

# Risk-oriented provision of mining operations safety at the enterprises of mineral resources sector in Russia

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**Abstract.** The development of the Russian economy for many years will be based on the effective use of mineral resources. At the same time the development of deposits characterized by the worst mining and geological conditions, while increasing the intensity of mining operations, leads to an increase in mining risks. In the paper, recommendations are given on a set of measures aimed at ensuring the safety of mining operations at the enterprises of the mineral resources sector in Russia based on the analysis of the current regulatory and legal framework and the assessment of factors that affect the growth of the probability of emergency situations. The obtained conclusions are drawn from the situation in the Russian coal industry. The proposed recommendations are based on a risk-oriented approach illustrated by the example of the coal industry. In the paper the directions for improvement of the mechanism of organizational-economic provision of mining operations safety at the enterprises of the coal industry are presented.

## 1. Introduction

Despite the significant growth of non-resource-based industries, the state cannot refuse from involvement of mineral and raw materials into economic circulation as the basis for the development of the Russian economy. According to the assessment of the Ministry of Natural Resources of Russia for 2017 the gross value of Russian mineral resources was 28 trillion dollars and had the following structure (table 1). At the same time, the state sets ambitious goals for the development of the Arctic in order to involve its natural resource and mineral resources potential in economic circulation [1].

To date 37% of the explored deposits have been put into industrial development, but it should be noted that from 1/3 up to 2/3 of all balance reserves with modern technologies of extraction and processing are unprofitable.

Analyzing the emerging situation, it is possible to identify the main problems of the development of the mineral resources sector, which have been formed for many years:

- Long operating time of most working mines (often beyond the established time limit).
- Depletion of large near-surface deposits easy to develop.
- Use of obsolete equipment and norms of technological design by mining enterprises in new mining and geological conditions.
- Lack of interest of mining companies in financing pilot and basic research.



**Table 1.** Structure of the gross value of mineral resources in the Russian Federation (for 2017).

Type of mineral resources	Share in the total cost
natural gas	32 %
coal	23 %
oil	16 %
ore mineral	14 %
other mineral resources	15 %

At the same time, the current development of mineral resources sector in Russia is characterized by a deterioration in mining and geological conditions with a simultaneous intensification of mining works, which ensures sufficient profitability of mining. These two factors, as well as a lack of qualification of employees and motivation for unconditional compliance with the requirements of mining safety rules and increase in labor productivity lead to an increase in mining [2, 3].

Despite the considerable attention paid by the state to the issues of mining safety through the tightening the requirements and support of relevant scientific research, the level of accidents at the enterprises of the mineral resources sector remains rather high, which is evident from the comparative assessment of the mining operations safety in the coal industry of Russia and the USA (table 2). At the same time, mine operators bear significant costs both implementing measures to prevent accidents and eliminating accidents.

**Table 2.** Comparative assessment of the mining operations safety in the coal industry in Russia and the USA (1991-2009).

Indicator	Russia	USA
Average annual production (billion tons)	0.26-0.30	1.05-1.10
Fatal injuries (person/year)	115-180	25-49
Fatal injuries (person/100 million tonnes)	54+/- 12	3.36+/- 0.55
Dead (person/10 thousand workers)	7.9+/- 1	3.8 (5.1 underground)

In the period from 2000 to 2016 at the mines of the Kuznetsk and Pechora coal basins, 9 major accidents occurred which resulted in the death of 385 miners.

The facts indicated above proves the need to search for new approaches to ensuring the mining operations safety at the enterprises of mineral resources sector in Russia.

## 2. Methods of research

A systematic analysis of the factors affecting the development of the mineral resources sector in Russia was carried out. The following groups of factors were accepted for consideration [4]:

- Infrastructural
- Environmental
- Market conditions
- Political
- Internal

Investigating the internal factors of the development of mineral resources sector in Russia, it is necessary to pay attention to the factors directly influencing the level of safety of mining operations:

- Regulatory framework and law enforcement practice
- Mountain-geological and natural-climatic conditions
- The need to ensure competitiveness
- Existence of deviations from technical and technological norms
- Degree of absence of demand on the part of the state and business for application of high-tech research in the mining industry

- Technological support of mining processes
- Staffing of modern mining industry.

### 3. Results and discussion

The conducted integrated analysis of the industry operating conditions made it possible to identify the main contemporary problems in the development of mineral resources sector in Russia:

- Depletion of favorable, well-explored reserves not far from the main consumers of raw materials and infrastructure;
- The occurrence of reserves at great depths in complex geological, gas and hydrodynamic conditions, as well as in nature protection zones;
- The need to develop the mineral and raw materials base of the northern and far eastern territories of Russia;
- Accumulation in large volumes of technogenic wastes leading to high pollution of territories;
- Incompleteness of information on the state of the subsoil, increased risk of explosive destruction processes, hard-to-predict rock bumps, emissions of gases, saturated brines and waters into mine workings in the developed fields;
- Dependence of mining enterprises on the supply of imported mining equipment and spare parts;
- Increase in energy costs, production costs and processing of mineral raw materials;
- Growth of volumes of difficult to enrich raw material;
- Volumes of extraction and processing of some types of raw materials are insufficient for domestic perspective demands with their simultaneous exporting.

All this is exacerbated by the problems accumulated in the mineral resources sector in Russia:

- Long operating time of most mines;
- Increase in the number of hazardous production facilities with close to the maximum or fully exhausted technical and technological resources;
- Use of out-dated equipment and norms of technological design by mining enterprises in new mining and geological conditions;
- Increased intensity of mining operations, new technologies do not meet the safety requirements;
- Lack of detailed study of the risks of negative industry-related processes and support of mining geotechnologies;
- Lack of modern regulatory and legal framework;
- Lack of interest of mining companies in financing pilot and basic research.

According to Rostekhnadzor, the main sources of danger and the reasons for the increase in accidents are:

- Poor quality of design and technical solutions;
- Critical level of wear and tear on plant and equipment;
- Poor or untimely performance of maintenance and repair works;
- Low motivation to ensure work safety and personnel qualification;
- Low technological and labor discipline;
- Lack of effective incentives to upgrade the production facilities and equipment of enterprises involved in industrial safety activities.

Noting the increase in the number of hazardous production facilities, it is possible to present the ranked structure of the operating coal mines of the Russian Federation in terms of the degree of hazard in mining (table 3). At the same time, it should be said that at present five coal mines are in operation in Russia, at which all types of hazards are present simultaneously, and in general there are two or more hazards at 33 mines [5].

**Table 3.** Ranked structure of operating coal mines of the Russian Federation in terms of the degree of hazard of mining operations (2017).

Type of hazard	Number of mines
Dust explosion	54
Rock bumps	33
Coal self-ignition	32
Sudden rock, coal and gases outbursts	30
Water irruption	25

Speaking about the most dangerous factor and type of emergency – explosion of methane-air mixture, it should be noted that often methane explosions in coal mines are caused by organizational and technological violations, which include:

- Selective mining of the most favorable layers in the formation;
- Operation of very gassy mines with a methane content more than 15 m<sup>3</sup>/t without their preliminary gas drainage;
- Absence of preliminary and low efficiency of current gas drainage of methane-bearing coal seams;
- Use of long-pillar method along the strike with the collapse of the roof without application any methods of its weakening and caving;
- Use of exhaust method for the ventilation of mines and combined schemes for ventilating the faces during the mining coal seams prone to spontaneous self-ignition;
- Contract bonus system.

It is necessary to give an example of the Australian coal industry, which occupies the first place in the world for its mining operations safety (fatal injuries 3.0 person/100 million tonnes), where the law prohibits the exploitation of coal mines with methane-bearing seams of more than 9 m<sup>3</sup>/t without preliminary gas drainage. In Russia very gassy mines with a methane content more than 20 m<sup>3</sup>/t are operated without pre-degassing.

Separately, we should touch on the environmental consequences of mining and mining activities. The impact of accumulated and newly generated wastes on the environment, loss of resources through waste accumulation, emissions and dumping, as well as the unsettled relationships between mine owners and environmental authorities (forest and water resources, land use, specially protected areas) not only reduce the competitiveness of the industry, but also leads to global environmental problems that can be solved by switching to the best available technologies [6, 7].

The facts mentioned above proves the need to switch to a new system of regulatory and legal support for mining safety, based on a risk-oriented approach with a preliminary assessment of the field by constructing a digital model with a forecast of mining risks and an economic evaluation of the investment project throughout the life cycle of the deposit [8, 9].

These problems require the improvement, creation and wide introduction of highly efficient exploration technologies, low-waste, resource-saving technologies for extraction and processing of solid minerals. It is necessary to develop combined technologies for extraction and deep processing of raw materials as a unified technological complex for the implementation of a complete, closed cycle of combined physical, technical and physical-chemical geotechnologies, optimizing the timing and order of phased commissioning of production facilities and mandatory waste disposal in the mined-out space. These tasks can be performed only through the development of domestic mining machinery to ensure import-independence, including through the localization of the most significant productions [10].

To stimulate mining companies to implement modern approaches ensuring the mining operations safety, it is necessary to use the experience accumulated in the framework of Eurasian technical and economic cooperation in the field of exploration, extraction and processing of solid mineral resources for the creation of appropriate trust funds financed by subsoil users [11].

#### 4. Conclusions

Thus, the following main directions for ensuring the safety of mining operations at the enterprises of the mineral resources sector in Russia should be indicated:

- Modern scientific support for the operation of mines with the assessment of risks of manifestation of negative technogenic processes throughout the life cycle of the field;
- Improvement of legal and regulatory risk-based regulation of integrated mining safety on the basis of scientifically-based approaches;
- Full-scale complex examination of large mining projects;
- Financing of pilot and fundamental research focused on ensuring the mining operations safety;
- Development of mechanisms for involvement of the results of scientific research in the real sector of the Russian economy, creating a regulatory and legal framework and principles for supervisory activities that ensure the mining operations safety.

At the same time, the following indicators should serve as targets (indicators) for ensuring the safety of mining operations: decrease in the number of workers in the zone of high mining risk (for example, by 25% every five years, starting from 2020). This can be done either by refusing to develop high risk deposits or by robotizing production processes with the transition to fundamentally new closed geotechnologies.

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