https://doi.org/10.33271/nvngu/2024-4/086

V. I. Golinko[*],
orcid.org/0000-0001-6069-0515,
V. A. Zabelina,
orcid.org/0000-0002-7678-7917

Dnipro University of Technology, Dnipro, Ukraine
Corresponding author e-mail: golinkongu@gmail.com

FEATURES OF THE ASSESSMENT OF OCCUPATIONAL RISKS UNDER HAZARDOUS WORKING CONDITIONS

Purpose. To improve the process of assessing occupational risks caused by hazardous working conditions, taking into account the exposure of hazardous factors, as a quantitative characteristic of the intensity and duration of the hazardous factor, and the available results of certification of workplaces in terms of working conditions.

Methodology. Theoretical studies are based on the use of the basic provisions of probability theory, methods of mathematical modeling, statistical processing of indicators of occupational morbidity and methods of risk assessment by constructing a matrix of consequences/likelihood according to the ISO 31010:2013 standard.

Findings. A matrix of consequences/likelihood for assessing the overall occupational risk to the health of employees caused by hazardous working conditions is proposed, which includes five indicators characterizing the severity of the consequences, and five indicators characterizing the probability of an event (qualitative and score ones). The peculiarity of the matrix is that the probability score directly reflects the multiplicity of exceeding the permissible values of hazardous production factors established by regulatory legal acts which characterize working conditions.

Originality. A new approach to determining the seriousness of the consequences of hazardous production factors has been proposed, which consists in taking into account the regularities of occurrence of occupational and work-caused morbidity of workers and the existing mechanisms for its prevention. The relationship between the prevalence of certain types of occupational morbidity of workers and specific working conditions (exposure to factors of the production environment) has been established.

Practical value. The results of the study allow employees of safety departments to assess the overall occupational risk to the health of employees, caused by hazardous working conditions, directly on the basis of the available cards of working conditions obtained as a result of certification of workplaces on working condition. Based on the results of the assessment, it is possible to determine the permissible time of the employee's work in hazardous working conditions, for which the permissible value of the risk of occupational disease is not exceeded.

Keywords: *occupational disease, risk, hazardous production factor, working conditions, exposure*

Introduction. According to the International Labor Organization, about 2.8 million people die annually in the world as a result of exposure to hazardous and harmful production factors persons [1]. It is characteristic that the mortality rate of workers from occupational diseases is more than 6.5 times higher than the mortality rate from occupational injuries [1]. This indicates the low effectiveness of measures and means to prevent the occurrence of occupational diseases. One of the reasons for this is the imperfection of existing approaches to assessing occupational risks caused by hazardous working conditions.

The concept of risk is now extremely widely used in all spheres of economic activity, including to assess the current state of working conditions and safety in the workplace and forecast their changes in the implementation of safety measures and means, the economic feasibility of measures aimed at improving the safety of equipment and the introduction of new safe technological processes.

According to DSTU ISO 45001:2019 [2], occupational health and safety risk is defined as a combination of the probability of occurrence of a hazardous event or work-related impact and the severity of the injury and deterioration of health that may be caused by the event or impact.

The risk management process is widely used in occupational health and safety management systems to substantiate management decisions to reduce the level of injuries and occupational diseases [3, 4]. There are a significant number of different approaches to risk management, the choice of which for organizations is not limited by law [5, 6]. An important condition for choosing one or another approach is its effectiveness and compliance with the working conditions at a particular facility.

In accordance with DSTU ISO 45001:2019 [2], certain requirements for the risk management procedure are established for occupational health and safety management systems. It is usually carried out in several steps: identification of dangerous and hazardous factors, determination of the consequences of their impact on employees, risk assessment, justification of preventive and protective measures, verification and improvement of the previous stages [7, 8]. To do this, the employer must have reliable and reasonable ways to identify risks in each workplace, as well as be able to analyze and, accordingly, manage them.

The variety of hazard manifestations corresponds to the variety of risk assessments, which is reflected in their classification. In the field of risk analysis, depending on the purpose, a wide variety of criteria are used, according to which their classification is carried out [9]. In the field of occupational health and safety, the concepts of occupational risk and occupational risk are widely used. According to DSTU 2293:2014 [10], production risk is defined as the probability of damage to the health of an employee in the course of employment, damage to property, the environment, which is caused by the harmfulness and/or danger of production and technological processes. Occupational risk, according to the current Hygienic Classification of Work [11], is the probability of violation (injury) of the employee's health, taking into account the severity of the consequences due to the adverse effects of factors of the production environment and the work process. The latter concept is harmonized with the concept of risk defined by international standards [2]. This leads to the fact that now the main focus is on the assessment and management of production risks.

Literature review. General requirements and recommendations for risk assessment in the occupational health and safety management system are set out in DSTU IEC/ISO 31010:2013 Risk management. Methods of general risk assessment (harmonized with IEC/ISO 31010:2009) [12]. The risk assessment process is defined as the sequential execution of the stages of identification, analysis and determination of risk. Identification is the process of identifying, recognizing, and describing risks. Analysis is the process of determining the nature and level of risk. Risk analysis consists of determining the consequences and their probabilities in relation to identified risk events, taking into account the availability and effectiveness of safety measures, as well as the level of risk. In this case, the level of risk is determined by a combination of results regarding the probability and consequences of the identified events [12].

In accordance with this, risk assessment is a thorough study of the factors that, under certain conditions, can cause harm, in order to assess the sufficiency of decisions already taken or the application of additional precautions aimed at improving working conditions and safety. To do this, the employer must have reliable and reasonable ways of determining occupational risk in each workplace, as well as be able to analyze and, accordingly, manage them.

DSTU IEC/ISO 31010:2013 [12] provides examples of more than twenty different methods that are recommended for general risk assessment and signs of choice of assessment methods. It should be noted that in order to assess risks using most of these methods, employees need to have a thorough training in mathematics and probability theory. Therefore, for the risk assessment process, expert methods should be used in the form of separate methods and their combinations according to the criteria of applicability [13].

In scientific publications on occupational risk assessment, the consequences/likelihood matrix and the "Bow Tie" model are often used [14, 15].

Scales for consequences/likelihood can have 3, 4, 5 or more levels. To rank risks, first find a sign of a consequence, and then determine the probability with which this consequence occurs.

Also, according to the ISO 31010 standard, two types of risk indicators can be used for risk analysis in occupational health and safety management systems: quantitative or qualitative (for example, low risk, tolerable, significant, critical, catastrophic or other similar assessments). Occupational safety and health specialists mostly use expert methods for obtaining estimates based on the analysis of the values of frequency and cost risk indicators and subjective risk perception.

The analysis of scientific publications devoted to the issues of occupational risk assessment shows a fairly significant number of them. This is primarily due to the lack of uniform simple methodological approaches that can be used to assess occupational risks. It is necessary to highlight one more characteristic feature identified in the process of analysis. It lies in the fact that the authors mainly pay attention to the assessment of occupational risk caused by the impact of hazardous production factors on workers, and in the analysis of occupational risk caused by hazardous production factors, similar approaches are used [4].

For example, the matrix of consequences/likelihood for assessing occupational risk caused by hazardous working conditions, which is given in [4], includes six qualitative indicators that characterize the severity of consequences, and six qualitative indicators that characterize the probability of an event. At the same time, both the severity of the consequences and the probability of occurrence of occupational diseases were determined on the basis of the value, level or magnitude of the hazardous factor. This approach is valid for random (stochastic) events, when the severity of the consequences and the probability of the event are independent indicators. In this case, the severity of the consequences and the probability of the event are not independent events.

As a rule, consequences/likelihood matrices [12] contain a scoring and/or qualitative risk assessment and, accordingly, a scoring and/or qualitative assessment of the severity of consequences and the probability of events. At the same time, the value of the risk score depends on the adopted scale for consequences and probabilities. In different organizations, in the practical application of the matrix of consequences/likelihood for risk assessment, there are quite different scales for assessing consequences and probabilities. The most commonly used scales are linear with a change in scores, for example, in the range from 1 to 5. In this case, the maximum score corresponding to the critical risk is 25 [4]. When using other scales for scoring assessing consequences and probabilities the maximum risk score is sometimes in the tens of thousands. All this requires additional calculations to determine the level of risk in the generally accepted range of scales, i. e. from 0 to 1, or from 0 to 100 %.

When assessing the severity of the consequences of exposure of workers to hazardous production factors, exposure to hazardous factors is practically not taken into account. At best, the exposure of factors taken into account is reduced to determining the frequency of exposure of the type: daily, shift-based, sometimes, often, etc.

The analysis carried out shows the presence of a number of unresolved issues in the practical use of methods for assessing occupational risks caused by hazardous working conditions. This requires the development of a one-size-fits-all approach that simplifies the procedure and can quickly adapt to specific working conditions.

Purpose. The aim of the article is to improve the process of assessing occupational risks caused by hazardous working conditions, taking into account the exposure of these factors, as a quantitative characteristic of the intensity and duration of the hazardous factor, and the available results of certification of workplaces in terms of working conditions.

Methods. To improve the process of assessing occupational risks caused by hazardous working conditions, analytical methods, methods of probability theory, statistical processing of indicators of occupational morbidity and methods of mathematical modeling and well-known approaches according to the ISO 31010 standard for risk assessment by building a matrix of consequences/likelihood were used in the work.

Results. The analysis of scientific publications devoted to the assessment of occupational risks shows that there are currently no uniform methodological approaches that can be used to assess occupational risks caused by hazardous working conditions. However, there is a clear understanding of what risks are to be assessed and why it is necessary to assess them. There are two main tasks that necessitate the assessment:

- assessment of the general occupational risk to the health of employees, working conditions, i.e. possible consequences of the negative impact of hazardous factors on the health of employees to substantiate preventive measures and choose areas of investment in safety;
- assessment of the individual risk of occupational disease of employees caused by hazardous factors, in order to substantiate preventive measures to prevent them.

Assessments of both the general occupational risk to the health of workers and the individual risk of occupational disease should be based on the available, usable materials of the study of working conditions. The calculated expressions should not contain indicators, the determination of which requires additional studies of working conditions. Therefore, the information basis for the calculation of occupational risk caused by hazardous working conditions should be the materials of certification of workplaces in terms of working conditions – a card of working conditions.

It is expedient to assess the overall occupational risk using a sufficiently tested and accepted method for use in the EU countries according to the ISO 31010 standard, by constructing a matrix of consequences/likelihood [12], the essence of which is to establish the seriousness of the consequences of the impact of hazardous factors on the human body and determine the probability of possible damage to health. The magnitude of the risk will be equal to

$$R = S \cdot P,$$

where R is the risk; S – severity of consequences; P is the probability of possible damage to health.

Taking into account the fact that occupational and work-related diseases arise as a result of constant long-term exposure of workers to hazardous production factors, the assessment of occupational risk caused by hazardous working conditions should be carried out on the principles based on causal rather than probabilistic relationships. Such an assessment should take into account the fact of constant (long-term) impact of hazardous factors of production on employees (exposures), the number of personnel working in the area of exposure to hazardous factors, the type of hazardous factor and its ability to cause irreversible changes in the employee's body that lead to occupational diseases, the severity of diseases and other indicators that characterize working conditions.

The probability of possible damage to health in this case can be assessed directly by the results of certification of workplaces in terms of working conditions. According to the ISO 31010 standard for risk analysis, two types of indicators can be used in occupational health and safety management systems: quantitative or qualitative (e.g. probability of possible damage to health: exceptional, unlikely, moderate, probable, high probable). When assessing the overall occupational risk to the health of employees, it is advisable to use a probability score, which, on the one hand, reflects the level of excess of hazardous factors of their maximum permissible concentrations (MPC) or levels for the relevant class of working conditions, and on the other hand, makes it possible to directly determine the generalized level of environmental risk in the generally accepted range of scales (from 0 to 1, or from 0 to 100 %) without additional calculations. Based on this, Table 1 provides a recommended score for the probability of possible damage to health.

The peculiarity of the given point assessment of the probability of damage to health is its bringing in line with the multiplicity of exceeding the maximum permissible concentration, levels and other characteristics of working conditions determined by the current hygienic classification [11].

Determination of the seriousness of the consequences of hazardous factors should be carried out taking into account the quantitative indicators of the occurrence of occupational and work-related morbidity of workers and the possibility of its prevention. This is possible by analyzing the prevalence of certain types of occupational diseases in different occupational groups characterized by specific working conditions, taking into account the exposure of workers to hazardous factors of the working environment. At the same time, it is necessary to take into account both the type of hazardous factor and their total number (according to which working conditions are classified as hazardous of a certain class and degree) and the direction of action. Based on this, Table 2 provides a recommended qualitative and point assessment of the severity of the consequences of hazardous factors depending on the possible damage to health. This issue needs further clarification from the point of view of occupational medicine.

Fig. 1 shows the matrix proposed by us for assessing the overall occupational risk to the health of employees caused by hazardous working conditions. In this case, the matrix of consequences/likelihood includes five indicators that characterize the severity of the consequences, and five indicators that characterize the probability of the event (qualitative and score ones). The peculiarity of the matrix is that the scoring assessment of probability directly reflects the multiplicity of excess of the concentration of harmful substances, or the value of the indicator that characterizes the impact on the employee of other factors established by regulatory legal acts of permissible values (MPC, levels, etc.). This approach to determining the probability score is based on the assumption of a linear dependence of the probability of occurrence of occupational diseases on the magnitude of the hazardous factor, which is largely valid and is characteristic of factors with a cumulative effect, that is, if they can accumulate and sum up in the employee's body. Thus, based on the results of studies of the impact of dust on the risk of pneumoconiosis occurred, the Instruction for measuring the concentration of dust in mines and accounting for dust loads was developed [16]. According to this instruction, the risk of pneumoconiosis in miners is determined by the magnitude of the dust load. In turn, the dust load on the body of coal mine workers depends linearly on the average variable concentration of dust in the air of the working area and the operating time under such conditions.

This approach makes it possible to assess the generalized level of environmental risk to the health of employees, expressed as a percentage or in fractions of one, directly from the results given in the matrix. Filling in the matrix is feasible for safety departments' employees and is carried out according to the available cards of working conditions, obtained as a result of certification of workplaces in terms of working conditions.

Another important task, which necessitates the assessment of occupational risks caused by hazardous production factors, is the assessment of the individual risk of occupational disease of employees, in order to justify preventive measures to prevent them.

Approaches to assessing the individual risk of an occupational disease differ significantly from the approaches to risk assessment according to the ISO 31010 standard [12], including our proposed approach to assessing the generalized level of environmental risk to the health of workers. The main differences are as follows:

Firstly, occupational diseases caused by the influence of hazardous production factors occur to a greater extent under the influence of their deterministic effects, rather than probabilistic, which is characteristic of injuries. Therefore, forecasting of occupational morbidity indicators, in contrast to forecasting the consequences of exposure to dangerous factors, should be based on principles based on causal rather than probable relationships.

Secondly, in the very term "risk of occupational disease" there is already a consequence of the influence of hazardous production factors – an occupational disease. That is, such a component of expression (1) as S – the severity of the consequences, is a priori known and given.

According to our recommended assessment of the consequences of hazardous production factors, the most serious consequences occur under the influence of harmful substances of hazard class 1, 2 and harmful substances of mainly fibrogenic action, which are characterized by cumulative effects. Among them, a special place is occupied by dust of predominantly fibrogenic action, as a result of which up to 70 % of severe occupational diseases occur in Ukraine.

The method for assessing the individual risk of occupational disease can be based on the approaches to determining the risk of occupational diseases of dust etiology proposed in [9]. The essence of which lies in the fact that occupational diseases occur to a greater extent under the influence of deterministic effects. Such effects are observed when exposure to a haz-

Table 1

Recommended score of the probability of damage to health depending on the class of working conditions

Class of working conditions	Multiplicity of exceeding the maximum permissible concentration of harmful substances, times [11]			Scoring	Qualitative indicator
	chiefly fibrogenic action	general toxic effects of 1, 2 hazard classes	general toxic effects of 3, 4 hazard classes		
Accepted	≤MPC	≤MPC	≤MPC	1	exceptional
hazardous 3.1	1.1–2.0	1.1–3.0	1.1–3.0	2	unlikely
hazardous 3.2	2.1–5.0	3.1–6.0	3.1–10.0	5	moderate
hazardous 3.3	5.1–10.0	6.1–10.0	10.1–20.0	10	probable
hazardous 3.4	>10.0	10.1–20.0	> 20.0	20	highly probable

Table 2

Qualitative and point assessment of the severity of the consequences of hazardous production factors is recommended

Type and total number of hazardous factors according to which the class of working conditions is determined	Severity of consequences	
	Qualitative indicator	Scoring
Meteorological conditions, light environment, aeroionization, hard work, etc. (when determining the class for one factor, as a result of which severe occupational diseases do not develop)	insignificant	1
Meteorological conditions, light environment, aeroionization, hard work, etc. (when determining the class according to several factors, as a result of which severe occupational diseases do not develop)	small	2
Harmful substances of 3, 4 hazard classes, noise, vibration (when setting the class by one factor)	moderate	3
Harmful substances of 3, 4 hazard classes, noise, vibration (when establishing a class for several factors)	significant	4
Harmful substances of 1, 2 hazard classes, harmful substances of predominantly fibrogenic action	unbearable	5

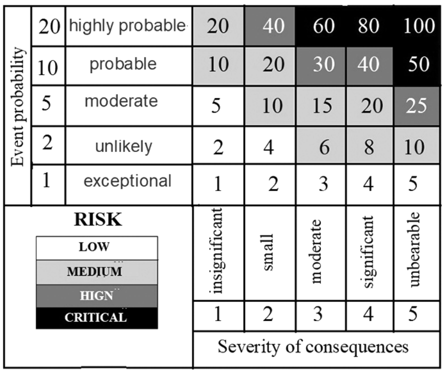

Fig. 1. Matrix for assessing the general occupational health risk of workers in hazardous working conditions

ardous factor exceeds a certain value, which is called a threshold. The greater the threshold, the greater the risk of disease. Based on this, occupational diseases do not occur when the exposure to the hazardous factor is insignificant, and when the threshold is exceeded, there is a linear relationship between the severity of the consequences and the exposure to the hazardous factor (Fig. 2).

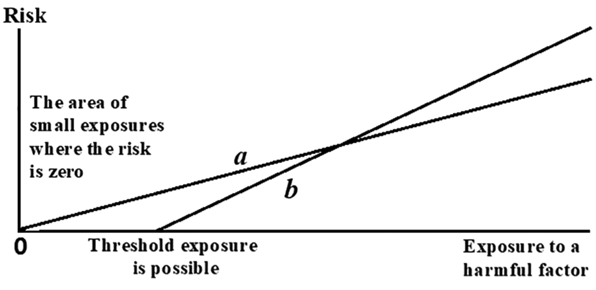

Fig. 2. Correlation of occupational disease risk with exposure to hazardous factor:

a – linear-non-threshold dependence; b – by linear-threshold dependence

Taking into account the fact that, according to [11], occupational diseases do not occur under accepted working conditions, the possible threshold exposure to a hazardous factor can be estimated by calculating the actual value of exposure to this factor under accepted working conditions (i.e., provided that the maximum permissible concentration is not exceeded) for the entire possible period of the employee's work. Obviously, the results of such a calculation will depend on the individual characteristics of the employee, the severity of the work, as well as the presence and number of other impacts on the employee's health. With the current state of research on the impact of hazardous factors on the risk of occupational disease, it is almost impossible to reliably establish a threshold exposure. Therefore, the definition of risk can be based on a non-threshold dependence, according to which any exposure to a hazardous factor causes a certain risk, and the value of risk linearly depends on the size of the exposure.

Despite the insufficient validity of the linear-non-threshold dependence of the risk of occupational disease on the exposure of a hazardous factor, based on the preventive nature of this approach, it is legitimate to assess the risk of occupational disease in proportion to the exposure.

Taking into account the above, we will consider the issue of assessing the individual risk of occurrence of such a common occupational disease in workers as pneumoconiosis. Studies of the impact of dust on the risk of pneumoconiosis in coal mine workers made it possible to establish a critical dust load for various types of dust (breed, coal), at which the probability of disease occurrence reaches 5 %, which are given in the Instructions for measuring the concentration of dust in mines and accounting for dust loads [16]. When determining the actual dust load of employee D (grams) in accordance with this instruction [16], the average variable concentration of dust in the air of the working area C (mg/m^3), the volume of pulmonary ventilation Q (m^3/min), the duration of the work shift t (min) and the number of worked work shifts N are taken into account. The dependence for calculating the actual dust load is as follows

$$D = 0.001kCQtN,$$

where k is a coefficient that takes into account the presence of a dust respirator.

When calculating the actual dust load, difficulties arise due to the lack of reliable information on the average variable dust concentration in the air of the working area, since now, due to the lack of controls, the measurement of the average variable dust concentration is not carried out. Under specific production conditions and the stability of the duration of operations of the technological process, it is expedient to experimentally establish the ratio between the maximum one-time and average variable dust concentration, and in the future not to carry out a rather complicated procedure for determining the average variable concentration, but to calculate it based on the results of certification of workplaces in terms of working conditions, taking into account this ratio.

In the paper [9], taking into account the recommendations of the instruction [16], under the conditions of performing work of medium severity, it is proposed to calculate the individual risk of occurrence of occupational diseases of dust etiology according to the expression

$$p_i = \frac{10^{-6} bkC_{mot}tN}{D_c}, \quad (1)$$

where b is the ratio between the maximum one-time and the average variable dust concentration, determined by the results of studies of specific production conditions and the duration of operations of the technological process; C_{mot} – maximum-one-time maximum permissible concentration of dust; D_c is the critical dust load (the dust load at which the probability of occupational disease reaches 5 %), g.

The coefficient k in the calculation can be defined as

$$k = \frac{1}{K_p},$$

where K_p is the respirator protection factor.

Taking into account the proposed approaches, an assessment of the general occupational risk to the health of employees of working conditions and an assessment of the individual risk of occupational disease in employees are carried out to justify preventive measures to prevent them. The assessment was made for the following conditions:

- hazardous factor – coal-rock dust with free silicon dioxide content, 5–10 %;
- maximum one-time dust concentration – 100 mg/m^3;
- the ratio between the maximum-one-time and average-variable dust concentration is 0.5;
- maximum permissible concentration – 4 mg/m^3.

The assessment was carried out in the absence of personal protective equipment (PPE) for respiratory organs, and under the condition of using dust respirators of different protection classes [17]. With the use of effective PPE, the impact of the hazardous factor on health decreases, as a result of which working conditions can be assessed as less hazardous (according to the certificate of conformity for PPE), but not lower than degree 3.1 of class 3 [11].

The results of the calculation of the total occupational risk to the health of employees of working conditions are given in Table 3. At the same time, the value of the permissible risk of occupational disease is less than 1 %, and the value of D_c for this type of dust is borrowed from [16] and is 510 grams.

For the specified hazardous working conditions in Table 3 also shows the estimated value of the permissible working time of employee T (years) at different lengths of the work shift, at which the risk of occupational disease does not exceed the permissible value. The calculation of T is performed according to expression (2), obtained on the basis of expression (1), provided that the number of shifts worked during the year is 250.

$$T = \frac{40 D_c K_p}{b C_{mot} t}. \qquad (2)$$

From the above example, it follows that when an employee works in hazardous working conditions of degree 3.4, the overall occupational risk to the health of employees is critical, and its score reaches the maximum possible value. The individual risk of occupational disease in employees during an 8-hour shift after the first year of work in such conditions exceeds the permissible value. When using dust respirators with protection class P1, when working conditions can be assessed as harmful degree 3.3, the impact of dust on health is reduced, but the occupational risk to the health of workers remains critical, and its score is halved. The individual risk of occupational disease in employees reaches an acceptable value after 3 years of work in such conditions. A high overall occupational risk to the health of workers remains even with the use of respirators with protection class P2, when working conditions can be assessed as hazardous to degree 3.2. To prevent the development of occupational diseases, the permissible duration of work in this case should not exceed 10 years for an 8-hour shift and 13.5 years for a 6-hour shift.

With the use of PPE with protection class P3, working conditions can be assessed as hazardous to class 3.1 class 3 [11]. In this case, the individual risk of occupational diseases of dust etiology during any possible duration of the employee's work does not exceed the permissible value. The overall occupational risk to the health of employees is medium, and its score remains quite high. This is due to the fact that dust respirators with half masks and full face masks with class P3 filters have a high initial breathing resistance and are quickly clogged with dust, and this leads to an even greater increase in filter resistance [17]. Therefore, even in moderate work, their use leads to overwork of workers and a significant decrease in their ability to work [18]. There have been cases of short-term displacement of the respirator by workers to restore breathing. It is obvious that the only possible way to reduce the overall occupational risk to the health of employees in this case is the introduction of effective means of collective protection, and the use of PPE is a justified measure only if it is impossible or economically inexpedient to provide acceptable working conditions by other measures.

The given assessment of the individual risk of occurrence of an occupational disease of dust etiology was carried out by us in the presence of one hazardous factor – dust, provided that the risk of occupational disease is determined on the basis of exposure to a hazardous factor. At the same time, there are certain difficulties in recognizing the cumulative effect of some hazardous factors [19], which requires the need to clarify the above approach or develop new approaches to assess the individual risk of occupational diseases under their action. Attention should also be paid to the peculiarities of individual risk assessment with the combined impact of a number of hazardous factors on employees, taking into account the complexity of the assessment of the joint action and the complexity of processing the initial data, especially with a significant number of impacts [20–22].

Conclusions. The proposed methodological approach to the assessment of occupational risks caused by hazardous working conditions, based on taking into account the exposure of hazardous factors, as a quantitative characteristic of the intensity and duration of the hazardous factor, allows taking into account the regularities of formation of occupational and production-caused morbidity of workers, as well as the existing mechanisms for its prevention.

Two main tasks have been allocated which necessitate the assessment of occupational risks caused by hazardous working conditions, this is the assessment of the general occupational risk to the health of workers, working conditions, which is necessary to substantiate preventive measures and choose directions for investment in safety, and to assess the individual risk of occupational disease in employees, to substantiate preventive measures to prevent them.

To assess the overall occupational risk, a matrix of consequences/likelihood is proposed, which includes five indicators that characterize the severity of the consequences, and five indicators that characterize the probability of an event (qualitative and point), the peculiarity of which is that the point assessment of probability directly reflects the multiplicity of exceeding the permissible values of the factors established by regulatory legal acts, which characterize working conditions.

Table 3

Results of the assessment of the general occupational risk to the health of employees, working conditions and individual risk of occupational disease in employees

Hazardous factor	C_{mot}, mg/m^3	b	C_{apc}, mg/m^3	Protection classes of respirators	K_p	Class of work condition	Scoring of overall risk	Qualitative assessment of overall risk	Permissible working time T, years	
									8 hours shift	6 hours shift
dust	100	0.5	4	–	–	3.4	100	critical	0.8	1.1
dust	100	0.5	4	P1	4	3.3	50	critical	3.4	4.5
dust	100	0.5	4	P2	12	3.2	25	high	10.0	13.5
dust	100	0.5	4	P3	50	3.1	10	middle	–	–

The basis for determining the risk of individual risk of occupational disease is the linear-non-threshold dependence of the risk value on the exposure to the hazardous factor, according to which any exposure to a hazardous factor causes a certain risk, and the risk value linearly depends on the exposure value.

An example of assessment of the general occupational risk to the health of workers of working conditions and assessment of the individual risk of occurrence of occupational diseases of dust etiology is given, in order to substantiate preventive measures for their prevention, which can be carried out directly on the basis of available cards of working conditions obtained as a result of certification of workplaces in terms of working conditions.

References.

1. International Labour Organization (ILO) (2019). *Safety and Health at the heart of the Future of Work: Building on 100 years of experience* (Report, Geneva). Retrieved from https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_686645.pdf.

2. *DSTU ISO 45001:2019 Occupational health and safety management systems. Requirements and guidelines for application (ISO 45001:2018, IDT)* (2019). Kyiv: UkrNDNC. Retrieved from https://zakon.isu.net.ua/sites/default/files/normdocs/dstu_iso_45001_2019.pdf.

3. Paltrinieri, N., Scarponi, G. E., Khan, F., & Hauge, S. (2014). Addressing dynamic risk in the petroleum industry by means of innovative analysis solutions. *Chemical Engineering Transactions*, *36*, 451-456.

4. Golinko, V., Cheberyachko, S., Deryugin, O., Tretyak, O., & Dusmatova, O. (2020). Assessment of the Risks of Occupational Diseases of the Passenger Bus Drivers. *Safety and Health at Work*, *1*(4), 543-549.

5. Wahyu, N. C., Trika, P., & Bagus, D. (2020). Risk Analysis Using Job Safety Analysis-Fuzzy Integration for Ship Maintenance Operation. *IPTEK The Journal for Technology and Science, 31*(3), 327-342. https://doi.org/10.12962/j20882033.v31i3.5655.

6. Lee, S., Landucci, G., Reniers, G., & Paltrinieri, N. (2019). Validation of Dynamic Risk Analysis Supporting Integrated Operations Across Systems. *Sustainability*, *11*, 6745. https://doi.org/10.3390/su11236745.

7. Hu, Y. (2019). *A New Mode of HSE Risk Management for Construction Projects. Risk Management in Construction Projects*. https://doi.org/10.5772/intechopen.84358.

8. Wahyu, N. C., Trika, P., & Bagus, D. (2020). Risk Analysis Using Job Safety Analysis-Fuzzy Integration for Ship Maintenance Operation. *IPTEK The Journal for Technology and Science*, *31*(3), 327-342. https://doi.org/10.12962/j20882033.v31i3.5655.

9. Golinko, V., & Hridyaev, V. (2022). Forecasting the risk of occupational diseases of dust etiology. *News of the Donetsk Mining Institute, 2*(51), 25-34. https://doi.org/10.31474/1999-981X-2022-2-25-34.

10. *DSTU 2293:2014 Occupational Health. Terms and definitions*. (2015). Retrieved from https://zakon.isu.net.ua/sites/default/files/normdocs/2-9773-ohorona_praci._terminy.pdf.

11. State sanitary norms and rules. Hygienic classification of work according to indicators of harmfulness and dangerous factors of the production environment, difficulty and tension of the labor process. (2014). *Official Gazette of Ukraine, 41*, 95-132 Retrieved from https://zakon.rada.gov.ua/laws/show/z0472-14#Text.

12. *DSTU IEC/ISO 31010:2013 Risk management. Methods of general risk assessment* (*IEC/ISO 31010:2009, IDT*) (2014). Kyiv: UkrNDNC. Retrieved from http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=66723.

13. Yang, X., Haugen, S., & Paltrinieri, N. (2018). Clarifying the concept of operational risk assessment in the oil and gas industry. *Safety Science*, *108*, 259-268. https://doi.org/10.1016/j.ssci.2017.12.019.

14. Kruzhylko, O., Storozh, Ya., Lyutak, Z., & Prakhovnik, N. (2017). Methodological principles of industrial risk assessment when planning preventive measures. *Problemy okhorony pratsi v Ukrayini, 33*, 15-21.

15. Loh, T. Y., Brito, M. P., Bose, N., Xu, J., & Tenekedjiev, K. A. (2019). Fuzzy-Based Risk Assessment Framework for Autonomous Underwater Vehicle Under-Ice Missions. *Risk analysis: an official publication of the Society for Risk Analysis*, *39*(12), 2744-2765. https://doi.org/10.1111/risa.13376.

16. *NPAOP 10.0-5.08-04. Instructions for measuring dust concentration in mines and accounting for dust loads* (2004). Retrieved from https://pdf.sop.zp.ua/npaop_10_0-5_08-04.pdf.

17. *DSTU EN 1827:2017. Personal protective equipment for respiratory organs. Half-masks without inhalation valves and with separate filters for protection against gases or gases and aerosols, or only against aerosols. Requirements, testing, marking* (2017). Retrieved from https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=75559.

18. Cheberiachko, S. I., Frundin, V. Yu., Cheberiachko, Yu. I., Stolbchenko, O. V., & Radchuk, D. I. (2017). Experimental studies of the influence of microclimate parameters on human performance during the use of filter respirators. *Ukrayins'kyy zhurnal z problem medytsyny pratsi*, *4*, 54-58.

19. Yuan, S., Yang, M., Reniers, G., Chen, C., & Wu, J. (2022). Safety barriers in the chemical process industries: A state-of-the-art review on their classification, assessment, and management. *Safety Science, 148,* 105647. https://doi.org/10.1016/j.ssci.2021.105647.

20. Liu, R., Liu, H.-C., Shi, H., & Gu, X. (2023). Occupational health and safety risk assessment: A systematic literature review of models, methods, and applications. *Safety Science*, *160*, 106050. https://doi.org/10.1016/j.ssci.2022.106050.

21. Paltrinieri, N., Comfort, L., & Reniers, G. (2019). Learning about risk: Machine learning for risk assessment. *Safety Science*, *118*, 475-486. https://doi.org/10.1016/j.ssci.2019.06.001.

22. Bazaluk, O., Tsopa, V., Cheberiachko, S., Deryugin, O., Radchuk, D., Borovytskyi, O., & Lozynskyi, V. (2023). Ergonomic Risk Management Process for Safety and Health at Work. *Frontiers Public Health, 11*, 1253141. https://doi.org/10.3389/fpubh.2023.1253141.

Особливості оцінки професійних ризиків за шкідливих умов праці

В. І. Голінько[*], *В. А. Забєліна*

Національний технічний університет «Дніпровська політехніка», м. Дніпро, Україна

Автор-кореспондент e-mail: golinkongu@gmail.com

Мета. Удосконалення процесу оцінки професійних ризиків, зумовлених шкідливими умовами праці, з урахуванням експозиції шкідливих факторів як кількісної характеристики інтенсивності та тривалості дії шкідливого фактору, так і наявних результатів атестації робочих місць за умовами праці.

Методика. Теоретичні дослідження базуються на використанні основних положень теорії ймовірності, методів математичного моделювання, статистичної обробка показників професійної захворюваності й методики оцінки ризиків шляхом побудови матриці наслідків/імовірностей за стандартом ISO 31010:2013.

Результати. Запропонована матриця наслідків/імовірностей для оцінювання загального професійного ризику для здоров'я працівників, обумовленого шкідливими умовами праці, яка включає п'ять показників, що характеризують серйозність наслідків, і п'ять показників, що характеризують імовірність події (якісних і бальних). Особливістю матриці є те, що бальна оцінка ймовірності безпосередньо відображає кратність перевищення допустимих значень, встановлених нормативно-правовими актами шкідливих виробничих чинників, що характеризують умови праці.

Наукова новизна. Запропоновано новий підхід до встановлення серйозності наслідків дії шкідливих виробничих чинників, що полягає в урахуванні закономірностей виникнення професійної й виробничо-зумовленої захворюваності працівників і наявних механізмів її попередження. Встановлено зв'язок поширеності певних видів професійної захворюваності працівників із конкретними умовами праці (експозицією чинників виробничого середовища).

Практична значимість. Результати проведеного дослідження дозволяють працівникам служб охорони праці оцінити загальний професійний ризик для здоров'я працівників, обумовлений шкідливими умовами праці, безпосередньо за наявними картами умов праці, отриманими за результатами атестації робочих місць. За результатами оцінки можливо визначити допустимий час роботи працівника у шкідливих умовах праці, за який не перевищується допустиме значення ризику виникнення професійного захворювання.

Ключові слова: *професійне захворювання, ризик, шкідливий виробничий чинник, умови праці, експозиція*

The manuscript was submitted 06.12.23.