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Methodological Problems of Assessing Occupational Hazards at Mining Enterprises and Their Solution

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Методологические проблемы проведения оценки профессиональных рисков на горнорудных предприятиях и их решение

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Current problems of the methodology for assessing occupational hazards, which is an integral part of the risk-oriented approach to the occupational and industrial safety management at mining enterprises, are considered.
The variety of mining-geological and mining-technical conditions of underground mining inevitably requires the development of adequate and effective methods of risk assessment, on which all future methods of engineering and organisational occupational and industrial safety management are structured.
The voluntariness and variability of risk assessment procedures in international practices and the obligation of detailed regulation in Russian practice, as well as the complexity of this new target for the practice of Russian mining enterprises, the recognition and solution of which by specialists have just begun, led not only to the lack of generally recognised risk assessment methods, but also to the methodology of their development in relation to labour conditions at Russian mining enterprises.
Based on a critical analysis of the structure and content of hazards and risks at underground mining enterprises, methodological techniques for constructing effective risk assessment methods have been formulated. The main attention is paid to the assessment of occupational hazards of anatomical injury or acute inhalation poisoning.
A detailed step-by-step analysis of any occurred adverse event (an accident in the course of a working person's performance of his/her labor function) has been carried out. Originating point is the concept of working environment and labor process “property”, which may cause harm of varying severity, up to the death of the effected person, in case of accidental contact effects on the employee's body.
It is shown how the logically related concepts of “hazard”, “occupationally significant hazard”, “hazard carrier”, “hazard source” allow us to build a clear procedure for identifying occupationally significant hazards and to logically carry out the procedure for risk assessment, including the assessment of various risk types by their level (degree) of admissibility and priority of making management decisions and protective measures.
This article reveals the essence of the problem and provides examples of drawing the specific methods, identifying and overcoming the "bottlenecks" of risk assessment at mining enterprises.
The study results are applied practically and can be recommended to specialists when assessing occupational hazards at mining enterprises.

Ключевые слова:
горнорудное предприятие, охрана труда и безопасность производства, оценка профессиональных рисков, понятийно-терминологический аппарат оценки риска, оценка риска, оценивание риска, опасность, носитель опасности, источник опасности, профессионально значимая опасность, матричный метод, вербальное ранжирование, вербально-балльное ранжирование, уровень профессионального риска, степень приоритетности риска, опасности и риски.

Рассматриваются актуальные проблемы методологии проведения оценки профессиональных рисков, являющейся неотъемлемой частью риск-ориентированного подхода к управлению охраной труда и безопасностью производства на горнорудных предприятиях.
Разнообразие горно-геологических и горнотехнических условий подземной добычи полезных ископаемых неизбежно требует создания адекватных и эффективных методов оценки риска, на которой затем строятся все способы технического и организационного управления охраной труда и безопасностью производства.
Добровольность и вариативность процедур оценки риска в международной практике и обязательность детального регламентирования в российской практике, а также сложность этой новой для практики российских горнорудных предприятий целевой задачи, осознание и решение которой только начаты специалистами, обусловили не только отсутствие общепризнанных методов оценки риска, но и методологии их разработки применительно к условиям труда на горнорудных предприятиях России.
На основе критического анализа структуры и содержания опасностей и рисков на подземных горнорудных предприятиях сформулированы методологические приемы построения действенных методик оценки рисков. Основное внимание уделено оценке профессиональных рисков анатомического травмирования или острого ингаляционного отравления.
Осуществлен детальный пошаговый анализ развития неблагоприятного события – несчастного случая в ходе выполнения работающим лицом своей трудовой функции. За исходный пункт взято понятие «свойство» производственной среды и трудового процесса, способное при случайном контактном воздействии на организм работающего персонала причинить вред различной степени тяжести, вплоть до смерти пострадавшего.
Показано, как логически связанные между собой понятия «опасность», «профессионально значимая опасность», «носитель опасности», «источник опасности» позволяют построить ясную процедуру идентификации профессионально значимых опасностей и логично осуществить процедуру оценки риска, включая оценивание различных типов риска по их уровню (степени) допустимости и приоритетности принятия управленских решений и защитных мероприятий.
Статья раскрывает сущность проблемы и дает примеры построения конкретных методик, выявляя и преодолевая «узкие места» оценки рисков на горнорудных предприятиях.
Результаты исследования применены на практике и могут быть рекомендованы специалистам при проведении оценки профессиональных рисков на горнорудных предприятиях.

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Introduction

The transition of the compliance practice of health and safety mandatory requirements fulfillment to a risk-based approach to the management decisions selection, a large number of new requirements of recent regulatory documents of so called regulatory guillotine, which took place on January 1, 2021, as well as new X section Labor Protection of the Labor Code of the Russian Federation which comes into force on March 1, 2022, revealed a layer of methodological challenges of occupational health and safety corporate management related, in particular, to the lack of generally recognized methods in the Russian Federation for identification, analysis and assessment of occupational risks, the type of risk for mining enterprises which is the largest by the number of cases and the most variable.

Such risk type variability on top of the variety of content and nature of labour conditions associated with diverse situations in underground mining, extracted ore treatment processes, large-tonnage products logistics requires adequate variability of risk identification, assessment and analysis methods.

This means that the starting point for development of various methods and their combination into a systemically linked complex for Russian mining enterprises is a unified scientifically grounded methodology, set out in the framework of the Russian-language research vocabulary.

This article is devoted to the findings presentation and development of the methodology.

Research Methods

The main objective of the study is to build a unified methodological concept of the essence, place and role of occupational risks among all the risks of a mining enterprise, which would make it possible to regulate the use of various methods of risk assessment and analysis in relation to the assessment of occupational risks that represent a subsystem of the occupational health and safety management system.

Theoretical analysis of reality, critical analysis of published works and regulatory legal acts, various standards: international, interstate, national Russian, as well as comprehension of the authors' practical experience in development and introduction of documents for occupational risk assessment at a number of enterprises formed the ideological basis of this work.

The research was aimed at creation (in addition to the methodology) of clear and practice-oriented methodologies for the risk assessment and evaluation.

An impact of the relationship of regulatory legal requirements and technical challenges on the occupational risks assessment methodology

Currently, a risk-oriented approach to the enterprise safety management is developed in the mining industry mainly within the framework of industrial safety [1–4].

The innovations of the recently adopted Federal Law On Mandatory Requirements in the Russian Federation dated July 31, 2020 No. 247-FZ built a new concept for the state regulation development also in the field of occupational health and safety based on a risk-based approach and mandatory requirements driven by the risk-of-harm concept. An important innovation was that from now on, the mandatory labor protection requirements including the occupational risks assessment enshrined in the new edition of the Labor Code of the Russian Federation shall be reasoned and performable.

In the Russian legislation and in practical methods, this problem is fully solved only for the so-called harmful occupational factors by means of a special assessment of labour conditions within the current hygienic rating system [5, 6].

The issues of occupational risk assessment for much more common events of anatomical injury and acute inhalation exposures (typical for underground mining operations) remain unresolved (see e.g. [7–15]).

Therefore, instead of risk assessment procedures generally accepted abroad, we use traditional approaches of statistical and/or monographic research of the general situation in the industry and individual cases of injuries [16–19].

The situation is complicated by the fact that the foreign risk assessment experience [20] in the framework of occupational health and safety [21, 22] of all persons employed by a production developer cannot be copied and transferred to the Russian management conditions because the foreign risk assessment is an extensive and voluntary procedure and its recommendations are more of a conceptual nature, while in the Russian Federation, the occupational risk assessment is mandatory, applies only to employees working under an employment contract and is strictly regulated with appropriate liability in the form of fines sanctions [23, 24].

At the same time, the legal strengthening of general mandatory requirements and their regulation is accompanied by the approval of the employer's right to develop their own "technical" assessment procedures and their variable application, which becomes especially important in the absence of technically competent solutions applicable in practice, as well as the methodology of their independent development by a production organizer.

The professional risk assessment procedure is included in the corporate management [25, 26] which simultaneously regulates, firstly, the labor activity of employees, and secondly, the production and economic activity of a production developer.

On the one hand, corporate management procedures are based on mandatory legal requirements, and on the other hand, their practical implementation rests on the natural and technical scientific laws. This duality of activity having legal and technical components is also appropriate for the risk assessment.

Although ultimately all actors of labor protection (employees, employers, state) are consequentially interested in professional risks of disability and results of their implementation, i.e. accidents at work and occupational diseases, the assessment of these occupational risks of disability is based on the hazard risk assessment (including harmful conditions), the damaging potential of which can lead to disability under certain conditions.

Creation of the Hazard Essence and Risks by Mechanisms of Adverse Events in Production

In order to understand the cause-and-effect links of hazards of the mining industry and risks of their impact, as well as results of their impact in the form of occupational risks of disability, let us consider the mechanisms of adverse events occurrence in more details.

Note that in the Russian-speaking Soviet and Russian professional discourse, the concept of "harmful and hazardous occupational factors" was and is being used. At the same time, harmful factors can turn into hazardous ones, and hazardous factors are the ones that cause injury or death of the victim. An exhaustive classification of these factors by the nature of their impact on the human organism is given in the interstate standard GOST 12.0.003-2015 Occupational safety standards system. Dangerous and harmful working factors. Classification, developed with our leading participation.

The Hazard concept was introduced into regulations and standards only in the new edition of the Labor Code of the Russian Federation (it will come into force on March 1, 2022), but, unfortunately, it is not defined quite correctly there: "hazard is a potential source of harm that poses a threat to life and (or) health of an employee in the course of employment".

In this definition, as in many others, Hazard is linked to the source of harm that only "potentially" threatens life and health. According to our practice this definition or a similar one is poorly understood in the hazard identification process at specific workplaces.

Our definition of hazard is based on the analysis of reality and rests on the fact that the material world of production consists of objects and processes of their interaction. All of them (objects and processes) have certain properties that we use, for example, the energy of the rock destruction by teeth of a mining machine cutting unit, or that we could not get rid of in the present-day mining, for example, the combustible gas bleeding.

We are convinced that those inherent properties of objects and processes which under certain circumstances, often random and almost unpredictable, can "harm" workers should be called "hazards".

We will not cite here many definitions of hazard published in scientific articles and provided in regulatory documents, which attribute various characteristics to hazard but do not take into account the fact that hazard is a property of objects and processes of the real world that can cause harm (for occupational risks it is required to add: to an organism of personnel employed in production to a disability or death of a victim).

Seemingly, this purely terminological definition of the "hazard" concept is very important from the methodological point of view for the risk assessment since it objectifies and specifies hazard and correlates it with the technological process properties. Such a definition turns the understanding of "hazard" not into a potential threat that is vague for perception and often unclear for an appraiser, but into a real specific property of the working environment and the labor process – labour conditions that can be identified within the hazard identification.

This definition, and our practice confirmed it, allows to make the hazard identification a clear and precise procedure for identification of presence / absence of properties of the production environment, labor process, equipment, tools, materials, raw materials and end products (especially chemical synthesis), as well as "personal properties" of personnel, the so-called human factor.

Since all of the above properties are different in normal, abnormal (in case of incidents) and emergency labour conditions of the production personnel, the risk assessment shall be carried out for all these conditions. At the same time, the search will focus on the identification of new properties that represent new hazards to working personnel.

The next important methodological technique of the hazard identification is the revealing of "hazard carriers". As we have already determined hereinbefore, hazard is a property characteristic of an object and an interaction process of these objects. For example, toxicity is a serious adverse property of many chemicals that have this property. The concept of toxicity is abstract without a specific substance.

The heuristic importance of the "hazard carrier" concept introduction to the risk assessment results from the concreteness of this concept, because the protection of a working person does not come from toxicity (it is unavoidable), but from the ingress of a toxic chemical substance into the body (or on skin and/or mucous membranes). It is possible to deal with the toxicity itself only after a chemical enters the human body, e.g. by an antidote introduction, but the risk assessment is needed not to treat the victim, but to prevent the effect of this chemical on the body of a working person.

Analysis of real situations at specific mining workplaces shows that in addition to the "hazard carrier", an important role is played by "hazard sources", which, as a rule, have "hazard carriers". For example, steam (the property of which – high temperature – is hazardous) as a hazard carrier is located in the hazard source – the steam line.

Practice has shown that even such above-mentioned hazard identification concepts introduced by us (only small nuances of discourse) are capable to transform the risk assessment procedure from an incomprehensible and abstruse to rather precise and clear for experts, and most importantly, with a minimal touch of the assessment subjectivity. A Hazard Identifier uses the Hazard Classifier and starts to search for the appropriate "sources" and "carriers", which is available, understandable and monotonous.

If a hazard carrier leaves the source, which in itself happens by accident, then it can affect a working person's body and cause harm.

The classical risk identification is a combination of the exposure possibility and the severity of consequences (result) [27]. The "combination" concept is of key importance in this definition, and its type, by the way, is unknown. The logic of the sequential development of the idea of two criteria combination without specification of this combination essence leads to the simplest matrix method of risk presentation since an elementary combination is a graphical cell intersection of two ranking scales steps: the possibility of impact, the significance of consequences.

Features of Risk Assessment and Evaluation

The Risk Assessment is [28, 29] a general procedure for identification of hazards and risks of their effects and determination of "occupationally significant hazards" and risks of their effects.

In our country, there is a fairly widespread opinion that the risk "value", "severity", "magnitude" can be calculated. Although the law says "risk assessment", the discourse is interspersed with attractive words – "risk calculation". The objective condition for the appearance of such, alas, misconception is the following.

Occupational risks are a part of the personnel labor activity, and their labor functions of "live labor" implement production functions of the technological process that is a part of the employer's business activity, which in turn is a part of the economic activity of a business entity.

The results of economic activity in general are both more significant and more serious for them in terms of economic indicators (the scale of income or damage) than successes/failures of business activities. The touchstone of such indicators is a quantitative measure – the number of certain monetary units. Therefore, the economic (and financial) risks of entrepreneurial activity have been of interest for a long time, and the possibility of using a "number" developed an idea of the quantitative "risk calculation" possibility. This is legitimate since the total damage / income is equal to the amount of damages/incomes, etc., since all criteria of the economic activity efficiency are built on a quantitative basis or have their own quantitative "indicators" where possible.

Accidents and incidents of production activity are much more significant (bigger) in their economic equivalent than the corresponding labor activity events – dangerous incidents or accidents, and therefore everyone knows that a lot of attention is paid to the prevention of accidents and incidents. Adverse events in production activities are associated with the functioning of equipment and technologies, but the problems of reliability with its probabilistic methods and calculation are in the first place.

The experience and traditions of these spheres (economic and industrial) dominate attempts of self-determination of professional risk assessment methods, for which no direct calculations are possible, and the assessment exists within the framework of verbal or verbal-point ranking methods.

The verbal ranking method uses a scale of order and a scale of names, and verbally formulates each gradation (rank, level, degree, magnitude, index, cell, interval) of the ranking scale.

The verbal-point ranking method, in addition to the verbal description of the gradations, which is indistinguishable from the description by the verbal method, additionally assigns a conditionally selected number of points to each gradation and then tries to use points as numbers. The Fine – Kinney method is a classical example of these methods [30, 31].

Verbal Description of the Gradation Essence in Risk Assessment

The choice of the "gradation" content is essential in the ranking. It shall be different from other gradations, and it shall be easy to identify in practice. In addition, it shall be written clearly and understandably for an appraiser.

The opportunity to find and download a ready-made risk scale from the Internet is a great detriment for the experts. This kind of scale is often erroneous, chosen uncritically. It allows to carry out the professional risk assessment required by law only formally.

It is not difficult to use well-known types of work-related accidents or illnesses that differ in severity to scale the significance of an adverse event. Significant differences between scientific ranking criteria and legally enshrined norms make an appraiser to face a dilemma, which will be probably never fully and rationally justified.

In general, the choice of scientifically based ranking criteria for the assessment of the risk significance of anatomical injury or acute toxic injury is as follows: no injury; micro-injury that does not cause disability; short-term disability; long-term disability; permanent occupational disability; permanent general disability; death of the victim. This scale is quite complete, detailed and rational, but limits appraisers in comparing their results with the results of other appraisers, since, alas, it is not generally accepted. The researcher using it can only use the data obtained from this scale. Unfortunately, all researchers strive to create their own scale by converting scales existing in the Internet.

According to our practice it is required to select the ranking gradations based on the criteria used by the authorities for the significance of various adverse events of anatomical injury and acute toxic poisoning: unrecorded accidents, including micro-injuries; accidents with minor injuries at a workplace; accidents with heavy injuries at a workplace; fatal accidents at a workplace; group accidents at a workplace.

When reading the above gradations, the heaviness of wordings, some illogicalness and "unevenness" of these practice-oriented gradations are clearly visible, but these drawbacks shall be neglected. The fact is that these gradations are used in representative statistics that can be introduced into scientific discourse, which makes the above system of gradations for occupational injury risks ranking acceptable for wide practical implementation.

Unfortunately, the assessment of occupational risks associated with harmful production factors is performed in a different way and is strictly regulated by the legislation on special assessment of labour conditions, as well as by the SanPiN (sanitary regulations and standards) of Rospotrebnadzor (Russian consumer protection agency). These assessments are based on completely different principles and are well scientifically and statistically substantiated, but they are suitable only for predicting the loss of health, e.g. hearing loss in case of prolonged constant exposure [32–39], and their results are almost impossible to incorporate into the overall occupational risks assessment. We have to proceed from the fact that this is a different type of professional risks, and take into account the results of their assessment at final stages of the overall risk assessment procedure.

Let us bring to notice that the use of such widespread gradations as "catastrophic consequences", "mass destruction", etc., is suitable only for the assessment of industrial or military risks, but not for occupational ones. Yes, such situations do happen in principle, for example, an explosion at the coal mine in China claimed more than 1,500 lives. But from the standpoint of explosion prevention we are talking about the explosion avoidance even if it takes the life of only one worker (as happens in potassium mines).

The determination of "possibility" gradations of the hazard impact on the human body seems to be formally simple but it is very difficult practically. Here all the variability of circumstances shows its probabilistic nature, which is not easy to describe in detail, and even in terms that are familiar and obvious to a risk appraiser.

It is not difficult to write a number of possibility scale gradations like: almost never, very rarely, rarely, often, very often, constantly. But how do we define these gradations in practice in a uniform way, because it is not clear what they mean?

For example, an injury of a worker at the same workplace cannot be constant or often, since labour conditions must be improved after the first incident so the event never happens again. Rewording of the same content with words like every shift, weekly, monthly immediately raises the question: what does an occupational safety and health division do, why is the personnel constantly injured?

Of course, an accident of a certain severity can, in principle, happen again, but in other labour conditions of other workers, since each accident is somehow unique. Such gradations are not suitable for the risk assessment at a workplace. They puzzle the appraisers. They can be used for the overall picture in an industry, a country, the world. But they do not give anything for the specific risk prevention at a specific workplace because you need to know the hazard and how or why it affects workers and causes these consequences for the victim.

The concept "rarely" is widely used in everyday discourse, but it shall be formalized and given some kind of "criterion content" in order to assess the occupational risk possibility/probability.

For example, real statistics for fatalities show 1–5 cases per 100 thousand employees a year in Europe, 1–2 cases per 10 thousand employees in Russia. It is about 100 times more often than the value taken (for psychological reasons) as practical zero of 1 case per 1 million opportunities per year.

However, the criterion of “rarity” for fatal occupational accidents cannot be applied to accidents of a different severity. It is known that there are much more cases of non-fatal injuries, which means that the "rarity" criterion is different [40].

This means that each significance (severity) gradation has a criterion for the "critical frequency" of events and, in general, one criterion will not be enough for the risk, a full range of criteria is needed.

We repeat that in order to assess the possibility one often uses such wordings as: an event occurs: constantly, every shift, weekly, monthly, several times a month, once every six months, once a year, once every three years, once every ten years, etc. Such wordings seem understandable, but the question is: where do these events take place – in an enterprise with 10 thousand employees or at one workplace for one hazard, e.g. rockfall. Yes, it is rare for large enterprises, but such events occur, because it is not always possible to foresee everything, and a slightly increased invisible fracturing caused by rock pressure leads to a sudden roof break. But how to assess it for a mine? Extremely rare, but possible?

The foregoing makes it possible to conclude that the classical assessment based on the statistics of events rarity does not work quite correctly, and therefore does not allow obtaining objective information. This is due to the fact that such occupational risk assessment is tied not to the possibility of exposure, but to the possibility of certain exposure consequences, and this is not the same thing.

We believe that in order to assess the hazard impact possibility, it is necessary to create the possibility scale in a different way.

In our practice we use the following scale: almost impossible; possible, but unlikely; possible in typical circumstances; highly possible (limited only by strict implementation of all technological regulations, safe work procedures and labor protection requirements).

Probability category point	Consequence category point			
	$S = 1$	$S = 2$	$S = 3$	$S = 4$
$L = 4$	$R = 4$	$R = 4$	$R = 12$	$R = 16$
$L = 3$	$R = 3$	$R = 6$	$R = 9$	$R = 12$
$L = 2$	$R = 2$	$R = 4$	$R = 6$	$R = 4$
$L = 1$	$R = 1$	$R = 2$	$R = 3$	$R = 4$

a

Probability category point	Consequence category point			
	$S = 1$	$S = 2$	$S = 3$	$S = 4$
$L = 5$	$R = 5$	$R = 10$	$R = 15$	$R = 20$
$L = 4$	$R = 4$	$R = 4$	$R = 12$	$R = 16$
$L = 3$	$R = 3$	$R = 6$	$R = 9$	$R = 12$
$L = 2$	$R = 2$	$R = 4$	$R = 6$	$R = 4$
$L = 1$	$R = 1$	$R = 2$	$R = 3$	$R = 4$

b

Probability category point	Consequence category point						
	$S = 1$	$S = 2$	$S = 3$	$S = 4$	$S = 5$	$S = 8$	$S = 10$
$L = 6$	$R = 6$	$R = 12$	$R = 18$	$R = 24$	$R = 30$	$R = 48$	$R = 60$
$L = 5$	$R = 5$	$R = 10$	$R = 15$	$R = 20$	$R = 25$	$R = 40$	$R = 50$
$L = 4$	$R = 4$	$R = 4$	$R = 12$	$R = 16$	$R = 20$	$R = 32$	$R = 40$
$L = 3$	$R = 3$	$R = 6$	$R = 9$	$R = 12$	$R = 15$	$R = 24$	$R = 30$
$L = 2$	$R = 2$	$R = 4$	$R = 6$	$R = 4$	$R = 10$	$R = 16$	$R = 20$
$L = 1$	$R = 1$	$R = 2$	$R = 3$	$R = 4$	$R = 5$	$R = 4$	$R = 10$

c

Probability category point	Consequence category point			
	$S = 1$	$S = 2$	$S = 3$	$S = 4$
$L = 4$	$R = 5$	$R = 6$	$R = 7$	$R = 4$
$L = 3$	$R = 4$	$R = 5$	$R = 6$	$R = 7$
$L = 2$	$R = 3$	$R = 4$	$R = 5$	$R = 6$
$L = 1$	$R = 2$	$R = 3$	$R = 4$	$R = 5$

d

Probability category point	Consequence category			
	$S = 1$	$S = 2$	$S = 3$	$S = 4$
$L = 3$	$R = 6$	$R = 9$	$R = 11$	$R = 12$
$L = 2$	$R = 3$	$R = 5$	$R = 4$	$R = 10$
$L = 1$	$R = 1$	$R = 2$	$R = 4$	$R = 7$

e

Probability category designation	Consequence category designation			
	$S1$	$S2$	$S3$	$S4$
$L5$	$R = 13$	$R = 7$	$R = 3$	$R = 1$
$L4$	$R = 16$	$R = 9$	$R = 5$	$R = 2$
$L3$	$R = 18$	$R = 11$	$R = 6$	$R = 4$
$L2$	$R = 19$	$R = 14$	$R = 10$	$R = 4$
$L1$	$R = 20$	$R = 17$	$R = 15$	$R = 12$

f

Fig. Examples of possible point risk ranking in matrices: *a* – *c* – the risk rank is obtained by multiplication of ordinal numbers of the probability and consequences categories; *c* – adapted according to [50]; *d* – the risk rank is obtained by adding of ordinal numbers of the probability and consequences categories; *e* – the risk rank is determined by diagonal selection of 12 possible numerical values; *f* – the risk rank is determined by developers of the matrix (adapted according to [51])

An important methodological issue is to determine the number of gradations placed on the ordinal scale. This number seems to be random. From the point of formation of the scale itself, it can be any number, but from the point of an appraiser, it is a very small amount that can be identified in practice.

There are three classical gradations – two extreme ones are clearly distinguishable – conditionally low and high, as well as medium, poorly distinguishable in practice.

If necessary, the medium gradation can be further divided into three gradations, which makes five gradations in total.

Practice has shown that 3–5 gradations of each scale are quite enough to assess the risk.

Verbal-Point Ranking in the Risk Assessment

After development of verbal gradations of the significance scale and the possibility scale we can assign a certain number – a point to each gradation.

The use of points for different risk components allows to create a certain risk index also expressed in points. In a number of cases it turns out to be convenient, the main thing is not to go beyond the conditionality of points, not to believe in the power of arithmetic operations with them.

When entering points, it should be considered that the gradations are unevenly distributed, and, for example, their numbering (or ranks) 1, 2, 3, 4, 5, etc., does not reflect the real difference in the assessed gradations. Experience has shown that it is more advisably to describe the difference in the severity of consequences close to their observed frequencies, i.e. not less than: 1, 10, 100, 1000, 10,000.

The good thing about the number "1" is that when it is multiplied by any other value it does not change the latter. The increment of the number is necessary so that the numbers are psychologically different, because they are only a conventional designation in points of the place of different gradations on the ranking scale.

The difficulties of the ranking generalization by different scales were clear half a century ago, when Fine and then Kinney assigned a conditional score to each gradation (rank, degree, level) of the measured qualitative variable and began to calculate a certain designated "calculated" risk in the form of a simple formula (for examples see works [41–44]):

$$R = L \cdot S,$$

where R is the estimated risk in points; L is the possibility of hazard exposure, in points; S is the significance of hazard consequences on the employee's organism, in points (the meaning of abbreviations: R for Risk, L for Likelihood, S for Severity).

Features of the matrix method affecting its reliability.

The matrix itself is a table. Despite the simplicity of its form the risk matrix is rich in its content, and any drawbacks of the "methodology" can lead to errors in the method and the risk assessment procedure as a whole (see, for example, [45–49]).

There are various possibilities of graphical construction of the matrix (figure).

The coordinates arrangement at the zero of the scale extending from 0 to infinity is traditional, it determines the similarity of the risk matrix construction. However, this construction of the matrix is focused on the lower left corner, i.e. at low risk levels. According to our experience it is advisable to construct the matrix differently.

There are two options for the matrix construction. The first option: both scales of the matrix are built from maximum to zero, with the consequences severity scale going down vertically and the event possibility scale going horizontally.

The second option is to build a vertical (severity of consequences) from 0 to maximum, and put opportunities horizontally from maximum to zero.

As a result, the choice of the risk matrix type is determined by the perceptual psychology of its creator, which shall be taken into account by new researchers.

The matrix type is arbitrary, but in one case it allows obtaining more reliable information, and in the other case it is more difficult and maybe even unachievable.

We have to consider that in the matrix method many appraiser forget about the fact that the given hazard exposure under consideration inevitably leads to these consequences. Therefore, the risk is not just a combination of possibility and significance, but the possibility of this and only impact that can lead to the considered consequence.

In order to clarify this issue it is required to look at this whole procedure not in the sequence of the event development, but in the reverse sequence, based on the final result of the consequences with the possibility assessment (this may or may not happen).

If we used the bow-tie analysis of events we would not go from left to right, from causes to effects, but from right to left, i.e. from effects to causes.

It is this methodological technique that makes it possible to determine and understand that in order to get a fixed result the risk essentially becomes not a "combination" difficult for a researcher to perceive, but a pure "possibility" (e.g. a minor injury due to a given hazard).

This clarification greatly simplifies the assessment procedure, since an appraiser now evaluates not the most probable combination, but a certain probability of a real event possibility, which is closer to practice. The assessment itself becomes clearer, simpler, more explicit but at the same time more time-consuming, because instead of making one choice from the entire spectrum of opportunity and significance gradations we shall make a choice of the opportunity gradation for each significance gradation which increases labor inputs several times (usually by 4–5 times).

The Risk of Injury of an Employee or the Risk of Injury at a Workplace

Any adverse event is studied in occupational health and safety from two viewpoints. Firstly, from the viewpoint of the event prevention, where an employer shall assess the risk of exposure to a hazard that can harm a victim, and secondly, from the viewpoint of compensation for damage caused to a victim by a harm-doer.

Of course, disability or death occurs with victims, and it is required to know the employees occupational risk in order to protect them. However, historically the occupational risk assessment is considered for a "workplace" where several people can work, and the English word "workplace" had a negative impact on the assessment, because in the legal language it means "a place of work" and not a physical work area where an employee works during working hours.

The increased attention to labour conditions at a workplace, implemented in the special assessment of labour conditions as a type of occupational risk assessment, masques the fact that employees move through the territory and space of the employer's production facilities at least twice: when they come to work and leave it. And many employees, e.g. electricians on duty, technicians or servicemen, do not have a permanent workplace at all, they move around all facilities controlled by the employer (temporary workplaces).

This circumstance must be taken into account during occupational risk assessment, since it includes the risks of falling when employees walk. If we look at the results of the occupational risk assessment, almost all of the respondents name the risk of injury due to falling while walking.

Moreover, the issue of group accidents prevention in the monographic analysis of injuries comes to the question: where can a group of people be injured at once? The answer is clear: it is where a group of employees gathers, or during an accident involving more than one workplace. For example, in case of fire, explosion, mine roof collapse, etc. and during movement: in buses, cages, trolleys of underground rail transport, etc.

The occupational risk assessment of these situations shall be studied separately, specifically, by special monographic methods and together with specific circumstances in addition to the classical assessment of hazards at a permanent workplace.

The Risk as a Priority Ranking Tool of Risk Management

The classical risk assessment method ends with an assessment of its acceptability to resolve the issue of further work with the identified risks. Our practice shows that the risk assessment is actually used to assess the priority degree for the development and implementation of measures to prevent a certain type of event (industrial accidents).

Thus, although the current requirements of regulatory acts (for example, the Model Regulations on special assessment of labour conditions) aim a risk appraiser at the assessment of occupational risks of all identified hazards (there are about a hundred hazards at each workplace of production shops), the real logic leads to an assessment of the priority of measures development and their implementation to improve labour conditions at a workplace, reduce the occupational risks level.

Therefore, after the risk assessment (actual possibility for a fixed consequence) for each consequences severity gradation, we determine its tolerance and management priority.

We consider the following risk priority scale to be justified for practical use:

– the high priority risk is the unacceptable risk in practice, in respect of which management measures shall be obligatorily implemented as a matter of priority;

– the increased priority risk is the practically acceptable risk at the level of ALARP/ALARA admitted (accepted) in the company [52]; this is the risk which does not require urgent implementation of control measures, but it shall be under constant careful control, and personnel shall be allowed to perform production operations of this risk under the condition of strict adherence to all previously defined and implemented safety measures and requirements;

– the standard priority risk is the acceptable risk that does not require special attention, and supports the adopted and already implemented system of labor protection measures.

Let us emphasize that the final result of the risk assessment is the risk management priority ranking. Now we can proceed to the risk management, where the persons who take protective measures against hazards and risks are again interested in the hazards, and not in the risks of their impact.

At this stage of the labour conditions special assessment procedures, the occupational risk assessment fulfilled its purpose: it determined the priority of work on the improvement of labour conditions and risk mitigation. Starting with the material specifics, the hazards, it leads us through the subjectivity and evaluation conventions of the matrix method and various ranking sequences to the objectively existing specifics, but now these are protective measures against hazards and risks of their impact on a working person's organism. A new stage of ensuring occupational safety and health management within the corporate governance system is opening.

Conclusion

The result of this study was the study and conceptual and terminological reflection of various aspects of the occupational risk assessment procedure associated with production activities, in accordance with the reality of underground mining operations at mining enterprises.

According to the current practice, the construction of adequate risk assessment methods, on the results of which all risk-oriented management is based within the corporate health and safety management systems, is practically impossible without this conceptual and terminological ranking.

Our developed methodological approach made it possible to build, firstly, a complex of risk assessment methods adequate to the reality of mining, and secondly, as a consequence of the first, a set of decision-making criteria, as well as the development and implementation of protective measures against hazards and risks.

It will increase the safety management reliability for underground mining by means of occupational risk management, including risks of the hazard impact on a worker's organism, and reduce occupational risk assessment costs.

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