On the Geological and Environmental Problems of Aging Mining Enterprises

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Abstract. The article considers the totality of environmental and geological problems of the Kryvyi Rih iron ore basin. The aim of the article is to analyze the mountain-ecological consequences of increasing (expanding) the pace of mining in densely populated regions with a well-developed infrastructure. Based on the analysis of the current situation in the city Kryvyi Rih (Ukraine), it was proposed to transfer the established trends to the potential future consequences of increasing mining in the Urals. The research methods are the method of logical and structural analysis, logical modeling, analysis of literary sources.

The main hypothesis of the study is a mining enterprise, which, regardless of current economic indicators, cannot be liquidated (reorganized) in a short time, since it requires preliminary systematic preparation. According to the results of the analysis, it was established that the main problems of mining enterprises are that they cannot be quickly eliminated, since this will negatively affect the natural environment, giving rise to numerous mining and geological problems, primarily related to hydrogeology and filling the voids. In case of refusal to solve these problems, serious consequences arise related to public health.

The solution of large and global environmental investment projects is complicated by the fact that competing enterprises often operate within the same basin, which objectively cannot independently combine investment efforts to solve environmental and geological problems. Based on the results of the article, the main conclusion is formulated that it is advisable to develop an appropriate methodology for controlled attenuation of mining operations.

1. Introduction

On the territory of the Russian Federation and other countries of the post-Soviet space, there is a large number of deposits whose operating life exceeds one hundred years. As a rule, these old fields have the infrastructure formed during the Soviet period, have a high level of provision with the passive part of fixed assets, proven technology, a sufficient number of skilled labor resources, but in parallel, they have a large number of mining and environmental problems associated with maintaining the current level of exploitation of deposits or increasing production by mining enterprises.

Among the oldest deposits include the Krivorozhsky iron ore basin. In our opinion, the problems of these enterprises can fully coincide with the mining enterprises of the Urals. It should be noted that the enterprises of Krivbass are located on the plain (Ukrainian Shield) and have been developed industrially for over 100 years, due to which the actual work depths often exceed the Ural ones, and due to the specifics of vegetation and water balance, the severity of these problems is more obvious.

2. Materials and methods
One of the key problems of old mining areas is the change in the natural landscape. The total area of the mining landscapes of Krivbass is 17.1 thousand hectares (an area comparable to the area of a city with a population of 300-500 thousand people, such as the city of Belgorod, whose area is 15.3 thousand hectares).

Today, the areal structure of the mining landscapes of Krivbass is as follows:
• open pit area is more than 4.2 thousand hectares;
• dump area - 7.0 thousand ha;
• area of extractive landscapes (sludge storage facilities) - 5.5 thousand ha;
• the area of mine dips and shear zones is 3.4 thousand ha [1].

However, the figures given are constantly changing due to the continuation and growth of mining operations associated with the dumping and excavation of underground voids. At the same time, the enterprises of Kryvyi Rih require a large amount of opening work due to the significant depth of the ore body.

In addition to the above-mentioned problem, Ukrainian experts note some other problems that can be attributed to mining and environmental problems. So, according to V. Peregudov, the main sources that have a negative impact on the environment of the Krivorozhsky basin are:
- production waste, the value of which significantly exceeds the volume of marketable products;
- lands disturbed by mining operations (quarries, sludge dumps, waste dumps, collapse zones, funnels, and displacements);
- career and highly mineralized mine water;
- emissions of pollutants (3B) [2].

Based on the above problems, it seems to us appropriate to analyze the mountain-ecological consequences of increasing (expanding) the pace of mining in densely populated regions with well-formed infrastructure. The analysis of the current situation in the city of Kryvyi Rih with its extrapolation to the prospects of the consequences of increasing mining in the Urals is the main goal of this article, in which there is a need to theoretically analyze the current situation with the identification of its fundamental causes and propose a conceptual model for overcoming the current situation.

The research methods are the method of logical and structural analysis, logical modeling, analysis of literary sources. The main theoretical paradigm is the feasibility of developing a methodology for controlled attenuation of mining operations. The main hypothesis of the study is a mining enterprise, which, regardless of current economic indicators, cannot be liquidated or reorganized in a short time, since it requires preliminary systematic preparation.

Similar studies were conducted by other authors, in particular, I. Solovey determined the criteria for sustainable development of the territory of the mining region after the completion of coal mining. The specified criteria by the author are divided into five features:
- an economic criterion, which is formed from the following signs: capital, operational, maintenance and monitoring costs, changes in the income of local authorities and residents, positive changes in the value of the real estate, investment, internal rate of return.
- The social criterion includes living conditions of the population, their state of health, employment opportunities, social policy, development of the region’s infrastructure.
- The environmental criterion includes climatic conditions (temperature, wind speed, precipitation), hydrology of surface and underground waters, the geology of the region, surface topography, physical and chemical properties of soils.
- The technical criterion combines the potential of mine facilities, the availability of machinery and equipment, technical methods for land use restoration, as well as technical factors that include the state and extent of changes in mine lands, as well as the distance to special services.
- The administrative criterion includes the availability of qualified manpower of managers for the implementation of the project, the adequacy of the budget, and regional potential [3].

3. Results
An analysis of the characteristic properties of mining production by Ukrainian researchers, taking into account natural factors, made it possible to identify the main reasons for its negative impact on the environment:

- The significant land intensity of mining production and the inevitable violation of the earth's surface when mining raw materials both open and underground methods;
- complex mining and geological conditions: a large depth of reserves development (open pit mining - up to 450 m, underground mining - over 1400 m) and water cut of deposits;
- the low natural quality of iron ore raw materials in the bowels and the need for its further enrichment with the involvement of highly ore-rich materials (the latter is typical for operating enterprises mainly with an open mining method);
- large volumes of production waste (overburden, dressing waste and low-grade lump ore of underground mining), low level of their use and, as a result, the need for permanent land allocation for storage;
- the lack of industrially proven effective technologies for the enrichment of oxidized quartzites and poor underground ores;
- significant volumes of dust formation as a result of technological processes and emissions of harmful gaseous substances during sintering of iron ore (production of sinter and pellets);
- pollution of ground and surface waters, the lack of effective technologies for the disposal of highly mineralized mine water, and their migration in the course of liquidation of individual mines [4].

Almost all of the components indicated by V. Peregudov form the problems of the mining enterprises of the Urals, except difficulties with the enrichment of ferruginous oxidized quartzites, which the Urals deposits are not rich in [5].

Particular attention should be paid to a rather serious, in our opinion, problem related to the hydrogeological component of production at great depths at which production occurs in the Kryvyi Rih basin: issues related to the water balance because our views completely coincide with the opinion E. Elchaninova and I. Golovko, who argues that: “in fact, it is not the restoration of disturbed aquifers that is being restored, but the formation of secondary aquifers with new parameters. This perception is because the geological structure of the disturbed rock mass is significantly different from the initial one, which was before the start of the minerals' mining ”[6]. At the same time, Russian authors S. Eldokhin and L. Futoryansky have actual data on the rates of “collapse” of depression funnels during the wet conservation of the Degtyarsky copper mine and the wet liquidation of the Valuev iron ore mine, which, in their opinion, can be used as analogues. The water inflow with the ageing of the mine during flooding is 4 years [7].

However, the flooding of underground mine workings leads to several negative hydrogeological, engineering-geological and environmental consequences: deterioration of the chemical composition of mine water, pollution of natural (ground and surface) waters, soils, flooding and waterlogging of the lands when the mine water spills to the surface, and deterioration of bearing capacity soils due to changes in their physical properties, etc. The displacement of contaminated mine air during the flooding of the exhausted space creates the threat of the accumulation of gas mixtures (methane, carbon dioxide, etc.) in basements, buildings, and structures, in soils, directly in the places of extraction from the workings before dispersion in atmospheric air. [8].

4. Discussion
It should be noted that due to the large scale of the depression funnel, a decrease in the groundwater level occurred in the significant (already arid) territories surrounding the city of Kryvyi Rih. Some of the liquidated enterprises are submerged, which leads to other local changes - flooding. According to O. Priymachenko, the development of the flooding process is accompanied by a change in the physical and mechanical properties of soils, a decrease in their bearing capacity and natural soil resistance, activation of dangerous geological processes (karst, landslides, suffusion), which leads to unforeseen precipitation of buildings and structures and their destruction [9], which ultimately lead to a significant reduction in soil fertility.
One more characteristic situation for Ukraine should be described. The share of water consumption in agriculture of the total water consumption for the period 1990-2008 decreased by 1.5 times, and the volume - from 10.9 to 2.4 billion m3. This is due to both a decrease in irrigated areas (from 2601 thousand ha in 1990 to 2179 thousand ha in 2008) and a decrease in water supply for irrigation (from 6289 to 1544 million m3, respectively). Sustainable pollution of surface and groundwater contributes to insufficient forest cover, a high level of river catchments' plowing, which indices of individual small rivers reaches up to 78%, while the level of agricultural development is more than 84% [8].

In addition to fertility problems for the steppe zone of the Kryvyi Rih basin, Ukrainian authors calculated the annual economic damage from environmental pollution, which, according to incomplete data, is estimated at $ 300 million, and the possible secondary consequences are difficult to predict in the authors' opinion. As for standard iron ores and their storage, which leads to the alienation of agricultural land. The annual alienation of land for these needs is 400-500 ha. Over the period of industrial development of the Kryvybas iron ore deposits, more than 25 thousand hectares of land were seized from agricultural organizations for the objects of mining enterprises [10].

Ukrainian experts are actively working on several environmental problems in the Kryvyi Rih basin. For example, V. Peregudov offers design solutions to reduce pollution of rivers and surface, ground, and open water. Reducing the production negative impact of the mining enterprises is carried out by implementing an additional set of design solutions:
- the construction of effective drainage systems that ensure the complete interception and return of filtration water to the circulating water supply system;
- Creation of anti-filter screens of tailings, implementation of measures for the prevention and localization of emergencies, primarily from the breakthrough of tailings dams;
- ensuring the hydraulic protection regime for closed mines, the maximum use of drainage, quarry and mine water in technological circulating cycles of enterprises;
- monitoring of groundwater and surface water within the area of quarries, tailings, and underground mining [4].

The authors also developed local projects, for example, the project “Reclamation of the area of funnel and failure zones of the Ternovskaya mine” of PJSC Krivorozhsky ZhRK [11] by placing overburden rocks from the Pervomaisky open pit of Severny GOK PJSC. The total area of funnel zones and dips recommended for backfilling is about 68 hectares, the volume for storing overburden rocks is 18.5 million m3. The volume of overburden production, which amounted to 23.4 million m3 in the whole plant over 2017 confirms the feasibility of implementing the developed design solutions with the further expansion of the technology development zone in other areas of disturbed lands [4].

The technologies indicated by the authors are mainly aimed at solving hydrogeological problems. However, there are solutions related to worked-out space. O. Khomenko and co-authors, solving the problem of modelling possible options for transforming worked-out spaces, believe that the formation of artificial pillars consisting of enclosing rocks and an array of mineral deposit not recovered during mining is effective. Artificial pillars perceive the pressure of bedrock and reduce tension in the area of reference pressure. They also disrupt the aerodynamic and hydrodynamic connection with the earth's surface and reduce air leakage through the worked out space and penetration of precipitation into the preparatory and treatment faces of the mine [12].

However, deeply scientifically substantiated and practically interesting approaches are, to a greater extent, local in nature and are aimed at solving specific problems of individual enterprises. In practice, the projects proposed for the solution require the implementation of certain investment programs, which seems problematic due to the conditions of ageing mining enterprises. At the same time, mining enterprises in the Kryvyi Rih basin belong to various owners, among which there are quite serious competitive processes. In particular, enterprises engaged in open mining of iron ore, such as, for example, the Ingulets mining and processing plant, the Northern mining and processing plant, the Central mining and processing plant, have in their assets enterprises for underground mining of poor ores owned by the international vertically integrated mining and metallurgical company Metinvest. PJSC Arcelor Mittal-Kryvyi Rih owns the Novokrivorozhsky open-pit mining enterprise, a mining and
processing plant, and ore management (former Kirov mine administration). Underground iron ore mining enterprise (5 mines) - PJSC Krivbaszhelezrudok is owned by Starmill Limited, a partner company operated by Metinvest and Privat. PJSC UGOK (Southern Mining and Processing Plant) is owned by PJSC Smart Holding. The Suha Balka NGO is owned by Berklemond investments LTD, a member of the DCH group. Besides, there are other owners of smaller mining enterprises.

It should be noted that part of the mining enterprises was liquidated as unprofitable, however, this process was not transparent and objective, as evidenced by official Ukrainian documents [13]. Therefore, it is difficult to assume the possibility of integration of these companies for the implementation of joint investment projects to solve mining and environmental problems.

The severity of the above problems is quite indicative of external factors. So, according to Ukrainian authors, neoplasms occupy a special place among the diseases in the old industrial regions. Up to 60% of patients with malignant neoplasms are concentrated in 9 regions of Ukraine, among which Donetsk (10.4%) and Dnepropetrovsk (7.2%) are in the first place. [1]. According to another author, Ukraine is in the top ten of the world community in terms of the rate of extinction of people and takes 60th place in terms of life expectancy. According to the Environmental Sustainability Index, the World Economic Forum in Davos (2002) ranked Ukraine 137th out of 142 countries [8] (the index allows evaluating the results of environmental policies, identifying the best results, as well as countries facing an environmental disaster, comparing economic growth with environmental protection [14]).

5. Conclusion
Undoubtedly, the measures proposed by environmental experts are quite effective and should be implemented, however, they have only tactical goals and do not put forward long-term programs related to ensuring comprehensive and balanced development of the studied region. Since the prospects for mining in the old industrial regions are determined to a large extent by fluctuations in world prices for minerals, it is early to talk about a serious increase in required investments in mining of the Krivorodsky basin.

Therefore, it is advisable to consider the objective need to develop a comprehensive program aimed at simultaneously reducing the rate of environmental pollution while maintaining or insignificantly reducing the existing rates of mining. In the authors' opinion, the expediency of increasing volumes, in this case, is absent, therefore, special attention should be paid to the refinement and improvement of the onboard content quality. At the same time, the resulting profit should be invested not only in the development of enterprises but also in the restoration and reduction of environmental consequences. However, we objectively understand that under the conditions of the joint ownership of the considered enterprises, the latter idea requires, along with exclusively academic research, the corresponding development of mechanisms of state influence on the processes taking place in the studied field.

6. References
[1] Son'ko S P, SHiyan D V 2012 Doslidzhennya zahvoryuvanosti naselennya staropromislovogo regionu za dopomogoyu gis (na prikladi krivbasu) Naukove vidannya Visnik Donec’kogo institutu social’noi osviti. Seriya Geografiya Tom UIII 8 126 p Donec’k, PVNZ «Donec’kij institut social’noi osviti» pp 89-93
[2] Peregodov V V, Protasov V P 2018 Reshenie problem minimizacji negativnogo vliyaniya proizvodstvennoj deyatelnosti predpriatij Krivorozhskogo zhelezorudnogo bassejna na okruzhayushchuyu prirodnuyu sredu Ekologiya i promyslennost’ [Tekst]: nauch.-prakt. zhurn. 1(54) uchreditel’ i izd.: Ukr. gos. nauch.-tekhn. centr "Energostal’" (H.: Energostal’) pp 24-30
[3] Solovij I P, Bezik Ya V, Kuleshnik T Ya 2014 Optimizacia zemlekoristuvannya pislya zavershennya vuglevidobutku u rusli politiki stalogo rozvitku Soč.-ek. problemi suchas. periodu Ukraïni Vip. 5(109) pp 79-84
[4] Peregodov V V, Protasov V P 2018 Reshenie problem minimizacji negativnogo vliyaniya proizvodstvennoj deyatelnosti predpriatij Krivorozhskogo zhelezorudnogo bassejna na
окруженности природного среду Экологиа i promyshlennost' [Tekst]: nauch.-prakt. zhurn. 1(54) uchredit'el' i izd.: Ukr. gos. nauch.-tekhn. centr "Energostalk" (H.: Energostalk') pp 24-30

[5] Chernyshov N M, Molotkov S P, Reznikova O G 2003 Zieloto-platinonosnost' glavnjejshih tipov zhelezoerdnyh formacij mira (informacionno-analiticheskij obzor) Vestnik Voronezhskogo gosudarstvennogo universiteta (Geologiya) 2 pp 137—162

[6] El'chaninov E A, Golovko I V 2007 Formirovanie vtorichnyh podzemnyh vodonosnyh gorizontov posle likvidacji shah GIA 8 URL: https://cyberleninka.ru/article/n/formirovanie-vtorichnyh-podzemnyh-vodonosnyh-gorizontov-posle-likvidatsii-shaht (data obrashcheniya: 20.04.2020)

[7] Elohina S N, Futoryanski L D 2002 K metodike prognoza skorosti zatopleniya podzemnyh parhor hryaborok Izvestiya UGU 15 URL: https://cyberleninka.ru/article/n/k metodike-prognoza-skorosti-zatopleniya-podzemnyh-paryhrobok (data obrashcheniya: 18.04.2020)

[8] Yakiv A V 2010 Zbalansovane vodo regulyuvannya v sistemah stabil'nego zemlekoristuvannya Ukraini. Zbirnik naukovih prac' NNC "Institut zemlerobstva UAAN" Vipusk 3 pp 48-68

[9] Prijmachenko O V 2013 Viktoristannya geoinformacijnych technologij u virshennym problem z pidtoplennym teritori Misto buduvannya ta teritori'al'ne planuvannya Vip. 49 nauk.-tekhn. zbirnik 658 pp 440-445

[10] Olejnik T A 2013 Povyshenie kachestva bydnych kuskovyh rud shahntoj dobychii Krivbassa metodom otsadki Zbaganennyh korisnih kopal' Nauk.-tehn. zb. Vip. 53(94) pp 44-56

[11] Peregudov V V 2015 Tekhnologicheskie i ekologicheskij aspekty ustochivogo razvitiya predpriyatiy gornodobyvayushchego kompleksa Suchasni tehnologij rozrobki rudnyh rodoivishch Ekologo-ekonomicni naslidki diyal'nosti pidpryemstv GMK: zb. nauk. pr. za rezultativii roboti III Mizhn. nauk.-tekhn. konf., 19 r., m. Krivij Rig: Vid. R.A. Kozlov pp 24–27

[12] Homenko O E, Počepev V, Sulaev V, Vladiko A, Fal'shtynskiy V 2004 Puti povysheniya effektivnosti raboty shaha Krivorozhskago zhelezorudnogo bazejnja nauk. visn. NGU 6 pp 3-5

[13] Zaremba V M 2007 Pro rezul'tati auditu efektivnosti provedennya restrukturizacii pidpryemstv pidzemnogo vidobutku zaliznoj rudi Byulet'en pidgotovleno za materialami Zvitu pro rezultat perevirkh efektivnosti provedennya restrukturizacii pidpryemstv pidzemnogo vidobutku zaliznoj rudi (Kii: Rahunkova palata Ukraïni) Vipusk 8 http://old.ac-rada.gov.ua/control/main/publish/article/876713;jsessionid=8191A00B740AA15969F386B9EB7AED5A

[14] Bakumenko Lyudmila Petrovna, Korotkov Petr Anatol'evich 2008 Integral'naya ocenka kachevstva i stepeni ekologicheskoy ustochivosti okruzhayushchey sredy regiona (na primere Respubliki Marij El) Prikladnaya ekonometrika 1 URL: https://cyberleninka.ru/article/n/integralnaya-otsenka-kachevstva-i-stepeni-ekologicheskoy ustochivosti-okruzhayushchey-sredy-regiona-na-primere-respubliki-mariy-el (data obrashcheniya: 01.05.2020)