

ASSESSMENT AND ANALYSIS OF OCCUPATIONAL RISKS IN UNDERGROUND MINING OF POLYMETALLIC ORES

*Iztileu Amanzhol¹, Nurlybek Zholmagambetov², Darhan Abitayev³, Sultan Kuserbayev⁴ and Aigerim Mereke⁵

^{1,5}Department of Chemical Technology and Ecology, Karaganda Industrial University, Kazakhstan; ²Department of Mine Aerology and Labor Protection, Karaganda Technical University, Kazakhstan; ³School of Public Health and Biomedicine, Karaganda Medical University, Kazakhstan; ⁴Department of Histology, Karaganda Medical University, Kazakhstan

*Corresponding Author, Received: 17 March 2023, Revised: 16 May 2023, Accepted: 9 June 2023

ABSTRACT: The desire of an industrial facility to successfully and stably develop economically confronts it with the problems of the apparatus being formed and its activities. The concept of occupational risk analysis in occupational safety practice is a scientific and methodological approach to risk management. This study aims to assess the degree of occupational risk for miners engaged in underground mining of polymetallic ore, considering the class of harmfulness of work. The analysis involves selecting risk factors that require attention and conducting both qualitative and quantitative approaches to identify and evaluate potential consequences and select appropriate measures to mitigate risks. The study determines the replaceable noise loads using mathematical calculations and characterizes the vibration load by an equivalent value or dose. The results of the hygienic assessment of the working conditions at the Orken-Atasu underground mine showed that the work activities of miners take place under conditions of exposure to intense noise and general and local vibration exceeding the MPL. Drillers, fixers, and machinists of drilling units experienced the highest vibration loads. The total dose of the daily vibration load varied from 1197.6-3855.6 Pa² · h, exceeding the permissible levels for a relative dose from 1.3 to 8 times. The study highlights the importance of a scientific and methodological approach to risk management in the mining industry.

Keywords: Labour protection; Working conditions; Accidents; Occupational diseases; Production processes; Industrial complex.

1. INTRODUCTION

Polymetallic ore mining has been, is and will be an industry characterized by the most dangerous and difficult working conditions, which, in particular, are characterised by harmful and unfavorable factors for health. In production conditions, as a rule, noise and vibration of various intensities and spectrum occur, which are created as a result of the operation of various machines, transport and technological equipment, aggregates, mechanisms, pneumatic and electric manual mechanized tools and other devices – all this causes a high probability of injury, a negative impact on people's health [1-3] (Fig. 1, 2). Today, there is a constant change in the structure of the mining industry. Mine owners provide enterprises with an increasing number of large working machines and mechanisms. Therefore, a qualitative and objective assessment of unfavorable production factors at all stages of the technological process and, first of all, noise and vibration are necessary [4-6].

Labor protection is of great importance in connection with the industrialization of the world. Despite the intensive development of this system, the issue of occupational diseases and accidents

takes place both in highly developed and developing countries. The desire of an industrial facility to successfully and stably develop economically confronts it with the problems of the apparatus being formed and its activities. In this context, the concept of occupational risk analysis in occupational safety practice is a scientific and methodological approach to risk management.

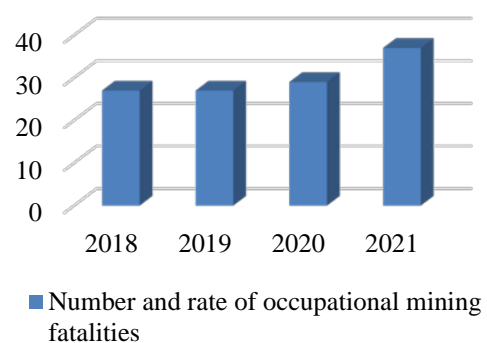


Fig. 1. Comparative schedule of occupational injuries in bituminous and all other coal mining industries, 2018-2021 [7]

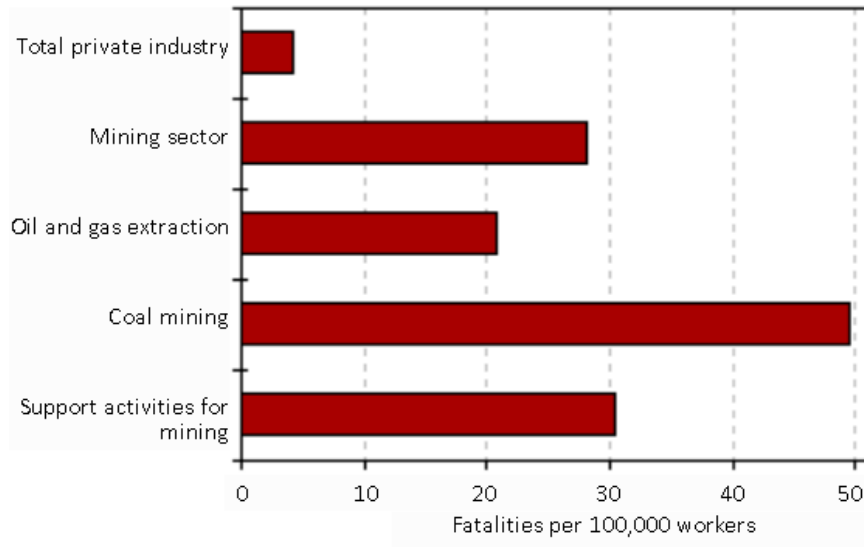


Fig. 2. Fatality rates, mining industries and total private, 2022

According to World Health Organization (WHO) data, noise and vibration rank 2nd and 3rd among 7 occupational risk factors in terms of medical and social damage. Their contribution to the global burden of diseases according to the DALYs indicator, reflecting disability and premature mortality, is shown in Fig. 3.

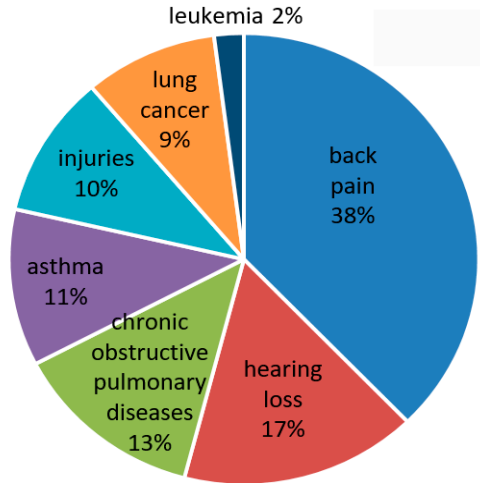


Fig.3. Contribution of noise and vibration to the global burden of diseases

Previously, coefficients 0.9; 0.6; 0.5; 0.4; 0.3 and 0.1 were recommended for calculating this indicator for cancer, poisoning, respiratory diseases, musculoskeletal disorders, pneumoconiosis, hearing loss from noise and skin diseases, respectively [8]. The results of the assessment of occupational risks in the workplace, considering the class of occupational hazards, allowed determining the magnitude, probability and consequences of risks in a particular workplace [9]. Depending on

the magnitude of the risk, appropriate measures have been identified to reduce or eliminate them [10-13].

It is becoming increasingly obvious that there is a need for a differentiated assessment of working conditions based on real production situations, a detailed study of the exposure dependence of the complex of biomedical indicators of the state of health of workers from harmful factors of the working environment, categorisation and structuring of occupational risk, systemic risk management [13]. The mining and coal industries are known to be associated with a high level of occupational risk due to the nature of the work involved, including exposure to noise, vibration, dust, and hazardous substances. As a result, workers in these industries are at a higher risk of developing occupational diseases and experiencing work-related injuries [14; 15].

Therefore, the purpose of the work is to assess the degree of occupational risk, considering the class of harmfulness of work in the field of miners engaged in underground mining of polymetallic ore. Furthermore, the study is important because it aims to provide useful information for national authorities, experts, and social partners of the country in their efforts to improve occupational safety and health in the mining and coal industries. This can be achieved by formulating a new medium-term sectoral program based on the findings of the study.

2. RESEARCH SIGNIFICANCE

This study highlights the importance of evaluating working conditions based on actual production scenarios and thoroughly examining the effects of harmful environmental factors on

workers' health. It emphasizes the need to categorize and structure occupational risks and manage them systematically. The study's results can guide the creation of effective risk management plans to improve the safety and health of mining industry workers. The study makes a significant contribution to occupational health and safety in the mining industry and can aid future research efforts.

3. MATERIALS AND METHODS

Conditioned upon socio-economic changes in the world, changes are also taking place in the concept of occupational medicine, with the transition from maximum permissible level (MPL) to occupational risk assessment and management. At this stage, it is necessary to remember the human factor and here it is necessary to mention the existence of individual occupational risk (IOR). Unfortunately, it is impossible to perform only a quantitative assessment of the individual risk of health damage in the workplace. That is why the authors insist on the need to assess adverse factors based on an integral indicator of harmfulness, namely, in the combination of quantitative and qualitative harmfulness of a dangerous factor.

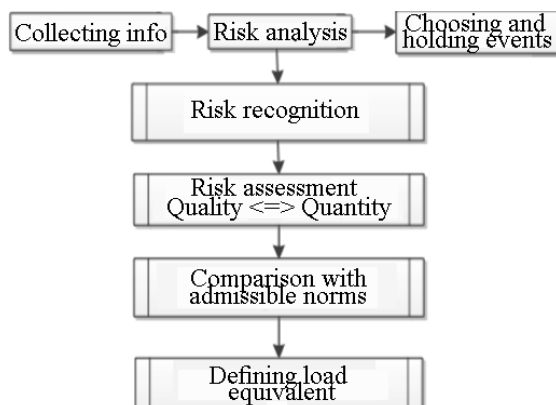


Fig. 4. Block diagram of risk assessment and analysis

The approach to the problem was demonstrated in the assessment of vibration and noise risks arising at the Orken-Atasu mine of Arcelor Mittal Temirtau JSC (joint-stock company), the largest steelmaking and mining enterprise in Kazakhstan (Table 1). To assess the possibility of continuing to work in unfavorable working conditions, it is necessary to calculate the permissible (safe) length of service in harmful working conditions. Fig. 4 shows a visualisation of the method of working with risks proposed by the authors.

The first stage of the analysis involves selecting the risk factors that require attention. The ultimate goal of the risk analysis stage is to establish the

"equivalent load" of the risk factor for a specific type of work, which serves as a basis for selecting and implementing appropriate measures to mitigate the risks. Two types of analyses are conducted during the risk analysis stage: quantitative and qualitative. Both approaches are important and should be used in conjunction with each other. The qualitative approach involves identifying risks, evaluating the potential consequences, and selecting appropriate measures to mitigate them. This analysis is typically performed during the business plan development stage. The quantitative analysis involves numerical measurements of the impact of changes in risk factors on project effectiveness, based on probability theory and mathematical statistics. This analysis is based on the basic version of the project's business plan, and it is performed following the qualitative analysis.

The study also determined the replaceable noise loads using mathematical calculations [16-18]. The vibration load was characterized by an equivalent value or dose, and the permissible dose of vibration per shift was calculated using the permissible adjusted value and the exposure time of miners (480 minutes). The initial data for calculating the vibration dose included the corrected value of the vibration parameter (vibration velocity or vibration acceleration) and the time of its impact on the miners.

4. RESULTS

Below is an assessment of replaceable vibro-acoustic loads at the workplaces of miners engaged in the underground mining of polymetallic ore. The results of time-lapse studies of the labour activity of miners of underground ore mining indicate that on average about 63.3% of shift time was spent on performing basic technological operations for sinking and excavating the ore. The degree of harmfulness and danger of working conditions under the action of vibroacoustic factors during underground work corresponds to Class 3 (harmful) 2 and 3 degrees of harmfulness (Table 2).

In the process of drilling holes in horizontal planes, various types of drilling rigs are used, which are equipped with four-stroke diesel engines with liquid cooling. Universal telescopic arrows are installed on the control panel. The design of the drilling booms ensures automatic maintenance of the parallelism of the automatic transmitters. Machinists for the management of scraper winches, loading and delivery machines and electric locomotives switch the control levers of mining equipment during the shift, which is accompanied by high stereotypical loads on the upper limbs, local stress on the hands, statistical load of the upper and lower limbs.

Table 1 Criteria for limit levels

Criteria	Noise		Vibration	
	constant noise	pulse noise	local vibration	general vibration
	115 dB	140 dB (200 Pa)	dangerous above the MPL by 12 dB (4 times)	limited comfort, fatigue, decreased performance, exposure limit, voluntary tolerance limit

Table 2 Gradation of working conditions when workers are exposed to noise, vibration, depending on the amount of excess of current standards

Factor/indicator, unit of measurement	Class of working conditions	
	3.2	3.3
	Exceeding the MPL to...dB/time (including):	
Noise, equivalent sound level, dB	15	25
Local vibration, equivalent corrected level (value) of vibration velocity, vibration acceleration (dB/time)	6/2	9/2.8
Total vibration, equivalent corrected level of vibration velocity, vibration acceleration (dB/time)	10	15

Drillers carry out the charging of boreholes manually with the help of pneumatic loaders such as ZP-2, ZP-5 and ZP-25. During the shift, the driller drills 30-50 holes to a depth of 1.5-2.4 m. At the time of drilling holes, the worker had to hold the drill by the handle and transfer the feed force to the rod and cutter through the back and handle. The physical and vibration load is transferred to the upper limbs. Crushers control the crushing of ore in jaw and cone crushers. Crushing of large pieces of ore is carried out manually using scrap. The fixers carry out the fastening of the roof with rebars and reinforced concrete rods using perforators, the weight of which reaches from 2.5 to 10 kg.

The fixers manually filled more than 12 frames of boards weighing 7-8 kg per shift, and installed about 40 pieces of reinforced nets weighing 30-40 kg. Concreting of the sides was carried out using a concrete paver of the "BM" type. Loading of the concrete paver was carried out manually. Manual labor was used when fitting and laying structures at a distance and height from 1.5 to 2 m. The face mounting required considerable physical effort

associated with lifting and installing temporary mechanical support posts (weight from 50 kg to 90 kg) or permanent support elements – heavy metal arches and reinforced concrete puffs. The work of the fasteners is associated with a significant late tension of the muscles of the back and lower extremities, as well as the impact of local vibration.

As can be seen from Table 3, the results of mathematical calculations of the dose (shift) noise load allowed us to establish that the miners are affected by a dose of noise from 0.55 to 2.61 Pa² · h with an 8-hour shift when working underground mining equipment. The values of the equivalent noise dose ranged from 0.066 to 3.178 Pa, which corresponded to an equivalent noise level from 70 to 104 dB.

At the same time, it should be noted that according to the difference between the received and permissible values of the noise level based on the dose approach, the excess of noise doses ranged from 1.6 to 80 times. That is, miners are exposed to noise during the working shift, exceeding the permissible noise doses from 0.6 to 2.6 times.

Table 3 Indicators of the dose (shift) noise load received by miners of underground mining of polymetallic ores

Workplace	Orken-Atasu Mine of Arcelor Mittal Temirtau JSC			
	Total noise dose, Pa ² ·h	Equivalent noise dose, Pa	Permissible dose, times	Noise dose ratio, number of times
Drilling rig drivers	15.880	1.986	16.0	50.0
Machinist for the management of scraper winches	2.040	0.255	2.0	6.3
Loading and haul truck driver	2.608	0.326	2.6	8.0
Machinist of an electric locomotive	1.512	0.189	1.5	4.0
Drillers	14.560	1.820	14.5	40.0
Sinkers	9.880	1.235	9.9	32.0
Fasteners	12.664	1.583	12.7	36.0
Underground miners	10.128	1.266	10.1	34.0
Explosives experts	0.528	0.066	0.5	1.6
Underground crushers	25.420	3.178	25.0	80.0
Underground locksmiths	0.704	0.088	0.7	2.5
Underground electric welders	0.616	0.077	0.6	2.0

Table 4 Indicators of the dose (replaceable) vibration load received by miners of underground mining of polymetallic ores

Orken-Atasu Mine of Arcelor Mittal Temirtau JSC				
Workplace	Total dose of total vibration per shift, Pa ² ·h	Equivalent dose of total vibration per shift, Pa	Total dose of local vibration, Pa ² ·h	Equivalent dose of local vibration per shift, Pa
Drilling rig drivers	524.4	43.7	3855.6	321.3
Machinist for the management of scraper winches	152.4	12.7	2413.2	201.1
Loading and haul truck driver	103.2	8.6	1514.4	126.2
Machinist of an electric locomotive	94.8	7.9	1197.6	99.8
Drillers			4353.6	362.8
Fasteners			4167.7	347.3
Underground crushers	586.7	48.9	966.0	80.5

The results of the calculation of the noise dose load identified that the highest replaceable noise loads were subjected to the machinists for the management of drilling equipment. So, the total dose of noise for them was 2.61 Pa² · h. The indicators of the equivalent dose were 0.326 Pa, which corresponded to the equivalent noise level of 89 dB and exceeded the permissible levels by 8 times. At the Orken-Atasu underground mine of Arcelor Mittal Temirtau JSC, calculations of the dose (shift) noise load at the workplaces of miners allowed us to establish that the crushers were subjected to high total noise doses during the working shift, the indicators of which reached 25.42 Pa² · h. The equivalent noise dose was 3.178 Pa, which corresponded to the level of 104 dB. At the same time, the excess of noise doses was 80 times. Similar doses were received by machinists for the management of drilling equipment and drillers.

Thus, the total noise dose received by them reached 15.88 and 14.45 Pa² · h, which corresponded to an equivalent noise level of 100 and 98 dB. The excess of noise doses when comparing the permissible and received reached 50 and 40 times, respectively. Underground miners, sinkers and fixers were exposed to high noise loads during an 8-hour work shift. Thus, the total dose of noise received by them ranged from 9.88 to 12.66 Pa² · h. The equivalent dose rates ranged from 1.235 to 1.583 Pa, which corresponds to an equivalent noise level of 95.8 and 98 dB.

The excess of noise doses varied from 32 to 36 times. Electric locomotive drivers, explosives experts, underground locksmiths and welders were exposed to noise dose loads from 0.53 to 1.51 Pa² · h, which corresponded to the equivalent level of 87.0-79.5 dB and the excess of noise doses ranged from 1.6 to 4 times. The equivalent dose rates ranged from 0.066 to 3.178 Pa, which corresponded to equivalent noise levels from 70 to 104 dB. At the same time, the excess of noise doses ranged from 1.3 to 50 times.

The next unfavorable physical factor that miners

of underground ore mining are exposed to is general and local vibration. All of the above workplaces are subjected to low- and medium-frequency vibration. Table 4 shows the results of a replaceable vibration load. The results of the calculation of the dose load of the total vibration revealed that the drivers for the management of mining equipment during the working shift were exposed to the total dose of the total vibration in the range from 94.8 to 152.4 Pa² · h. At the same time, the equivalent dose was on average, from 7.9 to 12.7 Pa.

The indicators of the averaged daily vibration local loads exceeded the permissible levels by 5 times in relative dose. At the Orken-Atasu underground mine, high levels of dose vibration load were experienced by drilling rig drivers and crushers, who during the working shift were subjected to a total dose of total vibration in the range of 524.4 and 586.7 Pa² · h, respectively. The equivalent dose of total vibration exceeded the permissible level by 10-11 dB. The indicators of the averaged daily vibration loads exceeded 11 times the relative dose. After 3-7 years of work in conditions of vibration exceeding the MPL, there is a risk of developing vibration disease.

5. DISCUSSION

The current socio-economic situation places the preservation of the health of the working population on the basis of the labour policy of each country [19]. At the same time, according to research [20], every fourth or fifth employee is exposed to negative factors of the working environment., A. L. Safonov [21] in his work found out that this state of affairs has developed conditioned upon the lack of economic interest and responsibility of the employer and insufficient motivation of employees to follow the observance of sanitary and hygienic standards themselves. Analyzing the concept of "risk management" it is necessary to consider the fact that there is no single definition of this concept. For example, the author [22] defines risk

management as a process of its control, covering all types of activities. And according to [23], risk management is reduced to developing a mechanism for minimising it by determining its effect and all characteristics. The authors [24] believe that excluding the monitoring of the enterprise environment and the environment in which the enterprise is included, from the cycle of risk analysis predicts the short-term nature of all decisions taken in the chosen policy. The conclusions obtained in this study do not contradict the mentioned works. However, unlike them, the current study focuses specifically on the assessment and analysis of occupational risks in underground mining of polymetallic ores.

Colleagues [25] suggest using the matrix method in assessing production risks at mining enterprises. In their opinion, this method is the most accurate, but this method requires an understanding of the principle of constructing matrices and also requires detailing risks to determine the profitability of their elimination. Compatriots conducted a study similar to the authors of this work on the basis of the Kazakhmys company, using an in-depth analysis of the method of police accounting for morbidity with temporary loss of working capacity [26]. Such an analysis is more demonstrative but immediately highlights weaknesses in the company's labor protection. Of particular importance is the analysis of international experience in the mining industry, including the mechanisms of its reform. While researchers [25; 26] discuss the use of the matrix method and police accounting for morbidity with temporary loss of working capacity, the current study takes a scientific and methodological approach to risk management. The authors of this article agree with the rationale of the importance of analyzing and addressing risks in the mining industry presented in the above work.

An interesting approach to risk management in mines is described in [27-29] – the risk of occupational diseases in workers of surface mines depends on the length of time of contact with harmful and dangerous production factors. The author is working on establishing a "risk class" based on a set of indicators of working conditions and the specifics of the labor process. The author analyzes the causal relationships of the occurrence of sensorineural hearing loss, vibration disease and sciatica of the lumbosacral region. The following method of assessment, analysis and management of the above-induced occupational risks is proposed:

- Identification of the main harmful and dangerous factors, the influence of which leads to occupational diseases;

- Identification of the "risk group" of workers who are more exposed to harmful and dangerous factors;

- Analysis of individual employee data: working conditions, use of personal protective equipment, work experience;

- Assignment of a "risk class" based on a personal statistical calculation of the probability of occurrence of an occupational disease, taking into account certain dangerous and harmful working factors, as well as work experience;

- Identification and prevention of harmful and dangerous factors.

The high efficiency of this method is assumed, but the method of application of this method in underground mining is not described. Humanity is evidence of a paradigm shift towards a risk-based approach to occupational safety. 95% of the new rules contain an indication of the need not only to conduct an assessment of occupational risks but also requirements for the application of their results [28, 30]. The solutions proposed in this paper make it easier to make decisions to improve working conditions.

Since the main source of noise and vibration in the underground ore extraction at the Orken-Atasu underground mine are the machines used, their selection and their hygienic assessment are of great importance, which will determine the dose loads for a particular workplace and reduce the levels of occupational risks, which in turn will allow making the right choice on measures for preservation and protection health of employees.

Vibroacoustic risks significantly affect human health. At ore mines, the incidence rate of workers with vibration disease is 30.3, and sensorineural hearing loss is 24.1 cases per 10000 workers who have passed a medical examination. During underground work, noise-vibration pathology is diagnosed mainly in sinkers, and miners of the treatment face [16, 31]. Initially, the responsibility for the health and life of the employee lies with the employer. However, given the specifics of mining operations, each employee must constantly use personal protective equipment – in most cases, they reduce the negative impact of noise, thereby personally preventing and reducing the effects of harmful and hazardous production factors.

6. CONCLUSIONS

The assessment of noise-vibration risks at the Orken-Atasu underground mine has shown that the time of exposure to a negative factor has a great influence. According to the results of processing the collected data, the average noise and vibration levels are different at different workplaces and exceed the MPL. The highest doses are received by drillers, fixers and machinists of the drilling installation. Based on mathematical calculations of total and equivalent doses of noise and vibration, dose (replaceable) loads of vibroacoustic factors

have been established for employees of leading professional groups employed in the mining industry, taking into account the use of techniques and equipment in the process of underground mining of polymetallic ores.

The results of a hygienic assessment of the working conditions of miners engaged in underground mining of polymetallic ores at the Orken-Atasu mine of Arcelor Mittal Temirtau JSC revealed that their work activities take place under conditions of exposure to intense noise exceeding the MPL from 2 to 19 dB, general and local vibration exceeding the MPL, respectively, from 3 to 19 dB. Thus, the results of the assessment of the dose (shift) noise load allowed us to establish that during the operation of underground mining equipment, miners are exposed to a total dose of noise during the working shift, the indicators of which vary from 0.53 and reached 25.43 Pa² · h.

The results of real dose loads of vibration allowed us to establish that miners of underground mining of polymetallic ores were subjected to various doses of vibration load during the working shift, which depended on the technical condition of mining equipment and compliance with their operating regime. It should be noted that the highest vibration loads of local vibration were experienced by drillers, fixers and machinists of drilling units. The total dose of the daily vibration load varied in the range of 1197.6-3855.6 Pa² h. The miners of these professions were subjected to a dose load, the indicators of which exceeded the permissible levels for a relative dose from 1.3 to 8 times.

7. REFERENCES

- [1] Gazimov V.G., Ruzakov V.O. and Shastin A.S., The main organizational issues of prevention of morbidity among the working population in modern conditions, *Occupational Health and Industrial Ecology*, Vol. 11, 2018, pp. 32-35.
- [2] Sahadi, The influence of the open environment on the work productivity of construction project workers, *International Journal of GEOMATE*, Vol. 23, Issue 97, 2022, pp. 228-235.
- [3] Halimah, P. and Chotib, Spatial entrapment of women workers in metropolitan areas. *International Journal of GEOMATE*, Vol. 20, Issue 80, 2021, pp. 98-104.
- [4] Shevko V., Karataeva G., Tuleev M., Badikova A., Amanov D. and Abzhanova A., Complex electrothermal processing of an oxide zinc-containing ore of the Shaymerden deposit, *Physicochemical Problems of Mineral Processing*, Vol. 54, Issue 3, 2018, pp. 955-964.
- [5] Gencheva V.I., Omelyanchik L.A., Fedoryak D.M., Brazhko A.A. and Zavgorodny M.P., Study of biological activity of some 4-S-derivatives of quinoline, *Biopolymers and Cell*, Vol. 22, Issue 6, 2006, pp. 475-479.
- [6] Tasdelen A. and Özpınar A.M., A Dynamic risk analysis model based on workplace ergonomics and demographic-cognitive characteristics of workers, *Sustainability (Switzerland)*, Vol. 15, Issue 5, 2023, Article number 4553.
- [7] Centers for Disease Control and Prevention. 2023. NIOSH Mine and Mine Worker Charts. <https://wwwn.cdc.gov/NIOSH-Mining/MMWC/Fatality/NumberAndRate?StartYear=2018&EndYear=2021&SelectedOperatorType=&SelectedMineType=> (Accessed February 25th, 2023).
- [8] Kameneva O.V., Stepinkin Yu.I. and Mamchik M.P., Occupational morbidity from noise exposure, *Innovative Science*, Vol. 47, 2017, Article number: 191.
- [9] Balabanov I.T., *Fundamentals of financial management. How to manage capital*, Moscow: Finance and Statistics, 2001, pp. 1-384.
- [10] Kudaeva I.V. and Chistova N.P., Aggregation platelets function in persons with vibration disease, *Meditsina Truda I Promyshlennaya Ekologiya*, Vol. 63, Issue 1, 2023, pp. 61-66.
- [11] Kuleshova M.V., Impact of vibration on the workers' psychological health, *Meditsina Truda I Promyshlennaya Ekologiya*, Vol. 63, Issue 1, 2023, pp. 47-52.
- [12] Ahmad S., House R., Holness D.L., Nisenbaum R. and Thompson A.M.S., Evaluation of neurological testing for hand-arm vibration syndrome. *Occupational medicine (Oxford, England)*, Vol., 73, Issue 1, 2023, pp. 36-41.
- [13] Khussain B., Brodskiy A., Sass A., Rakhmetova K., Yaskevich V., Grigor'eva V., Ishmukhamedov A., Shapovalov A., Shlygina I., Tungatarova S. and Khussain A., Synthesis of vanadium-containing catalytically active phases for exhaust gas neutralizers of motor vehicles and industrial enterprises, *Catalysts*, Vol. 12, Issue 8, 2022, Article number 842.
- [14] Khusain B.K., Shlygina I.A., Brodsky A.R. and Zhurinov M.Z., Quantum chemical modeling of reagents and products in the process of siloxane airtel formation, *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, Vol. 7, Issue 5, 2016, pp. 3073-3082.
- [15] Akinlolu M. and Haupt T.C., The hand-arm vibration syndrome: A bibliometric co-occurrence analysis of a neurological disorder in construction workers, *Lecture Notes in Civil Engineering*, Vol. 245, 2023, pp. 211-216.
- [16] Wang H., Meng R., Wang X., Sun J. and Wu J., Development and internal validation of risk assessment models for chronic obstructive pulmonary disease in coal workers,

- International Journal of Environmental Research and Public Health, Vol. 20, Issue 4, 2023, Article number 3655.
- [17] Dzhalalov G.I., Kunayeva G.E. and Moldabayeva G.Zh., Fluid influx to a battery of incomplete horizontally branched wells in deformed formation, News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, Vol. 3, Issue 447, 2021, pp. 29-33.
- [18] Morcinek-Słota A., Occupational risk assessment of mining workers at a lignite mine, IOP Conference Series: Earth and Environmental Science, Vol. 1132, Issue 1, 2023, Article number 012008.
- [19] Bukhtiyarov I.V., Bobrov A.F., Denisov E.I., Yeregin A.L., Kuryerov N.N., Losik T.K., Pochtareva Ye.S., Prokopenko L.V., Rybakov I.A., Stepanyan I.V., Fesenko M.A. and Chesalin P.V., Occupational risk assessment methods and their information support, Hygiene and Sanitation, Vol. 98, Issue 12, 2019, pp. 1327-1330.
- [20] Mazitova N.N., Current status and prospects of occupational medicine in the Russian federation, Annals of Global Health, Vol. 81, Issue 4, 2015, pp. 576-586.
- [21] Safonov A.L., National strategy for reducing occupational risks and creating safe working conditions in the workplace, Moscow: Social Protection, 2009, pp. 1-526.
- [22] Michalski T., Ryzyko w działalności człowieka. Podstawy ubezpieczeń, t. 1 Mechanizmy i funkcje, Warsaw: Poltext, [in Polish], 2001, pp. 1-180.
- [23] Shevko V., Afimin Y., Karataeva G., Badikova A. and Ibrayev T., Theory and technology of manufacturing a ferroalloy from carbon ferrochrome dusts, Acta Metallurgica Slovaca, Vol. 27, Issue 1, 2021, pp. 23-37.
- [24] Kubińska-Kaleta E., Kubiński W. and Petryshyn L., Environmental risk management in Huta Stali, In: Fifth international scientific technical conference "Ecologic economic problems of Carpathian Euroregion" (pp. 87-91), Warsaw: Naukovi Visti, 2008.
- [25] Kubiński V., Kubińska-Yabtson E., Petrov A., Dariush S. and Savon D.Yu., Analysis of risks in the mining industry related to work safety, Mining Information and Analytical Bulletin, Vol. 11, 2017, pp. 168-176.
- [26] Abitayev D.S., Yerdosov N.Zh., Zhumaliyev B.S., Mashina T.F., Serik B., Kalishev M.G., Shintayeva N. and Zhakenova S.R., Occupational risks and health status of persons working in the mining industry of central Kazakhstan, Medicine and Ecology, Vol. 2, Issue 95, 2020, pp. 41-45.
- [27] Shaykhlislamova E.R., Kudasheva A.R., Karimova L.K., Teregulova Z.S. and Volgareva A.D., Factors and indicators of occupational risk of development of musculoskeletal disorders in workers of underground mining of copper-zinc ores, Diary of the Kazan Medical School, Vol. 1, 2020, pp. 16-20.
- [28] Anisimov I.M., Management of the risks of occupational diseases of workers in the development of open-pit coal deposits, Kemerovo: Kuzbass State Technical University named after T.F. Gorbachev, 2019, pp. 1-56.
- [29] Baibatsha A.B., Kembayev M.K., Mamanov E.Z. and Shaiyakhmet T.K., Remote sensing techniques for identification of mineral deposit, Periodico Tche Quimica, Vol. 17, Issue 36, 2020, pp. 1038-1051.
- [30] Shevko V.M., Karatayeva G.Y., Amanov D.D., Badikova A.D. and Bitanova G.A., Joint production of calcium carbide and a ferroalloy of the Daubaba deposit basalt, International Journal of Mechanical Engineering and Technology, Vol. 10, Issue 2, 2019, pp. 1187-1197.
- [31] Baibatsha A., Geotectonics and geodynamics of paleozoic structures from the perspective of plume tectonics: A case of Kazakhstan, International Journal of GEOMATE, Vol. 17, Issue 71, 2020, pp. 194-202.