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

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Abstract

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

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

I. Introduction

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

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

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

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

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

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

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

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

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

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

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

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

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

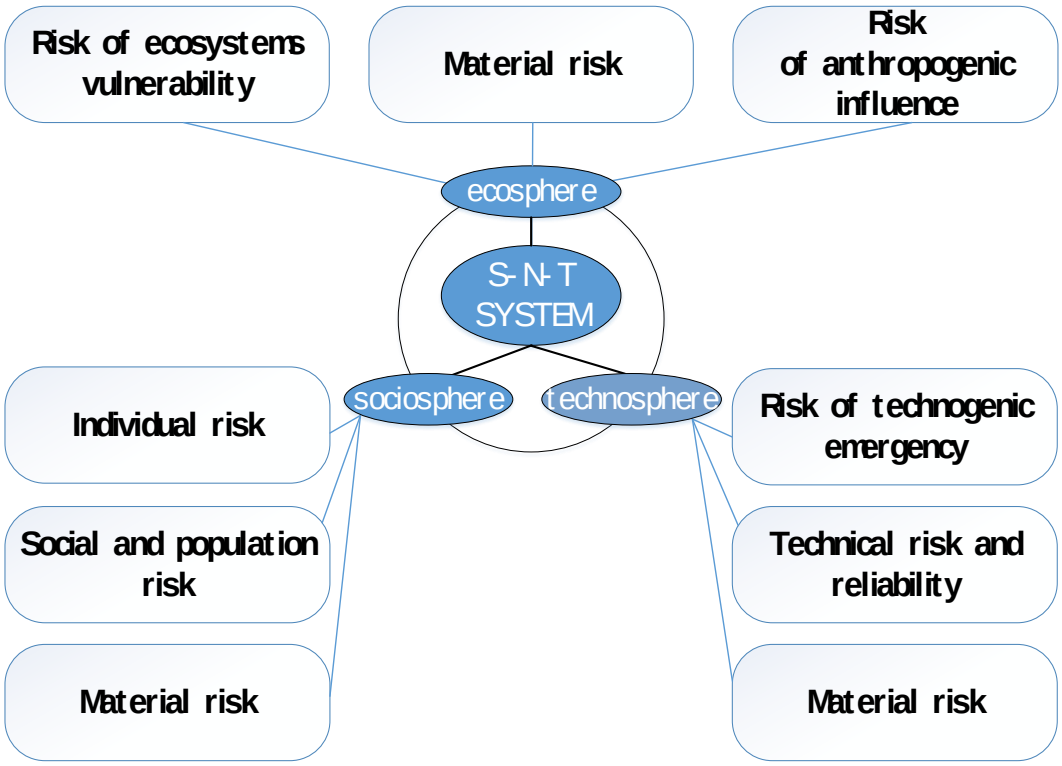

Figure 1: *The main elements and risks of the socio-natural-technogenic system (S-P-T system)*

II. Assessment of technogenic risk in Siberian regions

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

$$R = N_p / N_{\text{n}}, \tag{1}$$

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

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

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

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

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

(municipalities)".

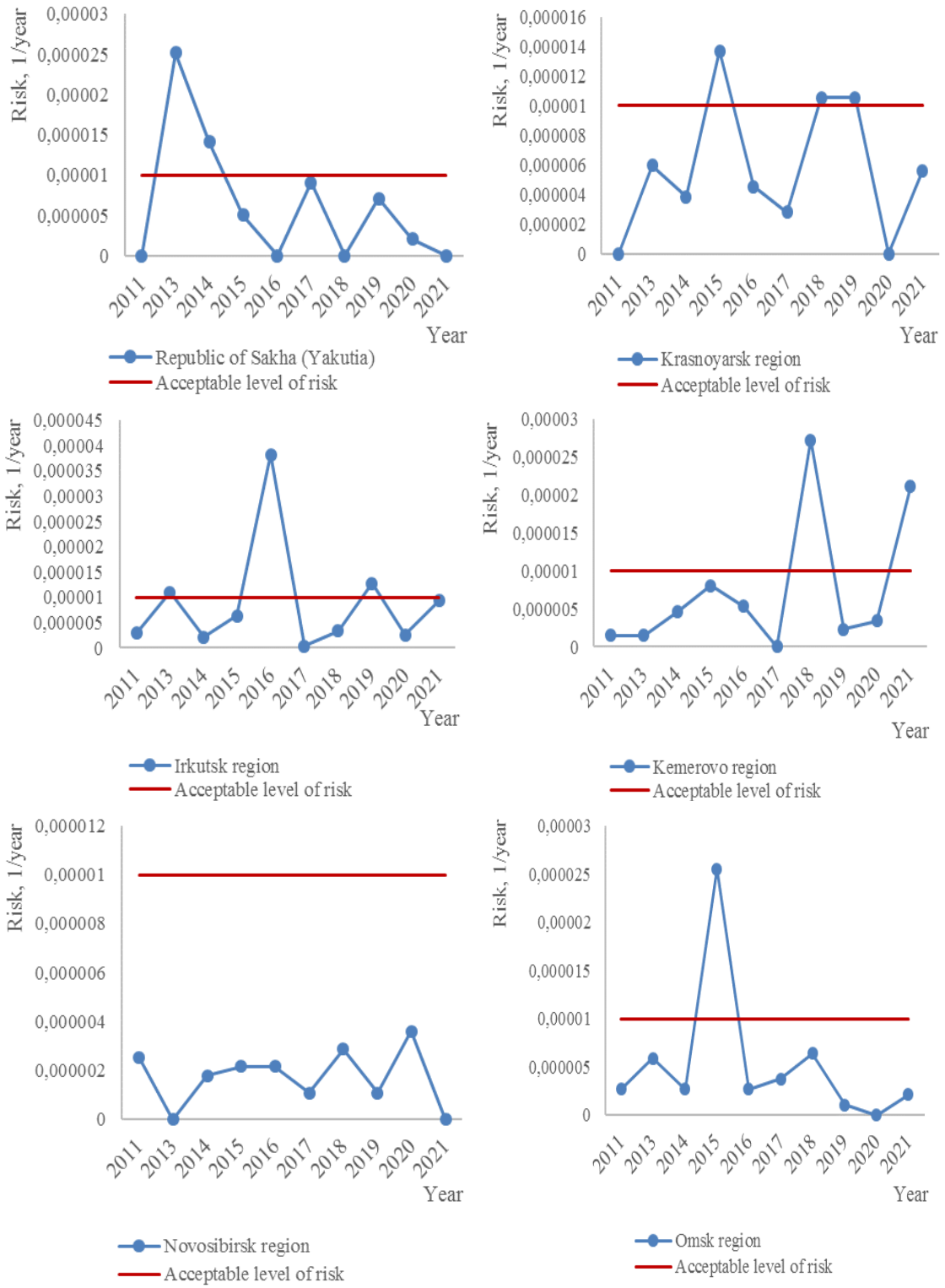

Figure 2: *Assessment of the individual risk of technogenic emergencies in the Siberia regions and the Arctic*

The NTD was prepared as part of the state assignment of the FRC ICT for the project "Development of a new generation of information systems for monitoring and assessing the risks of developing S-P-T systems for managing industrial regions of the country" and in accordance

with the Action Plan of the Russian Scientific Society for Risk Analysis for the implementation of the Sendai Framework Program for disaster risk reduction for 2015-2030 "Building the resilience of nations and communities to natural disasters" (adopted at the Third World Conference in Sendai, Japan on March 18, 2015).

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

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

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

risk levels. At the third stage, recommendations are developed for risk management at the level of municipalities.

III. Safety review of facilities of the Norilsk industrial agglomeration

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

IV. Safety review of facilities of the Norilsk industrial agglomeration

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

The information system allows solving the following tasks:

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

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

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

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

level).

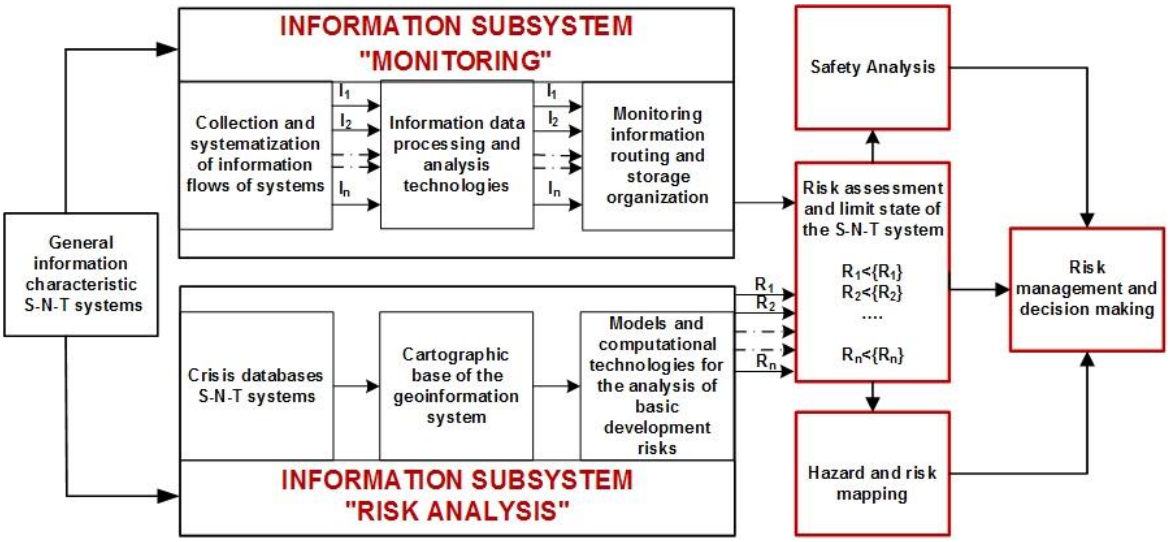

Figure 3: *Block diagram of the information system for territorial risk and security management*

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

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

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

V. Conclusion

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

The technosphere development in the northern regions against the backdrop of infrastructure development, economic growth and an increase in the living standards of the population leads to environmental problems for the natural environment and an increase in the risk of man-made accidents and disasters. The priority task is to ensure the technogenic, environmental and energy security of the strategically important objects, critical facilities, hazardous production facilities, objects of technical regulation and the territories of cold climate regions.

The contradictions between the requirements of industrial development and the development of new territories and the need to ensure natural, technogenic and environmental safety can only

be resolved with an integrated approach to planning and managing development risks based on interdisciplinary research.

Thus, the main tasks that need to be solved in the near future are: organizing a system of territorial management of the risk of catastrophic situations at hazardous industrial facilities based on an integrated interdisciplinary approach; development of means for diagnosing the technical condition, organization of technical and environmental monitoring; development of methods for estimating the residual life of CTS during their operation in cold climate regions..

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