Ecological risk analysis as a key factor in environmental safety system development in the Arctic region of the Russian Federation

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Abstract
Due to specific natural and climatic conditions combined with human intervention, the Arctic is regarded as a highly sensitive region to any environmental pressures. Arctic projects require continuous environmental monitoring. This poses for the government of the Russian Federation (RF) a tremendous task concerning the formation and implementation of sustainable nature management policy within the international framework. The current article examines the basic constraints to the effective ecological safety system implementation in the Arctic region of the RF. The ecological risks and their effects which influence the sustainable development of the region were analyzed. The model of complex environmental safety system was proposed.

1. Introduction
The Arctic region is characterized by rather vulnerable environmental conditions. Specific natural and climatic settings combined with intensive industrial activity have a negative impact on the Arctic ecosystems. This can cause significant environmental damage in a global context. The current climatic changes transfer the geopolitical setting of the Arctic. Decrease in sea ice coverage provides new transportation routes and access to resources, which in its turn can cause extra environmental and social threats. Therefore, the Arctic environmental conditions should be regarded as a complex system of interrelated factors. On the one hand, this region is exposed to the extensive global development; on the other hand, the changes in the Arctic region itself cause the response of the whole community.

The Arctic safety system is a key factor of sustainable development of the region. To address this issue effectively, it is essential to advance the cooperation between countries, transnational companies and research institutes. Arctic Monitoring and Assessment Programme (AMAP) [1], Protection of the Arctic Marine Environment (PAME) [2] and the Institution Building for Northern Russian Indigenous Peoples’ Project (North Development) are some examples of such cooperative work.

The global character of the Arctic environmental safety system proves the urgent need for the analysis of ecological risks, exposure and effects, their relationship with each other, as well as the necessity for the revision of the environmental law.

2. Materials and methods
The current study involves the following stages: identification of the basic constraints to the effective ecological safety system implementation, analysis of the Arctic ecological risks, and elaboration of the complex environmental safety system for the Arctic region of the RF. The study is based on a large
bulk of scientific articles, nominative documents, environmental government programmes and reports presented at international non-governmental conferences.

2.1. Basic constraints to the effective ecological safety system implementation in the Arctic region of the RF

The commercial development of the Arctic is restrained by a number of specific features of the region itself: difficult operating environment and climate, substandard infrastructure and high operating costs [3]. In due course, these regional features would have even greater effect on the hydrocarbon extraction, as well as the Arctic environmental conditions. Therefore, they should be considered while taking any operating and political decisions.

Every country develops natural resources in accordance with internal legal regulations, ecological monitoring and relevant international agreements. Despite the special status of the region and government intervention, the Arctic projects are more highly dependent on the economic viability than environmental concerns. For example, the present legal framework that governs petroleum resource production in many countries stimulates petroleum companies to monitor the compliance with the safety and environmental regulations by themselves, with economic viability being one of the basic motivating factors. It means that it is rather profitable for petroleum companies to invest money in safety and security arrangements as environmental costs may significantly exceed the amount of money spent on risk minimization.

Unlike other regions, the Arctic is characterized by a rather sensitive environment, which in its turn requires the RF and other Arctic states to comply with certain environmental standards, as well as to apply eco-friendly production technologies. Like other countries, Russia does not possess a complex of state-of-the-art eco-friendly production technologies that guarantee environmental preservation of the Arctic region. It highlights the urgent need to facilitate international cooperation in environmental safety system development.

Political risks and political background in general are also considered as a constraint to the effective ecological safety system development [4, 5]. The current political processes interfere with the reinforcement of international cooperation. A ban on the supply of state-of-the-art equipment and technology required for the development of Arctic Shelf to Russia, which is likely to cause significant environmental effects, is a vivid example of such processes. Thus, the absence of the required production technologies and the environmental negligence would definitely lead to negative effects within the global scale.

2.2. Ecological risk analysis in Russian Arctic

Risk analysis is one of the key issues to be addressed in elaborating effective Arctic development policy including environmental safety system.

Environmental risks relating to the Arctic region of the RF can be divided into three groups: natural-ecological, techno-ecological and socio-ecological (table 1).

| Risk type | Description | Effects |
|-----------|-------------|---------|
| Natural-ecological | Methane emission | Methane emissions from underwater wells significantly speed up the process of global warming, which in its turn leads to the release of new amount of methane. Methane emission volume can be compared with that of global ocean [6]. | Sharp increase in atmospheric methane concentration, which leads to unpredictable climatic changes. |
| Contamination by resistant organic matter | The process of global warming and permafrost degradation may lead to the release of toxic substances from chemical and nuclear disposal sites [7, 8]. | Sharp increase in air pollution concentration, population health risk. |
| Increase in ground ice thaw | Thermokarst development, ground distortion, thermal erosion. | Infrastructure deformation, reduction of building |
Techno-ecological

| Depth | Definition | Operation term, high flood risk. |
|-------|------------|----------------------------------|
| Accumulated ecological damage | The effects of anthropogenic activities within the sites of mining, heavy and processing industries, military-industrial complex. | Constant environmental threats in the Arctic region. |
| Constant technogenic burden | - During geophysical survey: hydraulic impact, noise exposure.  
- During drilling: discharge of brine water, toxic liquid and solid wastes into the sea, emergency oil spills, atmospheric emissions, seismic hazard factor increase.  
- During hydrocarbon transportation: emergency or intentional discharge of petroleum products (transportation mode - tanker); excavation and trenching in pipeline construction activities, post trenching and backfilling, rock dumping (marine pipeline engineering). | Permanent adverse impact on the Arctic ecosystems, extinction of living organisms, fresh water contamination, human losses. |

Socio-ecological

| Damages to the traditional lifestyle of aboriginal population | Constraints to the on-time adaptation of aboriginal communities to the ongoing changes. | Threat to traditional aboriginal population lifestyle. |
|----------------------------------------------------------------|----------------------------------|----------------------------------|
| Health impact | Specific climatic conditions. | Polar stress syndrome. |
| Integrated or isolated impact of natural-climatic and techno-ecological risks. | Increase in the frequency of reproductive losses. |

The above-mentioned risks were outlined and classified into three main groups with due regard to the influencing factors, as well as natural and climatic conditions of the region. The global character of climate change in the Arctic region primarily manifested in the decrease in extent and thickness of Arctic sea ice, as well as anthropogenic impact, cause a number of interrelated effects which could influence different spheres of regional development. These effects should be analyzed both separately and in an integrated manner.

3. Results and discussion

The analysis has revealed that the Arctic region is subjected to various large-scale ecological risks which can have both long-term and short-term effects. Besides, combined with other impacts, these effects could significantly increase the threat level and impede necessary response actions. Thus, the Arctic environmental safety system is comprised of a complex of factors which should be considered not only in various arctic projects implementation but also for sustainable development of the Arctic region itself.

As the RF has extensive territorial claims in the Arctic region and rather high population density in comparison with other Arctic countries, the environmental safety system is of great importance. The RF places emphasis on Arctic environment protection and minimization of the adverse effects of oil and gas activity in the region, especially with regard to continuing this work. The diversity and global character of the ecological risks reveal their strong interrelation with economic and social spheres of the Arctic region development, which in its turn proves the urgent need for the development of such an environmental safety system that would consider the specific features of the Arctic region and contribute to its sustainable development within the global scale. This fact is proved by the following initiatives: “Declaration on the protection of the environment and conservation of biological diversity during the exploration and development of mineral resources of the Arctic continental shelf in the Russian Federation” (Rosneft in cooperation with business partners: ExxonMobil, Statoil, Eni);
establishment of the committee for health, safety and environment for exploration works in the Kara sea (Rosneft in cooperation with ExxonMobil); establishment of the Russian Center for Development of the Arctic on Bely island (initiated by authorities of the Yamal-Nenets Autonomous District); Strategic Action Programme for Protection of the Russian Arctic Environment [9] and others. However, despite the above-mentioned initiatives, it is only the beginning of a rather long process. Insufficiency and fragmentation of the research data concerning the effects of ecological risks, as well as analyzed constraints prevent from minimizing adverse impact on the Arctic environment.

In this context, it is required to incorporate environmental issues into all spheres of the Arctic region development programme forming a complex environmental safety system (figure 1). Ecological risk analysis carried out at different levels should be a key factor of such an environmental safety system, which facilitates information exchange at the national and international levels. To increase the efficiency of the proposed system, the following actions should be taken:

- creation of research database relating to potential risks, exposure and effects;
- formulation of environmental standards which would clearly regulate the activities to be performed in the Arctic region;
- active cooperation of the government and companies in the Arctic environment protection;
- facilitation of international cooperation in environmental safety system development including the development of uniform legal regulation criteria for the Arctic environmental protection.

**Figure 1. A complex environmental safety system in Russia’s Arctic zone**
In the context of reinforced international cooperation, it is necessary to consider political instability which may cause the situation to escalate and lead to the tension between economic growth and environmental protection. Therefore, it is of great importance to draw the right lessons from the worldwide experience [10, 11] and find such solutions that would be effective not only in Russian Arctic territory but within the whole Arctic region.

4. Conclusion
Based on the scale of the Arctic environmental problems revealed due to the ecological risk analysis, it is possible to conclude that the contemporary environmental safety policy can hardly guarantee sustainable development of the RF Arctic region. The absence of systemic approach and complex ecological risk analysis impedes the development of strategies to minimize the negative impact on the environment and reduce the dependence of the Arctic projects on their economic viability.

Despite increasing number of environmental protection projects, the scale of the development and production activities that is planned in the Arctic region of the RF also suggests a turn towards ecological issues. To address this issue, the complex environmental safety system which considers the negative effects of the risks not only at the stage of strategy development but also during project implementation has been developed. The risk analysis, being an integral component of the proposed system, is of great importance as it enables to identify the definite hazard sources and predict their potential damage in order to provide the sustainable development the Arctic region within the acceptable risk levels.

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