https://doi.org/10.32056/KOMAG2023.1.5

Technology for increasing the level of environmental safety of iron ore mines with use of emulsion explosives

Received: 31.01.2023

Accepted: 29.03.2023

Published online: 03.04.2023

Oleh KHOMENKO [1], Maksym KONONENKO [1*], Inna MYRONOVA [1], Ihor KOVALENKO [2], Edgar Cáceres CABANA [3], Roman DYCHKOVSKYI [4]

Author's affiliations and addresses:

[1] Dnipro University of Technology, 19 Yavornytskoho Ave., 49005, Dnipro, Ukraine

[2] Ukrainian State University of Chemical Technology, 8 Gagarin Ave., 49005, Dnipro, Ukraine

[3] Universidad Nacional de San Agustin de Arequipa, Calle Santa Catalina Nº117, 04001, Arequipa, Peru

[4] AGH – University of Science and Technology, 30 Mickiewicza ave., 30059, Krakow, Poland

***Correspondence:**

e-mail: kmn211179@gmail.com

Phone: +38 067 662 62 05

Abstract:

Laboratory and industrial studies have established the total impact of environmentally hazardous substances, taking into account the distance from the source of emissions and the specific consumption of explosives. With the help of physicochemical analysis and biological testing, the dependence of the change in the conditional indicator of damage to bioindicators with an increase in the distance from the source of emission and the specific annual consumption of explosives was revealed. A methodology for calculating the environmental assessment of the state of atmospheric air around the mine ventilation shaft has been developed. The exponential dependence of the influence of surface concentrations of environmentally hazardous substances on the damage of bioindicators at the cellular and organismic levels has been established, which makes it possible to assess the state of atmospheric air at industrial sites of iron ore mines. The proposed technology of sand drilling, which involves the use of emulsion explosives in mining ore deposits in chamber development systems will reduce emissions of environmentally hazardous substances into the atmosphere and increase the level of environmental safety of iron ore mines.

Keywords: source of emission, concentration, environmentally hazardous substances, physicochemical analysis, emulsion explosives, environmental hazard index

Publisher: **KOMAG Institute of Mining Technology, Poland**

1. Introduction

Underground mining of iron ores is carried out with use of drilling and blasting method with explosives, in which the mine air, polluted by explosion products and iron ore dust, is released into the atmosphere without purification [1]. This generates an environmental hazard in the areas of operation of mining plants [2]. Long-term exploitation of deposits causes a negative impact on the environment, affecting almost all its elements, and leads to an increase in the levels of air pollution, contamination of water bodies, land, as well as to the accumulation of a significant amount of industrial waste in the mining regions of Ukraine. The range of anthropogenic impact on the biosphere depends on the volume of the main production, i.e. the volume of mined iron ore. This situation leads to a change in the natural conditions of living organisms, including humans, a decrease in biodiversity, an increase in morbidity, a decrease in quality and a reduction in the life expectancy of the population.

The level of environmental safety of underground iron ore mining operations remains quite low, due to insufficient knowledge of the mechanisms of mine and atmospheric air pollution by harmful emissions and the lack of effective means of controlling these emissions. As a result, pollution of environmental objects in the areas affected by iron ore mines increases. In this regard, scientific interest is oriented onto the establishment of patterns of air pollution from mine emission sources, which is the basis for the development of effective methods enabling to assess the level of environmental safety and to introduce highly effective environmental technologies. Therefore, an increase of the level of environmental safety in the extraction process of iron ores and an improvement of the condition of environmental objects in industrial regions is an urgent task.

2. Literature review

The mining industry is one of the most polluting industries in terms of production volume and the amount of pollutant emissions into the atmosphere. As a result of the activities of mining plants, organized and unorganized emissions of environmentally hazardous substances into the atmosphere have a technogenic impact on the air. This leads to pollution of the atmosphere in the surrounding areas, an increase in morbidity and a negative impact on living organisms [3]. At the same time, the nature and range of this impact in each case are different and are determined by the production rates, technical and zonal-climatic features of the deposits in operation.

The authors of the publication [4] presented the results of statistical data analysis of sanitary and hygienic indicators in the case of the environment in the Chervonograd mining region. Data concerning the number of samples of soil, water and atmospheric air, exceeding the standard values, were introduced into the single measurement system, namely to conditional pollution indicators of biological systems according to the methodology presented in the publication [5]. The performed studies of individual components of the environment according to sanitary and hygienic indicators, which considered their average value in the Chervonograd mining region (Lviv region, Ukraine), using an integral conditional indicator of pollution, showed that the level of environmental pollution in total should be defined as "above average", and the category of environmental hazard of the region's environment is "dangerous". Based on this, the authors concluded that significant environmental pollution in the region requires an implementation of measures aimed at improving the quality of the environment, and reducing the impact of the region's mining industry on biota and humans through an introduction of low-waste and waste-free technologies for the extraction and enrichment of minerals. In the conducted research work, there are no regularities of changes in biological indicators with an increase in the distance from emission sources, but only statistical data and a qualitative assessment of the state of the mining region are presented.

In the development process of ore deposits, the main method of extracting minerals is blasting. Almost a third of the explosives used in the mining industry are TNT-containing ones, which are a source of increased release of gaseous toxic emissions. A group of authors in the work [6] presents the results of experimental studies on the methods enabling to neutralize gaseous emissions during explosions in granite mining quarries. As a result of industrial research, it was found that the acceleration of chemical reactions during a transformation of explosives, caused by the presence of calcium hydroxide and sodium sulfate, reduces toxic emissions. The emissions reduction of carbon oxides and nitrogen is achieved by introducing neutralizers in special designs of clogging devices, by mixing with explosives, placing neutralizers at the junction of explosives and clogging, which does not affect the intensity of grinding rocks, and in some cases even improves it. After the secondary reactions take place, the toxic gases contained in the explosion products can be neutralized by alkali metal salts, oxides and alkaline earth metal hydroxides, since they easily bind the oxides of carbon and nitrogen to form the corresponding nitrates and nitrites.

The results of the study, presented in [7], consist in establishing the formulas of dispersion of the dust cloud after explosions in iron ore quarries of the Kryvyi Rih basin and the level of changes in the environmental hazard. On this basis, environmentally effective ways and means of reducing dust emissions into the environment have been developed. A methodology for calculating the height of dust cloud rise, taking into account the dispersion of dust particles and other influential factors, has been developed. Calculations of the dust cloud scattering showed that the emissions range of coarse iron ore dust is from 0.14 to 4.4 km, and finely dispersed – 40 – 70 km. At the same time, specific dust emissions with a total dispersion area of 28770 km^2 reach 1.302 kg/km^2. Dust cloud suppression is performed by water spraying [8]. An analytical formula for assessing the effectiveness of dust control in relation to the diameter of dust particles, water droplets, their speed of movement, the amount of water spray, the height of the cloud, as well as the total coefficient of capture of dust particles by water droplets has been established. A way to reduce the height of the dust cloud and gas emissions during explosions has been developed based on optimization of charges parameters. An improved design of borehole charges is proposed, which involves the use of a rubber plug with an anchor device as part of the hammering process. According to the results of the study, no regularities of changes in the stability of bioindicator plants, depending on the specific consumption of explosives during the explosions, were established.

3. Purpose

The analysis of the work performed in the direction of the technogenic impact of mining plants on the atmospheric air made it possible to establish that the research was carried out exclusively for quarries. An assessment of the impact of mining enterprises engaged in the development of ores using the underground method turned out to be needed. Lack of scientific substantiations of regularities of general toxico-mutagenic activity of atmospheric air and biological signs of agrophytocenosis in industrial sites and territories adjacent to the iron ore mine does not allow to assess the degree of impact on the flora, and, therefore, to take this into account in the technology of underground mining.

Therefore, the aim of the research work is to create a technology that increases the level of environmental safety of iron ore mines by reducing emissions of environmentally hazardous substances into the atmosphere.

To achieve this goal, the following tasks were solved:

- to assess the levels of pollution of environmental objects at different distances from the sources of emissions and to establish regularities of the impact of emissions of iron ore mines on the condition of atmospheric air;
- to assess the parameters of the environmental hazard of the iron ore mine regarding emissions into the atmosphere;
- to develop a technology for drilling and blasting, which increases the level of environmental safety of the underground mining of iron ores.

4. Methods

The tasks were solved by the following methods: laboratory tests with use of physicochemical method – to establish distribution formulas of ground concentrations of environmentally hazardous substances; biological testing – to assess the state of atmospheric air in the territory adjacent to the iron ore mine; methods of mathematical statistics – for processing test results, identifying relationships and assessing the reliability of the results of experiments; environmental analysis – to determine the level of

Publisher: **KOMAG Institute of Mining Technology, Poland**

reduction of environmental hazards using various technologies for drilling and blasting in the extraction process of iron ores.

5. Results

Ukraine has the 10th part of the world's iron ore reserves, a third of which accounts for the current production volume. The most significant deposits of iron ores are: Kryvyi Rih iron ore basin, Kremenchug iron ore district, Belozersk iron ore district, Konsky district of magnetic anomalies, Prydniprovsky iron ore region, Priazovsky iron ore district, Odessa-Bila Tserkva iron ore region and Kerch region. Of the listed iron ore deposits, the Kryvyi Rih-Kremenchug iron ore zone (basin) and the Belozersk iron ore region are currently being developed by open and underground methods [9]. The ores of the Kryvyi Rih basin are developed by 9 quarries and 8 underground mines, Kremenchug iron ore district – by 2 quarries, Belozersk iron ore district – by 2 underground mines. In order to reduce the negative impact on the environment during underground operations in 2011, all the quarries were transferred to using emulsion explosives (EVR). In underground mining operations, the introduction of EVR faced problems related to the development of drilling technology and charging machines for their use. Nowadays in the iron ore mines of Ukraine, TNT-containing explosives with the volume of 15-40% of the annual consumption of explosives are still used as the main explosives. After blasting operations, exhaust air from the mines is released without purification into the atmosphere through ventilation shafts. This is due to the fact that nowadays there is no effective equipment and treatment facilities for the capture and purification of gases that are emitted to the surface in significant volumes. Depending on the location of the mines and their ventilation shafts, the output stream of air affects negatively the condition of environmental objects and the health of the population living in the adjacent territory.

At present on the territory of the Krivoy Rog basin there are 8 mines. The structure of PJSC "Kryvyi Rih Iron Ore Plant" includes mines: "Batkivshchyna", "Pokrovska", "Kozatska" and "Ternivska", pjsc "Sukha Balka" – "Yuvileina" and "Im. Frunze", to PJSC "ArcelorMittal Kryvyi Rih" – "Them. Artema", to PJSC "Central Mining and Processing Plant" – "Them. Ordzhonikidze". The structure of PJSC "Zaporozhye Iron ore Plant" (PJSC "ZZRK"), which develops rich iron ores of the Yuzhno-Belozersk deposit (Bilozerka iron ore district, Zaporizhia region), includes the mines "Operational" and "Tunneling". According to the Target Regional Programme of transition of mining and processing plants to TNT-free, environmentally friendly EVR, in 2009 an iron ore plant with the most modern equipment and ore mining technology, which is PJSC "ZZRK" (Dniprorudne), was chosen as the basic enterprise. Therefore, the industrial site of PJSC "ZZRK" and the adjacent territory is a present testing area for research to improve the level of environmental safety.

During 2006 – 2010, measurements of the concentration of harmful gases in air samples were carried out with use of the Palladium-3M gas analyzer and the GX-M gas detector. With the help of these devices, the concentration of carbon monoxide and nitrogen oxides was measured for three ventilation shafts of mines. Sampling of the analyzed air was carried out during the inter-shift break after blasting in the mine. Next, the ground concentration of environmentally hazardous substances was determined, which is necessary to obtain a qualitative and quantitative assessment of their total impact on atmospheric air. Analysis of the values of ground concentrations of the total impact of environmentally hazardous substances has shown that with an increase in the distance to 1500 – 2000 m from the source of emission, the concentration value decreases by 3–5 times. Thus, the performed studies enabled to get empirical formulas that determine the ground concentration of environmentally hazardous substances in unit fraction of limiting of concentration (u.f. of LOC), taking into account the specific consumption of explosives and the distance from the source of emissions:

– for the "North-Ventilation" tube:

$$C_{sum.v} = 1.39 \cdot q^{1.65} \cdot e^{-0.001 \cdot L} \text{ u.f. of LOC} \tag{1}$$

where:

q – average annual unit consumption of explosives, kg/t;
L – distance to the source of release, m.

Publisher: **KOMAG Institute of Mining Technology, Poland**

– for the "South Ventilation" tube:

$$C_{sum.v} = 1.07 \cdot q^{1.24} \cdot e^{-0.0009 \cdot L} \text{ u.f. of LOC} \quad (2)$$

– for the "Drainage-Ventilation" tube:

$$C_{sum.v} = 0.72 \cdot q^{2.34} \cdot e^{-0.0008 \cdot L} \text{ u.f. of LOC} \quad (3)$$

The results of the study on the state of mine air in the conditions of PJSC "ZZRK" are fully presented in [10].

To assess the toxico-mutagenic activity of atmospheric air, test sites were identified, which were located in four directions of the world at the distance of 50, 100, 300, 500, 1000 and 2000 m from three ventilation tubes. Sampling of plant pollen at all the points of test sites was carried out during the spring-summer season in 2009-2011. The assessment of the toxicity or potential mutagenicity of atmospheric air was carried out according to the test "Sterility of plant pollen, Methodical recommendations 2.2.12-141-2007" [11] using the iodine method of staining. The essence of the method consists in staining of pollen cells of higher plants, depending on the starch content in them. Under the microscope, using a meter, sterile (non-viable) and fertile (viable) pollen grains were counted.

According to the results of the research, it was found that in 2009 the highest values of conditional damage indicators (UPU) of bioindicators in the range of 0.400 – 0.550 conventional units (USD) were observed at the distance of up to 500 m from emission sources. With the distance from emission sources (from 500 to 2000 m), there is a decrease in the UPU of bioindicators from 0.400 to 0.250 USD, and at the distance of more than 2000 m, the UPU decreases to 0.200 USD. In 2010, it was found that at the distance of 600 – 700 m from emission sources, the UPU decreased from 0.600 to 0.400 USD. Sources of UPU emissions are approaching 0.200 USD. According to the results of studies conducted in 2011, it was found that near emission sources at the distance of up to 500 – 600 m, UPU decreased from 0.600 to 0.400 USD. With an increase in distance from 500 to 2000 m, there is a further decrease in UPU from 0.400 to 0.250 USD. Over 2000 m UPU decreases to 0.200 USD, which is associated with a decrease in the negative impact of pollution.

According to the results of the study, an empirical formula was obtained that determines the UPU, taking into account the specific annual consumption of explosives and the distance from the source of emission:

$$UPU = 0.41 \cdot q^{-0.53} \cdot e^{-0.0003 \cdot L} \text{ u.f.} \quad (4)$$

Further studies of the toxico-mutagenic activity of atmospheric air have given a correlation between the UPU change and the value of the ground concentration:

$$UPU = 0.53 \cdot C_{sum.v} + 0.25 \text{ u.f.} \quad (5)$$

The main results of the study of toxic-mutagenic activity of atmospheric air around mine emission sources are presented in [12].

To determine the anthropogenic impact on the processes of ontogenesis of winter wheat in July 2011, wheat sheaves were selected from test sites at the area of 1 m^2, located along the predominant wind direction at distances of 50, 100, 300, 500, 1000 and 10000 m from the source of the emission. To establish the nature of the change in the biological characteristics of winter wheat, studies of ontogenesis indicators of trial sheaves were carried out. Analysis of the values of linear dimensions of wheat has been carried out. It was stated that environmentally hazardous substances coming from ventilation tubes significantly affect the linear dimensions of winter wheat ontogenesis, and contribute to their increase when approaching the source of exhaust. Due to a further analysis of the values of the weight indicators

Publisher: **KOMAG Institute of Mining Technology, Poland**

of wheat, it was found that harmful gases that came from the ventilation tubes also significantly affected the weight indicators of ontogenesis of winter wheat, and contributed to their increase when removed from the source of exhaust.

Further research enabled to obtain an empirical formula of biological yield from the value of the ground concentration of the total impact:

$$B_{biol} = 82.21 \cdot e^{-0.986 \cdot C_{sum.v}} \text{ c/ha} \tag{6}$$

In the absence of emissions, the biological yield reaches the maximum value of 82 c/ha. In the case of an increase in the ground concentration of the total impact to 0.5 hours from the LOC, which corresponds to the distance of up to 150 m from the source of emissions, the biological yield is expected to decrease to 50 c / ha, which corresponds to 40% of losses. When the ground concentration is reached, the total impact of the LOC value leads to a drop in yield of up to 60% or 1.4 times, which is about 30 centners per hectare. The obtained formula will provide a forecast of the biological yield of winter wheat with a change in the value of the total ground concentration impact of environmentally hazardous substances.

The experiment to determine the effect of technogenesis consisted in the germination of winter wheat grains. To do this, 100 prepared grains were placed on filter paper laid out in laboratory dishes. The germination of winter wheat grains was carried out for 72 hours while maintaining a constant ambient temperature of 25°C, while every 12 hours the number of germinated seeds was determined in order to assess their germination. After 3 days, the average length, cottage cheese and dry mass of the roots of grain seedlings selected at test sites at the distance of 50, 100, 300, 500 and 1000 m were determined, which were then compared with the grain indicators of the control site (10000 m) to obtain reliable results.

The analysis of the values of biological characteristics of sprouted wheat grains enabled to find out that environmentally hazardous substances coming from ventilation shafts significantly affect the crops of agrophytocenosis in the first generation, and contribute to an increase in technogenesis when approaching the source of exhaust. Studies on the influence of technogenesis on agrophytocenosis crops in the first generation of winter wheat enabled to establish correlation of changes in the phytotoxic effect and the amount of the ground concentration:

– by the length of the seedlings

$$FE_v = 0.008 \cdot e^{17.53 \cdot C_{sum.v}} \ \% \tag{7}$$

– by the length of the root system

$$FE_k = 0.046 \cdot e^{13.96 \cdot C_{sum.v}} \ \% \tag{8}$$

– by raw weight

$$FE_{syr.v} = 12.16 \cdot e^{2.95 \cdot C_{sum.v}} \ \% \tag{9}$$

– by dry weight

$$FE_{sukh.v} = 7.64 \cdot e^{2.94 \cdot C_{sum.v}} \ \% \tag{10}$$

The main results of the analysis of changes in the biological characteristics of winter wheat and the effect of technogenesis on winter wheat in the first generation are presented in [13].

To save time and increase speed of environmental assessment, the conducted research work necessitates a development of an algorithm for calculating the level of environmental hazard. Based on the results of the study of the ecological condition of atmospheric air, a methodology for calculating its

Publisher: **KOMAG Institute of Mining Technology, Poland**

parameters within the industrial site and in the territories adjacent to the mine in the following sequence was proposed.

1. Total ground concentration impact of environmentally hazardous substances

$$C_{sum.v} = 1.06 \cdot q^{1.74} \cdot e^{-0.0009 \cdot L} \text{ u.f. of LOC} \quad (11)$$

2. The UPU of indicators is determined by the formula (5);
3. The yield of winter wheat is determined by the formula (6);
4. The phytotoxic effect is determined by the formulas (7) – (10).

The results of many years of research on the ecological state of the atmospheric air of the industrial site and the territories adjacent to the mine, using physicochemical analysis and biological assessment, made it possible to make an environmental assessment of the condition of atmospheric air around emission sources. The necessary data on determining the environmental assessment of the condition of atmospheric air around the ventilation shaft of the mine are presented in Table. 1.

Table 1. Environmental assessment of the state of atmospheric air around the mine emission source

Ground concentration of total exposure, $C_{sum.\ v}$, u. f. of LOC	**Conditional indicator of damage *UPU*, u. f.**	**Biological yield, In_{biol}, c / ha**	**Level of damage indicators**	**Condition of atmospheric air**
≤ 0. 095	0 – 0. 150	≥ 74. 9	low	Favorable
	0. 151 – 0. 300		below average	Alarming
0. 096 – 0. 378	0. 301 – 0. 450	74. 8 – 56. 7	medium	Conflict
0. 379 – 0. 661	0. 451 – 0. 600	56. 6 – 42. 9	above average	Threatening
0. 662 – 0. 944	0. 601 – 0. 750	42. 8 – 32. 4	high	Critical
0. 945 – 1. 415	0. 751 – 1. 000	≤ 32. 3	maximum	Dangerous

From Table 1 it can be seen that the magnitude of the total ground concentration impact, UPU and biological yield of winter wheat, determines the level of damage to the indicators and the condition of atmospheric air within the industrial site and the territory adjacent to the source of emissions of the mine.

Analysis of the test results of atmospheric air near the ventilation shafts of PJSC "ZZRK" with the use of physicochemical analysis and biological assessment showed that the mine air coming from the tubes was saturated with environmentally hazardous substances that were generated as the result of underground mining, in particular blasting operations, having a negative impact on the surrounding flora. Therefore, the conducted studies need the use of modern environmentally friendly EVR and a development of new technologies for drilling and blasting, both during mine operations [14] and when performing cleaning activities [15].

The extraction of iron ores using the underground method is associated with drilling and blasting [16], which largely determine the efficiency of the field development [17]. Taking into consideration high costs of industrial TNT-containing explosives, danger during their transportation and the prospects for a development of mining plants, it would be advisable to use explosives manufactured directly at the blasting sites [18]. This is due not only to the safety of transportation [19] and mining [20], but also due to smaller volumes of exhaust explosion products [21]. The authors proposed the use of liquid EVR Ukrainite-PP-2 [22]. Thus, when 1 kg of such EVR is used, 0.056 mol or 1.25 liters of carbon monoxide is generated in the cloud. In addition, the presence of calcium oxide (CaO) in the exhaust products of the explosion ensures the absorption of nitrogen oxides, which can be generated in violation of the stoichiometric ratio of components or incomplete response of components during the explosive transformation of charges [23].

Publisher: **KOMAG Institute of Mining Technology, Poland**

The analysis of the technology of cleaning activities in mining blocks showed that the technology of ore extraction in chamber development systems involves the use of sucking fans [24], in which for the use of liquid EUR Ukrainite-PP-2 it is necessary to apply special means to keep EUR charges. Therefore, for the extraction of ore, it is proposed to improve the BPD technology, namely, to apply new technological schemes for conducting cleaning activities using EVR, when working out deposits with a capacity of more than 5 m (Figs. 1 and 2).

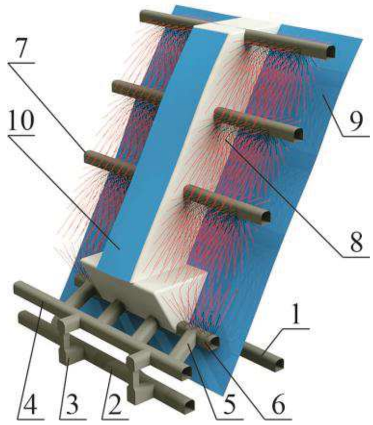

Fig. 1. Technological scheme of cleaning activities in blocks with the use of EVR for the fire bridge of ore with the capacity of 5 – 25 m: 1 – field view of the drift lying side; 2 – ore sliding drift; 3 – niche for a vibrating feeder; 4 – drift of the delivery horizon; 5 – loading device for self-propelled truck; 6 – trench drift; 7 – subsurface drilling drift; 8 – downward wells; 9 – lying side of the deposit; 10 – hanging side of the deposit

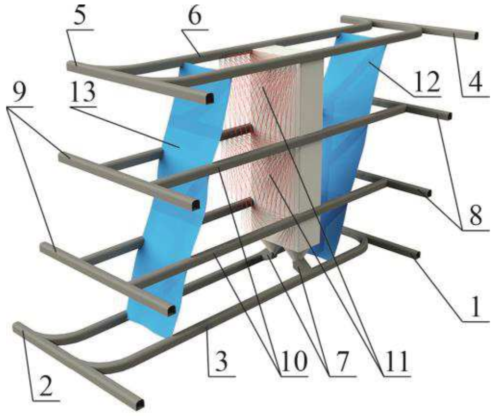

Fig. 2. Technological scheme of cleaning activities in blocks with the use of EUR for ore deposits with the capacity of more than 25 m: 1 – recoil drift of the lying side; 2 – recoil drift of the hanging side; 3 – recoil item; 4 – ventilation shaft of the lying side; 5 – ventilation shaft of the hanging side; 6 – ventilation and drilling item; 7 – niche for vibrating feeder; 8 – subsurface drift of the lying side; 9 – subsurface drift of the hanging side; 10 – drilling item; 11 – downward wells; 12 – lying side of the deposit; 13 – hanging side of the deposit

The essence of the proposed technology of ore extraction is that the drilling is carried out in the direction of the lower subsurface or floor [25]. After that, the downward wells are charged with the EVR [26]. Technological schemes for extracting downward wells during cleaning operations in chambers, using EVR, have been developed, to reduce the complexity of charging and reduce the cost of blasting operations due to eliminating special means for keeping EVR charges in wells.

Publisher: **KOMAG Institute of Mining Technology, Poland**

6. Conclusions

1. By determining the ground concentration in the result of total exposure to hazardous substances, it was established that their ground concentration is influenced by the distance from the emission source and the specific annual costs of explosives, which made it possible to identify formulas of changes in the total ground concentration impact of environmentally hazardous substances with an increase in the distance from each ventilation shaft of the mine. An assessment of the total toxico-mutagenic activity of atmospheric air enabled to find a correlation between the UPU change and the magnitude of the total ground concentration impact.

2. Studies of changes in the biological characteristics of winter wheat, which grows at different distances from the mine emission source, enabled to find that its linear dimensions near the emission source increase, and with distance from it decrease, and weight indicators, on the contrary, nearby – they decrease, and with increasing distance – they increase. According to the results of the study, a correlation of changes in the biological yield of winter wheat and the value of the total ground concentration impact and the distance to the source of emission was established.

3. By determining the consequences of technogenesis in the first generation, it was found that toxic gases coming from the ventilation shafts of the mine significantly affect cultures in the first generation, and contribute to an increase in technogenesis. The results of the study showed a correlation between the change in the phytotoxic effect and the value of the total ground concentration effect.

4. Based on the results of the study, an algorithm for calculating the environmental assessment of the atmospheric air condition at the mine industrial site and the territory adjacent to it was developed and an assessment scale was drawn up, which enabled to determine the parameters of environmental hazard of iron ore mine emissions.

5. To reduce the complexity of charging and reduce the costs of blasting operations by eliminating special means of keeping EVR charges in wells, technological schemes for extracting ore using downward wells have been developed when conducting cleaning operations in blocks using EVR for ore deposits with the capacity of more than 5 m. Developed technology of ore extraction during the treatment activities provides for the use of liquid EVR Ukrainite-PP-2. This solution will increase the level of environmental safety of iron ore mines by reducing emissions of environmentally hazardous substances into the atmosphere.

References

[1] Kolesnyk V., Pavlychenko A., Borysovs'ka O., Buchavyy Y.: Formation of Physical and Mechanical Composition of Dust Emission from the Ventilation Shaft of a Coal Mine as a Factor of Ecological Hazard. Solid State Phenomena 2018, 277: 178–187. DOI: 10.4028/www.scientific.net/ssp.277.178

[2] Buzylo V., Pavlychenko A., Borysovska O.: Ecological aspects of filling of worked-out area during underground coal mining. E3S Web of Conferences 2020, 201: 01038. DOI: 10.1051/e3sconf/202020101038

[3] Klimkina I.: Methodology of Socio-Ecological Monitoring using Cytogenetic Methods. NATO Science For Peace And Security Series C: Environmental Security 2013, 134: 351–364. DOI: 10.1007/978-94-007-6461-3_32

[4] Gorova A., Pavlychenko A., Kulyna S., Shkremetko O.: Ecological problems of post-industrial mining areas. Geomechanical Processes During Underground Mining 2012: 35–40. DOI: 10.1201/b13157-8

[5] Gorova A., Pavlychenko A., Kholodenko T.: Prospects for the bioindication methods implementation in the environmental management system of industrial enterprises. Annual Scientific-Technical Collection – Mining of Mineral Deposits 2013: 83–84. DOI: 10.1201/b16354-15

[6] Doludareva Ya.S., Kozlovskaya T.F., Lemizhanskaya V.D., Komir A.I.: Influence of the surface-active substances implementation in the rock failure area on the intensity of rock crushing by means of the pulse loads. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu 2012, (4): 93–97.

[7] Yurchenko A.: Methods of research of ecological safety increasing of large-scale blasting in quarries by the dust factor. Mining of Mineral Deposits 2014, 8(4): 487–496. DOI: 10.15407/mining08.04.487

Publisher: **KOMAG Institute of Mining Technology, Poland**

[8] Yurchenko A., Litvinenko A.: Dust suppression after huge blast in quarry by means of sprinkling. Mining of Mineral Deposits 2013, 7(4): 385–389. DOI: 10.15407/mining07.04.385

[9] Kholodov V.N., Golubovskaya E.V., Nedumov R.I.: Origin and Prospects of the Cimmerian Iron Ore Basin in Ukraine and Russia. Lithology and Mineral Resources 2014, 49(5): 359–380.

[10] Mironova I., Borysovs'ka O.: Defining the parameters of the atmospheric air for iron ore mines. Progressive Technologies of Coal, Coalbed Methane, and Ores Mining 2014: 333–339. DOI: 10.1201/b17547-57

[11] Gorova A.I., Ryzhenko S.A.: Methodical recommendations 2.2.12-141-2007. Survey and zoning of the territory according to the degree of influence of anthropogenic factors on the environmental objects using integral cytogenetic assessment methods. Recommended by the Ministry of Health of Ukraine (Order # 184 from 13.03.07.). DMP "Polimed, 2007: 36 p.

[12] Gorova A.I., Kolesnyk V.Ye., Myronova I.G.: Increasing of environmental safety level during underground mining of iron ores. Mining of Mineral Deposits 2014, 8(4): 473–479. DOI: 10.15407/mining08.04.473

[13] Myronova I.G.: Changing of biological traits of winter wheat that vegetate near emission source of iron-ore mine. Mining of Mineral Deposits 2015, 9(4): 461–468. DOI: 10.15407/mining09.04.461

[14] Kononenko M., Khomenko O., Dychkovskyi R., Cabana E., Mirek A., Dyczko A., Prostański D.: Using the methods to calculate parameters of drilling and blasting operations for emulsion explosives. Acta Montanistica Slovaca 2022, 27(4)

[15] Falshtynskyi V., Dychkovskyi R., Khomenko O., Kononenko M.: On the formation of a mine-based energy resource complex. E3S Web of Conferences 2020, 201: 01020. DOI: 10.1051/e3sconf/202020101020

[16] Kononenko M., Khomenko O., Savchenko M., Kovalenko I.: Method for calculation of drilling-and-blasting operations parameters for emulsion explosives. Mining Of Mineral Deposits 2019, 13(3): 22–30. DOI: 10.33271/mining13.03.022

[17] Kononenko M., Khomenko O.: New theory for the rock mass destruction by blasting. Mining of Mineral Deposits 2021, 15(2): 111–123. DOI: 10.33271/mining15.02.111

[18] Kholodenko T., Ustimenko Y., Pidkamenna L., Pavlychenko A.: Ecological safety of emulsion explosives use at mining enterprises. Progressive Technologies of Coal, Coalbed Methane, and Ores Mining 2014: 255–260. DOI: 10.1201/b17547-45

[19] Kholodenko T., Ustimenko Y., Pidkamenna L., Pavlychenko A.: Technical, economic and environmental aspects of the use of emulsion explosives by ERA brand in underground and surface mining. New Developments in Mining Engineering 2015 2015: 211–219. DOI: 10.1201/b19901-38

[20] Khomenko O., Kononenko M., Lyashenko V.: Safety improving of mine preparation works at the ore mines. Occupational Safety in Industry 2018, (5): 53–59. DOI: 10.24000/0409-2961-2018-5-53-59

[21] Myronova I.: Prediction of contamination level of the atmosphere at influence zone of iron-ore mine. Mining of Mineral Deposits 2016, 10(2): 64–71. DOI: 10.15407/mining10.02.0064

[22] Khomenko O., Kononenko M., Myronova I., Savchenko M.: Application of the emulsion explosives in the tunnels construction. E3S Web of Conferences 2019, 123: 01039. DOI: 10.1051/e3sconf/201912301039

[23] Khomenko O., Kononenko M., Myronova I.: Blasting works technology to decrease an emission of harmful matters into the mine atmosphere. Annual Scientific-Technical Colletion – Mining of Mineral Deposits 2013: 231–235. DOI: 10.1201/b16354-43

[24] Kononenko M., Khomenko O., Kovalenko I., Savchenko M.: Control of density and velocity of emulsion explosives detonation for ore breaking. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu 2021, (2): 69–75. DOI: 10.33271/nvngu/2021-2/069

[25] Khomenko O., Kononenko M., Myronova I.: Ecological and technological aspects of iron-ore underground mining. Mining of mineral deposits 2017, 11(2): 59–67 DOI: 10.15407/mining11.02.059

[26] Khomenko O., Kononenko M., Myronova I., Sudakov A.: Increasing ecological safety during underground mining of iron-ore deposits. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu 2018, (2): 29–38. DOI: 10.29202/nvngu/2018-2/3

Publisher: **KOMAG Institute of Mining Technology, Poland**