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ASSESSMENT OF THE ECOLOGICAL EFFICIENCY OF THE OPEN DEVELOPMENT OF NON-METALLIC DEPOSITS OF USEFUL MINERALS

Об'єктом дослідження є екологічна безпека функціонування гірничих підприємств. Одним з найбільш проблемних місць є значні відмінності гірничо-геологічних умов та геометричних параметрів кар'єрів, тип та технічний стан гірничо-транспортного обладнання, що застосовується на гірничих підприємствах, а також потреба доробки запасів в умовах зменшеної санітарно-захисної зони. Зміни процедури оцінки впливу на довкілля планованої діяльності гірничими підприємствами повинні передбачати розробку та впровадження додаткових технологічних рішень, що сприятимуть зменшенню забруднення прилеглих територій. Тому виникає необхідність в розробці уніфікованих підходів, використання яких дозволить аналізувати технологічні процеси гірничих підприємств та виявляти більш небезпечні з екологічної точки зору, на яких утворюється значні обсяги викидів забруднюючих речовин.

В ході дослідження проаналізовано три типові технологічні схеми розробки родовищ скельних будівельних матеріалів, що відрізняються продуктивністю виробництва та обсягами викидів забруднюючих речовин на прилеглі території. Встановлено, що використання стрічкових конвеєрів дозволяє зменшити зону впливу підприємства на екологічний стан прилеглих територій та мінімізувати екологічні ризики функціонування гірничих підприємств.

Для локалізації викидів забруднюючих речовин на території гірничого підприємства обґрунтовано схеми розміщення мобільних і пересувних дробильно-сортувальних установок в кар'єрі безпосередньо у вибоях або на робочих площадках. Це дозволить зменшити рівні забруднення навколишнього середовища та підвищити комфортність проживання населення на території гірничопромислових регіонів.

Завдяки застосуванню сучасних методів дослідження, методів картографічного моделювання і наукового прогнозування та використання комп'ютерних програм розроблено оптимальні екологобезпечні технології розробки родовищ. Їх застосовування дозволить зменшити обсяги викидів забруднюючих речовин за межі санітарно-захисної зони та покращить екологічний імідж гірничого підприємства. Такі підходи сприятимуть вдалому проходженню екологічного аудиту гірничих підприємств, отриманню міжнародних екологічних сертифікатів та освоєнню нових ринків збуту продукції.

Ключові слова: *родовища нерудних твердих корисних копалин, екологічна безпека гірничих підприємств, конвеєрний транспорт, дробильно-сортувальний комплекс.*

1. Introduction

In Ukraine, more than 40 % of non-metallic solid mineral deposits are located near populated areas, industrial and public facilities, along the borders of territories of natural-cultural reserves and other public facilities [1, 2]. About 3,000 deposits of such mineral raw materials as limestone, dolomite, granite, migmatite, gneiss, amphibolite, syenite, sandstone and others have been registered for the current period. Therefore, there is a need for their development, now and in the future, even when located within the regulatory sanitary protection zone (SPZ). These minerals are developed using drilling and blasting grinding of rocks [3, 4]. Therefore, the SPZ size is set at more than 1000 m [5]. Most of the natural mineral raw materials used for the production of building materials, chemical raw materials, and agricultural fertilizers are mined and processed under conditions of a reduced SPZ [6–8]. Under these conditions, mining enterprises put forward requirements to reduce the degree of pollution of air, water, soil and other environmental components to the level of maximum permissible concentrations (MPC), i. e. safe for public health [9–11].

The main technical and technological measures to reduce the harmful impact of the production processes of mining enterprises on the environment are defined as follows [5, 10, 11]:

– creation of explosive crushing of rocks ecologically safe using emulsion explosives, which form water vapor as a result of chemical transformation in the process of blasting rocks. As well as the initiation of charges of a special design with the help of safe seismic and percussion actions to the systems «Impulse» (Shostka state plant «Impulse», Ukraine), «Nonel» (Nitro Nobel, Sweden) and others;
– performance of excavation and loading operations in the bottoms of quarries with the previous irrigation of the rock mass with water solutions for sawmilling and similar irrigation of the transport routes of the quarry;
– carriage of rocks by wheel transport, which is equipped with reliable devices for capturing and neutralizing exhaust gases from burning diesel fuel over short distances or electrified types of transport (belt conveyors);
– processing of rocks into finished products on mobile and portative crushing and screening plants (MCSP,

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PCSP), which are placed in a quarry directly in slaughterhouses or at work sites. This allows to localize harmful dust-gas emissions into the atmosphere in the territory of the open space;

– storage of mining waste (opening rocks, processing waste – screenings) in internal dumps (depleted space);

– full development of all balance and off-balance reserves of non-metallic mineral raw materials to the economically and environmentally sound depth within the existing boundaries of the career field;

– reclamation of disturbed lands in agricultural and forestry directions, their recreation and revitalization.

One of the newest and little-studied among the above activities in the extraction and processing of non-metallic mineral raw materials should be the introduction and implementation of technology using MCSP, PCSP. At the present stage of the development of this technology, MCSP, PCSP complexes are placed in a quarry at temporarily non-working sites or at the bottom of the hole. The finished products from them are delivered by dump trucks to the cumulative surface transfer structure of the open quarry (TOQ). At this TOQ, dispatch of finished product fractions to main types of transport (railway trains, heavy vehicles) for delivery to consumers is carried out. An example would be the quarries for the limestone extraction, developing in Tiaginka (Kherson region) and Ternopil deposits. However, it is known from literary sources [5, 10] that finished or partially processed products from the site with MCSP, PCSP can be discharged with an environmentally safe belt conveyor to the surface of the quarry where the main transport vehicles are loaded. Similar technological schemes are developed for powerful ore open-cast quarries on which they are successfully applied.

For the conditions of the development of solid non-metallic minerals, which differ in the capacity of quarries and the type of mining transport equipment, the technological solutions have not been investigated. In addition, the vast majority of mining enterprises operate at small distances from settlements and their activities lead to a deterioration of the ecological status of mining regions.

Considering that the expediency of using MCSP, PCSP in the quarries under study was proved in [5, 10], an urgent task is substantiation of the environmentally friendly technological schemes for delivering finished products from the quarry and their delivering to the main transport vehicles. That is why the environmental justification of technological schemes for the development of mineral resources that are optimal for enterprises and the environment is relevant.

2. The object of research and its technological audit

The object of research is the environmental safety of the functioning of mining enterprises. The hazard level of mining depends on the resource-intensive technologies, they are used on them, as well as the effectiveness of used environmental protection measures. Extraction of minerals is accompanied by a complex negative impact on the components of the environment – formation of significant volumes of waste, pollution of atmospheric air, water bodies, as well as soil.

One of the most problematic places there are significant differences in the mining and geological conditions and geometrical parameters of the quarries, the type and technical condition of the mining and transportation equipment used in mining enterprises, as well as the need to refine reserves in a reduced SPZs. Changes in the procedure for assessing the environmental impact of a planned activity by mining enterprises should include the development and implementation of additional technological solutions that will help reduce pollution in the adjacent territories. Therefore, there is a need to develop standardized approaches, the use of which will allow analyzing the technological processes of mining enterprises and be more dangerous from an environmental point of view, where significant amounts of pollutant emissions are generated. This will make it possible to substantiate the technological schemes for the extraction and transportation of rock mass and minerals with minimal formation of pollutants and, accordingly, will contribute to improving the environmental image of the mining enterprise.

3. The aim and objectives of research

The aim of research is substantiation of the environmentally friendly technological schemes for the delivery, transfer, accumulation and dispatching of finished products to the main transport means when developing nonmetallic mineral deposits using MCSP, PCSP.

To achieve the goal, the following tasks were set:

1. To determine the features of the use of MCSP, PCSP on typical non-metallic quarries by environmental indicators.

2. To substantiate typical technological schemes for the development of deposits of rocky building materials, the use of which with minimal costs will ensure high production efficiency and reduce pollution of the adjacent territories.

4. Research of existing solutions of the problem

The long-term operation of mining enterprises in Ukraine is accompanied by the formation of multi-factor impacts on environmental components and the emergence of environmental risks at various stages of open quarry mining.

The authors of [12, 13] investigate the features of controlling the processes of grinding rocks by choosing the parameters of the well design and their recharging. The optimal parameters of blasting operations are determined, allowing to determine economically grounded technological schemes for the transportation of minerals to the earth's surface. The work does not take into account the environmental features of the application of the proposed mining and transportation system.

According to the authors of work [14], the most effective development of mineral resources can be provided with draglines. But this approach has no technical and economic prospects for use in open quarries for the extraction of non-metallic mineral raw materials.

The work [15] describes the features of creating a system of environmental and economic management of technological processes for the restoration of areas damaged by quarries. The solutions proposed by the authors require significant changes in technological equipment and financial costs.

In [16, 17], technological schemes for transporting rock mass using conveyors are justified, but the proposed solutions are very difficult to implement on working boards of quarries.

In the studies of the authors of work [18], the criteria for a comprehensive assessment of the environmental hazard of industrial enterprises are considered during the

environmental impact assessment procedure. The proposed approaches need to be adapted to the new requirements of the legislation in the field of the environmental impact assessment procedure of the proposed activity.

In [19, 20], methodological approaches to the integrated assessment of the environmental safety of natural and man-made complexes are considered. The developed approaches require consideration of the scale and consequences of the negative impact of mining enterprises on the ecological status of mining regions.

The authors of [21] substantiate the expediency of using information and analytical systems to predict the environmental risks of the operation of industrial facilities. The proposed solutions require consideration of the features of mining and transportation systems and technological schemes for the development of fields, including environmental criteria.

Most of the reviewed papers allow to identify and solve certain problems of managing the environmental safety of technological processes in the development of mineral deposits. But it is necessary to take into account that in order to develop optimal ecologically safe technologies for the delivery of overload, accumulation and shipment of finished products, it is necessary to take into account the conditions of the quarry location, availability of financial resources, as well as changes in environmental legislation.

Thus, the results of the analysis allow to conclude that in order to reduce the impact of mining enterprises on the environment, it is necessary to substantiate the requirements for technological schemes for the development of mineral resources taking into account environmental criteria.

5. Methods of research

When performing research the following methods are used:

– analytical – to assess effective options and solutions, determine the level of a rational mining and transport system;

– statistical – to summarize and predict the volume of excavation of rocks in systematic non-metallic deposits;

– graphic-analytical – for the design of the studied and recommended technological schemes;

– technical and environmental analysis and forecasting in the justification of appropriate technological and organizational solutions.

The use of modern research methods, methods of cartographic modeling and scientific forecasting, as well as statistical data processing using computer programs, allows to develop optimal ecologically safe field development technologies.

6. Research results

Studies [5, 10] prove the feasibility of the phased development of non-metallic solid mineral deposits with the mining of rocks with large excavation layers. Complexes of MCSP, PCSP are placed on concentration horizons, as a rule, on the lower of the 2–3rd species, in a steep layer, a mining ledge. MCSP, PCSP are positioned so that the distance of transportation of the rock mass from the face of this ledge by a wheel loader is minimal, or at the face when excavating rocks from the face by an excavator (Fig. 1).

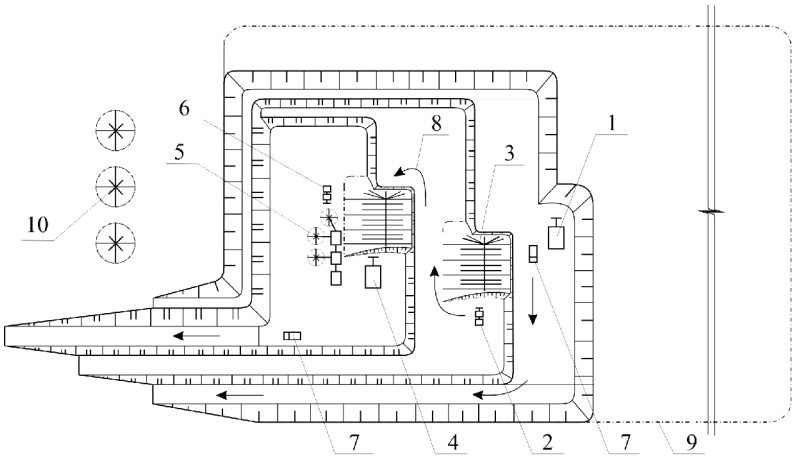

Fig. 1. Technological scheme of the quarry with the transportation of finished products from mobile and portative crushing and screening plants (MCSP, PCSP) by the dump trucks: 1 – excavator for opening works; 2 – wheel loader for mining; 3 – erosion of the mineral after its grinding by an explosion; 4 – mining excavator; 5 – MCSP, (PCSP) at the working site of the mining ledge; 6 – loader of finished products in dump trucks; 7 – dump truck; 8 – direction of the flow of mineral extracted on the upper ledge; 9 – marginal contour of the career field; 10 – surface fractional compositions (pile)

Mineral from the top of other ledges is delivered to MCSP, PCSP through rock descents on the slopes of horizons and through transport berms and crossing tracks.

After processing on MCSP, PCSP, finished products are fractionally accumulated in conical piles near the installation at the ledge site. From these piles, product fractions are shipped for further transportation to the surface. The following technological schemes are considered:

Scheme A – fractions on MCSP (PCSP) are loaded into mining dump trucks by wheel loader. Dump trucks deliver crushed stone and sand fraction to the TOQ surface of the pile type with conveyors in the gallery, to which the products are supplied with a vibration mechanism: vibratory feeders with active side platforms. Production of the specified conveyor is loaded into the means of main transport (the current technological scheme).

Scheme B – on the lateral non-working board of the quarry (in semi-trench or on pylons) lifting conveyor is installed (Fig. 2).

The lifting conveyor is connected to the discharge pile conveyor of intra-quarry TOQ. TOQ pile is divided by sections for the accumulation of finished product fractions, each section is equipped with a vibrating feeder for output to the discharge conveyor. Dispatched products are supplied to the surface by means of trunk transport by a lifting conveyor. To the TOQ, the fractions are delivered by dump trucks, which are loaded onto the MCSP by wheel loaders.

Scheme C – MCSP, PCSP installed at the bottom of the concentration horizon. In the immediate vicinity of the place of the bunker mobile section connected to a mobile conveyor loader (MCL). MCL has the ability to transfer

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the finished product fraction to the upper platform of the ledge from the bottom, as well as to the bottomhole conveyor or to another MCL. The belt conveyor system in the working area of the quarry delivers finished products to the side TOQ, similar to the structural layout, as in scheme B. From TOQ, finished product fractions are delivered with a under-pile conveyor to the elevating conveyor (Fig. 2), which is directly involved in loading the main types of transport on a surface. According to the results of the study [10] in the working area of non-metallic quarries, it is advisable to use several MCLs to transfer finished products from MCSP, PCSP to the side TOQ. The MCL bunker mobile section, which is located at the MCSP, PCSP loaded by wheel loaders. Supply of finished products from conical piles of MCSP, PCSP to the side TOQ is carried out fractionally.

The studied technological schemes B and C are equipped with side TOQ of the pile-vertebral type. In scheme B, the TOQ sections are loaded (formed) by wheel loaders (Fig. 1) by unloading buckets from a shunting platform located at the level of the spine of the pile (Fig. 3). When implementing Scheme C, similar in design layout, TOQ is formed by an over-pile conveyor (Fig. 3).

The TOQ of the described type in the first period of operation of the quarry is placed under the non-working side, leaving for this a suitable site – the site, hence some volumes of minerals under this site are preserved. After the formation of the internal dump of overburden and other waste in the developed space of the first-stage open quarry, the said TOQ site is equipped on this dump. At the same time, the lifting conveyor is transferred to the slope of the internal blade, where its route is pre-formed according to the recommendations [10]. Upon completion of these works, it is possible to work out the preserved reserves of raw materials under the semi-trench of lifting conveyor and the TOQ platform under the side board.

Thus, in schemes B and C, all the processes of mining, processing and dispatching of finished products, as well as the transportation of rocks and products are carried out within the quarry field. The only exception is the process of loading fractions of finished products in the means of main transport. In scheme A, the accumulation of the finished product and its overload on the TOQ is also carried out on the daily surface. At the same time, in schemes B and C, the majority of transportation is carried out by environmentally friendly (acceptable) conveyor transport. Carrying out all the production processes in the career space in compliance with the above technical and technological measures to reduce their harmful effects, it is possible to minimize it as much as possible.

There is no doubt that the main criterion for the selection of the technological schemes under consideration when applying them on the presented non-metallic quarries should be an environmental criterion. Such criterion can be the concentration of the main pollutants (according to [10]) in the atmosphere within the reduced to 300–400 m SPZ from the quarry boundaries. Also important is the level of noise from the production processes within the specified limits (Table 1).

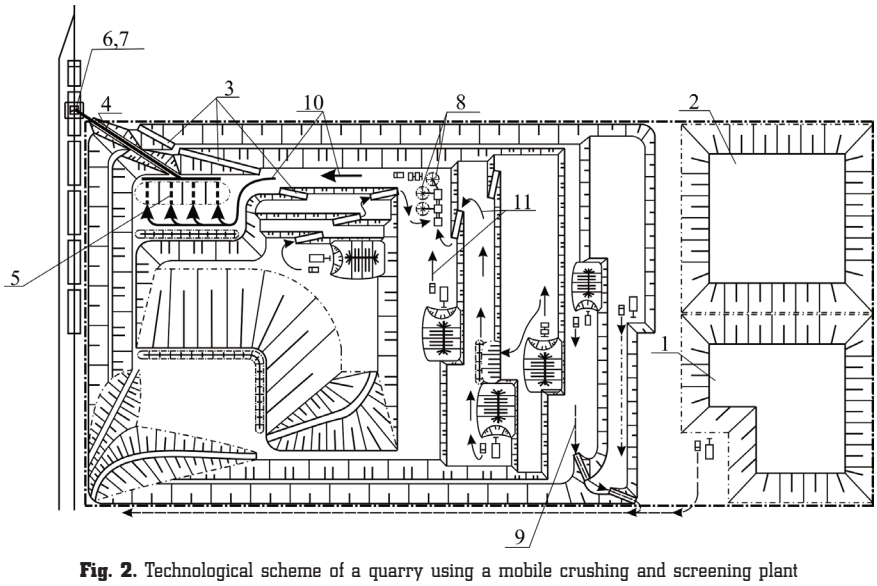

Fig. 2. Technological scheme of a quarry using a mobile crushing and screening plant in a quarry and an intra-quarry warehouse of finished products: 1 – near-edge dump of opening rocks, 2 – temporary man-made deposit of associated minerals; 3 – internal semi-trench-pylons; 4 – conveyor lift; 5 – platform for receiving TOQ finished products; 6, 7 – loading bunker to the railway transport; 8 – mobile crushing and screening plant (MCSP); 9 – direction of movement of overburden and waste in the developed space; 10 – direction of movement of finished products from MCSP to the TOQ site; 11 – direction of delivery of the mineral from the faces to the MCSP

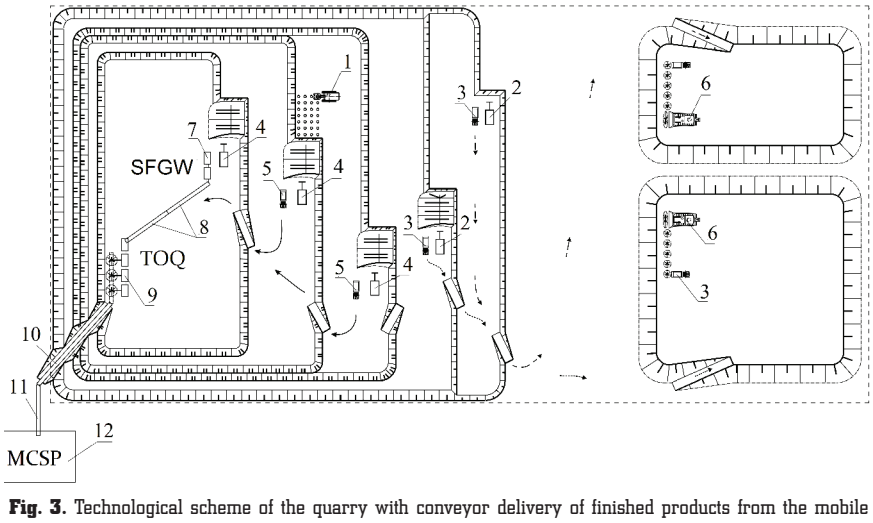

Fig. 3. Technological scheme of the quarry with conveyor delivery of finished products from the mobile crushing and screening plant to the surface warehouse: 1 – drilling rig; 2 – excavator on the aperture; 3 – dump truck for transportation of opening rocks; 4 – excavator for mining; 5 – dump truck for transportation of minerals; 6 – a bulldozer on the formed tailings; 7 – mobile crushing and screening plant; 8 – intra-quarry path of mobile conveyor loaders; 9 – TOQ; 10 – inclined (lifting) conveyor; 11 – surface horizontal conveyor; 12 – surface finished goods warehouse (SFGW) for dispatching to the main transport

Table 1

Pile-type TOQ indicators

No.	Indicators	Indicators for considered schemes		
		Scheme A	Scheme B	Scheme C
1	Capacity of TOQ pile sections, m^3	6000	3900	3900
2	Length of TOQ pile at the bottom, m	44	28	28
3	The number of vibratory feeders in the TOQ gallery, units	6	6	6
4	The power of the drive electric motors on the TOQ, kW	148	55	55
5	Unit costs of resources for the TOQ: – electricity, kW h/m^3; – diesel fuel/fuels and lubricants, kg/m^3	 0.45 0.57/0.03	 0.18 0.21/0.012	 0.18 0.21/0.012
6	Project depth of the quarry, m	130	130	130
7	Depth location of the conveyor in the quarry, m	–	80	80
8	Mineral productivity, thousand m^3/year	1350		
9	Length of conveyor lines, m	72	450	610
10	Path length of rocks and fractions, km: – dump trucks/wheel loaders	 1.33/406	 0.1	 –/0.1
11	Quantity, units: – dump trucks (40 tons)/wheel loaders (8 m^3)	 4/2.5	 3/3	 –/3
12	Engine power of mechanisms, kW/unit: – dump trucks/wheel loaders	 405/354	 405/354	 –/354
13	Mileage of transport, thousand km/year: – dump trucks/wheel loaders	 282.04	 186.08/20.32	 –/20.32
14	Electric power of conveyor lines, kW	148+(–)	122+(55)	175+(55)

Selected technological schemes must comply with environmental safety requirements. Therefore, their assessment should be carried out according to environmental criteria. These criteria can be considered taking into account the minimum amount of emissions of harmful substances (dust, gas) into the atmosphere. When performing calculations of indicators of environmental criteria, emissions of gas, harmful substances and dust formation were taken in the course of transport operations.

As a result of the research it is found that the best indicators of industrial, economic and environmental criteria have technological schemes B and C. This can be explained by the fact that most of the traffic is carried out by environmentally friendly (acceptable) conveyor transport.

It is established that the maximum concentrations of pollutants at the border of the SPZ and the residential area for the studied technological schemes B and C do not exceed the MPC. So, the prospect of introducing on existing Ukrainian non-metallic quarries of solid minerals with reduced size of the SPZ technological schemes for the development of option B and C, taking into account environmental factors, is undoubted.

Thus, the most environmentally safe is the development of deposits of rocky building materials when using the first parts of the MCSP (PCSP) in quarries, issuing fragmented rock mass to the surface by conveyor transport. The manufacture of varietal finished products occurs on the surface by sorting it on stationary or semi-stationary screening installations. Fractions of finished products are delivered from warehouses to other vehicles for delivery to consumers.

Improvement of technological schemes is recommended to ensure efficient production within dense residential buildings, or reduced sanitary protection zones, with a minimum acceptable environmental load on the environment. Technological bases for mining in technogenically loaded regions of Ukraine have been developed to ensure minimal impact of mining enterprises on the environment. In addition, the use of an integrated approach due to the need to establish environmental, technological and economic criteria that determine the direction of further use of mining areas.

7. SWOT analysis of research results

Strengths. The proposed approach allows to assess various schemes of mining and transportation of rock mass to the surface according to the results of the impact of a certain technological process on the environment. Reasonable technological schemes can solve the problem of reducing the negative impact of mining enterprises on the environment. Planning of mining objects will reduce the level of its conflict component in the aspect of the formation of environmental costs and the targeted use of man-made landscapes.

The use of conveyor transport will not only contribute to the reduction of emissions of pollutants, but will also provide further optimization of the processes of internal and external dumping. This, in turn, will not only reduce the seizure and loss of land resources, but also allow for timely implementation of measures to revitalize post-mining territories.

Weaknesses. The environmental danger of open-quarry mining of non-metallic mineral resources depends on many factors: the parameters of the quarries, the power and type of mining equipment, the location of the quarry in relation to the residential zone and the like. Production activities of a mining enterprise are accompanied by negative impacts on environmental components. The increase in the level of pollution of environmental objects can cause the occurrence of ecological-dependent diseases among the population living in the areas of mining.

To solve the problem of reducing the negative impact of mining enterprises on the environment, the problem arises of optimizing technological schemes for mining and transporting mineral resources. To determine the optimal parameters of the technological scheme of mining, it is necessary to involve engineering and technical personnel of mining enterprises, scientists, and also representatives of environmental organizations. This, in turn, increases the cost of production, but will reduce the negative impact on the environment and improve the environmental image of the company.

Opportunities. Research results form a methodological approach to the selection and justification of technological schemes for the placement of mining equipment in open quarries, which ensures a minimal impact on the ecological condition of the adjacent territories. The obtained results require periodic adjustments to meet the requirements of changes in legislation on environmental impact assessment, strategic environmental assessment and other regulatory documents.

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The use of research results will allow the company to timely identify environmentally hazardous technological processes of production and reduce pollution levels in the surrounding areas. This, in turn, will improve the working conditions of the company's employees, as well as reduce the number of environmental-related diseases in the population of mining cities, and will enhance the social responsibility of the enterprise and ensure its sustainable functioning.

This allows the company to quickly identify critical from an environmental point of view, technological processes and timely implement appropriate environmental measures. Such approaches will contribute to the greening of the mining industry, the successful passage of the environmental audit of mining companies, obtaining international environmental certificates and, accordingly, the development of new markets for products. The results can also be used to solve environmental problems of the functioning of mining enterprises in other countries.

Threats. In order to implement effective environmental protection measures in the field of the development of mineral deposits, there is a need to attract an environmental specialist to the staff of the enterprise. The environmental specialist will ensure timely monitoring of the emissions of pollutants by justifying ways to minimize them, as well as developing ways to reduce the environmental hazard of the mining enterprise. The implementation of most environmental protection technologies at mining enterprises is limited by the need for large-scale modernization of technological schemes for the development of deposits, as well as the updating of relevant technological equipment. It should be noted that in most cases, enterprises do not have sufficient material and technical capabilities to implement environmental protection measures. That's why the technological schemes developed by the authors ensure the achievement of relevant environmental indicators with minimal enterprise downtime and financial costs.

8. Conclusions

1. It is proved that the placement of mobile and portative crushing and screening plants in a quarry directly in the face or on the work sites allows localizing harmful dust and gas emissions into the atmosphere on the territory of the mining enterprise. The expediency of the use of MCSP, PCSP in typical non-metallic quarries according to environmental indicators has been substantiated.

2. Three typical technological schemes have been developed for the development of deposits of rocky building materials, differing in production capacity and emissions of pollutants to adjacent territories. It has been established that the use of belt conveyors (with placement both on non-working and working sides of the quarry) allows reducing the environmental risks of the functioning of mining enterprises. The maximum concentrations of pollutants at the SPZ border and the residential area for these technological schemes do not exceed the MPC. This will reduce environmental pollution levels and increase the comfort of living in the mining regions.

The use of technological schemes for the development of option B and C in the Ukrainian and foreign nonmetallic quarries of solid minerals with reduced sizes of the sanitary protection zone is environmentally sound. Typical technological schemes for the extraction and processing of non-metallic mineral raw materials have been proposed that can be used both at existing mining enterprises and at those that are being designed and are planned to be launched in cramped conditions of dense development of settlements.

References

1. Gumenik I., Lozhnikov O. Current condition of damaged lands by surface mining in Ukraine and its influence on environment // New Developments in Mining Engineering 2015: Theoretical and Practical Solutions of Mineral Resources Mining. CRC Press / Balkema, 2015. P. 139–143. doi: http://doi.org/10.1201/b19901-26
2. Mormul T. M., Terekhov Ye. V. Environmental and economic estimation of technological solutions in terms of land resource conservation in the process of open-cast mining // Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu. 2017. Issue 3. P. 122–128.
3. Yurchenko A., Litvinenko A., Morozova T. Study of dust cloud spraying parameters in terms of its suppression // New Developments in Mining Engineering 2015: Theoretical and Practical Solutions of Mineral Resources Mining. CRC Press / Balkema, 2015. P. 71–74. doi: http://doi.org/10.1201/b19901-14
4. Kozlovskaya T. F., Chebenko V. N. Ways of decline of y-level of ecological danger in districts mining by the opened method // Transactions of Kremenchuk Mykhailo Ostrohradskyi National University. 2010. Issue 6 (65). P. 163–168. URL: http://www.kdu.edu.ua/statti/2010-6-1(65)/163.pdf (Last accessed: 10.03.2018)
5. Symonenko V., Hrytsenko L., Cherniaiev O. Organization of non-metallic deposits development by steep excavation layers // Mining of Mineral Deposits. 2016. Vol. 10, Issue 4. P. 68–73. doi: http://doi.org/10.15407/mining10.04.068
6. Prokopenko V. I., Litvinov Yu. I. Environmental orientable imperative of developing the technology and excavation of horizontal fields // Naukovyy visnyk Natsionalnoho Hirnychoho Universytetu. 2017. Issue 2. P. 51–57.
7. Berry P., Pistocchi A. A Multicriterial Geographical Approach for the Environmental Impact Assessment of Open-Pit Quarries // International Journal of Surface Mining, Reclamation and Environment. 2003. Vol. 17, Issue 4. P. 213–226. doi: http://doi.org/10.1076/ijsm.17.4.213.17476
8. Cyclical-and-Continuous Method and in-Pit Crushing Operation Experience in the World / Drebenstedt C. et. al. // Gornyi Zhurnal. 2015. Issue 11. P. 81–87. doi: http://doi.org/10.17580/gzh.2015.11.17
9. Increasing ecological safety during underground mining of iron-ore deposits / Khomenko O. Y. et. al. // Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu. 2018. Issue 2. P. 29–38. doi: http://doi.org/10.29202/nvngu/2018-2/3
10. Technological aspects of ecological finalization of nonmetallic career during their liquidation and conservation / Symonenko V. I. et. al. // Bulletin of National University of Water Management and Nature Resources Use. 2016. Vol. 2. P. 148–158.
11. Technical, economic and environmental aspects of the use of emulsion explosives by ERA brand in underground and surface mining / Kholodenko T., Ustimenko Ye., Pidkamenna L., Pavlychenko A. // New Developments in Mining Engineering: Theoretical and Practical Solutions of Mineral Resources Mining. CRC Press / Balkema, 2015. P. 211–219. doi: http://doi.org/10.1201/b19901-38
12. Rock fragmentation control in opencast blasting / Singh P. K. et. al. // Journal of Rock Mechanics and Geotechnical Engineering. 2016. Vol. 8, Issue 2. P. 225–237. doi: http://doi.org/10.1016/j.jrmge.2015.10.005
13. Pyra J., Soltys A., Winzer J. Analysis of the blast-induced vibration structure in open-cast mines // Journal of Vibroengineering. 2017. Vol. 19, Issue 1. P. 409–418. doi: http://doi.org/10.21595/jve.2016.17289
14. Environmental noise management in the area of opencast mines / Lilic N. et. al. // Tehnika. 2017. Vol. 72, Issue 1. P. 47–52. doi: http://doi.org/10.5937/tehnika1701047l
15. Neustupa Z. An information system for managing the reclamation of a landscape degraded by opencast mining // Acta Montanistica Slovaca. 2004. Vol. 9, Issue 1. P. 9–15. URL: https://actamont.tuke.sk/pdf/2004/n1/3neustupa.pdf (Last accessed: 10.03.2018)

16. The harmonization and optimization of diagnostic methods for a belt conveyor / Helebrant F. et. al. // Management Systems in Production Engineering. 2012. Issue 2 (6). P. 39–44.
17. Moni V., Klouda P., Skraban V. Comprehensive Check Measurement of Key Parameters on Model Belt Conveyor // Management Systems in Production Engineering. 2013. Issue 11 (3). P. 24–27.
18. To issue of ecological safety quantitative evaluation at EIA / Statiuha G. O. et. al. // Eastern-European Journal of Enterprise Technologies. 2010. Vol. 6, Issue 6 (48). P. 44–46. URL: http://journals.uran.ua/eejet/article/view/3347/3147
19. Kozulia T. V., Emel'ianova D. I., Kozulia M. M. Complex ecological estimation of natural and manmade complexes which basis on MIPS- and risk analysis // Eastern-European Journal of Enterprise Technologies. 2014. Vol. 3, Issue 10 (69). P. 8–13. doi: http://doi.org/10.15587/1729-4061.2014.24624
20. Bugaieva L. M., Osmanov M. M., Statiuha G. O. Using system dynamics methods to study the sustainable development of regions of Ukraine. Eastern-European Journal of Enterprise Technologies. 2010. Vol. 2, Issue 10 (44). P. 22–25. URL: http://journals.uran.ua/eejet/article/view/2772/2578
21. Antonets A. V., Pliatsuk D. L. Analysis of information-analytical systems development of environmentally dangerous situation modeling // Technology Audit and Production Reserves. 2015. Vol. 6, Issue 2 (26). P. 8–12. doi: http://doi.org/10.15587/2312-8372.2015.56800

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DEVELOPMENT OF REAGENTS FOR PROTECTION OF EQUIPMENT OF WATER SUPPLY SYSTEMS FROM SCALE AND CORROSION

Об'єктом дослідження є екологічно безпечні водоциркуляційні теплообмінні системи в промисловості та комунальних господарствах. На діючих підприємствах в процесі модернізації систем водокористування часто переходять на використання інгібіторів корозії металів та накипоутворення. Після тривалого періоду експлуатації даних систем заміни обладнання не проводиться. Одним з найбільш проблемних місць реконструкції є наявність продуктів накипоутворення та корозії на внутрішній поверхні теплообмінного обладнання. Ці утворення знижують ефективність теплопереносу і нівелюють ефективність інгібіторів корозії та стабілізаторів накипоутворення.

В роботі проведено оцінку ефективності композицій, запропонованих в якості травильних розчинів для очищення поверхонь металу від осадовідкладень, а також в якості стабілізаторів накипоутворення. В ході дослідження використовувалися композиції, створені на основі неорганічних кислот в присутності уротропіну, уротропіну з тіокарбамідом.

Результати досліджень вказують, що найменшою корозійною агресивністю серед розглянутих варіантів характеризується композиція Р-29. Глибинний показник корозії 0,118907 мм/рік. Показник руйнування хімічноосадженого гіпсу складає не менше 90 %.

З метою ефективного та тривалого використання теплообмінного обладнання доцільно застосовувати інгібітори корозії та накипоутворення. В роботі представлена нова композиція Р-33, яка в концентрації 20 мг/дм³ (жорсткість води 230–490 мг-екв/дм³, Т=90 °С, τ=5 год) забезпечує стабілізаційний ефект 56,0–93,3 %, а протинакипний ефект – 95,5–99,3 %. З підвищенням концентрації реагенту до 50 % стабілізаційний та протинакипний ефекти сягають 100 %.

Розроблені композиції для очищення поверхонь теплообмінного обладнання на основі доступних недорогих реагентів, які переважають аналоги за ефективністю, характеризуються низькою корозійною активністю та забезпечують видалення з поверхні металу малорозчинних хімічно стійких речовин (гіпсу). Композиція Р-33 переважає аналоги тим, що забезпечує стабілізацію щодо осадовідкладень у розчинах гіпсу в присутності карбонатів кальцію та магнію при високих температурах.

Ключові слова: *стабілізатор накипоутворення, інгібітор корозії, водоціркуляційні системи, відновлення поверхонь металевого обладнання, корозійна агресивність водних середовищ.*

1. Introduction

At existing enterprises, in the processes of modernization of water use systems, in particular, cooling systems, they often switch to the use of corrosion inhibitors for metals and scale formation. However, after a long period of operation of these systems, full replacement of pipelines and equipment is not performed. The internal surfaces