Information and analytical support of the Arctic industrial-natural complexes safety

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Abstract. Recently, increased attention has been paid to issues of information and analytical support for the Russian Arctic security. However, risk management problems are especially acute for lower levels of management hierarchy. Therefore, it is relevant to consider issues of managing technogenic-ecological industrial-natural complexes safety of the Arctic. In this article, these features are considered on the example of a heat power plant. Accidents related to oil and oil products spills are considered as a typical example. In first part of the work, main goals and objectives of prevention, forecasting and elimination of accidents consequences are given, the features of operational management in event of an emergency are revealed. It is shown that Arctic industrial-natural complexes safety management is a complex interdisciplinary area of fundamental and applied research. The structure of information-analytical complex for risk management has been formed. The second section presents some research and developments in field of information-analytical support of industrial-natural safety. Directions for further research are outlined.

1. Introduction
Information-analytical support issues for safe functioning and development of Russian Federation Arctic zone (AZRF) industrial-natural complexes (INC) have recently received increased attention of researchers. Conceptual, legislative, methodological, organizational and technical bases are being formed. In 2020, Russian Federation President Decree "On the Fundamentals of Russian Federation State Policy in the Arctic for the Period up to 2035" [1] was issued, according to which the AZRF is proposed to be used as a strategic resource base to accelerate Russia's economic growth, and the Northern Sea Route is considered as one of growth drivers. At the same time, the approved policy among the main priorities defines preservation of the Arctic environment.

A general analysis of research and development shows that insufficient attention is paid to lower levels of management hierarchy - regional, municipal, facility - in terms of ensuring technospheric safety. At the same time, as practice of Arctic INCs functioning shows, it is at these levels that problems of safe development are especially acute.

In this regard, it is of undoubted interest to analyze how different aspects of man-made and environmental risk management are refracted at level of INC. In this article, these features are considered on example of a heat and power complex (HPC) - an object that is critically important for
polar regions economy functioning and development. As scenario of typical possible accident, spill of oil and oil products (for example, fuel oil used by HPC), actual for the Russian Arctic, was taken.

The article includes two sections.

The first section is based on existing regulatory and methodological base and is devoted to issues of facility (INC, HPC) safety management in case of oil spills. The main goals and objectives of prevention, forecasting and accidents consequences elimination are given, the features of operational management in emergency are revealed.

The second section presents some research and developments in field of information-analytical safety support. The technologies and software products developed, among other things, by the authors of the article are described.

The conclusions are formulated in the conclusion.

2. Basics of oil spill response management at level of industrial-natural complexes

The main objective of management in context of this section is to prevent and respond to oil spills. Achieving this goal involves solving a number of tasks:

- determination of the level of emergency;
- drawing up a plan for the prevention and elimination of emergencies associated with oil spills;
- control of socio-economic consequences of emergency, monitoring of environment at the facility and adjacent territories;
- interaction order determination of organizations involved, management, forces and equipment;
- resources adequacy justification for emergency response;
- drawing up a calendar plan for the emergency response;
- planning of emergency consequences liquidation.

Starting point for managing oil spills is formation of INC characteristics array: contact information, enterprise profile, technological processes descriptions, size and boundaries of INC territory, sanitary protection zones and / or security zones, personnel number. The composition of characteristics clearly indicates the need for a multidisciplinary approach to solving the problems of INC safety management support. It includes both characteristics that make it possible to unambiguously identify object, and characteristics related to the "ecological" and "natural-climatic" feature spaces. So parameters of pollution zones are determined taking into account hydrometeorological conditions (for example, taking into account the movement of lower atmosphere of the Earth), time of year, day, terrain, territories usage and other characteristics. The latter, in particular, includes the presence of large reservoirs or territories of their catchment areas in possible oil spills area.

Within these zones, the constant readiness of the facility for emergency response is achieved by round-the-clock duty, personnel training, provision of a year-round convenient access to the industrial site, availability of fire fighting equipment and equipment for emergency response. The company can either independently organize the measures listed above, or conclude contracts with third-party organizations for provision of relevant services. For example, contracts may be concluded with professional emergency rescue teams (ERT).

An important stage in planning of emergency response is to determine range of scenarios for accidents progress. Consideration should be given to both the maximum volume of product spills and spills under the most likely scenarios.

Analysis of the composition and parameters for enterprise technical equipment allows us to classify following areas as the most dangerous from the point of view of possible oil products spills: tank farm, process pipelines (fuel oil pipelines), railway discharge platform.

The most common causes of accidents include: defects in materials and equipment used, violation of building codes, mechanical damage, personnel errors, extreme natural influences. According to statistics, 70% of accidents are caused by human factors.

The volume of oil product spill depends on number of parameters: amount of damage; internal diameter and length of pipeline; volumes of containers for storage and transportation; time of stopping pumps and closing valves, etc.
The assessment of the risk of oil spills is carried out on basis of forecast for certain type emergencies frequency, as well as the consequences of accidents in form of estimated volume spill and area of contaminated surface.

The causes of spills can be divided into two groups.

The first group includes leaks, containers overflow in case of equipment failures or personnel erroneous actions (in some cases due to the reaction of the human body to geomagnetic situation anomalies), the formation of holes and other equipment defects. The frequency of such causes ranges from one thousandth to sever al times a year. Leakage volumes are usually small (from 2-3 liters to 0.5 m³). Moreover, the largest spills are the least likely.

The second group includes quasi-instantaneous equipment destruction and oil products spill. It is the destruction of equipment that entails the maximum possible spills, which can be accompanied by explosions and fires. The most dangerous option is explosion and destruction of reservoir, followed by fire. The most likely scenario is product leakage before valve operates and possibly the liquid ignites. In such accidents, the following are considered as damaging factors: thermal radiation of burning spills; air shock wave; fragments from the explosion of pressure vessels. The most dangerous damaging factor is the thermal radiation of burning spills, which is aggravated by the presence of strong vortices in the lower atmosphere, which occur in the "circumpolar" latitudes.

Taking into account the factors listed above, as well as natural and climatic conditions and features of technological process and equipment, possible emergency scenarios are formed. Calculations are performed for all scenarios, while, according to the legal regulations, spill must be localized within no more than 6 hours.

Currently, when defining the category of emergency, the following classification is used:

- non-emergency oil spills;
- local emergency (spills up to 100 tons); characterized by transition outside of production site and its development within the organization territory, but does not go beyond the boundaries of the object.
- a municipal (local) emergency is characterized by oil spills from 100 to 500 tons; characterized by development or going outside the organization territory, possibility of damaging factors impact on nearby places population and other organizations (objects), as well as environment.
- a territorial emergency is characterized by large spills (from five hundred to one thousand tons within the border of a constituent entity of the Russian Federation, or a spill from one hundred to five hundred tons outside the boundaries of the municipality);
- a regional accident is characterized by spills from one thousand to five thousand tons or by a spill from five hundred to one thousand tons that go beyond the boundaries of the subject of the Russian Federation;
- a federal accident corresponds to a spill over five thousand tons or going beyond the borders of the Russian Federation.

Further, main stages of operational management and emergency consequences elimination are briefly highlighted.

In case of an emergency, following actions are performed: notification of emergency; priority provision of personnel and population safety, medical care; monitoring the situation and the environment; containment of spills. An operational plan of emergency response is being developed, issues of territories and water bodies eliminating pollution are being considered.

As an example of typical accident, a recent major emergency can be noted. On May 29, 2020, an oil spill occurred at the facility of the Norilsk-Taimyr Energy Company (NTEC). As a result of the depressurization of the reservoir, more than 20 thousand tons of oil products spilled into the nearby water bodies and rivers [2]. This accident could have caused a major environmental disaster, the damage from which would have exceeded hundreds billions of rubles. However, thanks to the prompt and well-coordinated work of the personnel of NTEC and the Ministry of Emergency Situations, the spill was localized in a timely manner, although the elimination lasted for a long time. In December 2020, the Norilsk Nickel Company reported, with reference to the results of the Big Norilsk
Expedition of the Siberian Branch of the Russian Academy of Sciences, that the accidental spill did not have a negative impact on the ecosystems of nearby water bodies and rivers [3].

Summing up the description of the subject area, the following conclusions can be drawn.

The safety management of industrial and natural complexes in the Russian Arctic is a complex interdisciplinary area of fundamental and applied research.

Support for management of technogenic and ecological safety of complexes should be carried out within a single information platform.

The main blocks of information-analytical support combine the following modules (Figure 1): object model (INC), regional management system model, analytical complex of tasks to be solved.

Unified information environment

Figure 1. Information and analytical support of security management

3. Research and development
To date, a number of software systems have been developed, the functionality of which is focused on providing information support in various emergency situations - both during operational activities and in advance planning.

For example, NARAC [4] can simulate progress of various emergency and, based on the results obtained, issue recommendations for drawing up an emergency response plan. NARAC is universal software, but there are also specialized solutions. In [5], it is proposed to use models for optimizing fire risk management measures at oil and gas facilities. If we talk about the development of planning documentation as early planning stage of measures to combat emergencies, then we can note the software [6], which allows automating the creation of safety data sheets for hazardous industrial facilities.

The authors of this work have proposed [7] a complex information technology for managing technogenic-environmental safety of activities in the Russian Arctic. The technology includes the formation of typical problem model, work with legal documents, a request for archival materials, a mathematical formalization of problem, calculations, and the release of a standard document. Certain components of developed technology received certificates ([8], [9]).
For the tasks of regional industrial-environmental safety management support, a model has been developed for assessing the level of information uncertainty about situation parameters [10]. The model defines an order relation on a finite set of uncertainty options characterized by a common features set. Each option is associated with mathematical models for describing the uncertainty and assessing the associated risk. As part of decision-making information support systems, the model makes it possible to form quantitative assessments of risks associated with the incompleteness and inaccuracy of the knowledge used.

Within the framework of research under the RFBR project No. 18-29-03022 -mk, technologies and methods of intelligent analysis of situations are being developed for information and analytical support of the work of situational centers based on modeling situations in generalized conceptual spaces. An approach to the formation of hierarchical structure complex conceptual space on basis of basic "subject" conceptual spaces, capable of providing a classification of various situations in industrial-natural complexes from an interdisciplinary point of view, is proposed [11].

The use of an interdisciplinary approach allows a more detailed assessment of the risks of possible emergencies consequences and emergencies for systems and objects of various nature that are affected by emergencies. The proposed mechanisms for coordinating decisions and actions of decision makers (DM) responsible for the "components" of measures set to prevent emergencies and / or liquidate the consequences of emergencies are based on the use of the concept of situational awareness (SA) of each decision maker. The developed method for the numerical assessment of SA in hierarchical and network-centric [12] structures makes it possible to model any possible interactions between various participants (groups) to ensure safety, including prevention and / or elimination of emergency consequences.

In the implemented approach, it is assumed that the network-centric security structure is functionally and geographically a network, each node in which has its own goal, set by some quality criterion. Initially, the network is peer-to-peer (peer-to-peer) in the sense of equality of nodes in terms of decision making. Depending on the current situation, each network node can change its rank becoming the center of some connected part or the entire system as a whole. At the same time, it gets the right and the opportunity to coordinate the interactions of the nodes that have become subordinate to him (included in his area of responsibility - AOR [13]).

To determine the current rank and AOR of each node of the network-centric system, it is proposed to apply the concept of SA. A solution to the problem of dynamic distribution of the roles of agents (DM) in a coalition is developed when solving a common problem or implementing a common plan. The distribution of roles is called dynamic, since the assigned roles are not predefined and are formed based on the preferences of agents [14]. A cognitive approach to the operational formation of areas of responsibility of various decision-making nodes based on the analysis of situational awareness of decision-makers in the SCS nodes is proposed. The mechanisms for determining the coordinator node in the current situation and coordinating the joint activities of the nodes included in the same AOR have been determined [15]. The purpose and novelty of the development is to metrize the space of all the main aspects of SA, which makes it possible to objectify the assessment of the achieved SA degree. The latter is especially important in the widespread case, when various components of the INC security are included in the areas of responsibility of various decision makers. For this case, the proposed approach makes it possible to improve the coordination of decision-makers' actions and prevent conflicts between them.

The results obtained were tested at hazardous industrial facilities of the Murmansk region, including JSC "Murmanskaya CHPP", JSC "Murmanoblgaz".

Along with the problem of comprehensive information-analytical support for decision-making process in the field of risk management and combating emergencies, it should also be noted that not enough attention is paid to the problem of visualizing situation in the emergency zone, possible options for action at a given point in time. Some researchers back in 2014 [16] noted the growing role and prospects of using information visualization technologies in the field of emergency response. Nevertheless, even now this problem is not given sufficient attention in domestic studies [17].
It is worth noting studies [18] and [19], in which visualization of the situation was one of the significant elements. In [18], to visualize the current situation in the emergency area and assess the consequences, it is proposed to use geoinformation technologies (GIS technologies).

It should be noted that in assessing the consequences of emergencies, GIS technologies will be especially relevant. So, in [19], examples are shown and an approach is proposed for using geoinformation systems in solving various problems, in particular, in the eco-monitoring of the hydrochemical composition of water bodies. The described methods, after appropriate adaptation, can be successfully applied in assessing the consequences of oil spills in the Russian Arctic.

A detailed analysis of existing developments shows that for each block of information and analytical support (see Figure 1), you can choose an appropriate solution. However, the main disadvantage of the existing applications is that they are "scattered" and are not integrated into a single information environment, which does not allow comprehensively provide information and analytical support for the process of planning emergency response and prompt response to emergency situations. Moreover, existing research and development practically do not take into account the specifics of the Arctic regions.

4. Conclusion
The safety management of industrial-natural complexes in the Russian Arctic is a complex interdisciplinary area of fundamental and applied research.

Support for technogenic-environmental safety management of complexes should be carried out within a single information platform.

A complex of functions and tasks of risk management is described in order to combat possible industrial-natural accidents at facilities of the regional and lower levels.

Ensuring the security of INC is carried out within the framework of regional socio-economic systems of the Russian Arctic and requires coordination with other areas of functioning of these systems.

The main disadvantage of existing applications is that they are scattered and not integrated into a single information environment, which does not allow comprehensively provide information and analytical support for the planning process of combating emergency situations and prompt response to emergency situations.

The research and development performed does not sufficiently take into account the specifics of the Arctic regions.

Acknowledgments
The results were obtained within implementation of the state task of the IIMM KSC RAS (No. 0226-2019-0035). The practical implementation of developments for the tasks of ensuring industrial and environmental safety was supported by the Russian Foundation for Basic Research (projects No. 18-29-03022 and No. 18 05-60125).

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