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ANALYSIS OF THE RISK STRUCTURE OF INJURIES AND OCCUPATIONAL DISEASES IN THE MINING INDUSTRY OF THE FAR NORTH OF THE RUSSIAN FEDERATION

Purpose. To determine the value of the components and the impact of environmental factors on the risk structure of workplace injuries and occupational illnesses in the mining industry of the Far North of the Russian Federation, conditioned by the combined influence of workplace factors and unfriendly climatic conditions.

Methodology. The methodology for solving this issue is based on a comparative analysis of the dynamics of the risks of occupational injuries and illnesses over a decade, both for Russia at large, for Murmansk region and the Komi Republic in particular, and for their mining industries, with further calculation of the “background” risk depending on the environmental and climatic specifics of the northern territories.

Findings. The paper contains a correlation analysis of workplace injuries and occupational illnesses in the Russian Federation, Murmansk region and the Komi Republic. The background rate of their risk is calculated. It was established that background risks for the territories of the Far North of the Russian Federation are adequately described by linear correlation. The specific weight of the background risk at the overall risk of injuries and illnesses for mining industries of Murmansk region and the Republic of Komi is established.

Originality. A method for calculating the value of the “background” risk and identifying its dynamics over a decade is developed.

Practical value. The objectivity of assessing the risks of occupational illnesses and workplace injuries in the mining sectors of the Far North of the Russian Federation by factoring in the value of the “background” risk is increased.

Keywords: *occupational morbidity, linear correlation, background risk*

Introduction. About 125 million health and safety incidents occur annually in the world. On average, about 220 thousand people die. Mortality from on-the-job injuries today ranks third in the world [1]. Work-related injuries, including the cause of fatal accidents, depend on many factors, including the geographical location and type of production activity.

Reducing work-related injuries and occupational illness is one of the most important tasks of modern society, the solution of which will make it possible to increase the social and economic security of the working population. This task is particularly relevant for the mining industry in the Far North of the Russian Federation. The countries possessing such territories primarily include: Finland, Norway, Sweden, Denmark, Canada, North America (Alaska). In the Russian Federation, about 80 % of Russia’s minerals are mined in the Northern and North-Eastern regions of the country: Murmansk, Arkhangelsk, Magadan regions, the Komi Republic, and the Kamchatka Territory. Coal, gold, various types of ores, oil, gas and other minerals are mined at deposits located in these regions.

In contrast to regions located in other climatic zones, in the Far North of the Russian Federation, injuries and occupational illness are influenced by climatic and environmental factors unfriendly to humans: low air temperature, heavy precipitation, strong wind, polar night, deficiency of ultraviolet radiation, and others. These factors affect the psychophysiological state of the population living and working in these regions, which in turn leads to increased occupational illness and work-related injuries compared with similar indicators for other regions. This trend is most noticeable for the mining industry, where the risks of occupational illnesses and work-related injuries are significantly higher than the average for other regions.

In this regard, the establishment of the structure of the risks of injuries and occupational illnesses for the mining industry of the Far North of the Russian Federation, by identifying the so-called “background” risk characterizing the environmental impact, makes it possible to increase the accuracy of determining the risk associated with organizational and technical factors, which will result in improving management methods.

Materials and methods. Assessment of the consequences of occupational injuries and work-related illnesses is based on the use of various risk categories. A significant amount of research has been devoted to the development of methods for calculating these risks, both in our country and abroad [2, 3].

In Finland, for example, the method of Elmery system risk assessment [4, 5], which makes it possible to establish the likelihood of conditions that lead to injuries and occupational illness, has gained great popularity. The method is based on observations that cover all the most important components of occupational safety, such as: the use of protective equipment, order at the workplace, safety when working with equipment, occupational health and ergonomics, which are grouped into seven areas of assessment: production process; tidy and well-ordered; safety at work with machinery; environmental factors; ergonomics; passages and driveways; opportunities for salvation and first aid. Each item is evaluated based on the good/bad principle. An item is deemed "good" if it meets the minimum level of legal requirements, as well as good experience in ensuring security in a particular enterprise. The Elmery index is calculated as the ratio of the number of points rated "good" to the total number of points analyzed and varies in the range from 0 to 100. For example, a 60 % result indicates that the potential risk of consequences of failure to meet specified requirements is 40 %.

The Canadian Occupational Safety and Health Center (CCOHS) recognizes the potential use of various methods and techniques for risk assessment. The main task in this case is the choice of the method that best suits the specific situation. The center's staff are suggested an approximate procedure for calculating risks [6, 7]. Based on it, risk assessment forms have been developed that allow documenting the procedure used and decision-making methods.

In the USA, methods such as FMEA (Failure Mode and Effect Analysis), HAZOP (Hazards and operability analysis), FTA (Fault tree analysis) are used to assess risks. The HAZOP method, for example, is a risk analysis procedure consisting of a process of detailing and identifying operational failures and deviations in the operability of equipment, a process unit, or a system, leading to various undesirable consequences [3].

In Norway, the risk assessment system has three simple questions:

1. What could go wrong?
2. What can be done to prevent this?
3. What can be done to reduce the consequences if this happens?

Risk assessment is carried out in collaboration with employees, security officials and trade union representatives. To assess the risks, maps of all hazards and problems at the workplace are filled in, then an analysis is made of how often the employee is exposed to a particular risk, and possible scenarios for solving the problem are considered. After the analysis, the employer builds a risk-to-delivery matrix, where they receive a complete overview of all the hazards at the workplace, after which an action plan is drawn up to implement measures for labor protection and risk prevention [8].

A distinctive feature of risk assessment in Russia is the use of not only qualitative criteria (high, medium, low risk), but also quantitative indicators characterizing various types of risk (individual risk, collective risk, economic damage, expected value of damage) [9, 10].

Much attention is paid to determining the magnitude of the risks of injuries and occupational illnesses, depending on its causes [11, 12]. So, for example, A. M. Grishina has shown that reducing the risk of injury can be achieved by reducing violations associated with errors during technological operations [9, 10]. In a number of works, the risk structure at coal mining enterprises was proposed to be determined as the sum of the background risk due to the level of development, added individual risk, and added systemic risk associated with violations of safety requirements [11].

Karnachev I. P. argues that the transition to the concept of occupational risk management involves shifting the emphasis from responding to accidents after the event to preventive measures, i.e. risk management of an employee's health damage. It is necessary to implement the concept of key risk indicators in the process of managing safety and labor protection in the organization [13].

At the same time, the degree of knowledge of the problem of the adverse environmental parameters impact in severe climatic conditions on injuries and occupational illnesses of in-mine personnel cannot be considered satisfactory. Among the available studies, first, the works by N. N. Dal can be used. N. N. Dal first introduced the concept of "background risk" of occupational illness and calculated its value for the mines of Vorkuta. However, the lack of statistical data characterizing the risks of injuries and occupational illness for a representative time did not allow her to assess the dynamics of their "background" values and to reveal patterns of change in this important parameter [14].

The lack of evidence-based methods for assessing the "background" values of the risks of injuries and occupational illnesses of in-mine personnel prompted the authors to write this article.

The choice of measures to minimize the risks of work-related injuries and occupational illnesses should be based on information about the structure of these risks and their dynamics for past periods and at the current time. Determining the structure of risks makes it possible to establish a correlation between the controllable and uncontrollable factors that determine them. The first should include all factors associated with production activities, and the second should include external conditions, depending, for example, on environmental parameters, characterized by the degree of air pollution of the residence of the mining personnel, the geographical location of the enterprise, including the ratio between the duration day and polar night, the intensity of ultraviolet radiation, meteorological conditions of the area, and so on. External conditions affect the psychophysiological state of the personnel of the mining enterprise.

The procedure for determining risk structures is based on the assumption that the general risk of injuries (occupational illnesses) is the result of the combined action of two types of risk: the general risk for the territories of the Far North (*F.N.t.*) $R_{F.N.t.}$ is calculated by the average risk in Russia ($R_{F.av}$) $R_{RF.av}$, and risk due to external conditions (*EXT.C.*) characterizing these territories $R_{EXT.C.}$; overall risk to mining enterprises (*M.I.t.*) $R_{M.I.t.}$ is calculated by risk value $R_{EXT.C.}$ and risk determined by industrial activities (*I.A.*), ($R_{I.A.}$). Formulas (1, 2) relating these risks are obtained based on the dependence for the probability of the sum of joint events and have the following form

$$R_{F.N.t} = R_{RF.av} + R_{EXT.C\cdot} - R_{R.F.av} \cdot R_{EXT.C.}; \quad (1)$$

$$R_{M.I.t.} = R_{EXT.C.} + R_{I.A.} - R_{EXT.C.} \cdot R_{I.A.}. \quad (2)$$

When solving these equations with known common risks of injuries (occupational illnesses) in the territory under consideration $R_{F.N.t.}$, mining enterprise $R_{M.I.t.}$, as well as the average risk for the Russian Federation $R_{RF.av.}$, it is easy to calculate the risk values for the territory under consideration, due to the influence of external conditions, $R_{EXT.C.}$ and the risk determined by the industrial activities R_{IA}. The values of risks $R_{F.N.t.}$, $R_{M.I.t.}$ and $R_{RF.av}$ are determined on the basis of statistical reporting data and their subsequent correlation analysis for the period under review.

Determination of the dynamics of injuries and occupational illnesses in the mining industries of the Russian Federation and its northern regions. The magnitude of the risks of occupational illness and work-related injuries is calculated as the ratio of the occurrence of injuries or occupational illnesses to the total number of working population or mining personnel. To determine them, we used statistical data characterizing injuries and occupational illnesses, respectively, for Russia as a whole and for its mining enterprises located in Murmansk region and the Komi Republic [15, 16] (Figs. 1–4).

The calculation results indicate that the dynamics of the risk of injuries and occupational illnesses for all considered cases is satisfactorily described by a linear dependence with correlation coefficients exceeding 0.75 with a statistical reliability of 0.95 [17]. The linear correlation regression coeffi-

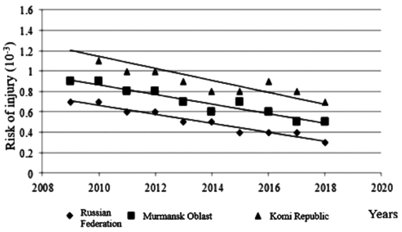

Fig. 1. The dynamics of the risk of work-related injuries in the Russian Federation, Murmansk region and the Republic of Komi

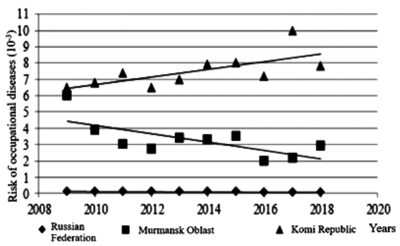

Fig. 2. The risk dynamics of occupational illnesses in the Russian Federation, Murmansk region and the Republic of Komi

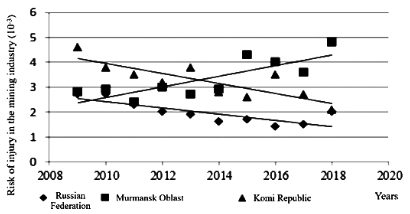

Fig. 3. The dynamics of the risk of work-related injuries in the mining sectors of the Russian Federation, Murmansk region and the Republic of Komi

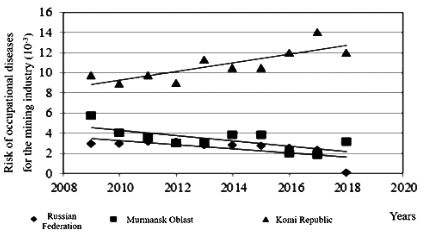

Fig. 4. The dynamics of the risk of occupational illnesses in the mining industry of the Russian Federation, Murmansk region and the Republic of Komi

cients determine the annual rate of change in the risks of injuries and occupational illnesses [18, 19]. Moreover, a negative value of the regression coefficient corresponds to a decrease in risk (Fig. 1), and a positive value – to its increase (Figs. 2–4).

Determination of the structure of risks of work-related injuries and occupational illnesses. As follows from the above graphs, an increase in the risk of work-related injuries during the period under review occurs for the mining industry of Murmansk region (Fig. 2), and an increase in the risk of occupational illnesses both for the Komi Republic as a whole and for its mining industry (Figs. 2, 4). It also follows from the graphs in Figs. 1, 2 that the risks of work-related injuries and occupational illnesses in Murmansk region and in the Komi Republic are higher than in the Russian Federation.

In accordance with the above methodological approach, for each of the regions considered, the risks of injuries and occupational illnesses associated with the negative environmental impact of the risk $R_{EXT.C.j.(o.il)}$ ("background risks") and the risks determined by the production activities $R_{I.A.j(o.il)}$ were calculated

$$R_{EXD.C.j.(o.il)} = (R_{F.N.t.j.(oil.)} - R_{RF.av.j.(o.il.)})/(1 - R_{RF.av.j.(o.il.)}); \quad (3)$$

$$R_{I.A.j.(o.il.)} = (R_{I.M.t.j.(o.il.)} - R_{EXT.C.j.(o.il.)})/(1 - R_{EXT.C.j.(o.il.)}), \quad (4)$$

where $R_{EXT.C.j.(o.il)}$ stands for "background risks" of injuries (index *j*) and occupational illnesses (index *o.il*); $R_{I.A.j(o.il)}$ –production risks of injuries (index *j*) and occupational illnesses (index *o.il*); $R_{RF.av.j(o.il)}$ – average values of risks of injuries ((index *j*) and occupational illnesses (*o.il* index) for the Russian Federation, $R_{M.I.t.j(o.il)}$ – overall risks of injuries (index *j*) and occupational illnesses (*od* index) for mining enterprises; $R_{F.N.t.j(o.il)}$ is the overall risk of injuries (index *j*) and occupational illnesses (*o.il* index) for the considered territories of the Far North of the Russian Federation. Formulas (3, 4) are used to calculate the "background values" of the risks of work-related injuries and occupational illnesses, and production risks in relation to mining enterprises of Murmansk region and the Komi Republic, which can be attributed to the territories of the Far North of the Russian Federation. The results of calculating the "background values" of risks are presented in Table. (Background risks of work-related injuries and occupational illnesses ($R \cdot 10^{-3}$).

Fig. 5 shows the proportion of "background risk" in the overall risk of injuries in Murmansk region for 2013 and the proportion of "background risk" in the overall risk of injuries in the Komi Republic for 2016. Figure 6 shows the proportion of "background risk" in the overall risk of occupational illnesses in Murmansk region for 2009 and the proportion of "background risk" in the overall risk of occupational illnesses in the Komi Republic for 2009 as well.

In general, background risk values were calculated from 2009 to 2018. It turned out that the background risk of injuries for Murmansk region and for the Komi Republic is decreasing over the years, as is the risk of occupational illnesses in Murmansk region. The background risk of occupational illnesses for the Komi Republic changes slightly over the years, within

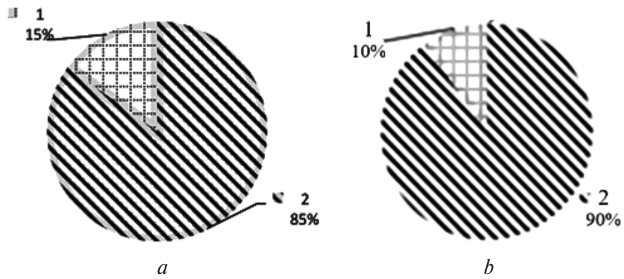

Fig. 5. The proportion of "background risk" in the overall risk of injury:

a – in Murmansk region; b – in the Republic of Komi; 1 – background risk; 2 – risk caused by organizational and technical factors

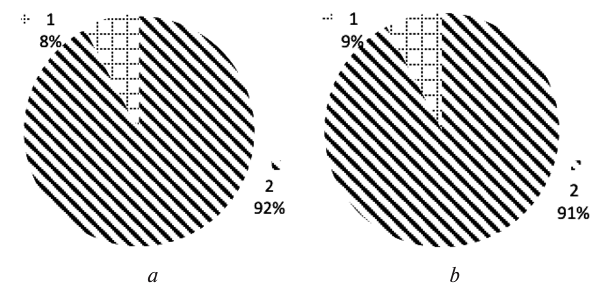

Fig. 6. The proportion of "background risk" in the overall risk of occupational illnesses:

a – in Murmansk region; b – in the Republic of Komi; 1 – background risk; 2 – risk caused by organizational and technical factors

Table

Background risks of work-related injuries and occupational illnesses ($R \cdot 10^{-3}$)

	In Murmansk region		In the Komi Republic	
Year	Injuries	Occupational illnesses	Injuries	Occupational illnesses
2009	0.19	0.6	0.74	0.65
2010	0.15	0.39	0.44	0.68
2011	0.16	0.3	0.39	0.74
2012	0.16	0.27	0.45	0.65
2013	0.12	0.34	0.4	0.70
2014	0.16	0.33	0.43	0.79
2015	0.26	0.35	0.39	0.80
2016	0.17	0.2	0.58	0.72
2017	0.17	0.22	0.39	1
2018	0.12	0.29	0.32	0.78

the limits of calculation accuracy. Thus, assuming that the values of the "background risk" of injuries and occupational illnesses in the mining industry correspond to these values for the region under consideration, to calculate the risk of work-related injuries due only to organizational and technical factors, the overall risk of injuries (Fig. 3) should be reduced by 10–15 %.

Similarly, to find the risk of occupational illness, determined only by production factors, the overall risk of occupational illness risk (Fig. 4) should be reduced by 8–9 %.

Conclusions. The dynamics of the risk of injuries and occupational illnesses for all considered cases is satisfactorily described by a linear dependence with correlation coefficients exceeding 0.75 with a statistical reliability of 0.95.

1. In areas of the Far North of the Russian Federation, in addition to organizational and technical factors, environmental factors leading to increased risks of work-related injuries and occupational illnesses, determined by organizational and technical factors, should be taken into account.

2. Environmental factors can be taken into account based on the use of "background risk" calculated by comparing the risks of injuries and occupational illnesses specific to the mining industry (coal mining and mining enterprises).

3. The presence of "background" risk allows us to clarify the structure of the risks of work-related injuries and occupational illness that characterize the mining industry of Murmansk region and the Komi Republic.

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Аналіз структури ризиків травматизму та профзахворювань у гірничодобувній промисловості крайньої Півночі Російської Федерації

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Мета. Встановлення значення складових і вплив факторів навколишнього середовища на структуру ризиків виробничого травматизму та профзахворювань у гірничодобувній промисловості крайньої Півночі РФ, що визначаються спільним впливом виробничими факторами й недружніми для людини кліматичними умовами.

Методика. Методика рішення цього завдання заснована на порівняльному аналізі динаміки ризиків виробничого травматизму та профзахворювань за десятирічний період як у цілому для Росії, Мурманської області і Республіки Комі, так і для їх гірничодобувних галузей з подальшим обчисленням «фонового» ризику, що залежить від еколого-кліматичної характеристики північних територій.

Результати. У роботі виконано кореляційний аналіз виробничого травматизму та професійної захворюваності в Російській Федерації, Мурманській області й Республіці Комі. Розраховані фонові значення їх ризику. Встановлено, що фонові ризики для територій крайньої Півночі РФ задовільно описуються лінійною кореляцією. Виявлена питома вага фонового ризику в загальному ризику травматизму та профзахворювань для гірничодобувних галузей Мурманської області й Республіці Комі.

Наукова новизна. Новизна проведених досліджень полягає в розробці методу обчислення величини «фонового» ризику й виявленням його динаміки протягом 10-річного періоду.

Практична значимість. Полягає в підвищенні об'єктивності оцінки ризиків травматизму та профзахворювань у гірничодобувних галузях територій крайньої Півночі РФ за рахунок обліку величини «фонового» ризику.

Ключові слова: *професійна захворюваність, лінійна кореляція, фоновий ризик*

Анализ структуры рисков травматизма и профзаболеваний в горнодобывающей промышленности крайнего Севера Российской Федерации

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Цель. Установление значения составляющих и влияние факторов окружающей среды на структуру рисков производственного травматизма и профзаболеваний в горнодобывающей промышленности крайнего Севера РФ, определяемых совместным влиянием производственными факторами и недружественными для человека климатическими условиями.

Методика. Методика решения этой задачи основана на сопоставительном анализе динамики рисков производственного травматизма и профзаболеваний за десятилетний период как в целом для России, Мурманской области и Республики Коми, так для их горнодобывающих отраслей с последующим вычислением «фонового» риска, зависящего от эколого-климатической характеристики северных территорий.

Результаты. В работе выполнен корреляционный анализ производственного травматизма и профессиональной заболеваемости в Российской Федерации, Мурманской области и Республике Коми. Рассчитаны фоновые значения их риска. Установлено, что фоновые риски для территорий крайнего Севера РФ удовлетворительно описываются линейной корреляцией. Выявлен удельный вес фонового риска в общем риске травматизма и профзаболеваний для горнодобывающих отраслей Мурманской области и Республики Коми.

Научная новизна. Новизна проведенных исследований состоит в разработке метода вычисления величины «фонового» риска и выявлением его динамики в течение 10-летнего периода.

Практическая значимость. Заключается в повышении объективности оценки рисков травматизма и профзаболеваний в горнодобывающих отраслях территорий крайнего Севера РФ за счет учета величины «фонового» риска.

Ключевые слова: *профессиональная заболеваемость, линейная корреляция, фоновый риск*

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