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SYSTEMATIC APPROACH FOR ENSURING THE RESILIENCE OF ECOLOGICAL-ECONOMIC SYSTEMS OF THE RUSSIAN ARCTIC (PART 1. RESILIENCE MANAGEMENT PRINCIPLES)

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Abstract. *Background.* The study is aimed at design and development of methods and approaches to ensuring, assessment and regulation of the ecological robustness of Arctic regions in order to resilience and management efficiency enhancement of the ecological-economic systems performance of the Arctic. To date, this problem is of particular importance under conditions of intensive industrial development of the resource base of Arctic territories, which reduces the stability of Arctic ecosystems and negatively affects the health and life quality of the population. *Materials and methods.* The research work consists of two parts. In the first part the proposed principles of resilience management and criteria for ensuring the environmental safety of the Arctic region, based on the postulates of the theory of sustainable development and the concept of acceptable risk, are considered. In the second part the environmental safety metrics and systematic approach to assessing the level of ecological robustness of the Arctic ecosystems, based on expert methods for resilience analysis of organizational and technical systems, are discussed. *Results and conclusions.* The fundamental principles and a set of criteria for ensuring environmental safety for various types of economical activity in the Arctic region have been developed. A general systematic approach to the ecological robustness analysis of the Arctic region according to selected principles and criteria, based on the joint application of a hierarchical multi-level decomposition scheme "principle – criterion – indicator – index" and models for quantitative and qualitative assessment of the complex system resilience, is proposed. The use of developments provides the formation and advance of the legal regulatory framework (national public standard) for governing various types of economical activity in the Arctic region, as well as improving the quality of managerial decisions made by state, regional and enterprise authorities in the field of environmental safety and environmentally friendly, responsible nature management.

Keywords: ecological-economic system, resilience management, safety principles and criteria, estimation procedure, environmental quality control, sustainable development, acceptable risk concept, Arctic region

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МЕТОДИЧЕСКИЙ ПОДХОД К ОБЕСПЕЧЕНИЮ ЖИЗНЕСПОСОБНОСТИ ЭКОЛОГО-ЭКОНОМИЧЕСКИХ СИСТЕМ РОССИЙСКОЙ АРКТИКИ (ЧАСТЬ 1. ПРИНЦИПЫ УПРАВЛЕНИЯ УСТОЙЧИВОСТЬЮ)

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Аннотация. *Актуальность и цели.* Работа направлена на создание и развитие методов и подходов обеспечения, оценки и регулирования экологической устойчивости арктических регионов для повышения жизнеспособности и эффективности управления функционированием эколого-экономических систем Арктики. Особую значимость эта задача приобретает сегодня в условиях интенсивного промышленного освоения ресурсной базы арктических территорий, что снижает устойчивость арктических экосистем и негативно влияет на здоровье и качество жизни населения. *Материалы и методы.* Работа состоит из двух частей. В первой части рассматриваются предложенные принципы управления устойчивостью и критерии обеспечения экологической безопасности Арктики, основанные на постулатах теории устойчивого развития и концепции приемлемого риска. Во второй части обсуждаются система показателей безопасности и методический подход к оценке уровня экологической устойчивости арктических экосистем, базирующийся на экспертных методах анализа жизнеспособности организационных и технических систем. *Результаты и выводы.* Разработаны основополагающие принципы и система критериев обеспечения экологической безопасности для различных видов хозяйственной деятельности в Арктике. Предложен общий методический подход к анализу экологической устойчивости Арктики по выбранным принципам и критериям, основанный на совместном применении иерархической многоуровневой схемы декомпозиции «принцип – критерий – индикатор – показатель» и моделей количественной и качественной оценки жизнеспособности сложных систем. Использование разработок обеспечивает формирование и развитие нормативно-правовой базы (национального общественного стандарта) для регулирования различных видов хозяйственной деятельности на территории арктических регионов, а также повышение качества принимаемых управленческих решений органами государственного, регионального и корпоративного управления в области экологической безопасности и экологически ответственного природопользования.

Ключевые слова: эколого-экономическая система, управление жизнеспособностью, принципы и критерии экологической безопасности, методика оценки, контроль качества окружающей среды, устойчивое развитие, концепция приемлемого риска, Арктика

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Introduction

The problem of ensuring environmental safety and ecological resilience (robustness) does not lose its relevance at the present stage of human development. First of all, this is due to the high social significance of friendly interaction issues between individuals and the environment and balanced nature management in terms of risks for the viability of society. An important place in studying this objective is occupied by the information and analytical support problems of environmental protection activities at different levels of situational management of ecological safety and resilience. Such support implies the timely allocation, on-line processing and analysis of the required information for making reasoned managerial decisions in the field of environmental protection. Decision support tools implemented in the form of intelligent information systems and based on mathematical and computer modeling methods are increasingly being used to solve the above problems. When evaluating and analyzing the consequences (failures) of decisions made, this allows, on the one hand, taking into account the multicriteria of choosing alternative security management programs for different scenarios of the situation development, and, on the other hand, to find a compromise between the reachability and sufficiency of target indicators optimized at different decision-making levels.

Over time, the information structure of decision-making in the field of environmental protection and sustainable development maintaining is continuously becoming more complex. The regulatory base is changing and the legal framework is improving. In addition, the new forms and mechanisms of organizational management of the ecological security and resilience are emerging. The tightening of legislation and requirements for the greening of industrial production in order to reduce the ecological damage caused to the environment does not always lead to the desired result, and in some cases is even ineffectively. In real practice, this forces most enterprises to engage in so-called "greenwashing" [1], that is, creating the appearance of greening production and the transition to green technologies for the consumer, supervisory and regulatory authorities, and not the introduction of the best available technologies [2], high-end ecological security and resilience standards.

De facto, not a single economic activity that ensures the progressive sustainable development of the country can be carried out without ecological security and resilience. This is especially true for the Russian Arctic, which is characterized by the extreme vulnerability of its eco- and social systems. Intensive industrial development of the resource base of the Russian Arctic reduces the stability of the Arctic ecosystems and negatively affects the health and quality of life of the population living in these territories.

One of the ways to ensure a balance of economic and ecological interests, as well as "soft" control (motivation and stimulation) of the business entities behavior is the voluntary adoption of an agreement between society and enterprises located in the Arctic regions of Russia, specifying the rules for their activities, taking into account the requirement to ensure environmental safety and ecological robustness. The draft of such an agreement is a prototype of a certain set of rules for the economic entities behavior operating in a certain territory and represents a National Public Standard for ensuring environmental safety and ecological resilience [3]. The voluntary nature of such a form of behavior and interaction lies in the fact that although the provisions of this standard are not mandatory, however, the economic entities that adopt it guarantee the implementation of these provisions, realizing the importance of maintaining the integrity of the environment, compliance with safety standards and responsibility for the quality of life in front of future generations.

The objective of this study is to improve the methods and approaches to ensuring, assessing and regulating the ecological security and resilience of the Arctic regions in order to enhance the robustness, protectability and management efficiency of the ecological-economic system performance of the Russian Arctic.

The study consists of two main parts. In the first part we propose principles of resilience management and criteria for ensuring the environmental safety of the Arctic region, based on the postulates of the theory of sustainable development and the concept of acceptable risk, are considered. This part traditionally includes three sections. In the first section, the problem statement is given. The related work and methodological foundations of the study are discussed in the second section. The third section provides a general description of the proposed principles for ensuring the environmental safety of the Russian Arctic, as well as the characteristics of the developed set of criteria for assessing ecological security and resilience for various types of economic activity in this region. In conclusion, the results and resume based on the research materials are expressed.

Problem statement

The Russian Arctic is a critically important and strategically significant macro-region for the economy and national security of our country, which has its own specificity and is characterized by a sensitive environment and harsh climate. In turn, this significantly affects the quality of life of the population, the development of infrastructure and industrial production, especially in remote northern communities and regions. To maintain the sustainable development of the Russian Arctic and reduce the vulnerability of the objects localized on its territories in the conditions of intensive development of the Arctic natural resources, it is quite necessary to holistically ensure the resilience (robustness) and security of regional critical infrastructures (ecology, energy, transport, etc.) [4, 5] by means of engineering and implementation of systems capable to withstand the emergency and crisis situations of a natural, man-made and socio-economic nature. At present, such a class of systems include decision support systems that allow risk managers and security experts to obtain a realistic assessment of the resilience level of regional critical infrastructures in order to develop effective action plans in critical situations, as well as minimize economic, reputational and other risks associated with the adoption of managerial decisions made in the field of ensuring various types of security, including ecological, which is the subject of inquiry of this study. The resilience (robustness) is de-

defined here as the ability of an ecological-economic system to self-recovery of its normal state and system functions after the destructive impact of multiple threats on the elements of the system.

Taking into account the interdependence of critical infrastructures, the decisions made at different levels of management should be coordinated and beared on generally accepted standards and requirements for ensuring regional security [6], and an integral assessment of the ecological-economic system resilience should be formed based on the intersectoral interaction of the control elements of these infrastructures. This is necessary to develop a systematic understanding of what ecological robustness (security plus resilience) is and how to manage it in certain conditions. In the general case, in the field of environmental protection, management is understood as the control and quantitative change of some parameters of an object based on the analysis of its state in order to reduce the negative impact on the environment. At the same time, the current trend of both domestic and foreign studies is the simultaneous accounting of both quantitative and qualitative information in decision support systems for managing ecological security. Practice shows that in this area today most of the control problems are solved at a qualitative level, that is, through organizational management [7]. A joint analysis of the qualitative attributes and quantitative characteristics of critical infrastructures within the risk assessment of ecological security/resilience and generation of guidelines to decision makers at the verbal level requires the application of the state-of-the-art modeling methods, expert analysis and fuzzy logic procedures. However, there are practically no methodological approaches to obtaining such a comprehensive assessment based on interpretable analytical information on the state (level) of ecosystem resilience and expert knowledge. This is reflected in the system effectiveness used for ensuring ecological security and the quality of making managerial decisions in terms of the relevance of measures implemented in practice to the real environmental situation. According to expert judgements, preventive control and audit of ecological security threats is more economically beneficial than mitigation or elimination of the threat implementation consequences in the face of uncertainty on the impact of these threats on facilities of regional critical infrastructures. At the same time, the operability of generating guidelines to decision makers in an automated or automatic mode and their correct interpretation by control actors play a significant role in maintaining ecological security and resilience, both in terms of the completeness of information (situational awareness) on the state of ecosystems and influencing factors, and the consistency (concordance) of decisions made at different levels of management.

Thus, the development of new models and methods for formal analysis and assessment of the critical infrastructures resilience of ecological-economic systems and their implementation in decision support systems to justify measures to ensure the ecological security of the region is an urgent and challenging research problem. To solve this problem, a holistic methodology for the synthesis of risk management programs and preventive analysis of ecological security is needed, which supports the possibility of flexible adaptation of the organizational management system to the dynamics in the socio-economic and legislative sphere while maintaining a balance of interests of stakeholders represented by the state (regulatory authorities), business entities and civil society. The methodology should be applicable to all types of critical infrastructures and take into account the sectoral (industry) specificity of critical facilities of the regional economy, their risk level and probable scenarios of environmental impact, based on uniform standards for ensuring ecological security. To form a general picture of the ecological situation in the region with a certain set of critical infrastructures involved in the review, the methodology tools must operate with a unified metric based on the levels of maturity of management processes and obtained by aggregating qualitative and quantitative assessments of resilience indicators into one measurable value on a selected scale characterizing the achieved level of ecological security under given conditions.

Conceptual framework and Background

The basic principles of the National Public Standard “Ecological security of the Arctic” [3] are essentially the rules for ensuring ecological security and environmentally responsible resilient nature management when conducting all types of economical activity in the Arctic regions. The foundations for the development of these rules are the concept of sustainable development [8] and the concept of acceptable risk [9]. The paradigm of economic growth [10], stimulated by ever-increasing consumption led humanity to a global environmental crisis, clearly marking the limits beyond which humanity cannot go. These limits are due to physical characteristics of the planet Earth, finiteness of resources traditionally used by mankind to meet the ever-increasing needs. The consumer society artificially creating new needs inevitably will lead humanity to disaster [8, 11, 12]. The paradigms of sustainable development and acceptable risk may eventually become an alternative to the paradigm of economic growth.

The concept of sustainable development arose as an attempt to avoid a global environmental disaster, to develop a new paradigm of the existence of mankind. From the philosophical point of view, the new paradigm is based on the concept of conscious activity [13, 14] and systemic contextual thinking [15]. Systemic thinking does not focus on the “bricks” basic, it is interested in the basic principles of organization. Systemic thinking is contextual, which is the opposite of analytical thinking. The meaning of the term “systemic thinking” is related to the concept of “Deep ecology” [16]. Deep ecology does not separate neither people nor anything else from the natural environment. It sees the world not as a collection of isolated objects, but as a network of phenomena which are fundamentally interrelated and interdependent. The deep ecology recognizes the original value of all living beings and sees people only as a special tiny web in the web of life.

Native and small peoples of the Arctic still demonstrate an approach to life developed by centuries of existence in severe Arctic conditions described by Arne Ness in the concept of deep ecology. In modern conditions, it is necessary to return to the formation of life patterns on the basis of this principle, but using all the experience of civilization. The Arctic, due to the special vulnerability of its natural and social systems, the natural instability of the economic system, should be the first region of the world for introduction of life patterns developed on the basis of systemic contextual thinking. In this regard, the generally accepted principles of sustainable development should be adjusted to the Arctic conditions.

According to study [17] the main principles of sustainable development and management of critical infrastructure resilience in the Arctic region are the following:

1) The principle of "destruction of barriers" (the equivalence of environmental, economic and social approaches is recognized when choosing a development strategy). Implementation of this principle in the organization plan of measures to ensure ecological security and resilience should be reflected in the management strategy and taken into account the following aspects:

- When planning any new economic activity, the principle of preservation of existing ecosystems must be respected;

- Any economic activity should bring an improvement of living conditions of the local population;
- Environmental impact assessment and assessment of the impact on local communities should be carried out not only at the project planning stage, but periodically (one time in 2 years) by independent researchers and experts with the development of plans for improvement the ecological and social situation.

2) The principle of "pragmatism", which determines that sustainable development at the regional level as a social and political process in which the detection of effective mechanisms for control and ensuring ecological security and resilience is an ongoing process. Implementation of this principle in the organization plan of measures to ensure ecological security and resilience should be reflected in the management strategy also and taken into account the following aspects::

- Preference of technological solutions with low energy and resource costs;
- Materials and energy must be taken from renewable or recycled sources;
- When planning any new economic activity, the principle of "cost of renewable resources" must be respected. State-of-the-art nature management is based on misconceptions on inexhaustibility and low cost of renewable resources (natural waters, atmospheric air, soil, bioresources, etc.) or lack thereof. Some features of the natural conditions of the Arctic are the attribution of these natural resources to the category of "exhaustible" and providing them for use on loan, including for waste disposal;

- Wastes from production and consumption should be minimal, and recycling of secondary resources should be as complete as possible;

- Inadmissibility of secondary pollution of the environment when placing waste;

- Inadmissibility of using the principles of “dilution” to reduce the technogenic burden on the environment;

- The principle of compensation for inflicted and incurred damage to the environment must be respected also;

- The stable system tends to restrain maximally the process of excrescence, to minimize its impact on the environment, to restrict energy and resource consumption;

- Integration of progressive environmental principles, participation of influential public and democratic control are implied in the process of preparation and making decisions on the development or manufacturing of new productions;

- The complex problem-solving requires the cooperation of various parties: representatives of business, local authorities, representatives of national governments, non-governmental organizations, universities, research centers, etc.

The principle of morality (the question of how to "build in" moral principles in management and decision-making processes is an important element of the development concept). The principle of morality in the Arctic should be interpreted as "nothing can be more important than another", no one can benefit at the expense of others. Therefore, any projects in the Russian Arctic should be implemented primarily to improve the living conditions and for the development of infrastructure, local communities, native peoples. Thereto, it is necessary to find mutually beneficial conditions for the implementation of economic projects.

The main development goal is the improvement of creative potential of human, search for ways to organize the harmonious existence of local societies including harmonious in relation to nature, organization of the process of searching for new knowledge and its application for comprehensive improvement and harmonization of life in the Arctic regions. Implementation of the principle of morality in the organization plan of measures to ensure environmental safety should be reflected in the mechanisms for holding public hearings and discussions of any new technological and social projects.

In addition to the concept of sustainable development, for establishing the general resilience management principles of the Arctic ecological-economic systems, there were used materials of the Marine Stewardship Council Fisheries International Standards for fishery and processing of fish products, international and domestic standards for forest management, the Maritime Doctrine of the Russian Federation [18], the Environmental Doctrine of the Russian Federation [19], the National Security Strategy of the Russian Federation (approved by the President of the Russian Federation Decree No. 400, July 02, 2021) [20], the Foundations of the public policy of Russian Federation in the Arctic until 2035 [21], the Strategy of the Arctic region development and national security ensuring of Russian Federation until 2035 [22].

Since the National Public Standard [3] is the source document for the formation of environmental requirements for organizations and enterprises engaged in economical activity in the Arctic regions of Russia, the objectives of the standard include the provision in the internal documents of the enterprise dedicated to ensuring ecological security and resilience:

- general requirements for technologies and production that take into account the natural features of the Arctic regions and that ensure the maintaining the robustness of industrial-natural complexes;
- formulation of economic and non-economic measures to promote the introduction of state-of-the-art "Arctic" eco-technologies;
- requirements and measures of enterprise responsibility for carrying out measures for elimination and mitigation of accumulated environmental damage;
- the content of the measures for stimulating the introduction of ecological culture and new models of the environment friendly behavior;
- the content of the measures for stimulating the introduction of corporate ecological responsibility mechanisms.

The central principle of the sustainable development concept is achievement of the balance of economic efficiency, social justice, natural environment preservation for life demands and satisfaction of the needs of present and future generations. However, this principle cannot be used to formalize the global goal in studying and modeling of Arctic socio-economic systems and regional critical infrastructures, because it is exclusively valid only for world ecological-economic system that is considerably closed.

Additionally, the sustainable development concept based on the principle of "do no harm" could not be implemented in current circumstances, because of security risks and threats to development remain elusive. The absolute safety is unachievable and minimally acceptable one is inefficient. Therefore, it seems expedient and reasonable to use an acceptable risk principle well-known in security theory of complex systems. This principle operates with risks which are reachable and justified (tolerated) in terms of socio-economic and ecological issues of security and resilience ensuring. The acceptable risks are the enough risks that the society is willing to put up with in order to obtain certain positive results of its activities. The acceptable risk rate is defined by the level of knowledge achieved, the socio-economic capabilities of the state, public opinion, as well as regional peculiarities. Justification of the acceptable risk of regional ecological-economic systems is an independent scientific research problem. Unacceptable risk is the maximum risk when it is necessary to implement special measures to mitigate or eliminate it. For example, the maximum acceptable risk for ecosystems is one in which only 5 % of biogeocenosis species may suffer.

The acceptable risk concept is based on the following fundamental principles [23–25]:

1. There is always a level of risk that can be considered as acceptable in the given circumstances.
2. The level of risks can be reduced to an acceptable value by spending a certain amount of assets on anti-crisis measures implementation.

3. The level of acceptable risk is a subjective estimation characteristic.
4. The level of acceptable risk can be measured.
5. The level of acceptable risk is never zero.
6. There is always a level of risk that will remain uncompensated after mitigation measures have been implemented.
7. The acceptable risks are 2–3 orders of magnitude stricter than the actual ones, i.e. an introduction of such a class of risks is directly aimed at personal security ensuring.

The methodology of acceptable risk management is focused on following practical policies [26, 27]:

1. The principle of forming the novel security goal-setting and switching the focus from the absolute security policy, which is oriented only on enhancing technical systems for security reasons, to a ecological-economic system resilience policy, which is focused on improving the public health, personal and societal security and the quality of the environment as a whole.
2. The principle of joint qualitative and quantitative analysis of the natural and man-caused hazard factors based on the human health quality indicators and ecological security indices, as well as the risk management and resilience assessment methodologies.
3. The principle of determining an acceptable balance between threats and benefits from a particular economical activities which is based on an estimation and impact accounting of the social preferences, economic opportunities and environmental constraints of the latter, i.e. the principle of acceptable risk evaluation.
4. The principle of reorientation of the security control systems and switching the focus from classical risk management and auditing concentrated mainly on threat monitoring, adverse event prediction and prevention to resilience management oriented both on analysis and control of vulnerabilities and hazards, and absorption, adoption, mitigation and elimination of negative factors impact on ecological-economic systems performance, personal security and environmental conditions.

The proposed strategic approach is based on the attitude towards the Arctic regions not only as the most important source of raw materials for the further country's development, but also as a unique mega-region, whose population generates a significant share of the gross national product in extreme conditions, outpacing most regions of the country in its per capita production rates, ensuring Russia's strategic presence in the North and the Arctic. A new approach to the development of the Russian Arctic involves overcoming the tendencies of using the labor of workers with the psychology of “casual workers” and shifting the focus to “inhabiting” the North, creating comfortable conditions for the permanent life of people, active safe development and systemic reproduction of human potential.

The main problem of implementation of the sustainable development provisions into the practice is declarative nature of principles and a variety of options of perusal. Since the existence of standard for ensuring ecological security and resilience implies the subsequent practice of its application to real activity of enterprises in the Arctic, then it is more reasonable to apply the hierarchical multi-level decomposition scheme “Principle – Criterion – Indicator – Index” adopted in the world practice. At the same time, the principles are universal for any type of economic activity. At the level of criteria, sectoral differences can be indicated which are determined by the specificities of the regional industry. Indicators and indices are based on criteria and can be represented both in quantitative and qualitative form. Indicators determine the reading of the criterion, its consideration from various points of view and applying it in practice. Indices, on the one hand, indicate in which documents the indicator should be reflected, on the other hand, they implement the principle of binary code – “yes/no”. In addition, the index always gives an unambiguous answer whether the information on the indicator is contained in the document or not.

To compare and matching the qualitative and quantitative values of particular indices in the calculation procedures of the integral indicator of ecological security and resilience, the theory of fuzzy sets, relations and measures, the methods for verbal analysis of decisions and coordination methods based on the theory of multi-level hierarchical systems, can be used [28]. The study [28] results that in order to maintain systemic concordance of the main elements of ecological security the resilience metrics must satisfy the SMART principle:

- Simple (indices should be simple and understandable);
- Measurable (indices must be measurable – quantitatively or qualitatively);
- Agreed-upon (indices must be coordinated, consistent and harmonized);
- Realistic (indices must be up-to-date and meet the constraints on available resources);
- Time-bound (indices must be limited in time).

Besides, all indices should be relevant and ranked according to the measure of significance for specific conditions.

The absence of one or more indicators/indices, or non-compliance with any of the criteria may be due to the fact that the enterprise does not conduct the activity described by these criteria. This fact is not an obstacle to joining and using the rules and mechanisms of the standard. If the business model of the enterprise economical activity contains inconsistencies with the principles and criteria of the standard, then to join and use the standard the enterprise should independently make alterations in their production management strategy and documentation and consequently in their economical activity to eliminate these inconsistencies. List of organizations that adopted the rules of standard should be published in the open access materials and regular updated. In addition, the list can be drawn up according to the regional principle for its transfer to the regional authorities of the Russian Arctic. The presence of such list will enable at the entity level of business entity to make more deliberated managerial decisions when bidding on public procurement and selecting flexible ways of environment friendly and responsible corporate policy pursuing.

Principles and the Set of Criteria

The Arctic ecological security and resilience management principles (P) and criteria (C) are given below. The backbone materials used as a background for the set of criteria forming are adopted from the standard [3].

The first principle (P1) considers the compliance with Russian legislation and international legal enactments signed by the Russian Federation and contains 6 criteria which are decomposed in 14 indicators including 47 indexes.

C1. In the course of any economical activity in the Russian Arctic, the certified business entities shall respect all national and regional legislations as well as administrative standards.

C2. The certified business entities shall conduct all types of charges, deductions, taxes and other payments provided by the current legislation.

C3. A certified business entities must comply with the terms and conditions stipulated by international agreements signed and adopted by the Russian Federation such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Biological Diversity, etc.

C4. The certified business entities must comply with regional regulations; the contradictions between local laws and federal regulations shall be considered by the certification authority in each specific case in terms of achieving certification objectives, and with the participation of all interested or affected parties.

C5. The certified business entities must ensure security and resilience of the Arctic territories used in its economical activities from any prohibited and illegal actions.

C6. Managers and owners of certified business entities must demonstrate commitment to the rules of the national ecological security standards and requirements.

The second principle (P2) lies in the implementation of rights and obligations of owners and users upon natural objects in the Russian Arctic. This principle contains 2 criteria which are decomposed in 5 indicators including 20 indexes.

The long-term rights to own and use land, forest, water, biological resources, as well as the right to explore, develop, extract and process minerals must be clearly defined, documented and formalized in accordance with the law.

C1. The certified business entities shall clearly define the long-term rights to use natural resources at a certain territory (e.g., property right to land, customary law or leasehold, rights to use inland water bodies, quotas for biological resources, etc.).

C2. The certified business entities shall not interfere in the control of their economical activities conducted by the local community that has the legal or customary rights to own or use the resources and the right to exercise control over activities to protect their rights and resources, as well as other organizations to which this right is legally transferred.

The third principle (P3) consists in the consideration of right and interest of the native people and contains 4 criteria which are decomposed in 17 indicators including 85 indexes.

The legal and traditional rights of native people to own, use and manage their lands, territories and resources must be recognized and respected.

C1. The certified business entities shall not raise difficulties for authorized organizations of local people to monitor the economical activities on their lands and territories.

C2. The economical activity of the certificated business entities shall not directly or indirectly threaten the existence or deplete resources, and threaten or restrict the rights of native people of possession the resources.

C3. The certified business entities should accept and ensure the safety of places of the unique cultural, environmental, economic and religious value precious to native people living at the territory belonging to the economical activity of the business entity.

C4. Within the provided regulations, the certified business entities shall compensate the damage to native people for exploitation of their territories used for traditional industry and farming program. Methods for compensation sum calculation shall be officially agreed with native people in their free and informed participation prior to economical activity.

The fourth principle (P4) expects the reasonable nature management in the Russian Arctic and contains 5 criteria which are decomposed in 36 indicators including 161 indexes.

Organization economical activity should facilitate the effective complex and wasteless (if possible) use of nature resources in order to increase the economic effectiveness and get a wide range of environmental and social benefits.

C1. The economical activity of the certified business entities shall be directed to maintain the economic effectiveness, and yet, shall be founded with the account to possible environmental and social consequences. It has to provide investments to support environmental security.

C2. Economical activities conducted by the certified business entities shall provide decrease in consumption of energy and natural resources (air, natural waters, soils, and other landscape elements), waste reduction; and they should not damage other natural resources.

C3. Economical activities of the certified business entities shall be aimed at strengthening and diversifying the local economy in order to avoid its dependence on one type of product. As the organization of practical nature protection measures depends on the conditions of local economy.

C4. A single economical activity maintained by the certified business entities shall consider, support and encourage (if possible) the increase of other natural resources.

C5. The quantity of renewable resources exploited by the certified business entities shall not exceed the amount guaranteeing the resource restoration.

The fifth principle (P5) assumes the minimization of negative impact on the Arctic environment and consists of 8 criteria which are decomposed in 138 indicators including 616 indexes.

Economical activity maintained by the certified business entities shall guarantee preservation of biological diversity and related values, water resources, soils, and unique and fragile ecosystems and landscapes; by this means environmental functions and ecosystem integrity of Arctic will be preserved.

C1. The certified business entities shall conduct an environmental impact assessment taking into account the volume and intensity of their activities, as well as the uniqueness of resources involved in economical activities. Such assessment shall be fixed into the production management system, and it shall consider the situation at the territorial level, as well as the impact of machines and other equipment at the local level. Environmental impact assessment shall be conducted prior to the start of any economical activities.

C2. The certified business entities shall take into account and use in their activity existing rules for the protection of rare and endangered species and their habitats (e.g., breeding and feeding grounds). Protected areas and areas with restrictions on use shall be created depending on the scale and intensity of the activity, as well as the uniqueness of the resources involved in the sphere of business activity. Hunting, fishing, trapping and gathering are to be under control.

C3. Ecological functions and values of the exploited resource shall be maintained in its original form, improved or restored. This includes the following components:

- participation in the financing of programs for the study, conservation and restoration of the natural-industrial systems of Arctic regions;
- measures for recultivation or restoration of ecosystems;
- measures to preserve natural diversity at the genetic, species and ecosystem levels;
- measures to accounting natural cycles that affect the productivity of resources involved in the sphere of economical activity;
- branch specificity of measures for recultivation or restoration of ecosystems.

C4. The certified business entities shall take into account the presence of representative (reference) sections of ecosystems on the territory of its economical activity that must be allocated and protected in their natural state and mapped with regard to scale and intensity of economical activities, as well as uniqueness of the resources involved in the sphere of economical activity.

C5. The certified business entities shall develop and implement written guidelines for: monitoring and minimizing the impact on the environment during the extraction of resources, logging, road construction and other mechanical disturbances; protection of water and biological resources.

C6. Management system in the certified business entities shall promote the development and implementation of environmentally friendly non-chemical methods for ensuring the ecological security of production (e.g.: in forestry – the refusal to use pesticides, in marine technologies to prevent the consequences of oil spills – refusal to use dispersants, etc.). In case of the use of chemicals, appropriate equipment shall be used and personnel must undergo appropriate training to minimize human health and environment risks.

C7. In the certifiable business entities, chemicals, containers, liquid and solid inorganic wastes, including POL, shall be removed from a territory of carrying out of economical activities to specially equipped places in an environmentally acceptable way.

C8. Use of invasive species the certified business entities shall be thoroughly controlled and actively monitored to avoid adverse environmental consequences. Use of genetically modified organisms is prohibited.

The sixth principle (P6) is a principle of the planned development of Arctic territories. This principle contains 7 criteria which are decomposed in 30 indicators including 97 indexes.

In its economical activity, the certified business entities shall be guided by long-term development plans, which shall be drawn up in writing, taking into account the development strategy of the Arctic regions, as well as taking into account the scale and intensity of works carried out. These plans shall be performed and clarified in a timely manner. It shall have clearly determined the long-term objectives and goals of carrying out economical activities, as well as means of their achievement.

C1. When planning the productions development in the Russian Arctic, the certified business entities shall be guided by the eco-efficiency of developing productions. Eco-efficiency shall be achieved through the provision of competitively priced goods and services that meet the needs of consumers and improve the quality of life, with a constant reduction of environmental impact and reduction in energy and material consumption throughout the whole life cycle up to the level corresponding to the carrying capacity of Earth.

C2. When conducting work in the Russian Arctic, the enterprises shall have a continuously updated plan of action to use all opportunities to reduce the company's environmental impact. There is a number of practical tools and approaches that are developed and being developed with a purpose to help the enterprises to improve the environmental performance of its work.

C3. When conducting work in the Russian Arctic, the enterprises shall have a continuously updated plan for management of waste as of technogenic resources.

C4. The development plan, i.e. the document of internal long-term planning of economical activities, and supporting documents shall contain:

- 1) the management objectives and problems;
- 2) a description of the resources to be used, environmental constraints, pattern of the environmental management, land use and land ownership, socio-economic conditions, as well as the pattern of use of adjacent territories;
- 3) a description of the applying management system for the utilized natural resources, based on environmental researches and information obtained as a result of the inventory of resources;
- 4) the rationale for the level of the annual quota of resources used and selection of types of biological resources to be harvested;
- 5) the conditions for monitoring the dynamics of changes in the state of the resource (increment or depletion);
- 6) the ecological security measures based on the results of environmental impact assessment;
- 7) a plan for identification and protection of rare and endangered species;
- 8) the maps describing the location of the used resources, including the boundaries of specially protected areas, planned economic activities;
- 9) the description and rationale for the technologies used and methods of development, extraction, preparation, processing and usage of resources and appropriate technics and equipment.

C5. The development plan of the business entities shall be regularly revised, based on the monitoring results or obtained new scientific and technical data, considering change of environmental and socio-economic conditions.

C6. The certified business entities must have employee advanced training and new employee training.

C7. The certified business entities must have a system of public informing on their economical activity plans and results of their implementation, including summary of the ecological security ensuring countermeasures and consequences.

The seventh principle (P7) claims the need of transparent monitoring and environment impact assessment. This principle contains 7 criteria which are decomposed in 18 indicators including 77 indexes.

The certified business entities shall perform ecological security threat prevention by monitoring of the used resource and environment conditions, production process, supply chain, economical activity and its social and ecological consequences, according to the scale and intensity of economic indices.

C1. Frequency and nature of monitoring in the certified business entities shall depend on the volume and intensity of economical activity, as well as on relative complexity and vulnerability of the environment. The monitoring procedure shall be reasonable and reproducible in time to get comparable results and evaluate the changes.

C2. Economic measures shall provide scientific researches and data collection required for monitoring in any certified business entity, in accordance with the scale and intensity of production.

C3. The certified business entities shall provide certifying and supervisory authorities with documents that allow tracking the movement of its products from the point of origin – a process known as the supply chain.

C4. The certified business entities shall use the monitoring results when implementing the economic measures plan, and in case of its revision.

C5. The certified business entities shall make publicly available the monitoring results summary, respecting the data confidentiality.

C6. The business entities shall understand the need for autonomous participation or in cooperation with other regional organizations, enterprises and administration structures to design a complex risk management system of environmental monitoring of defined areas of water and coastal territories, allowing to prevent emergency situations related to spills of oil and oil products, as well as promoting elimination of emergency situations at early stages of development.

C7. The business entities shall understand the need for engineering and development of the Arctic geophysical monitoring system, independently or in cooperation with other administrative organizations and structures in the region, to minimize the impact of extreme geophysical processes (natural and man-made) on human environment, including communication and navigation systems, transport and energy infrastructure, as well as ensuring functioning of the Northern Sea Route and security of transit and transpolar air routes in the Russian Arctic.

Since environment pollution in the Russian Arctic is caused not only by enterprises that perform their economical activity in the Arctic regions, but a considerable part is formed by a number of Arctic environment components (sea ice, bottom sediments, mosses and lichens, some animals) that accumulate pollution for many years, there is a need to perform monitoring by independent environmental organizations. In such a case, organizations ready to join the National Public Standard “Ecological security of the Arctic”, shall provide assistance in the following issues:

- development of the of state environmental monitoring system in the Russian Arctic, i.e. expansion of the monitoring sites network to cover remote territories, system monitoring and evaluation of atmospheric air toxic substance concentration change dynamics, integration with the global monitoring network;

- enhancement of the system of state environmental monitoring in the Russian Arctic based on use of objective and measurable environment situation evaluation indicators, design of environment pollution monitoring and control system, that uses modern monitoring tools of terrestrial, air and space deployment, integrated with existing and creating international environment monitoring systems, and providing detection and forecast of dangerous and extreme natural phenomena in the Arctic regions of Russia, including negative climate changes, as well as detection and prediction of natural and man-made disasters in proper time;

- development of a unified national system of monitoring and pollution of the environment of the Russian Arctic synchronized with analogous international systems;

- introduction of new and improvement of existing methods for atmospheric air quality study, i.e. widening the list of pollutants to be controlled with monitoring stations;

- implementation of practice of the environment pollution complex study, i.e. simultaneous monitoring of atmospheric air background pollution and soil cover or snow pollution monitoring.

The eighth principle (P8) declares the need of creation and maintaining of special nature conservation areas. This principle contains 4 criteria which are decomposed in 13 indicators including 53 indexes.

Performing economical activity in the areas of high nature preserving value shall result to keeping or increasing of characteristics determining the value of these areas. Adoption of resolution related to areas of high nature preserving value shall be planned with a special precaution, carefully considering any possible negative consequences.

C1. Studies detecting territory feature availabilities of high nature preserving value shall be performed in accordance with the scale and intensity of economical activity, taking into account the perspective development plans of the business entity being certified.

C2. A special attention shall be focused on ecological-economic values of used areas and determination of ways to safe and preserve them, in the framework of consultative part of certification.

C3. The certified business entities shall have a safety management plan for natural preserving territories within the boundaries of its economical activity. The safety management plan shall include and apply such environment protection activity methods that will contribute to keeping or raising the characteristics of the areas of high nature preserving value. These measures shall be planned with great caution, carefully considering potential negative consequences. All of these measures shall be purposely included in a brief summary of the management plan available for the community.

C4. Efficiency of the measures taken by the business entity being certified to maintain and enhance the characteristics of areas of high nature preserving value shall be evaluated based on annual monitoring.

Conclusion

At present, the justification of measures and the generations of guidelines for ensuring ecological security and resilience is an urgent scientific problem affecting all areas of national economical activity. The fundamentals of state-of-the-art ecological security management systems are regulatory documents and standards that regulate the behavior of business entities, supervisory authorities and the population in a certain area. The practice shows that the results of interaction between these actors largely determine the managerial decisions made that affect both the state of the environment and the development of industrial production. At the same time, the problem of ensuring ecological security and engineering an appropriate management system, due to its multi-aspect nature, is difficult to formalize and has an insufficiently well-defined structure. In the sequel, this affects both the risk assessment methods of the ecological-economic system performance and the automation facilities of these risk management, and can lead to adverse consequences for ecosystems due to the adoption of erroneous or unreasonable managerial decisions, which, in turn, will require considerable costs for elimination and mitigation of these consequences. Thereby, it is quite necessary to conduct scientific research aimed at developing methodological and algorithmic support tools for ecological security and resilience management in order to preparation and making effective managerial decisions in this control system.

In this vein, the present study was carried out. Consequently, the following findings were obtained. The fundamental principles and a set of criteria for managing and ensuring ecological security and resilience for various types of economical activity in the regions of the Russian Arctic have been developed. The proposed principles and criteria are based on the postulates of the theory of sustainable development and the concept of acceptable risk. The set of key indicators of ecological security and resilience can be expanded and deepen subject to the changing legislation, preferences of experts and the current state of affairs in the socio-economic sphere.

Further research in the problem area under consideration will be continued in the direction of developing a general methodological approach to assessing the overall level of ecological robustness (security and resilience integral index) of Arctic ecosystems according to selected principles and criteria is proposed. The approach is based on the joint application of a hierarchical multi-level decomposition scheme "principle – criterion – indicator – index", methods of expert analysis and models [29] for resilience quantitative and qualitative assessment of the organizational and technical systems. Follow the next Part 2 (Assessment procedure and criteria) of this paper.

The use of research contributions maintains the enhancement of the regulatory and legal framework, as well as the development of the new forms of organizational management in the field of environmental protection in terms of engineering tools and mechanisms for the implementation of the National Public Standard for ensuring ecological security and resilience in the Arctic regions of Russia as a streamline of the Arctic sustainable development. The introduction of such tool outfit in practice will promote to the flexible regulation of various types of economical activities in the Arctic regions, as well as improving the quality of managerial decisions made by state, regional and corporate governance in the field of environmentally responsible nature management.

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