possibility and necessity of iterative approaches, i.e. improving the results of risk assessment by repeatedly improving the quality of the initial information. Each of the types of risks requires its own risk assessment methodology, but all of them are characterized by common principles and approaches to risk assessment, regardless of where the risk is considered, in the "human-environment" system or in the "social and hygienic monitoring" system. The methodology for analyzing and managing risks procedurally is fairly well developed. It is reflected in the guidelines of environmental protection agencies in various countries.

The risk identification scheme consists of several blocks (stages).

First stage: qualitative identification of hazards. This is the process of identifying a problem: for example, sources of pollution, potentially hazardous harmful substances, and their toxicity are identified. In this case, various methods of risk identification are used [2]:

- statistical, based on the analysis of the accumulated statistical data of the events that have occurred, their repetition rate;
- analytical, based on the study of cause-and-effect relationships;
- expert assessments of events, implying an assessment of the probabilities of manifestation of environmental hazard factors by processing the results of expert interviews.

Second stage: defining the boundaries of the risk zone. The process of quantitative hazard assessment includes consideration of the scheme of the maximum possible flow of a harmful substance and the establishment of the geographical boundaries of its impact, i.e. complete product life cycle; for example, for a chemical, this is an exposure assessment: obtaining information about what real dose loads are faced by certain groups of the population. The third stage: assessment of the ways of exposure to the stressor. It provides for the consideration of the general scheme of the impact of the harmful substance on the biota, as well as its direct impact on human health, as a result of which a quantitative assessment is made between the exposure dose of the pollutant and the cases of harmful effects, and the "dose effect" relationship is established.

At these stages, parameters are selected by which the following is assessed:

- the degree of toxicity of the harmful substance;
- content in various environments;
- changes in the activity of various biochemical parameters in organisms of animals and plants, primarily enzymes;
- violation of reproductive functions and the survival of various test objects (daphnia, microorganisms, fish, etc.).

## IV. Discussion

Summing up the above, we note that, given due attention to such an important aspect of the economic activity of a construction organization as environmental protection, it is possible to significantly minimize the negative impact on the environment by factors of construction production, including on natural objects with increased vulnerability and objects, protection and the preservation of which is of particular importance. Only the correct and responsible organization of work at the preventive stage - the analysis and calculation of environmental risks, the adoption of timely measures to prevent, and not eliminate the consequences of man-made factors and emergencies, can ensure the preservation of a favorable environment for current and future generations. Integrated environmental safety management system, the unification of management of all aspects of environmental safety within a single specialized structure. The management should be based on an information center that continuously receives information about the state of the environment in the controlled area, in particular, about the state of the environmental background at each point of the territory, the state of the ecosystem, the degree of concentration of construction (real estate), and the proposed construction. The same environmental safety management structure carries out an independent assessment of the environmental impact of a new object declared for construction, performs an examination of the location of the construction object, determines the environmentally friendly boundaries of the selected construction site, carries out legal expertise of construction projects, controls compliance with the boundaries of the land allotment, promptly responds in case of violation of legal environmental norms, in case of violation of the environmental parameters of the construction project, bringing to administrative or criminal liability for violations of the law. The system for assessing the environmental safety of construction (SOEBS) should be built on an extra-regional, extra-administrative principle, in order to exclude the pressure of the administrative authorities of the territories. And also to interact with sectoral and interstate structures of environmental safety management. The creation of an integrated environmental safety system will ensure environmental control of construction throughout the entire life cycle of a construction facility, from the emergence of an idea to the liquidation of the facility.

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# FAST METHODOLOGY (WARNING TOOLS) FOR TRACKING CHANGES OF THE AQUATIC ORGANIC MATERIAL

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**Abstract**

*Increasing dissolved organic matter (DOC) in aquatic ecosystems can lead to disturb the balance, deterioration of the water quality, and a more expensive water purification process. As a significant part of the aquatic DOC, organic adsorbing compunds (OACs, amphiphilic/hidrophobic type), can impact on the both abiotic and biotic elements. In this study it was demonstrated that the no–expensive methodology can be used for the fast monitoring/evaluating water quality with respect to the content and the surface activity (i.e. hydrophobicity) of the DOC. This includes measurement of the total adsorption efect of OACs at the mercury electrode by electrochemical methods. The concept has been applied to rivers from the agricultural district (Sava and Lonja), and from the highly protected area (Krka as a part of National Park) as well as to the marine lake ecosystem (Rogoznica Lake).*

**Keywords**: dissolved organic carbon, surface activity, organic adsorbing compunds, hydrophobicity, natural waters

## I. Introduction

The widespread problem of water pollution is endangering aquatic ecosystem health, and ultimately can affect the human health [1]. One of the threats against good water quality is increasing content of dissolved organic carbon (DOC) in freshwaters into different regions around the world [2]. Some studies have been reported that there is link between climate change and increasing content of the DOC [2]. Organic matter (OM) transport to water bodies can lead to disturbance of the balance in the aquatic ecosystem and to deterioration of the water quality, giving a more complex and expensive water purification process [2,3]. Besides natural organic matter (NOM, originating from terrestrial sources or produced *in situ*), distinct classes of hydrophobic pollutions (e.g. peticides, biphenyls and polycyclic aromatic hydrocarbons) resulting from human activity (particularly in agriculture and industry) can be present in natural aquatic systems [4].

Due its different origins and complex composition, the various types of DOC have appreciably distinct physico-chemical properties including its surface activity (SA). One way of characterizing DOC quality is determination of the surface activity as a bulk parameter by electrochemical method, i.e. measurement of the total adsorption effect of the organic adsorbing compounds (OACs, amphiphilic or hydrophobic type) at the mercury electrode. Such measurement usually is expressed as an equivalent adsorption effect of a certain amount (mg $dm^{-3}$) of model surfactant the nonionic polyoxy ethylene-t-octylphenol, Triton–X–100 [5–12]. These classes compounds are the most reactive part of the DOC because they tend to adsorb at different natural phase boundaries in aqatic environments and on that way they can impact on the both abiotic and biotic elements/processes [4, 8─12]. Therefore, the SA of DOC is directly related to its hydrophobic/hydrophilic properties, in other words to its quality and reactivity.

Here we will look which information about aquatic organic material can be obtained from the analysis of the surface activity of DOC in the natural water samples using methodology that has been developed within the group at the Ruđer Bošković Institute in Zagreb, Croatia [5─12].

## II. Methodology

Natural samples were collected from the two different water areas: (1) Sava and Lonja rivers in the agriculture area (45.5194° N 16.5314° E, Posavina region), and the karst Krka River as a part of the highly protected area (43.8666° N, 15.9725° E), the Krka National Park); (2) the small (10 276 $m^2$) and shallow (maximum depth, 15 m) marine lake ecosystem (43°32′ N, 15° 58′ E) Rogoznica Lake, Dalmatia. Rogoznica Lake can be taken as typical representative for highly stratified and euxinic marine environment on the Adriatic, i.e. Mediterranean cost [8─9]. After sample filtration through 0.7 μm Millipore filter, DOC was determined by the high–temperature catalytic oxidation (HTCO) by the accreditated method according to HRN EN ISO/IEC 17025:2017 on the TOC-5000 Model, Shimadzu, Japan. SA was determined on the basis of capacity current measurements using a.c. voltammetry in *out of phase* mode as already described [5 ─12]. Electrochemical measurements were performed on an μ-Autolab analyser (Eco Chemie, Utrecht, the Netherlands) connected to a 663 VA Stand multimode system (Metrohm, Herisau, Switzerland) equipped with a static mercury drop working electrode (SMDE). The reference electrode was an Ag/AgCl (3 M KCl). A platinum electrode served as the auxiliary electrode. The SA was expressed as equivalent in mg $L^{-1}$ to a model substance, of Triton-X-100. The detection limit was 0.01 mg $L^{-1}$ equivalent of T-X-100, with LOQ of 0.03 mg $L^{-1}$.

## III. Results and discussion

Figure 1 show graphical characterisation of DOC in samples of investigated waters. This approach can be used to describe the quality of OM in terms of hydrophobicity/hydrophilicity. It is based on comparison of the correlation of SA/DOC values obtained in samples with those of the model substances selected as being main classes of OACs in natural waters. More hydrophobic model substances have higher SA/DOC values [5,8,11].

The differences in the composition of the OM between rivers Sava, Lonja and Krka are clearly visible (Fig. 1). Low DOC concentration in the Krka River indicate an extremely clean and noneutrophic water system. Concerning the OM type in the Krka River, the poor surface activity of DOC measured at the hydrophobic surface of the mercury electrode, suggest its highly hydrophilic character [6]. Taking into account that Krka is karst river, it is no surprise that has the lower content of fulvic material. In the Sava River, DOC and SA values are twice high than in the Krka River, and data for SA/DOC ratio are grouped around fulvic acid line, pointing to the more hydrophobic nature of the studied OM. A relative high SA/DOC ratio was detected in the Lonja River as a consequence of the fact that this river receives water from the main melioration channel close to sampling location (45.5194° N 16.5314° E) [5]. The hydrophilic OM, similar to polysaccharide─xanthane and saturated fatty acid types predominate in the Lonja River waters. Detected compounds can be considered as indicators of the degradation processes.

The seasonal variability of OM properties was observed in the marine environment of Rogoznica Lake (Figure 1). It can be seen that the type of OM significantly vary from season to season with more hydrophobic material recorded in summertime.

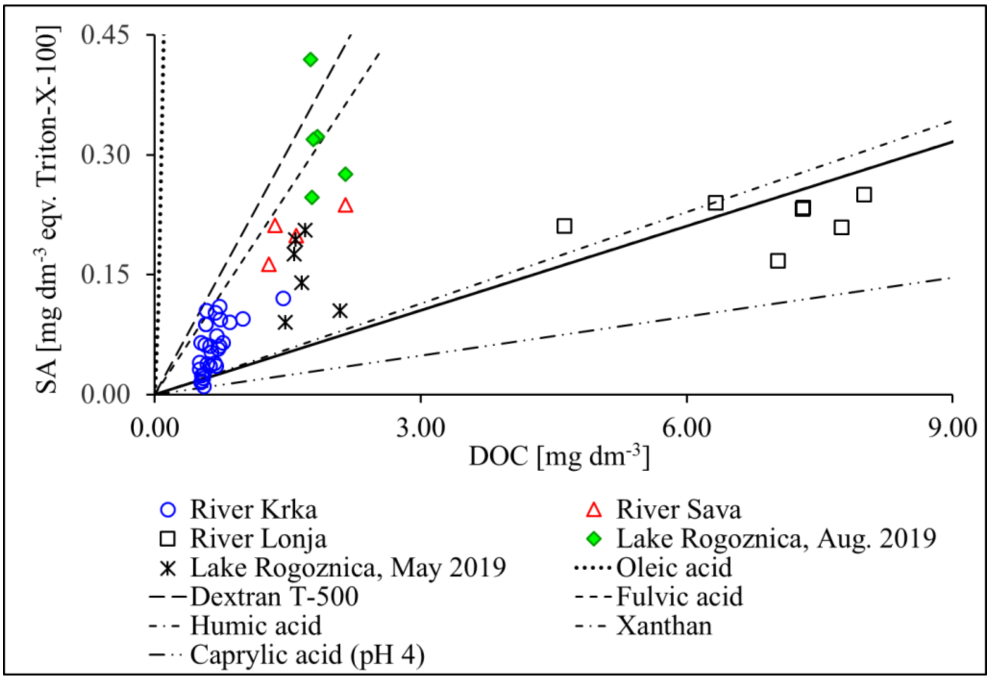


**Figure 1:** *Correlation of SA/DOC in samples collected: (a) in the rivers from the agricultural district, Sava (Central Posavina) and Lonja River (Lonja field), in period 2017─2019; (b) in the River Krka (part of the National Park Krka), in 2012 [6]; (c) along the depth profile (0─12 m) of Rogoznica Lake (highly stratified and euxinic marine lake in Dalmatia) in 2019. Lines correspond to model substances [5,8]*

By using an integral method that include the measurement of the DOC concentrations and determination of its surface activity by electrochemical method, it was possible to reveal qualitative properties based on the hydrophobic/hydrophilic nature of OM in different aquatic systems. However, the varibility of DOC concentrations is not so pronounced in Rogoznica Lake in the investigated period, implaying on the importance for monitoring of the nature/reactivity of the OM, especially in the small water bodies as isolated water systems. Due to morphological characteristics and relatively small volume, these systems react rapidly to external pressures, and biogeochemical signal of such processes can be several times multiplied with respect to the larger water areas such are open sea and the ocean [6,8,9].

## IV. Conclusions

Considering that the changes in the composition of OM can have implications for water quality and ecosystem health, the rapid method described above is very useful as early warning tool for detection quality and tracking the organic matter dynamics in marine and fresh waters. It is important to emphasise that the rough differentiation of DOC into hydrophobic/hydrophilic type is only a first step in OM characterisation. For detail analyses, electrochemical measurement needs to be combined with other more selective methods such as spectrophotometry and chromatography.

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# RESISTANCE OF GEOSYSTEMS OF THE CHECHEN REPUBLIC TO EXTERNAL INFLUENCES

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**Abstract**

*Analysis of the current state of landscapes allowed to zoning the landscapes of the republic by the degree of anthropogenic disturb. Territories with various anthropogenic disturbs reveal a clear connection with certain types of mountain landscapes. Within the high-altitude and middle-class tiers of landscapes, the pattern of man-made disturb belongs to the striped class and is formed within the high-altitude landscape zones. In the northern (low-) part of the republic, due to the unevenness of the man-made load, it acquires a mosaic pattern. Here, it is not the high-altitude, but the geomorphological factor in the placement of certain types of environmental management. The time of residential areas to the bottoms of river valleys is very rigidly manifested.*

**Keywords:** stability of landscapes, anthropogenic disturbance of landscapes, coefficient of disturbance, functioning of geosystems

## I. Introduction

The most urgent task of modern geography is to understand the patterns of changes in the natural environment in conditions of increasing anthropogenic impact on it. At the same time, the main attention is paid to the study of the stability of geosystems, which is carried out both at the local and regional levels. Sustainability is the ability of natural systems to restore damaged properties. In addition, it reflects their ability to adapt to the changed environmental conditions, to move into a new state [1,2]. When assessing the stability of geosystems, not only their structural features are analyzed, but also their interaction with other (including taxonomically larger) geosystems. In that case, stability is the opposite of stability, considered as part of the structural properties of the geosystem. According to Isachenko A.G. "... To assess the nature and depth of the impact and determine its permissible limit, beyond which irreversible and undesirable changes in the geosystem occur, it is necessary to find out the stability of the latter to man-made loads. Every geosystem, as we already know, is adapted to a certain natural environment, within which it is stable and functions normally. Many technogenic factors, especially the so-called pollution, i.e. artificial geochemical loads have no analogues in nature, and the resistance of geosystems to such disturbing factors has a specific character" [6].

## II. Material and methods

The term "stability" came to geography from mechanics. However, the lack of sufficient data for calculations, the variety of systems and their components, the use of unambiguous quantitative indicators of the latter, the study of individual components, and not the geosystem as a whole, the aggregation of parts of which leads to the emergence of new qualities that are not reduced to the properties of the elements individually, cause significant methodological difficulties in solving such problems. In addition, "it is often thought that, having studied one object, they already know everything about two exactly the same objects, since two are one and one. At the same time, however, they forget that it is also necessary to investigate what is hidden behind this "and" [3,4,5,]. In each specific case, various characteristics of the object, its properties, relationships with surrounding objects and with the environment are considered [6].

The identity of the most general patterns of changes in the nature of material-energy exchange and structural-dynamic features of the geographical environment [4] predetermine the characteristics of the reaction of geosystems to the impact characteristic of each hierarchical level, since "they" relate to geographical patterns of different order" [5]. Along with this, the essence of the concept of "sustainability" for the systems of the regional level of the organization remains searchable. We have developed the basic principles of studying the stability of geosystems at the regional level of the organization. They were tested on the example of predictive surveys of the orientation of the transformation of geosystems of the North-Eastern Caucasus, which occurs under the influence of natural changes and anthropogenic activity.

The territory of the Chechen Republic is located on the northern slope of the Greater Caucasus. The main morphological features of the foothill and mountainous parts of the region are due to neotectonic movements, during which the relief of the Caucasian mountain range, composed mainly of sedimentary rocks, was rejuvenated. This determined the complexity and originality of the landscape structure of the region, which is characterized by contrasts, often exceeding the differences between geographically separate regions. Each geosystem is geographically localized and bears the seal of both its location and a larger system. Therefore, outside of the study of geochores - heterogeneous spatial systems formed by geographically adjacent geomers - genetically homogeneous systems, collectively representing a structural, dynamic and functional whole [5], it is practically impossible to study the features of stability and the nature of anthropogenic transformations of geosystems. Geosystems reflecting the natural features of the region are represented by very diverse geochores - from highly fragmented alpine forms of habitats to marine accumulative sandy plains in the north with sparse vegetation cover. The nodal system - macrogeochora (districts) are represented in the region by 8 geographical objects (Fig.1). Relationships with the environment are the most important part of the functioning of the geosystem. The synthesis of these relations, the processes of self-development of geosystems and the history of their formation allows us to identify the so-called "generalized characteristic of the organization's compliance with the environment" [5].

## III. Results and discussions

Thus, the concept of the stability of geosystems is considered by us more broadly, taking into account the existing internal and external intersystem connections of the geosystem, the nature of their changes, based on the analysis of its position relative to the cores of geosystems, age, the nature of inter-component relationships, hierarchy, etc. In accordance with this, the following criteria are distinguished for assessing the stability of geosystems: - originality – belonging of geosystems to one or another regional subdivisions, reflecting the typical/atypical nature of their distribution within the studied territory, the conditions of their functioning; - diversity - the variability and complexity of the subsystems that make up the geosystem and their interrelations, allowing us to judge their stability; - modifications - deviations from the root (background) norm, reflecting the degree of stability and direction of the transformation processes of geosystems; - the position in certain parts of the area that determines the conditions for the existence of geosystems; - the age of geosystems – their relict or youth. In both cases, the systems are weakly resistant to any external influences due to poor adaptation to environmental conditions.

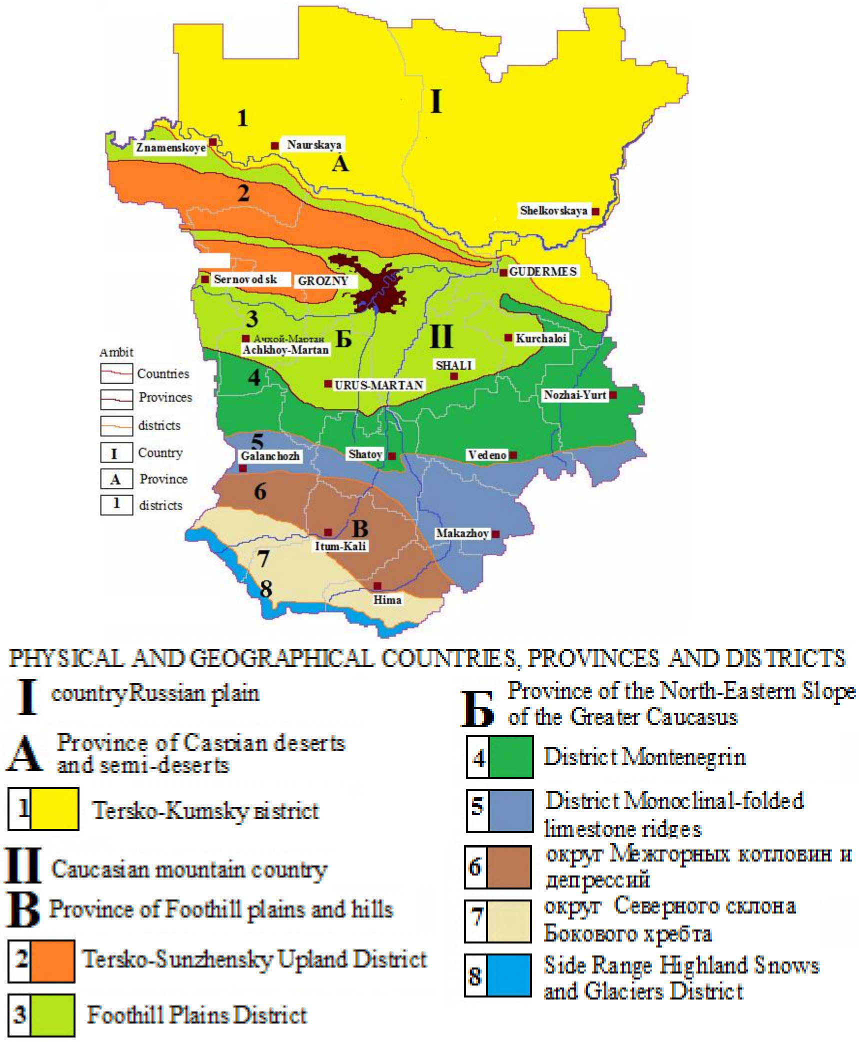


**Figure 1:** *Scheme of physical and geographical zoning of the territory of the Chechen Republic*

The use of the proposed criteria made it possible to combine the geosystems of the region into five large categories according to the degree of stability.

Almost the entire territory of the republic is characterized by intensive and diverse anthropogenic activity, which in the Sunzhi Valley becomes a noticeable factor contributing to the transformation of geosystems. At the same time, the highest technogenic and chemical pollution is characteristic of the central part of the republic, where the industrial centers Grozny, Argun, Gudermes are located, which belong to the largest environmental pollutants.

Areal sources of anthropogenic impact on geosystems are represented by agricultural lands, oil and gas deposits, building materials (sand, clay, gravel), as well as intensive, as a rule, continuous logging. This determines their essential transformations. With the frequent occurrence of fires, the existence of beech geosystems becomes problematic even in the most favorable natural conditions for them. These patterns are also characteristic of oak types of geosystems. In this case, small-leaved species or shrubby and herbaceous formations become forest-forming.

The destruction of the forests of Chechnya by fires began more than 300 years ago, the command of the tsarist troops destroyed forest vegetation by arson. Grassy transformed rows appeared on the site of oak geosystems, as significant changes in environmental conditions occurred as a result of fires. "The change in the phytoclimate alone and the changes in the soil climate going on in parallel with it can be very noticeable and lead to such changes in the conditions of the soil regime that may be completely unfavorable for the restoration of the former vegetation, in our case beech geosystems

The total overlap of time fluctuations of extreme values of the functioning of systems and the environment created conditions conducive to structural changes in the geosystems of the region, which were activated in the process of anthropogenic impact. Under the influence of factors of climate xerophitation in the eastern and southeastern parts of the territory, the areas of small-leaved and shrubby geosystems are expanding and beech and oak geosystems are being pushed to higher levels.Anthropogenic impact largely changes the prevailing conditions, intensifying processes unfavorable for the functioning of geosystems. In particular, the thermal regime of geosystems is changing at the regional level. This is observed both in the age-old change in thermal conditions in the area of active development of the territory, and in particular fluctuations noted for certain types of geosystems [5].

At the same time, due to the greenhouse effect on the planet, a further increase in the average air temperature with a gradient of 0.26 0C per decade is expected, which will increase by 3 0C by the end of the century. The consequences of such a sharp warming can be catastrophic, especially in the boreal zone. Already at present, there is a tendency in the Chechen Republic to transform beech and beech-hornbeam geosystems that are at the limit of their optimal development, more thermophilic. A number of weather stations in the region located in various natural zones and belts of the North-Eastern Caucasus show a decrease in precipitation against the background of climate warming. There is a high intensity of regional climate warming, characterized by a linear trend of 0.6-0.8 0C.

The decrease in the moisture content of landscapes goes at a rate of 0.3-1.6 mm / year. In the long-term course of soil temperature, stable positive trends are also observed, which causes gradual degradation of the soil cover of the region, significant changes in the water and thermal regimes of soils are recorded here. This contributes to the rapid change of one type of natural geosystems to others that are less demanding of moisture and thermophilic.

This has also changed the direction of soil formation processes in the region. Under the influence of anthropogenic activity, the general trend of soil changes in forest geosystems located in the ecotone zone with steppe ones is their settling, which is expressed in approaching the surface of the carbonate horizon, a decrease in acidity, the appearance of salinity, compaction, and the formation of a columnar structure.

Beech geosystems located in the south of the temperate zone are currently functioning in the conditions of a continental climate formed in the Pliocene. These are systems with rigid connections of their constituent elements, which have a weak compensation mechanism to external influences, since the loss of even one of them affects the entire system and can cause its destruction. The possibility of their normal existence is ensured by preserving environmental conditions (soil, moisture, temperature) and the softening role of the phytoclimate, which is created by the forests themselves. Violation of this balance often leads (by fires, continuous logging) to the complete destruction of beech geosystems. This is evidenced by numerous examples of their dynamic substitutions. These communities, being relict (of the tertiary period), are stable in time and do not return to the original indigenous communities even when the anthropogenic impact is removed.

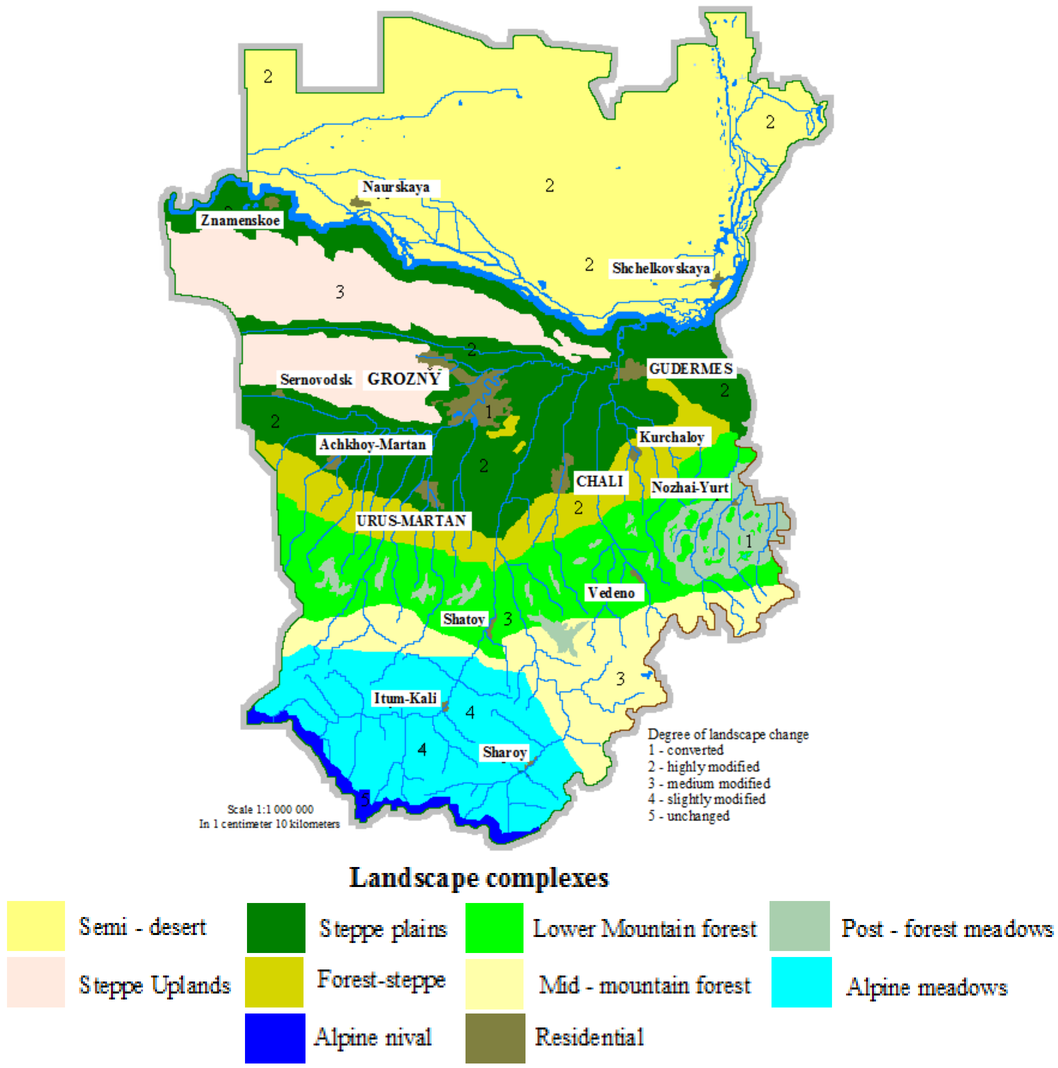


**Figure 2:** *Cartographic diagram of anthropogenic disturbance of landscapes*

## VI. Conclusion

The degree of stability of the landscapes of the Chechen Republic and their disturbance by anthropogenic influences is revealed, illustrated by a series of thematic maps. According to the degree of anthropogenic disturbance, 5 classes are distinguished: unchanged, the area of which is 10%, slightly modified - 25%, medium-modified - 30%, strongly modified - 25%, transformed - 20%.

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# THE ROLE OF FORECASTING IN THE MANAGEMENT OF ENVIRONMENTAL ENGINEERING ISSUES AT ENTERPRISES OF THE MINERALS SECTOR IN THE CONTEXT OF NEW CHALLENGES AND THREATS

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**Abstract**

*The paper outlines the principal threats and challenges that are facing the minerals sector of Russia and the world, including the EU carbon tax, ban on imports of certain products in different countries of the world (for instance, on asbestos-containing products and high-sulphur and high-ash coals), shortage of land in mining countries, and/or changes in land planning regulations. These threats and challenges are considered in their relationship with environmental safety issues at mines and in mining areas. Related environmental engineering tasks are examined. The role of forecasting in the accomplishment of these tasks and in environmental risk reduction is highlighted. The author proposes a systemic eco-technological approach to effective comprehensive forecasting of mining area's environment quality.*

**Keywords:** **f**orecasting, environmental risk, threats and challenges, environmental engineering tasks, minerals sector enterprises

## I. Introduction

Environmental safety issues in mining business are currently very important. Mining operations produce a substantial adverse impact on all components of the environment. In Russia, their contribution to total wastes amounts to 90%[1]. [1]. In other countries, these figures vary in a broad range. Thus, in the European Union mineral companies account for around 65% of total wastes [7], while in the US this proportion amounts to 50% [8]. Environmental safety is a particularly important problem for old industrial[2] areas, where human impacts have reached a critical value[3]. The list of these regions includes some areas in the Russian Federation (for instance, the Middle Urals, including Sverdlovsk Oblast).

Today, the enterprises of the minerals sector face a broad variety of qualitatively different environmental engineering tasks, threats, and challenges[4].

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[1] Data were obtained by mechanical counting using information from Rosstat, the federal state statistics service [1]

[2] Old industrial region is an area with outdated and technologically backward industry [2]

[3] The author defines critical value as maximum permissible burden, an indicator of the effect produced by one or several pollutants on the environment which, if exceeded, may impact the environment adversely [3]

[4] Challenge is a set of circumstances that are not necessarily hazardous but implying a compulsory response if they have arisen.

Threat is the most specific and immediate form of hazard in the economic sphere, presenting a set of adverse conditions and factors that are likely to impair economic security [4]

What follows is a description of some of the existing threats and challenges facing the minerals sector and related environmental engineering tasks.

**Challenge. Introduction of carbon tax.**

EU member countries are introducing a carbon tax on suppliers of high carbon footprint commodities to EU. This tax is imposed, first of all, on companies producing and exporting cement, electricity, fertilizers, iron and steel, and aluminum. In fact, producers of these commodities would have to buy a special certificate that would enable them to sell carbon-intensive products. The tax is aimed at reducing greenhouse gas emissions [5].

**Threat.**

In connection with the introduction of this kind of tax, Russian exporters of such goods to the EU are facing a threat of losing competition on the European market to producers of similar goods who have introduced low-carbon "green"[5] technologies, with a consequential repartitioning of the market.

**Environmental engineering tasks.**

This threat may have an essential economic effect on carbon-intensive product exporters and force mining companies to take appropriate actions to decrease greenhouse gas emissions, diversify business, introduce "green" technologies, and modernize production facilities.

Greenhouse gas emissions could be reduced through both low-cost interventions (for example, by improving thermal insulation of buildings, installing heat meters and thermostats, upgrading heating network insulation, introducing smart heating, ventilation and air-conditioning control systems, stopping gas leakages, etc.) [9] and more costly measures such as off-schedule modernization or production shutdown (for example, closure of coal-fired power stations) and introduction of "green" power generation technologies, including new nuclear, wind, solar and hydroelectric power stations. The latter is exactly what Enel is undertaking [10]: this Italian company has sold its coal-fired power stations in Russia and is setting up new non-polluting wind power stations.

**Challenge. Ban on import and use of certain products.**

Currently, EU countries, USA, Canada and many other countries do not allow the use and import of asbestos-containing products and high-sulphur (more than 1 %) and high-ash (over 16%) coals. This is done, first of all, for the purpose of reducing human-induced burden on the environment and human health.

Asbestos-containing products are banned for import to EU countries and USA since asbestos dust can provoke such dangerous diseases as asbestosis and occupational dust bronchitis [11]. The use of high-ash and high-sulphur coals is forbidden because of their considerable effect on ambient air and human health. These types of coal are forbidden for import not only in the above countries but also in China [12]

**Threats.**

A ban on import of certain products may result in decreasing sales or even closure of whole production facilities in general.

**Environmental engineering tasks.**

Bans on import of products presenting environmental and human health hazard may, on the one hand, produce a positive effect on the environment of the regions that used to import such goods but also cause considerable ecological problems for the enterprises and areas where these products were mined and refined. Major mining enterprises and refineries often operate a continuous process designed for a certain level of daily output. With the mining output decreasing, the effect on the environment does not decrease proportionately, staying on the same level for some sources or sometimes even increasing. Thus, for instance, such influencing factors as volumes of effluents to nearby reservoirs and water streams or dusts from waste storage and

5 There is no common definition of the term «green technologies». In EU, green technologies are understood as best available techniques [41]

mining sites do not decrease but may even increase as the enterprise starts experiencing a shortage of usable funds and, hence, is having to reduce expenditure on environmental protection.

The solutions to these problems could be:

1. Business diversification, i.e. pursuing new, more eco-friendly lines of business (for example, the Uralasbest company in the city of Asbest, Sverdlovsk Oblast, Russia launched a thermal insulation production facility)
2. Modernization (for example, introduction of technologies for additional treatment of coal to reduce its ash and sulphur content, as was done by the coal mining enterprises in Australia to ensure its sales on China's market, which in 2015 imposed a ban on imports of coals that do not meet environmental criteria. [12]

**Challenge.** Shortage of land in Russia, EU countries, USA and other mining countries and/or changes in land planning regulations.

**Threats.** Shortage of land entails the need to develop new, more compact waste dumping technologies. It is important to note that such technologies are not always environmentally safe. An example of technological solution of this kind is increased waste dump height. However, the higher the dump height, the more dust it generates.

Besides, sites for mining wastes may be allocated at some distance from the mineral mines, thus complicating the company's mining logistics, increasing expenses on waste rock transportation and making it necessary to develop complex approaches to their transportation.

Another threat arising out of the shortage of land is the probability of increased social tensions in areas where new dumping sites are supposed to be allocated. Vivid examples of social tensions associated with this threat are local protests in the Russian Federation during the construction of Tominsky GOK, a mining project in Chelyabinsk Oblast [13], and Dakota Access Pipeline protests in the USA [14].

One of the solutions to the above threats is introduction of new waste recycling technologies, which could help reduce volumes of waste and, accordingly, reduce areas of land needed for locating dumping sites.

These threats and challenges create significant risks for enterprises in the minerals sector, including environmental, economic, social, demographic, technological, technical, etc.

An important role in the resolution of the above problems and environmental risk reduction belongs to forecasting.

Forecasting is widely used in characterizing environmental and economic processes and tackling various environmental engineering and related problems, and it is described in detail in research literature and textbooks, and in regulatory documents.

In our opinion, all approaches to forecasting the quality of the environment in various industries can be conventionally divided into the following: regulatory; graphic, statistical and physico-mathematical.

The regulatory approach is closely connected with standardization [15-16] and calculation of prognostic concentrations of pollutants at specific points in ambient air, water, and soil. This approach is employed by supervising agencies for exercising environmental quality control at enterprises and sites, and it enables them to force businesses to implement certain requirements of the legislation of the Russian Federation.

Formally, this standardization-based approach [18] could be described as follows:

$$L = f(a);\ 0 < a < m,\ \ m = f(e) \qquad (1)$$

where L is a prognostic value that is a multiple of MAC at a specific point in the atmosphere, hydrosphere, or soil; m is the concentration of a pollutant in the atmosphere, hydrosphere, or soil; e is a group of indicators that determine the concentration of the pollutant in the atmosphere, hydrosphere, or soil.

This approach is currently mandatory for use at any industrial enterprise. A limitation to the use of this approach is the invariance of the production process parameters. If output is changed, it becomes necessary to re-compute the quality forecasts for air, water, and soil.

The main disadvantage of the approach is that it enables one to take into account only a limited number of factors which do not allow for the specifics of the mining complex.

**Graphic approach.**

We understand the graphic approach as environment quality forecasting based on specialized maps with essential information marked on them.

Formally, this approach to forecasting may be represented as follows:

L=$f$ (a,b,c…) (2)

where L is the values of the indicators on the map, a,b,c are the factors on which L is dependent.

An example of this approach is ref. [17], in which the photogrammetric method was used for evaluating and forecasting ambient air quality. In this study, the researchers analyzed the structural elements of a stack plume (including average linear dimension, plume displacement, plume volume, outline to area ratio, and plume contour asymmetry). Using available data, this approach is employed for research-based planning of industrial enterprises and residential areas and development of protected and recreational areas around mining facilities. In our opinion, this method enables all processes to be assessed in dynamics in relation to any project or area. The doubtless advantages of the method are visual representation and forecasting of pollutant distribution in air. Its disadvantage is that it cannot be used in relation to facilities being designed, and for forecasting soil pollution. The applicability of this method to forecasting water body pollution requires additional studies. In ref. [19], a similar approach is suggested for forecasting the occurrence of dangerous natural processes. To this end, the authors propose to develop forecast maps (plans) showing the location of sites that have not yet been identified as such but are potentially dangerous in terms of rock burst.

**Statistical approach.**

The statistical approach includes such methods as trend analysis, correlation-regression analysis and some others.

The trend and correlation-regression analysis methods may be formally represented as follows:

$$\bar{y}_x = f(x)$$

where $\bar{y}_x$ is the arithmetic (conditional) mean of all possible values of parameter Y which corresponds to the value X=x.

Trend analysis is used for the forecasting purposes in [20-25] to tackle the following tasks: assessing the influence of meteorological parameters on technogenic pollution with carcinogenic chemical substances; forecasting oil prices; planning operations in current economic contexts; and forecasting the demographic situation.

The correlation-regression method is used in [26-32] for solving the following problems: forecasting an appropriate dose of the coagulant needed for the treatment of industrial effluents discharged into a river; selecting a method for protecting the environment against pollution in asbestos mining; performing research into possibilities of reducing the depletion of the planet's water resources; forecasting coke production macroeconomics under uncertainty; addressing the issue of sustainable social and economic development of an area; forecasting agricultural output; forecasting gas-well flooding start and end times; forecasting market demand for mining machinery and equipment in the long term.

The essential limitation of the trend analysis method is that it allows one to take into account only one factor that influences a specific process, while in the correlation-regression method it is impossible to account for all related factors at once.

Physico-mathematical modeling methods, including neural networks, fuzzy sets and numerical methods, are widely used for tackling various environmental engineering and related tasks, such as in [32-36] for selecting a relevant water-treatment reagent, forecasting agricultural crop yields, rationalizing factors that influence complex decision-making in safe colliery design; substantiating factors that influence the forecasting of dangerous natural processes, for modeling the processes of geofiltration and hydrogeomigration. We believe that these methods are very important today; however, their use requires considerable knowledge in the field of mathematical modeling and mathematical statistics and application of specialized software, which, in our opinion, does not allow them to be used by companies for efficient forecasting of this or that situation.

Today forecasting methods find various applications in the minerals sector, including technological, technical, organizational, economic, health and safety, safe mining and environmental engineering tasks. However, many of the authors do not give proper attention to the forecasting of environment quality, especially at official level. Current issues that are resolved by forecasting methods are largely narrow-focused and aimed at isolated environmental engineering tasks, including those in the minerals sector.

It is important to note that, in the domestic and international literature, the forecasting methods are practically never used for addressing complex environmental safety issues of mining enterprises in a comprehensive way. Besides, the forecasting methods used do not account adequately for factors characteristic of enterprises in the minerals sector, such as mineral species, method of concentration, ore grade, mining method and other technological factors.

In our opinion, effective comprehensive forecasting of environment quality in mining areas should employ a systemic eco-technological approach that would allow for a whole range of qualitatively different factors, including technical, technological, economic, demographic, logistical, geological, hydro-geological, climatic and ecological ones. All these factors should be considered in a systemic way, with appropriate weight coefficients given to each of them. Also, different factors in differing conditions may allow the use of different methods of forecasting. Thus, in cases where essential baseline information is lacking, it should be possible to use expert judgment-based forecasting [37, 38]; if a significant amount of information is available over a long period of time, then trend analysis forecasting could be employed; whereas a final prognostic forecast would require the use of a multifactorial method of correlation-regression analysis and/or neural networks and fuzzy sets. The latter make it possible to consider several factors at once, take into account the seasonal component, and feature machine learning capabilities.

The above-mentioned systemic eco-technological approach, if used for forecasting the quality of the environment, should be versatile to allow comprehensive, efficient and prompt forecasting of environment quality to be performed by enterprises in the minerals sector employing various mining and refining technologies under various mining, geological, climatic and environmental engineering conditions. In so doing, the executive management of an enterprise should be enabled to make decisions efficiently concerning control of the nature-technology system under uncertainty.

In general terms, the systemic eco-technological approach proposed in this paper could be represented as follows:

$$S = f(a, b, c);$$

where S is a systemic indicator characterizing the environmental situation for an enterprise or an area, based on which the management of this enterprise or area could make relevant management decisions; a, b, c represent a set of qualitatively different factors, including technical, technological, ecological, demographic, geological, hydro-geological, etc., translated into a dimensionless form by the method of qualitatively different indicators [38, 39, 40]. The values of these factors are obtained by means of various forecasting techniques (judgmental, statistical, probabilistic, etc.) and presented in numerical and graphic forms with the use of GIS.

Thus, based on the foregoing, we can conclude that at the present stage of its development, the mining science should enable comprehensive forecasting of possible threats and challenges faced by an enterprise and their consequences from the point of view of ensuring environmental and economic security and interrelation with ecological factors. To this end, it is necessary to develop an algorithm for the application of available forecasting methods. Furthermore, in relation to the above-stated problems these methods may be used both separately and collectively depending on the objective in view. Thus, for instance, initial data could be processed, depending on their amount and quality, by different forecasting methods (for example, it makes sense to use the expert-judgment based method for dealing with weakly structured or insufficient data); long time series data with no essential influence of other factors could be subjected to trend analysis, while data influenced by a number of factors at once may need to be considered by the correlation-regression analysis method. Once initial data have been processed, a high-level forecast may be produced using fuzzy sets and/or neural networks, which enable one to take into account the seasonal component and uncertainties, and possess machine learning capabilities.

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# OİL AND GAS PERSPECTIVES OF THE UMID STRUCTURE IN CONNECTION WITH ITS HISTORY OF GEOLOGICAL DEVELOPMENT

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**Abstract**

*It is known that the preservation of the planet's ecosystem is one of the most important issues in geology and in all spheres of industry. The minimum number of wells drilled during geological exploration plays an important role in eliminating damage to nature. The study of paleogeographic, paleotectonic conditions and lithofacies composition of the stratigraphic section of the studied structure is very important for determining the exact number and location of wells that will be drilled for exploration and production in the future. It is these studies that significantly reduce the risk of drilling unpromising wells.The paleogeographic curve and the depositional rate chart have been analyzed. The Umid structure started its development no later than in Pliocene. Both the paleogeographic and the paleotectonic environments within the area were favorable for the necessary amount of organic matter to be accumulated and preserved. Development of the Umid structure intensely continued in later stages.*

**Keywords:** Umid uplift, depositional rate chart, paleoprofiles, graph of the fold development rate, paleogeographic curve

The tectonic structure of the Umid uplift was once again confirmed, the location of a mud volcano was determined, a longitudinal fault that crosses the crestal part of the uplift was precisely located and the boundaries of the mud volcano breccias were determined. Well 8 with a target depth of 6500 m was drilled 1125 m south from well 1 on the north-eastern limb of the Umid uplift, provided that it cuts horizon VII of the Productive Series (PS) within the vault zone. Logging at 6006 m revealed that horizon V and horizon VII of the PS had been crossed at depth of, respectively, 5475-5582 m and 5923-6006 m. Horizons V and VII of the PS are positively estimated on well logs. Thus, the values of the apparent special resistances of horizons V and VII vary within, respectively, 10-12 and 30-32 Ohm*m. SP curves are well differentiated. Gas shows and drilling mud influx were identified while testing horizons VII and V in the well at 4550 m.

The Umid uplift is located 20 km south-east from the Bulla-deniz oilfield and is separated from the Babek structure by a saddle (Figure 1.) [1, 4].

Thus, only 4 wells (#1, 4, 6, 8) out of 10 drilled within the Umid structure crossed potentially productive horizons. Geophysical properties of the productive horizon's section have confirmed presence of hydrocarbon accumulations in horizons V and VII of the PS (is considered analogous to the FLD (Fasila suite)). Lower Pliocene (PS), Agcagil, Absheron and Quaternary sediments are present in the geological structure of the Umid uplift.

Tectonically, the Umid uplift is a brachianticlinal structure of the north-west to south-east strike (30-35 km long, 4-5 km wide) [3]; its height within the north-eastern and south-western limbs is, respectively, 800m and 1000m. The south-eastern periclinal part of the Umid uplift is complicated with a mud volcano of the same name (Figure 2.).

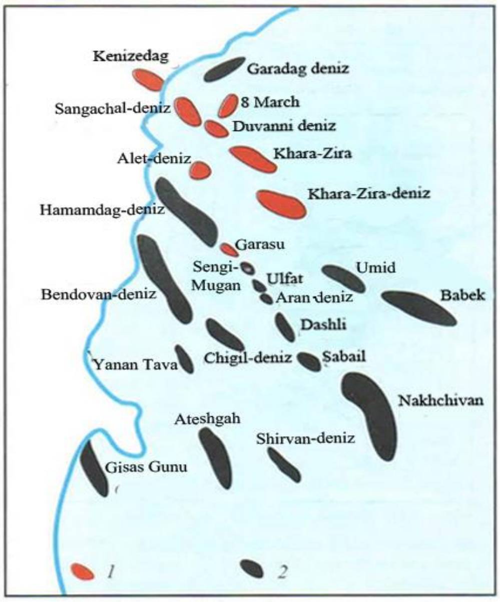


**Figure 1:** *Location of structures within the Baku archipelago:*
*1 – identified oilfields; 2 – perspective structures*

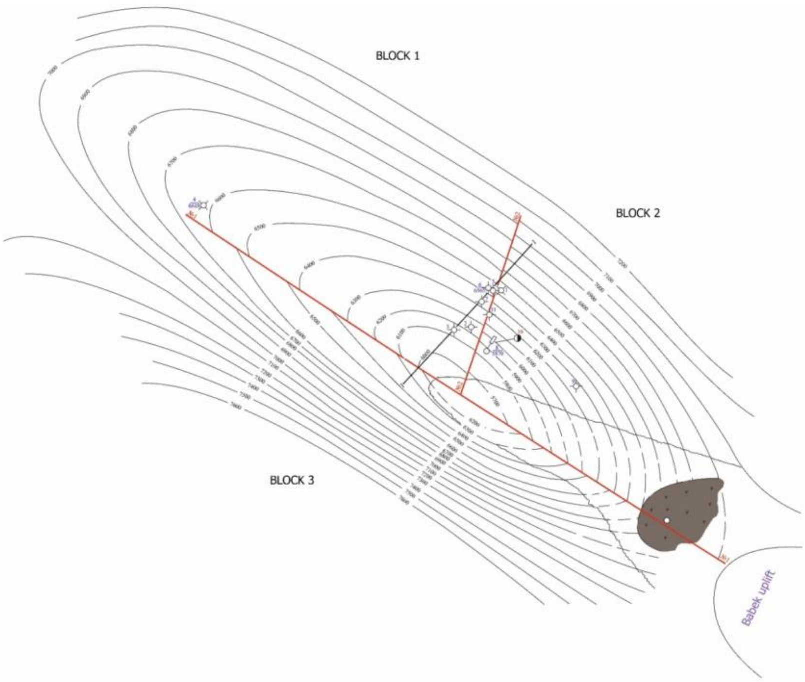


**Figure 2:** *Schematic structural map for the top of horizon VII of the Productive Series (after R.Jafarov and S.Hajıyev).*

The Umid structure is of asymmetric shape with varying dips of its beds in the limbs. Based on horizon VII data, the bed dips gradually increase with depth and are 20-25° and 35-40° in the north-eastern and south-western wings, respectively. The uplift joins the Bulla-deniz anticline through its north-western pericline by means of a deep and wide saddle and the Babek structure through its short south-eastern pericline. A regional longitudinal fault crosses the structure's crest with 100-450 m throw, the fault crosses the entire stratigraphic section and divides the structure into two blocks that correspond to the north-eastern and south-western limbs. Through that fault the south-western wing of the uplift has dropped by 200 m relative to the north-eastern one. As mentioned earlier, the Umid uplift joins the Babek structure in the south-east through a small narrow saddle. This junction can be observed in the overlying sediments and both structures manifest themselves as a single one in deeper layers. This case is typical for structures located within Baku and Absheron archipelagos. Lokbatan-Puta-Gushkhana, Sangachal-Duvanni-Khara-Zira island, Guneshli-Azeri-Kapaz oilfields are to name a few. This situation is typical for the platform type oilfields and the possible reason is related to a mud volcano activity [2].

As is generally known, sedimentation complexes present in the geological structure of any region form within certain paleogeographic environments and, depending on that environment, source rocks, reservoir and impermeable, that is, cap rocks may develop in the typical lithostratigraphic section of the region to a certain extent. That is why studying the paleogeographic environment for formation of sedimentation sets developed within the region play an important role in estimating hydrocarbon perspectives of the same region.

In order to study some paleogeographic and paleotectonic environments of formation of sedimentary sets of the area under investigation paleogeographic curves and depositional rate charts have been built and analyzed based on typical lithostratigraphic section.

According to typical lithostratigraphic column of the Pliocene and Quaternary deposits, they mainly consist of psammitic and pelitic terrigenous marine facies. Such lithofacial content is the indication of their formation in a relatively shallow basin. Nevertheless, sediments that make up the typical column show that the basin's depth varies within the relatively short timeframe, i.e. the environment favorable for the formation of psammitic facies. At the same time, higher clay content of the column indicates that the basin was of the average depth, which was favorable for formation of pelitic facies. Frequent alternation of clayey and sandy beds is indicative of frequent level fluctuations of the sedimentary basin floor within the geologic time. At the same time, regularly alternating lithostratigraphic sequences can be identified in the typical lithostratigraphic column. For example, every lithofacial sequence is dominated by either pelitic or psammitic layers. This pattern is observed along the entire drilled and studied section of the sedimentary mantle, i.e. the sequential alternation clearly manifests itself along the stratigraphic depth from the Upper Miocene to the Quaternary. This situation, in turn, shows that the basin floor had been subject to rhythmic fluctuations and these movements had been continuous throughout the geological time. As clearly seen from the paleogeographic curve, an average depth basin was present during the Pontian stage in the area under investigation (Fig. 3).

Uplifting and subsidence processes alternated during the lower Productive Series age, i.e. Qala suite (QaS) period. Thick pelitic facies indicate presence of the average depth basin in the area. Rhythmic alternation of sandstone and clay beds in the Qala suite section is the sign of temporary shallowing of the basin at the time. During sub Qirmaki suite (SQS) period rhythmic alternation of sandy and clayey beds is observed. SQS column shows dominance of pelitic facies in the lithofacial sequence. This case also indicates that the basin floor has been subject to rhythmic fluctuations, i.e. to uplifting and subsidence during some geological time.

In spite of presence of alternating sandy and clayey beds during initial periods of the Qirmaki suite (QS) column, the lithofacial sequence is dominated by pelitic facies. This is indicative of the basin floor being subject to fluctuational movements as well, that is, uplifting and subsidence during certain period of time. More frequent alternation of clayey and sandy layers suggests frequent variations of the sedimentary basin floor level during geological time. Uplifting and subsidence processes alternated each other at that period.

Psammitic facies only (that contain gas at that time) are observed in the VIII horizon's section. Formation of psammitic facies is a sign of the shallow basin floor. Frequent alternation of sandy and clayey beds is observed within the supra Qirmaki clayey suite (SQCS). Relatively rhythmic alternation can be tracked all along the column as well, what is indicative of the basin floor being subject to rhythmic fluctuational movements, i.e. rising and subsidence within some geologic time. Rhythmic alternation of sand and clay layers is observed during the upper Productive Series, that is, in horizon VII section, which is oil and gas bearing. Pelitic and psammitic facies predominate throughout certain intervals. We can infer that rising and subsidence processes alternated during that period. Horizon V is oil and gas bearing as well and rhythmic alternation of sand and clay beds is also seen in this horizon. Psammitic facies predominate in the lithofacial sequence. Alternation of uplifting and subsidence processes can also be deduced. Alternation of sand and clay layers is observed by the end of the upper Productive Series. The typical lithostratigraphic column shows no signs of sedimentation complexes at approximate depths of 1700m and 4380m, i.e. sedimentation break is present, what leads to a conclusion that the area under investigation was the region of erosion. The beginning of the Agcagil stage shows alternation of clay and sand beds with alternating rising and subsidence processes.

Alternating sandy and clayey beds at the onset of Absheron stage are considered as a sign of frequent basin floor fluctuations during geological time. Greater thickness of pelitic facies by the end of the Absheron stage is associated with the average depth of the basin at the time. Interruption in sedimentation is also observed by the end of the Absheron stage. It should be noted, that the great thickness of sediments that represent stratigraphic units under consideration indicates relatively higher depositional rates and, for this reason, the paleogeographic environment was favorable enough for accumulation and preservation of organic matter in most of them during corresponding time intervals. In researchers' opinion, there is direct proportionality between depositional rates and amount of accumulated organic matter in the basin. Taking this into account and based on the typical lithostratigraphic column of the area we tried to identify the potential of corresponding lithological targets as source rocks by means of determining the depositional rates during individual geological time intervals. By source rocks we mean a sedimentary bed that is capable of generating commercial hydrocarbon volumes in an environment with favorable temperature and pressure conditions [1].

According to the depositional rate chart the Pontian stage is characterized by sedimentation rate of 83 m/my. Sedimentation rate dramatically increased in Lower Pliocene (lower Productive Series stage) relative to other geological time intervals and was 1970 m/my. The depositional rate decreased to 432 m/my during the upper Productive Series stage and further drastically decreased during Agcagil stage to 52 m/my. Starting from the Absheron stage the deposition rate tripled relative to previous periods and was 181 m/my (Figure 3.).

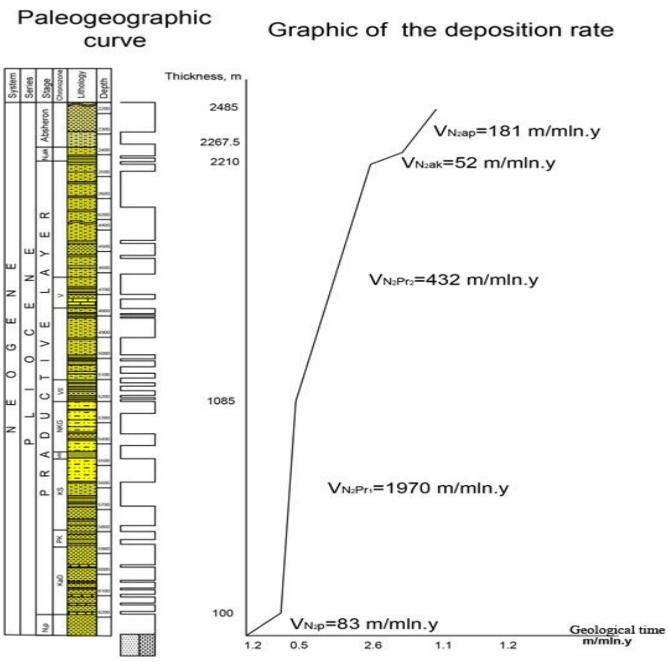


**Figure 3:** *Depositional rate chart*

According to N.B. Vassoyevich, V.A. Sokolov et al., if the depositional rate in a basin is below 50m/my, the amount of organic matter accumulated in potential source rocks, as a rule, is below the Clarke number. In other words, this type source rocks are not capable of generating commercial oil and gas. In case the depositional rate within a favorable (subaqueous) paleogeographic environment is 50-140 m/my, then the possible amount of the organic matter in potential source rocks may be up to 1-2%.

If the depositional rate is from 140-160 m/my to 600 m/my, potential source rocks may accumulate above 2% and, in favorable environments, up to 10% of organic matter. Finally, if the depositional rate in a basin is from 600 m/my to 1400-1600 m/my, then the amount of organic matter accumulated in potential source rocks may reach 16-20% and, in exceptional cases, up to 30%. Thus, by comparing the depositional rates during individual time intervals of the area under investigation with the abovementioned figures, we can infer that the amount of organic matter accumulated in corresponding potential source rocks was above the Clarke number, to say the least, what is indicative of presence of a favorable environment in the source rocks.

The built depositional rate graph shows the maximum sedimentation rate at the lower Productive Series stage and the figure is, as mentioned above, 1970 m/my. It should be noted, that in spite of a relatively low rate observed during the Pontian stage it is above 50 m/my, i.e. even at that time the amount of organic matter is greater than the Clarke number. Thus, analysis of the paleogeographic curve and the depositional rate graph show that the area had paleogeographic and paleotectonic environment favorable for accumulation and preservation of required amounts of organic matter.

In order to successfully complete the exploration works, paleoanalysis is considered as the deepest and most successful analysis method. To objectively estimate oil and gas perspectives of the area under investigation, we built a number of paleoprofiles based on a profile through the Umid structure and a graph of the fold development rate on the basis of these paleoprofiles (Figure 4.), in order to clarify the time of the structure origination and its further development features. A paleoprofile built for the end of the Pontian stage shows that the sedimentation process covered the entire area at the time. Nevertheless, the depositional rate at that stage was greater than the fold development rate. A paleoprofile built for the lower Productive Series stage shows that during this period of geologic time the depositional process continued to encompass the entire area, but the thickness of sediments lessened towards the crests of the structures. This is a sign of simultaneous fold development and sedimentation processes. Yet, the depositional rate was greater than that of the fold development too.

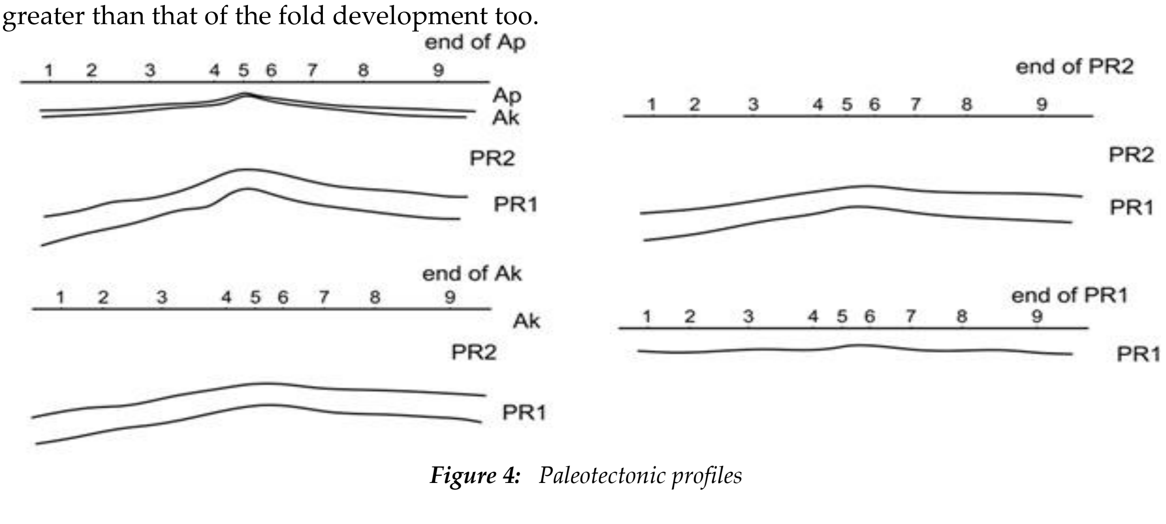


***Figure 4:*** *Paleotectonic profiles*

A paleoprofile built for the end of the upper Productive Series stage reflects a continuing depositional process. The thickness of the accumulated sediments also attenuated towards the crest of the uplift during this span of time. The paleoprofiles plotted for the end of the Agcagil and Absheron stages show sedimentation processes going on and covering, as during previous time intervals, the whole area. The conducted paleoanalysis lets us infer that the development of the uplift under investigation and sedimentation processes occurred simultaneously and increase in the development rate is observed by the Quaternary. Based on paleostructural and paleotectonic development properties the Umid structure may be positively estimated from point of view of oil and gas perspectives. The paleosections enable tracking the onset of development of the local uplifts, their further development features during the time span under consideration, generation and further development of individual faults. The graph of the development rate of the local uplifts enables determining generation time of the uplift and its further development rates. Identifying the onset of the local uplift development, whether its development syndepositional or postdepositional in nature, allows more objective estimation of its hydrocarbon perspectives (Figure 5.).

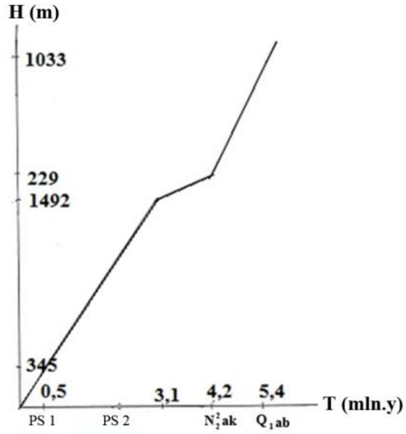


**Figure 5:** *Graph of the fold development rate*

According to the graph of the fold development rate the Umid structure started to develop no later than in Lower Pliocene and continued its development during the following time spans.

## Conclusions

1. Based on analysis of the paleogeographic curve and the depositional rate chart we can infer that both paleogeographic and paleotectonic environments were favorable for accumulation and preservation of required amounts of organic matter in the area.

2. The Umid structure started its development no later than in Pliocene, which intensely continued in later stages and was syndepositional in nature.

3. Based on the location of the Umid structure, which is within the same tectonic area as the highly saturated with gas condensate Bulla-deniz field, similarity of the parameters for horizons V and VII, favorable fluid migration pathways within the depression zone, presence of a favorable environment for hydrocarbon migration and accumulation, the results of conducted paleoanalysis back up the statement that this structure is also hydrocarbon bearing.

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# CARBON SEQUESTRATION IN LANDSCAPES OF THE CHECHEN REPUBLIC

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**Abstract**

*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.*

**Keywords**: reduction of emissions, carbon, acceleration of convergence, climate, decarbonization, ecosystems.

The landscapes of the Chechen Republic (CR) are characterized by exceptional diversity, which is associated with the confinement of its territory to the Ciscaucasia and the northern slope of the Greater Caucasus [1]. The presence in a small area of a wide range of landscapes (from semi-desert in the north to glacial-nival in the south) attracts the attention of many researchers. Modern exogenous processes are manifested on the territory of the republic very intensively. Their occurrence and course are due to many factors. As a result of economic activity, industrial and motor transport enterprises of the Chechen Republic in 1991, 482 thousand tons of harmful substances were emitted, including 342 thousand tons in Grozny. Main pollutants: hydrocarbons (50%), carbon monoxide (32.8%), sulfur dioxide (8.7%), nitrogen oxides (4.3%). In subsequent years, the level of pollution increased sharply due to the influx of pollutants from the combustion of oil flares and artisanal oil refineries [2].

The main reasons for the high level of air pollution are [2-3]:

- unsatisfactory fulfillment of the state plan for environmental protection ("Grozneftegaz", "Groznefteorgsinetez", "Chechen Cement Plant");
- the slow pace of implementation of low-waste and non-waste technologies (the firm "Terek", "Red Hammer");
- weak departmental control over the state of air pollution and the efficiency of treatment facilities (Grozneftegaz, Terek Firm, Agro-industrial complex).

Efforts to mitigate the effects of climate change must stabilize atmospheric concentrations of greenhouse gases at levels that prevent dangerous anthropogenic interference. For example, the Intergovernmental Panel on Climate Change (IPCC) defines several categories of climate impacts on ecosystems and societies, from risks to vulnerable ecosystems to large-scale changes in temperature and precipitation patterns [3]. To avoid dangerous anthropogenic interference, the climate policy debate has focused on limiting the average global temperature rise to an average of 1.5–2°C over pre-industrial times. Current models predict extreme weather events and biophysical impacts of greater magnitude for a global warming of 2°C than 1.5°C, but severe uncertainties in the range of impacts limit regional risk assessments [4]. In any scenario, probabilistic risk assessments based on coupled climate-carbon cycle models show that dangerous interference with the climate system can only be avoided if the climate response goes beyond pure carbon neutrality and results in persistent net negative emissions from reductions. $CO_2$ emissions in the atmosphere [5].

Recent long-term studies and meta-analyzes show that combined organic and inorganic fertilizers have a significant effect on soil carbon sequestration. The use of nitrogen has a stimulating effect on carbon preservation, including the decomposition of organic matter, a decrease in the carbon distribution profile of the root mass and mycorrhiza, the placement of carbon in various organic fractions of the soil, the microbial composition and activity of suppressing heterotrophic respiration, etc.

The use of lime in herbal ecosystems in the Chechen Republic can have a neutral or positive effect on soil carbon stocks. In addition to the potential effect of fertilization on carbon storage in the soil, the frequency and intensity of use of grasses is of key importance. With intensive grazing, about 25–40% of the consumed but not digested biomass returns to the pasture in the form of excrement [6].

Even when more than 80% of ground produce is harvested under intensive mowing conditions for hay or silage, carbon losses can be offset by the use of manure. The intensity of using herbs depends not only on the return of carbon and nitrogen to the soil, but also on the effect of photosynthetic capacity and carbon decomposition of plants in plant communities. In addition, the intensity of harvesting is reflected in soil-plant relationships, affecting the volume and quality of root residues and, thereby, the volume of organic matter and carbon in the soil of the Chechen Republic (Fig. 1) [7].

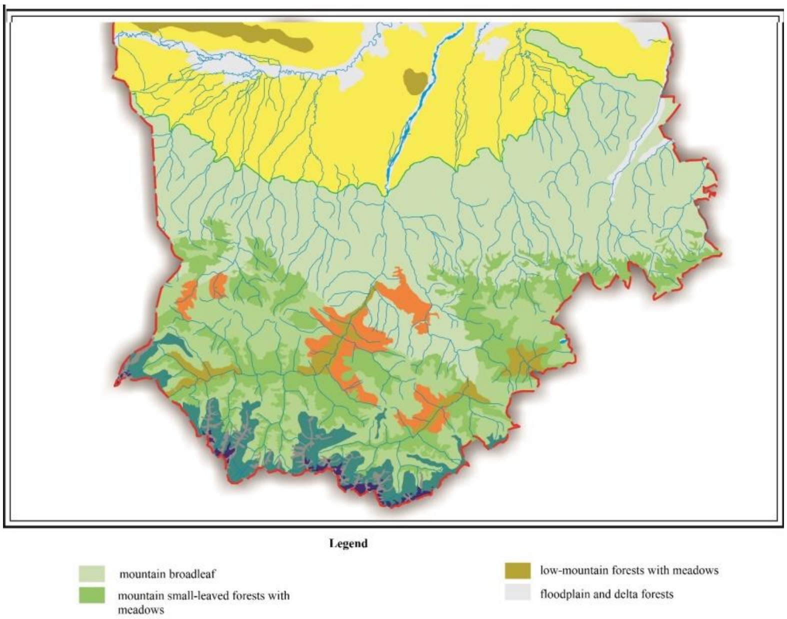


**Figure 1:** *Distribution of the main forest resources of the Chechen Republic*

For this reason, the intensive use of herbal biomass reduces carbon sequestration. The duration of the biomass produced and its quality are reflected in the sequestration of soil carbon. Plowing grasses in crop rotations leads to a decrease in soil carbon. Tillage has a significant impact on nutrient content and soil mineralization processes.

Natural climate solutions have been proposed as a way to achieve effective reductions in $CO_2$ emissions. Recent estimates indicate that NCS can provide more than one-third of the cost-effective climate change mitigation required to stabilize warming below 2°C through 2030. Current NCS techniques consist of conserving, restoring and managing natural areas to increase land-based carbon stocks, which are an easy-to-implement way to reduce $CO_2$ emissions while providing a range of co-occurring socio-economic and environmental benefits (5–8). However, there is a critical and growing gap between the development of scientific knowledge and practical implementation at the required pace and scale. At a practical level, the methods for implementing $CO_2$ reduction initiatives are poorly defined, as best practices are sector-specific and highly dependent on the individual characteristics of the ecosystem [6].

For example, current practices include afforestation, reforestation and forestry; zero tillage and other farming methods; wetlands and other blue carbon recovery projects; and sustainable cropping or grazing on rangelands. However, most of the NCS research involves oversimplified landscapes and hypothetical participants, while real-world solutions involve space constraints, ownership difficulties, and limited resources. Dangerous human interventions can be prevented while improving human conditions through coordinated carbon sequestration, biodiversity conservation and action for social equity. [7] However, the gap between basic science and mitigation strategies still needs to be bridged for rapid implementation on the ground in heterogeneous landscapes.

The ability of managed and natural ecosystems to remove $CO_2$ from the atmosphere is limited by the laws of physics and ecological processes that govern photosynthesis and the breakdown of organic matter. In general, the rate and amount of carbon sequestration through NCS is slow and low compared to the rate and amount of $CO_2$ released from burning fossil fuels (9). Consequently, five principles have been proposed as a general framework for identifying significant $CO_2$ reduction requirements in the context of the broad demand for atmospheric restoration [8]:

1. Increasing carbon stocks in large landscapes requires quantifying baselines and predicting carbon storage potential based on geography, land-use sector, land cover and soil resources.

2. Efforts to reduce $CO_2$ emissions will require additional resources (eg water and nutrients). Minimizing these costs is critical to increasing long term carbon sequestration.

3. Large areas are needed for ecosystems that reduce anthropogenic $CO_2$ emissions. Public-private partnerships are critical to identifying and allocating land for long-term carbon storage.

4. The carbon sequestration potential of landscapes depends on their ability to serve as permanent carbon sinks, which varies from region to region depending on socio-economic and environmental factors.

5. Net $CO_2$ emission reductions are low compared to those from forest fires and land use practices. Thus, reducing emissions in the landscape is as important as accelerating carbon sequestration [9].

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# REDUCING RISKS THROUGH IMPROVEMENT OF PREDICTION MODELS

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**Abstract**

*Management or avoidance of risks or mitigation of undesirable outcomes are linked to specific actions, as well as to prediction models. These prediction models should be improved to obtain "better" predictions and thus, manage risks, and take measures for their reduction. We consider such algorithm of event prediction, which, using parallel data, can obtain prediction with high reliability that, in its turn, helps to reduce risks or completely avoid them*

**Keywords:** Risk management, Parallel data, Prediction models, model improvement algorithm.

## I. Introduction

At this point, fundamental research studies on safety theory and risks are very important. They can be practically used for reducing risks in the fields of industry, energy, transport, construction, and agriculture [1].

There are many risks in our world. Some of them impact individuals, others pose danger for the entire society, and some specific risks impact only certain fields and activities. Because of damage caused by risks, protection from them and avoidance of negative outcomes are very important.

Risk management has great importance in the economy, as well as risk reduction. This mainly applies to those risks, which can be identified. These processes should be equipped with the appropriate models and procession of information needed for identification. As it is discussed in [2], systemic use of all existing information is one of the main parts of risk analysis, which allows to evaluate the risks of undesirable accidents and events.

For reduction of risks, we consider the algorithm for prediction improvement built by us, which helps to predict such events, as the risks associated with natural disasters. In particular, we single out prediction of earthquakes, landslides and mudflows.

## II. Use of improved algorithm of earthquake prediction models for avoidance of undesirable risks

Let us review several models of earthquake prediction specifically for Georgia. The information was taken from the online map of earthquakes [3], where there are maps, lists, data and information on earthquakes, and a seismic map of the world. In Table 1, the list of earthquakes occurred on the territory of Georgia is given, which belong to the earthquakes with moderate strength (magnitude 4-5). We took earthquake magnitude, occurrence date, time and name of epicenter as characteristics of each earthquake. The table contains earthquakes occurred in 2020-2021. UTC means the Coordinated Universal Time.

**Table 1:** *Earthquakes occurred in Georgia in 2020-2021*

| N | Magnitude | Date | Time | Epicenter |
|---|---|---|---|---|
| 1 | 4.7 | 16.08.2021 | 00:49 (UTC) | Georgia, Kvemo Kartli region, Dmanisi municipality |
| 2 | 4.1 | 15.08.2021 | 22:36 (UTC) | Georgia, region of Samtskhe-Javakheti, Ninotsminda municipality |
| 3 | 4 | 14.07.2021 | 06:35 (UTC) | Georgia, region of Samtskhe-Javakheti, Ninotsminda municipality |
| 4 | 4.1 | 17.04.2021 | 20:07 (UTC) | Georgia, Colchis National Park |
| 5 | 4.3 | 13.03.2021 | 10:00 (UTC) | Georgia, region of Racha-Lechkhumi and Kvemo-Svaneti, Onsky municipality |
| 6 | 4.3 | 21.04.2020 | 05:23 (UTC) | Georgia ('velo Sak art) |

Designate the set of actually occurred earthquakes with $p_{real}$. Designate the earthquake prediction models with: $Mod_1, Mod_2,$ ... etc. which provide some predictions through their predecessors (for example, for earthquakes - when it would occur, at which location and with which magnitude). We must choose only those models from these models, which satisfy the necessary condition, i.e. Intersection of the set of model predictions with the set of actual events should result in the set of actual events. We call this condition a necessary condition for choosing a prediction model [4]. This condition in case of earthquake means the following: If during the $T$ time there were occurred, for example, six earthquakes (as in our example), only those models should be considered that predicted all these six earthquakes. Assume that such are the following models: $Mod_1, Mod_2, Mod_3, Mod_4, Mod_5$ . In our case it is not essential, what specifically is each model and based on which predecessors of the earthquake it makes the prediction.

In Table 2, the numbers of predictions for each of these models, the numbers of successful and failed predictions are given. Let's calculate the probability of success for each model.

It is obvious in this Table, that the sum of successful and failed predictions is equal to the total number of predictions. As for the probability of success [5, 6], it is calculated for each model and determines, how many times earthquake prediction was made and how many times an actual earthquake occurred. Assume that we consider the necessary predecessors and the models created for them: $A_1, A_2, ..., A_n$, where n is the number of considered predecessors. t is the time during which we make the analysis, and the number of actually occurred earthquakes is m. We calculated the number of earthquakes predicted by each predecessor: $p_1, p_2, ..., p_n$. For example, $A_i$ the model, which was based on $i$ predecessor, predicted earthquake occurrence $p_i$ -times.

**Table2:** *The characteristics of "necessary models"*

| Model | Number of predictions | Successful Number of predictions | Failed Number of predictions | Probability of success in % |
|---|---|---|---|---|
| $Mod_1$ | 100 | 6 | 94 | 6.00 |
| $Mod_2$ | 95 | 6 | 89 | 6.32 |
| $Mod_3$ | 99 | 6 | 93 | 6.06 |
| $Mod_4$ | 98 | 6 | 92 | 6.12 |
| $Mod_5$ | 99 | 6 | 93 | 6.06 |

For each $p_i$ let's calculate quotients of the number of actually occurred earthquakes $m$, write it in % and designate with $K_i$:

$$K_i = \frac{m}{p_i} 100\%$$

For example, if earthquake actually occurred 4 times, and we calculate the value $K_i = \frac{4}{20} 100\% = 20\%$ , then the probability of success for $A_i$ will be 20%.

The probability of success also can be considered the probability of prediction correctness of specific model. Designate this last value with $L_m$ and link the ratio $L_m = \frac{u}{v}$,*100% to its value, where $u$ is a number of actually occurred events, and $v$ is a predicted number of event occurrence obtained in the given $p_m$ model.

**Table 3:** *The characteristics of the "necessary models" for the pairs*

| Model | Number of predictions | Successful Number of predictions | Failed Number of predictions | Probability of success in % |
|---|---|---|---|---|
| $Mod_1 \cap Mod_2$ | 17 | 6 | 11 | 35.29 |
| $Mod_1 \cap Mod_3$ | 20 | 6 | 14 | 30.00 |
| $Mod_1 \cap Mod_4$ | 15 | 6 | 9 | 40.00 |
| $Mod_1 \cap Mod_5$ | 13 | 6 | 7 | 46.15 |
| $Mod_2 \cap Mod_3$ | 15 | 6 | 9 | 40.00 |
| $Mod_2 \cap Mod_4$ | 10 | 6 | 4 | 60.00 |
| $Mod_2 \cap Mod_5$ | 16 | 6 | 10 | 37.50 |
| $Mod_3 \cap Mod_4$ | 17 | 6 | 11 | 35.29 |
| $\boldsymbol{Mod_3 \cap Mod_5}$ | **8** | **6** | **2** | **75.00** |
| $Mod_4 \cap Mod_5$ | 18 | 6 | 12 | 33.33 |

The theorem proved in [7]: From the given predictions, always can be chosen at least two such predictions, for which the probability of correctness of simultaneous occurrence is greater or equal than the probability of correctness of the best prediction model:

$\min(P_{ij}) \leq P_g$, where $i, j = 1 \dots n$ .

In this theorem, $P_{ij}$ designates the probability of correctness of simultaneous occurrence of two prediction models $P_{ij=}P_i \cap P_j$., and $P_g$ designates the set containing the least number of predictions, which at the same time will be the best prediction model. $P_g \leq P_i$, where $i = 1 \cdots n$.

According to this theorem, we should consider pairs of models. Let's compose Table 3 with the values corresponding to Table 2, for each possible pair of all five models, considered in the example, whose total number will be 10.

After analysis of Table 3 we see that the best result is obtained from the combination of two models $Mod_3$ and $Mod_5$ (although the separate probabilities of success for them are not best, the combined probability of success is increased up to 75%, even though separately these models have significantly lower values of success: 6.06% and 6.06%. For the considered examples, it is possible that two pairs of the models show the same result. If this is the case, it should be decided by means of expert and material and technical resources needed for work of these models, which one should be used. The diagram corresponding to Table 3 see on Diagram 1:

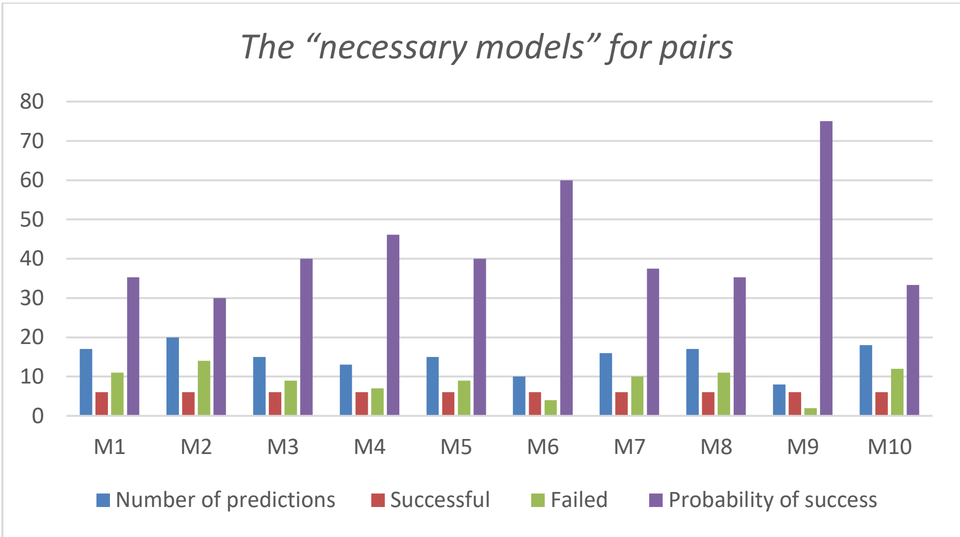


**Diagram 1.** *The characteristics of the "necessary models" for pairs*

Keys used in Diagram 1:
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= $Mod_4 \cap Mod_5$.

The next stages of the prediction algorithm based on parallel data [papers] is consideration of model triples. See Table 4.

**Table 4:** *The characteristics of the "necessary models" for triples*

| Model | Number of predictions | Successful Number of predictions | Failed Number of predictions | Probability of success in % |
|---|---|---|---|---|
| $Mod_1 \cap Mod_2 \cap Mod_3$ | 10 | 6 | 4 | 60.00 |
| $Mod_1 \cap Mod_2 \cap Mod_4$ | 9 | 6 | 3 | 66.67 |
| $Mod_1 \cap Mod_2 \cap Mod_5$ | 11 | 6 | 5 | 54.55 |
| $\mathbf{Mod_1 \cap Mod_3 \cap Mod_4}$ | **7** | **6** | **1** | **85.71** |
| $Mod_1 \cap Mod_3 \cap Mod_5$ | 9 | 6 | 3 | 66.67 |
| $Mod_1 \cap Mod_4 \cap Mod_5$ | 8 | 6 | 2 | 75.00 |

After analysis of Table 4 we see that the best result is obtained from the combination of three models $Mod_1$, $Mod_3$, and $Mod_5$. The combined probability of success for them is increased up to 85.71%.

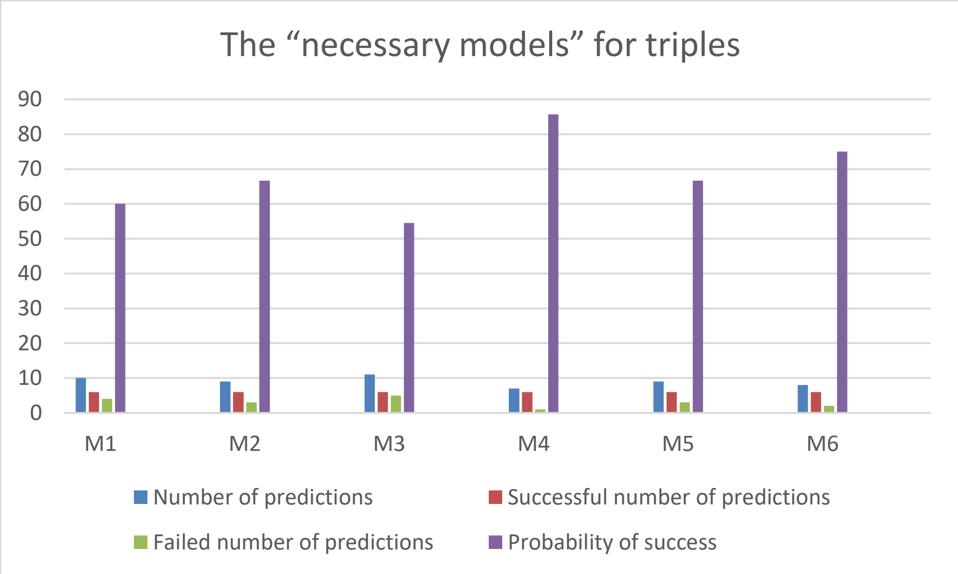


**Diagram 2.** *The characteristics of the "necessary models" for model triples*

We introduced the following keys for Diagram 2:

M1=$Mod_1 \cap Mod_2 \cap Mod_3$; M2=$Mod_1 \cap Mod_2 \cap Mod_4$;
M3=$Mod_1 \cap Mod_2 \cap Mod_5$; M4=$Mod_1 \cap Mod_3 \cap Mod_4$;
M5=$Mod_1 \cap Mod_3 \cap Mod_5$; M6= $Mod_1 \cap Mod_4 \cap Mod_5$;

## III. Conclusion

It is obvious that the more is the number of intersections of prediction models, from which we choose the best, the better would be the result, compared to the case of less number of intersections. But we should take into account that greater number of models need greater number of data (predecessors), which can be obtained by spending considerable amount of material resources. Collection and analysis of large amount of data is an unresolved issue for small, low income states. Exactly for these cases it is important to theoretically choose two or three models of prediction, for which intersection of predictions would give best results. While collection of information, in this case, would be needed only for these chosen models, thus sharply reducing the costs of information procession.

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# MANAGEMENT OF ENVIRONMENTAL AND ECONOMIC RISKS IN THE SYSTEM OF SUSTAINABLE ECONOMIC DEVELOPMENT

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**Abstract**

*Today, the words "sustainable" and "development" are often used when choosing a concept for promotion, growth or a description of a government strategy. The popularity of the term "sustainable development" came when a close relationship was established with such a direction as the "green economy". Green Economy is an area initiated by the United Nations (UN). In 2008, the UN came up with a proposal for a Green Economy, which was backed up by global research. The initiative was supported at the country level, as investments in the environment went in the context of sustainable development. Thanks to this initiative, the green economy, in conjunction with the eradication of poverty, has been included in the 2012 Rio + 20 agenda and recognized as a tool for contributing to the functioning of the vision for sustainable development. The UN developed an exhaustive definition of the "green economy", which included a story about both improving human well-being and increasing social justice, at the same time talking about reducing environmental risks and reducing environmental deficits. The last decades have raised the importance of the green economy concept to a scale comparable to the strategic priorities of many countries and intergovernmental organizations.*

**Keywords:** world economy, environmental risks, natural resource, sustainable development, ecological development.

## I. Introduction

The concept of sustainable development is multidisciplinary, systematic, complex and perhaps even revolutionary. Deriving a capacious and comprehensive definition of this concept is undoubtedly a rather difficult task. The term sustainable development was first used in 1980, when the concept of the whole concept was still quite simple. It was mentioned in the framework of the document "World Conservation Strategy", prepared by the International Union for Conservation of Nature and Natural Resources (IUCN). The World Wildlife Fund (WWF or WWF) and the United Nations Specialized Agency for the Conservation of the Biosphere (UNEP) took part in the development of the document. This strategy is the first international document on the conservation and rational use of the resources of the biosphere and individual ecosystems [1]. The report argues that for development to be sustainable, it must support the conservation of resources, not hinder. It targets policy makers, conservationists and development professionals [2]. The report defines the principles of protection of ecological processes and life support systems, conservation of genetic diversity and sustainable use of resources of various ecosystems. In addition to highlighting priority conservation issues and ways to address them, it formulates the first definition of sustainable development. Within the framework of their activities, the organizations made the following definition: sustainable development is a strategy for the preservation of the natural resources of the earth [1]. In 1987, the World Commission on Environment and Development (WCED) published a document entitled Our Common Future. This report argues that critical global challenges are primarily associated with unsustainable consumption and production patterns. The authors called for the development of a strategy that connects development and the environment, strengthened international cooperation in the field of environment and development, evaluate and propose new forms of cooperation that can go beyond existing models and increase the level of understanding and commitment on the part of individuals, civil society organizations, businesses, institutions and governments. This document offers a broader and more loose definition that reads as follows: sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs [2]. This document, in another way, called the "Brundtland Report", has been adopted by almost every international institution, agency and research and production association (NGO). Countries that made a conscious effort to understand the concept of sustainable development, agreed with it and were close to making changes not only at the international level, but also at the national level, faced challenges in implementing sustainable development policies and saw the risks that hinder implementation. Sustainable development is also associated with identifying the limits and possibilities of establishing restrictions and regulations for the development of socio-natural and technological systems and the impact on them, otherwise it can be interpreted as a reaction to the constantly growing development risks in a technological society. There is a common space of risks, of which it is advisable to single out environmental risks, since they have a direct relationship with the concept of sustainable development and the green economy [3], the term of which was used earlier.

Environmental risk is the likelihood of an event having adverse consequences for the natural environment and caused by the negative impact of economic or other activities, natural and man-made emergencies [4]. Environmental risks stand out from risk societies, as it is a multifactorial system of causal causes and consequences, which are most often long-term (for example, radioactive contamination). By their nature, environmental risks are characterized by spatial distribution, multiplier effects, accumulation and irreversibility. But the most striking characteristic of environmental risks is interconnectedness. For example, over-deforestation leads to deforestation and destruction of wildlife habitats, leading to depletion of biodiversity. Deforestation not only accelerates soil erosion, but also causes greenhouse gas emissions and concentrations in the atmosphere, thereby increasing the likelihood of climate change. A negative change in one area can aggravate another area, and vice versa.

## II. Methods

Environmental risk assessment is a comprehensive justification of the consequences of economic activities in conditions of a high degree of uncertainty and potential danger to the environment and public health. Environmental risk assessment, both qualitative and quantitative, includes accompanying uncertainties, the likelihood of occurrence and the severity of known or potentially adverse impacts based on hazard identification and hazard characterization [6]. Assessment of environmental risks is directly related to the study and analysis of the expected impact of natural and man-made processes on human health and the quality of the environment. One of the methods for assessing environmental risks can be the method of systems analysis. This method is an integration of the following processes: hazard identification, hazard characterization and exposure assessment. Environmental risk assessment requires a wide range of skills, as it is necessary to process information and data from various sources and apply mathematical knowledge in the modeling process. When using this method, the risk assessment and hazard analysis of an object is carried out in several stages [3-4].

First step. In the first step, we need to do a preliminary hazard analysis. To identify and describe possible hazards, it is necessary to study information about the structure and components of the object, about the technological schemes, the equipment used and its reliability, about the chemical and thermodynamic characteristics of the materials used at the object, etc. It is necessary to determine under what circumstances they can cause harm. We associate all identified possible dangers with production processes and draw up a list of possible incidents.

Second phase. During the second stage, we consider all possible hazards with a detailed description of possible consequences and accidents and assess the possible probabilities of their occurrence based on mathematical modeling. Stage three. The last stage includes the completion of the system analysis by forecasting and assessing emergency risk [7]. As a result of the risk assessment, the required level of security can be established. Reducing the level of risk and a favorable risk comparison result ensures that the situation is safe. The scope of environmental risk assessment is gradually expanding, and the importance of the relationship between risk assessment, risk management and risk communication is becoming evident [8]. Risk management is the process of balancing competing interests and concerns. Each risk management decision will be a "balancing act" of competing priorities, and sometimes a trade-off between seemingly conflicting principles may be required. Environmental risks and their countermeasures always entail positive and negative environmental, economic and social trade-offs [9]. It is clear that risk management must go beyond a single risk assessment in order to mobilize interdisciplinary expertise in assessing multiple scientific and social risks. In addition, stakeholder participation plays a key role in the design and implementation of long-term and self-sustaining risk management and resilience measures. Public access to information, risk communication and stakeholder participation in decision-making are fundamental to the countermeasure identification process. However, effective measures to manage risk and promote resilience require interdisciplinary, multidimensional, multidimensional research. Universities should be major players in transforming the multidisciplinary science platform to support risk management and promote sustainability [9].

## III. Results

The most important component of the strategy for sustainable territorial development is the preservation of the natural environment, its reproductive capabilities in the context of solving the global problem of preserving the Earth's biosphere as the main prerequisite for the sustainable development of world civilization. Ensuring environmentally sustainable development of the country is largely associated with the solution of a number of major interregional problems of a national character and international border environmental problems. Air and water pollution, especially through the transfer of pollution from neighboring countries in a number of border regions of the country, the depletion of biodiversity has spread to most of the country. The imposition of various types of anthropogenic impact on the environment leads to the emergence of acute complex environmental problems, which, at the same time, have a clearly expressed regional character. An important place in the strategy of sustainable territorial development is occupied by the fulfillment by Russia at the regional level of international obligations in the field of environmental protection, which corresponds to the objective processes of globalization of various spheres of human activity. In order to ensure sustainable development of the economy and prevent harm to the state of the environment a rational approach to organizing the production process of any economic activity is needed [7-8].

The decision-making process in the economy at all levels of management takes place under conditions of constantly existing risk. Identifying, assessing and managing risk is a prerequisite for any effective business activity. Therefore, the problem of risks in relation to individual enterprises or individual economic actions occupies an important place in economic theory and practice. One of the most important factors hindering the balanced and stable regional development of the economy is environmental and economic risk, the analysis and assessment of which must be considered integral parts of the rational nature management mechanism. At the same time, it should be noted that the level of knowledge of environmental and economic risks in nature management, assessment and management of them is insufficient, and, therefore, remains relevant for scientific research. In this work, an attempt is made to define the concept of "environmental economic risk", substantiate its essence in the interaction of its two components: environmental and economic [5].

The conditions for the formation of a risk situation include: uncertainty, the presence of an alternative solution (including refusal to choose), the ability to assess the future result of the chosen alternative. Economic risk refers to the likelihood of incurring losses expressed in monetary terms. On the basis of the main reason for the occurrence, economic risks can be divided into: natural-natural - risks in the event of the manifestation of the forces of nature, environmental - risks associated with the consequences of environmental pollution; political - risks arising from the different political situation in the country; transport - risks, in the case of the carriage of goods by a vehicle; commercial - risks that arise due to the uncertainty of the result of the transaction, and carry a danger in the form of losses. Environmental risk - the likelihood of negative changes in the environment, including long-term consequences, due to a negative impact on the environment. There are three main components of environmental risk: assessment of human health and the possible number of victims, assessment of the state of biota (primarily photosynthetic organisms) by biological integral indicators, assessment of the impact of pollutants, man-made accidents and natural disasters on humans and the environment. Any excess of the limits of permissible environmental risk in certain industries must be suppressed by law. For this purpose, they limit or suspend the activities of environmentally hazardous industries at the decision-making stage. The permissible environmental risk is assessed with the help of the state environmental expertise, and if it is exceeded, the materials submitted for approval are rejected. An environmental risk factor exists at any production facility, regardless of their location. Under environmental and economic risks in the work of N.P. Tikhomirov understands the risks of economic losses, damages that may be at objects of various levels of public organization due to the deterioration of the state (quality) of the environment. The part "economic" in the term "environmental and economic risk" emphasizes that objects subject to this risk are part of the economic subsystem and the losses incurred by them have an economic (cost) assessment; the part "environmental" indicates the cause of the risk [4].

## IV. Discussion

Any human activity is related to the natural environment, therefore, getting feedback from the natural environment is inevitable. Due to this inevitability, it becomes necessary to assess the potential environmental risk, the danger of planned or already ongoing economic activity in order to maximize the satisfaction of the needs of a generation, but not on the basis of ecosystem degradation. Currently, a comprehensive reassessment and reorganization of the entire ecological sphere and modern lifestyle is taking place. It is necessary to develop the field of environmental analysis, environmental awareness and literacy, a culture of environmental safety and environmental readiness to protect and preserve natural and material resources in the environment. Human activity, supported by knowledge of the laws of nature, is able to save the planet [6]. The planet and its nature needs interaction, and not the cruel influence of people on it. This transformation can be facilitated by a good level of ecological and moral culture, the formation of which must begin at a young age and continue throughout life. Humanity's ability to intuitively assess and manage risks is fundamental to human survival and development. Those who were adept at recognizing risk and studying danger survived to reproduce, while those who could not inevitably perish from environmental hazards. While dealing with "risk" is a long-standing practice, the concept of "assessing and managing risk" is relatively new as it has been formally recognized and practiced using this terminology over the past 20-30 years. During this period, as risk issues have become more complex and the relevant scientific knowledge has become more detailed, the need for guidelines that provide a framework for risk assessment and risk management has become more evident.

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# ASSESSMENT OF CHANGES IN THE GEOLOGICAL ENVIRONMENT DUE TO TECHNOGENIC IMPACT (FOR EXAMPLE, DASHOGUZ REGION)

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**Abstract**

*Nature of technogenic impact depends on the nature of development of territory and the design features of structure. In accordance with this, type of construction, type of structure and technology of operation are selected as signs of typification. These signs determine the scale of changes in the geological environment (regional or local) and their nature (areal, point or linear). The greatest regional changes occur during reclamation measures that cause the processes of flooding and secondary salinization of lands, which everywhere leads to activation of subsidence process. Reservoirs and sections of large main water pipelines are associated with the flooding of large depressions in the relief and, as a result, formation of a vast zone of groundwater backwater and flooding, for example, Lake Sarykamysh, located in the north in the Dashoguz region.*

**Keywords:** geological environment, construction, flooding, technogenic impact, irrigation, groundwater level

The area of human geological activity is the geological environment - the upper part of the earth's crust and the outer shells of the Earth. The geological environment is formed as a result of a complex and long-term interaction of the outer shells of the Earth under the influence of endogenous and exogenous forces. The totality of all types of human impact on the geological environment is called technogenesis. These impacts are primarily engineering and construction, agricultural, industrial, hydraulic engineering and other industries. The technogenic impact of man is always directed at a certain area of the earth's crust and causes consequences due, on the one hand, to the properties and processes of this part of the geological environment and, on the other hand, the nature and intensity of the impact on it.

The nature of the technogenic impact depends on the nature of the development of the territory and the design features of the structure. In accordance with this, the following are selected as signs of typification the type of construction, the type of structure and the technology of operation. These signs determine the scale of changes in the geological environment (regional or local) and their nature (areal, point or linear) [4]. The greatest regional changes occur during reclamation measures that cause the processes of flooding and secondary salinization of lands, which everywhere leads to the activation of the subsidence process. The flooding of large depressions in the relief and, as a consequence, the formation of a vast zone of groundwater backwater and flooding, for example, Lake Sarygamysh, located in the north in the Dashoguz region, is associated with reservoirs and sections of large main water pipelines [1].

Local changes in the geological environment are caused by industrial and civil construction and the development of mineral deposits. The construction and operation of roads and railways activates aeolian and suffusion processes - an example is the Aksu-Babadurmaz section on the foothill plain of the Eastern Kopetdag. Features of the geological structure, relief, hydrogeological and engineering-geological conditions, climate - all this, together with the technogenic impact, determines the nature and degree of changes in the geological environment.

In terms of area, the greatest regional changes under the influence of various ameliorative construction occurred on sandy loamy alluvial plains along large rivers (Etrek, Tejen, Murgap) and along the Garagum Canal (along the foothill plain of the Kopetdag). The most intense changes also occur in the deltas of large rivers, for example, the Amyderya, which has a low natural outflow. Changes in the geological environment in the Aral Sea region caused by a decrease in the level of the Aral Sea and partial drainage of its bottom are distinguished into independent types. This led to the formation of a saline desert, the salts of which are constantly blown by the wind. A significant part of the territory of Turkmenistan is covered by this process.

Self-flooding is inherent in almost all cities, caused by large volumes of water consumption, changes in the natural pathways of groundwater flow, imperfect technology of production processes, and possibly low quality of utilities.

In the areas of industrial enterprises, the degree of pollution of surface and ground waters is also high. Along the routes of highways and railways, power lines and pipelines, environmental changes are associated with the destruction of the upper soil layer, the development of deflation and subsidence processes, the intensification of linear erosion, soil and groundwater pollution [4]. The regional northwestern direction of the groundwater flow (from the Amyderya River to the Caspian Sea) controls the nature of flooding and salinization of the territory, which reaches its maximum in oases (groundwater comes to the surface). In the foothill plains with good drainage, the changes are, of course, less pronounced.

Loess rocks in flooded zones have been significantly changed, where they have lost one of their main properties - subsidence. On irrigated lands, subsidence processes are maximally developed and are accompanied by the formation of sinkholes and subsidence cracks. Drainage water discharges from the Kopetdag Foothill Plain into the Garagum Desert poison biocenoses of the desert, entail pollution of groundwater and surface watercourses over a large area. Intensive development of the country's territory at the present stage of management has led to profound changes in the geological environment, which are manifested at the local and regional level and depend on the nature and type of technogenic impact. Some regions are already experiencing the results of the irreversible changes that have begun. For example, this is primarily the Aral zone, which includes the Dashoguz region [1]. In connection with the problem of the drying up of the Aral Sea, the processes of drying and salinization of lands, degradation of the ecological situation, a significant deterioration in the quality of drinking water continue, in this regard, an extremely unfavorable epidemiological situation is developing in this region.

In geological activity, underground waters produce a more destructive effect than constructive [3]. So, destructive activity is manifested in dissolution and leaching, which increase with increasing temperature, pressure and content of acids and alkalis in water. First of all, halogen rocks, chloride, sulfate, carbonate, and also sulfide deposits are exposed to the destructive action of ground and surface waters.

The location of Turkmenistan inside the mainland determines the sharp continentality of the climate, which manifests itself in large daily and annual fluctuations in meteorological factors. The territory of the country belongs to the drainless basins of the Aral and Caspian Seas, belongs to the geographic zone of extratropical deserts of the northern hemisphere and has a general inclination from the south-east to the north-west. This region belongs to a zone with a very arid climate, which directly affects all components of the natural environment, including groundwater.

Groundwater, due to its relatively easy accessibility, is of great importance for the national economy as a source of water supply for industrial enterprises, cities, towns, settlements in rural areas, etc. They are characterized by a constant inflow, accumulate both in loose porous and solid rocks [3]. The depth of the GWL depends on the nature of the relief and human economic activity, the intensity of which has increased significantly in recent decades. On the territory of Turkmenistan, the depth of the GWL table varies from 0 to 100 meters or more. Groundwater with a shallow depth of occurrence is widespread in irrigated areas, which are confined to the main waterways of the country. So, along the channel of the Garagum river, the waters occur at depths from 1 m to 3-5 m. As the distance to the Kopetdag mountains and the sands of the Garagum desert increases, the depths of the GWL increase. In the valley of the Amyderya river, the depth of groundwater on the left bank ranges from 2 m to 3 m, on the right bank of the river and in the central part of the Dashoguz oasis up to 5 m. In the southeastern and northwestern directions from the Amyderya delta, the depth of the GWL increases, reaching 100 m and more meters [1].

In Tejen, Murgap and Serahs oases, located within the deltas of Murghap and Tejen, the depth of the GWL is 2-6 m. As the distance from river valleys increases, the depth of groundwater naturally increases, reaching values over 40 m in the Central and Low-lying Garagum. Deep bedding of GWLs are confined to the sandy massif of the Amyderya -Murgap interfluve, to the Kopetdag mountain-fold structure, the Koytendag mountain massif, the Big and Small Balkans and the Badhyz-Garabil Upland, where the depth to water reaches 50-70 meters and more. The underground waters of the foothill plain of the Kopetdag are uncovered at depths of 10 to 20 m and more.

Under conditions of an arid climate, due to the short duration of the fallout and the small amount of atmospheric precipitation, as well as the weak drainage of the area, the groundwater runoff does not develop; in the expenditure part of the groundwater balance, evaporation prevails and their salinization occurs. Near rivers, reservoirs, reservoirs, etc., groundwater is largely desalinated and, in terms of quality, can meet drinking water standards. Groundwater in most of the territory of Turkmenistan is characterized by high mineralization, reaching 50 g/dm$^3$ or more (mineralization is the sum of all minerals dissolved in water, expressed in grams of absolutely dry residue obtained by evaporation of 1 liter of water). Deposits of fresh (up to 1.0 g/dm$^3$) and slightly saline (up to 3.0 g/dm$^3$) groundwater are relatively few in number [1].

Engineering and construction activities of a person and other man-made causes change the natural regime-forming factors and contribute to the emergence of new ones, this is how an artificial (or disturbed) regime of groundwater is formed. Human activity can manifest itself in an increase or decrease in GWL, in a change in their chemical composition, flow rate and temperature.

Under the influence of anthropogenic factors, the GWL can rise by 10-15 m and more. On irrigated areas, due to the seepage of irrigation water into the soil, the GWL rises everywhere. This leads to transpiration (increased evaporation) of groundwater and an increase in their mineralization, therefore, irrigation systems are not designed in our country without the use of drainage. The lowering of the groundwater level is caused by prolonged pumping of water for water supply, drainage of wetlands, construction dewatering, drainage and other methods. The more intensive the work on the extraction of water from the bowels of the earth, the greater the depth of the GWL decreases [2].

The water resources available in the region are limited and, if an increase in irrigated lands is necessary, water should be released through more rational water management on the lands of existing irrigation. At the same time, the task of mobilizing water resources for watering the drained coast of the Aral Sea and stopping the desertification of the Amyderya river delta should be solved. Consequently, in the near future, a reduction in water supply to already developed areas should be expected. Changes in the water regime in the developed and developed territories should also be reflected in the change in the level and salinity of groundwater. It can be expected that the introduction of water-saving technologies in the developed areas will entail a slight decrease in the maximum GWL, but the average depth of occurrence will remain less than 3 m.

The degree of groundwater mineralization in irrigated areas with a weak degree of drainage will in most cases increase, and the ratio of the components will remain unchanged, except that the share of hydrocarbons may decrease. In quantitative terms, the increase in mineralization will depend on many local factors and, first of all, on the initial degree of mineralization and the level of artificial drainage. For areas where groundwater salinity is 1-3 g/dm$^3$, it can increase to 3 g/dm$^3$ with a transition from weak sulfate aggressiveness to aggressive discharge (sulfate ion content is more than 800 mg/dm$^3$).

In areas of new irrigation with a groundwater depth of 10-15 m and more, as a result of a sharp increase in recharge during irrigation, the groundwater horizon will rise until a steady state is achieved, the level of which will be determined by the outflow conditions. The areas planned for irrigation are alluvial-deltaic plains and the periphery of fan cones, which have very difficult conditions for groundwater outflow. Therefore, here over a number of years, the average annual GWL will consistently increase until the "critical depth" (2-3 m) is reached, at which the process of intensive evaporation of groundwater begins to operate and the artificial drainage system begins to work, providing land reclamation well-being [ 1].

Based on the experience of irrigation of territories similar in hydrogeological conditions: the deltas of the Tejen, Murgap, and Amyderya rivers, the average annual increment of the GWL should be expected to be of the order of 1 m. decrease to 5 g/dm$^3$, water will retain high sulfate aggressiveness). When the level of "critical" depths is reached, further dynamics of mineralization and aggressiveness of water will depend on the system of reclamation measures.

The conditions for the guaranteed outflow of groundwater in the areas of new irrigation can be created in the upper parts of the fan fans on the Underkopetdag foothill plain when water is pumped from the Garagum river by machine. Here, the rise of the GWL will be limited by an increase in their outflow to the periphery of the fan and will not reach the "critical" depths. At the periphery of alluvial fans, an increase in the inflow of groundwater that does not have a regional runoff will cause swamping of the discharge zone with high sulfate aggressiveness, if measures are not taken in a timely manner to build vertical drainage systems or to intensively exploit fresh groundwater above the discharge zone.

Regional trends in the development of exogenous geological processes in the coming decades will be primarily associated with the drying up of the Aral Sea: increased desertification and salinization. Flooding is common in all large irrigated areas. The process of flooding will intensify in connection with the construction of irrigation facilities and the rise of the GWL, which will lead to secondary soil salinization, therefore, the main reclamation measures will be land leaching and the construction of a collector-drainage network.

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# MINGECHEVIR DAM BREAK RISK MANAGEMENT SYSTEM

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**Abstract**

*The paper deals with results of the modeling of remote control system of physical stability of hydraulic-fill dam. Case study application has been made for Mingechevir dam on Kura river. This dam is highest in Europe that was constructed through sprinkling. The offered model includes aero-geodetic benchmarks maintained in the body of dam, floating water level measure station on reservoir and water level (water discharge) recorders on rivers Kura, Iori and Alazani. The remote system supplied with solar battery, digital measurement sensors with GSM/GPS connection with Dam Management Office.*

**Keywords:** dam stability, river, reservoir, remote control, aero-geodetic benchmarks, water level recorder

## I. Introduction

Like all technical facility also dams hold a potential risk of breaking [1]. In some sense, the term "dam protection" is a misnomer. Since disasters are, from the point of view of the dam, inherently random in nature, no dam can be "protected". On the other hand, the experience accumulated from the natural disasters and dam failures of the past few years suggest that having the right information, in the right format, at the right time in the hands of the competent people significantly reduces the consequences of disasters and accelerates the recovery process.

By the quantity of major dams (height of a dam> 60m and power of HPS > 100MW) the Kura River basin takes 14th place in the world. The first on the list is Yangtze river (China) with 26 major dams [2]. There are 8 major dams on Kura River basin. Its intended purposes are hydropower, flood control, irrigation, etc. to achieve balanced and sustainable development of the country.

The largest of them is Mingechevir hydraulic-fill dam, which was put into operation in 1953. This dam is highest in Europe that was constructed through sprinkling [3]. The height of dam is 81 meters, a crest length 1550 meters, width on the dam crest 16.7 meters and total capacity of soil 15.6 million cubic meters. Unfortunately, for the existence period the dam inspection, evaluations, modifications and upgrades of the Mingechevir dam was never spent. Therefore, it dam can be considered as an "old dam". Practically right off after constructions of dam and fillings of reservoir of the same name (with length 70km, width from 3 to 18km, deepest point about 75 meters, total area 605 $km^2$, and water storage in reservoir is more than 16$km^3$) the safety issues became actually: collected waters can break embankment dam and catastrophic flash flood will carry by Kura river valleys, destroying all on the way. Potential flood area is 800 000 hectares with around 3.5 million of inhabitants. From the other hand, heavy flooding and/or break one of dams in neighboring Georgia (Khrami, Chitakhevi, Jinvali HPSs, and Sioni, Tbilisi, Dalimta reservoirs etc. [4]) will be enough for catastrophic "domino" destruction of all downstream dams in Azerbaijan. Sad lessons of destruction of the cascade of dams in August, 1975 in Southern China [5] can repeat in the cascade of dams on Kura river basin at any time.

To this end, there is a need for more adequate legal frameworks for dam operation and control of physical stability. The presented paper is devoted results of the first attempt in modeling of the remote control system of dam physical stability.

## II. Risk factors

The large scale field works carried out by authors covers the physical, environmental, ecological and socio-economic aspects of integrated flood and dam-break risk analysis in Kura river basin [6]. This activity is arranged into several themes:

- ✓ Risk analysis - hazard sources, pathways and vulnerability of receptors.
- ✓ Preliminary efforts for risk mitigation.
- ✓ Pilot applications - for Mingechevir hydraulic-fill dam.
- ✓ Co-ordination and management.

The modeling of the remote control system is first step of pilot applications.

The physical stability of Mingechevir dam is multi-parametric issue. Some more important factors influencing dam stability may be classify as below:

- ✓ Geological structure of riverbed in dam location;
- ✓ Seismic activity of region in dam location;
- ✓ Engineering data of dam and position of the depression curve;
- ✓ Genesis of maximum runoff conditions in Kura river and water level in reservoir;
- ✓ Process of sedimentation in reservoir;
- ✓ Anthropogenic accidents in upstream;
- ✓ Dam operating conditions etc.

Wear and tear of the hydro-technical facility in Mingechevir HPS, hydraulic-fill dam and reservoir of similar name, absence of due supervision of safe exploitation make substantial the crevasse of water reservoirs and holding lagoons of runoffs that can result in catastrophic consequences.

An importance among enumerated factors there are seismic activity and water level in reservoir. According to the risk assessment carried out by authors the investigated hydraulic-fill dam are vulnerable to earthquakes.

The Caucasus is located in one of the most active Alpine-Himalayan collision belt. Over the past two thousand years, there have been many earthquakes in the Caucasus. Some have been catastrophic, resulted in thousands of deaths, infrastructure destruction and environmental degradation. Sometimes damage caused by earthquakes may be more linked to landslides generated after them than to the actual earthquake.

Since 1800, over 2,000 significant earthquakes have been recorded in the Caucasus, 1,200 in the last half of the 20th century. While they differed in intensity, their capacity was generally less than 8MSK. Compared with the most active seismic regions of the world, (Japan, California) the Caucasus seems calm. However, over the past decades several powerful earthquakes of 6-6.5M have shook the region (Spitak, 1988; Sachkhere, 1991; Barisakho 1992; Eastern Turkey 1976, 1983 and 1992; North Iran, 1990 and 1997; Baku 2000). Among these earthquakes, the most disastrous was the Spitak 9MSK earthquake. After this earthquake, some of the regions of the Caucasus, including Mingechevir dam location were declared 9MSK earthquake zones [7].

Rivers of the Kura basin has extremely irregular discharge throughout a year [8, 9]. Ration of extreme discharge to average discharge level is 1.63-6.67 which makes sometimes to overcome its negative impact. Therefore, water level in reservoir is depending on grade of intake flow from Kura, Iori and Alazani rivers. In addition to it, there is intensive sedimentation process in reservoir [10].

## III. Modeling of the dam stability remote control system

As mentioned above, physical stability of dam is multi-parametric issue. Therefore, modeled remote control system includes five main parts:

- ✓ Aero-geodetic benchmarks on body of dam;
- ✓ Floating water level measure station on reservoir;
- ✓ Water level (water discharge) recorders on rivers Kura, Iori and Alazani;
- ✓ Appropriate software and algorithms;
- ✓ Dam Management Office (DMO) and Early Alert System.

The first point on list implicates establishment of aero-geodetic benchmarks in body of dam for regular observation over possible dam translocation. The 20 benchmarks with digital transformer of location with GSM/GPS communication should be installed 3÷4 meters deep in the body of dam. It will allow to distant measure total annual linear motions ≥2÷3 sm. The second point implicates establishment of the floating automatic water level measurement station with solar battery and GSM/GPS communication with DMO. According to the offered model the wireless network of water level recorders with GSM/GPS communication will be established in most important points of Kura, Iori and Alazani rivers in upstream of the Mingechevir dam.

The principle scheme of the data collection system is presented on Figure 1. The sensors maintained on benchmarks and water level recorders makes digital data logger of the results of measurements and communicates them through GSM/GPS transmission to DMO. Every sensor supplied with solar battery which is guarantee of autonomy activity of system and provides powering of GSM/GPS. During daylight running time the solar batteries simultaneously charges accumulators (Figure 2.). Simultaneously reception of signal from all of sensor locations and using appropriate software / algorithms supports to "real-time" on-line regime working of DMO. Sensor locations are presented on the Figure 3.

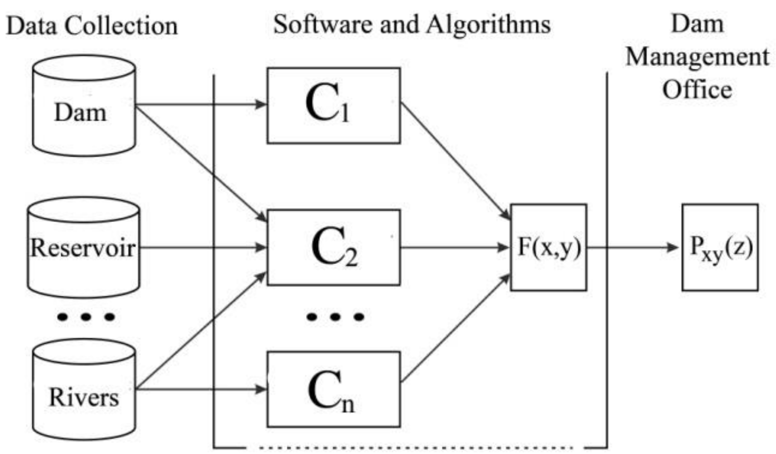


**Figure 1:** *Data collection system*

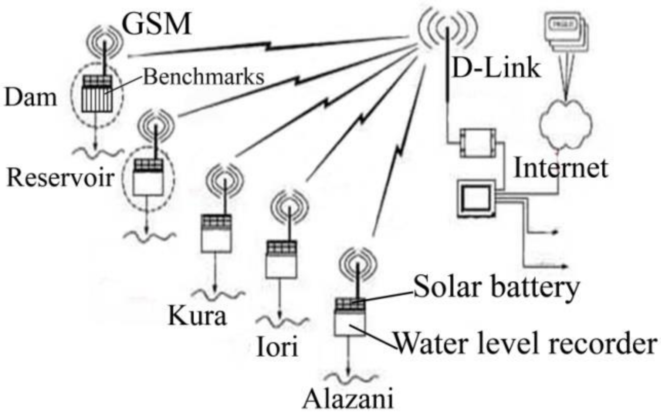


**Figure 2:** *Principle scheme of offered remote control system*


**Figure 3:** *Sensor locations*

**Concluding remarks.** The Mingechevir hydraulic-fill dam safety problem of such size and complexity requires a structured approach to the risk management and risk mitigation. The presented paper is first results in modeling of the remote control system of Mingechevir hydraulic-fill dam physical stability.

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