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RESEARCH OF THE IMPACT OF OPEN-PIT MINING ON THE LAND AND WATER RESOURCES IN KRYVBAS

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Abstract. Main effects of mining operations on the land and water resources while mineral mining are considered. Identify that intensive open-pit and underground development of mineral deposits has resulted in the disturbed natural environment, which, in turn, have changed geomorphological and hydrogeological structure of the region. Current stage of the disturbed land and water resources are determined in terms of Kryvyi Rih iron-ore basin. The analysis showed that as a result of mining and technical activities in Kryvbas, minimum 15-20 mln ha of land are disturbed, 59 % of this area is used for different mine workings, 38 % is covered with waste rock dumping or waste from mineral concentration, and 3 % is the sites of subsidence, caving, and other land surface disturbances due to underground mining. Thus, about 1 km^3 of drainage water is extracted annually during mineral extraction. As a result, natural landscapes have been replaced by new technogenic objects, which, in turn, have changed geomorphological and hydrogeological structure of the region. Key technological objects of the largest enterprises of Kryvbas mining industry as well as their parameters are studied. Dynamics of the accumulation of emissions and discharges of the production wastes of Kryvyi Rih iron-ore basin enterprises as well as their location are shown. Identify that by means of gross discharge of the contaminating substances. On average, more than 235.62 thous. t/year enter the air with the dust. Also identify that the largest mining enterprises of Kryvyi Rih Region discharge on average 2296.8 thous. m^3/year of the contaminated water. Certain measures are proposed to facilitate reduction of the impact due to open-pit mining on the indicated environmental components. They are aimed at involve implementation of resource-saving technologies along with reclamation of the technogenic objects.

Keywords: mining operations, impact, technogenic object, waste dump, land resources, water resources.

1. Introduction

Long-term intensive open-pit and underground development of mineral deposits has resulted in the disturbed natural environment. In particular, natural landscapes have been replaced by new technogenic objects, which, in turn, have changed geomorphological and hydrogeological structure of the region. This process has provoked climatic microchanges; it has affected the soil and vegetation cover, altered the ground water flow, influenced the surface water quality etc. [1]. Due to interaction of mining objects with all components of natural environment, these changes influence the atmospheric air, flora and fauna, and the population living within the mining region. Thus, study of the influence of mining operations upon the land and water resources is a topical issue requiring constant monitoring, data updating, and solution of the target tasks.

Current state of the disturbed land and water resources in terms of Kryvbas. All environmental processes are interconnected. Consequently, at all stages of mineral development the components experience certain changes while influencing each other directly or indirectly. The changes become obvious either immediately or in a considerable period of time.

In Fig. 1, a scheme of the open-pit mining influence on the land and water resources with the aftereffects is represented according to the author's data [1, 2].

Technogenic objects have made the fertile agricultural lands impossible to be used; they have also become a source of constant negative influence on the regional ecological situation.

Rock mass extraction, ground water pumping, and mass dumping on the land surface cause irreversible environmental processes. That prevents from using plough land;

harms green vegetation; changes regional hydrogeological regime local relief and air flows; contaminates land surface, air and water basins with the production waste. In future, all those factors influence both life quality and health of the population [3, 4].

Problem statement and state of its solution. Mining enterprises consume up to 2.79 m^3 of fresh water while disposing into a hydrogeological network from 0.01 to 0.03 m^3 of the contaminated water per each ton of the extracted raw material. 220 mln m^3 of the contaminated water, including more than 20 mln m^3 of the highly mineralized one, come annually into the Saksahan and Inhulets rivers as a result of operation of the Kryvbas mines and open pits. About 1 km^3 of drainage water is extracted annually during mineral extraction [1].

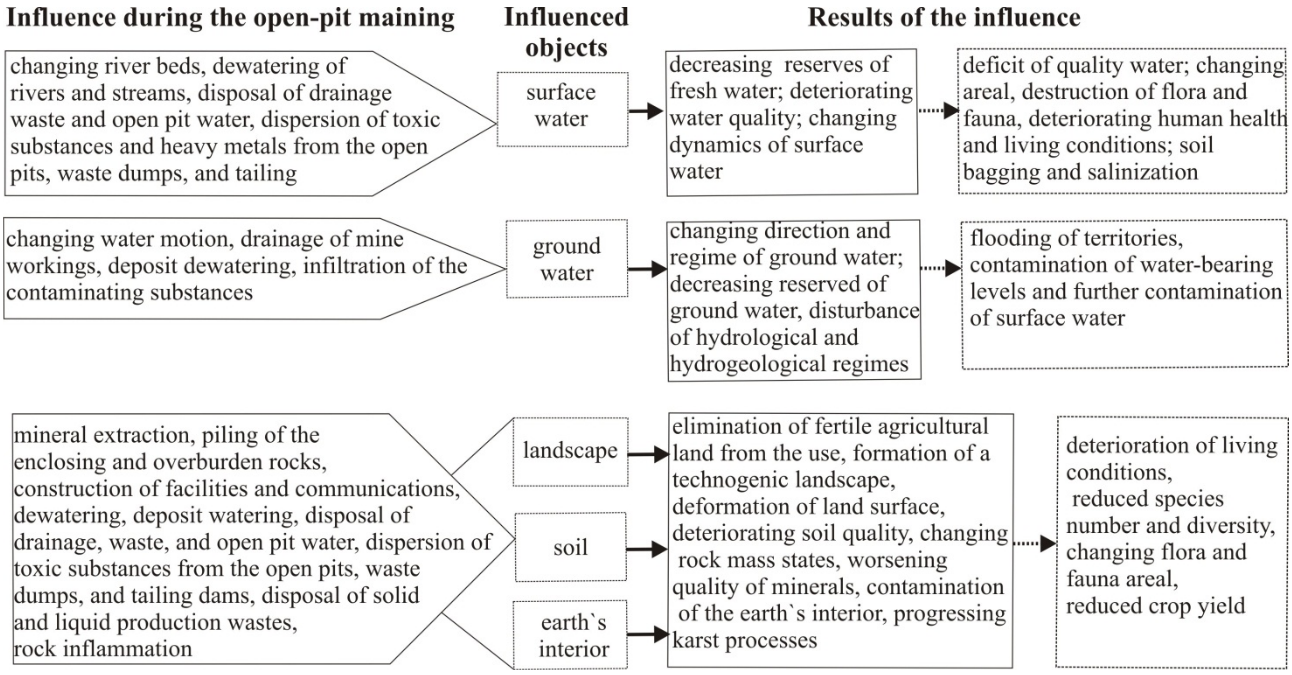

Figure 1 – Results of the open-pit mining influence on the land and water resources

As a result of mining and technical activities in Kryvbas, minimum 15-20 mln ha of land are disturbed, 59 % of this area is used for different mine workings, 38 % is covered with waste rock dumping or waste from mineral concentration, and 3 % is the sites of subsidence, caving, and other land surface disturbances due to underground mining. Technogenic changes in a relief are the prerequisites of arising environmental problems: expansion of the mined-out space, surface subsidence, land elimination for dumping, disturbance of hydrogeological regime of the ground waters, their mineralization above the accessible concentration accompany any mining production [5-6].

A series of studies performed by national and foreign scientists deals with the analysis of the problems, development of recommendations and measures to reduce environmental impact of mining technologies on the environment and geological medium. The most prominent among them are the papers of Voinytskyi, A.P., Dubrovskyi, V.P., Boholiubov, V.M., Kuzyk, I.M., Artamonov, V.M., Tsekhmister, D.P., Trofymov, V.T., Korolev, V.A., Herasimova, A.S., Kolisnyk, V.Ye., Malakhov, G.M., Lysyi, A.E., Artiukh, V.M., Utyshyn, V.O., Dolhova, T.I., Hnieushev, V.O. and others. Despite considerable contribution of the prominent scientists, there are still some unsolved problems concerning individual parameters of the environmental impacts, measures for their eliminations etc. Thus, the **purpose** of the paper is a detailed analysis of technogenic influence of the Kryvbas mining enterprises on the land and water resources for the development of optimal measures to reduce their impact.

2. Methods

Effect of the iron ore mining on the Kryvbas land and water resources.

The Kryvbas territory is characterized by complex and diverse natural and engineering-geological conditions. A lot of areas belong to the category of technogenically loaded ones. Kryvyi Rih iron-ore basin is being developed by both underground and open-pit mining. Main production capacities are provided by 5 mining and processing works (GZK): Southern, Northern, Central, Inhuletskyi, and "ArcelorMittal Kryvyi Rih" PJSC that extract ore in terms of 9 open pits.

Table 1 considers the largest mining enterprise objects influencing the Kryvbas water and land resources.

Table 1 – Objects influencing the Kryvbas land and water resources while iron-ore mining

Enterprise	Object	Characteristics (capacity, area)
1	2	3
PJSC "Arcelor Mittal Kryvyi Rih"	Open pit #3	Production of cast iron, steel, and ferroalloys. Total area of the mining and processing production – 4084.9 ha of land: open pits – 648 ha, external dumps of waste rock – 1119 ha, tailing dams– 863 ha, industrial site – 822 ha of land
	Open pit # 2-bis	
	Waste dump "Dalnii"	
	Waste dump "Stepovyi"	
	Waste dumps "## 2, 3"	
	"Temporary waste dump # 4"	
	Mined-out space of open pit # 1	
	Waste dump "Stepovyi-2" (under construction)	
	Tailing dam "Obiednane. Fourth card"	
	Tailing dam "Myroliubivske"	
	Tailing dam "Central"	
JSC Southern GZK	Open pit "Southern GZK"	Open pit length – 3000 m, width – 2650 m, depth– 375 m (at the moment of development completion – 615 m)
	Waste dump "Livoberezhnyi"	Designed volume – 225 mln m³, Capacity: shales – 1185800 thous. t Area: 818 ha /considering SPZ – 985 ha
	Waste dump "Pravovoberezhnyi"	Designed volume – 68 mln m³, designed base area – 435 ha Area: 261.1 ha / considering SPZ – 346.0 ha
	Tailing dam "Voikove"	Capacity: 373 411 500 t. Area: 536.7 ha/ considering SPZ – 727.0 ha
	Tailing dam "Obiednane. First card"	Capacity: 250 635 000 t. Area: 481.0 ha/ considering SPZ – 667.0 ha
	Tailing dam "Obiednane. Second card"	under construction *

continuation of table 1

1	2	3
JSC Northern GZK	Hannivskyi open pit	Hp = 300 m, Sp = 737 ha
	Pershotravnevyi open pit	Hp= 320 m, Sp = 660 ha
	Open pit " Pershotravnevyi "	Capacity: 910 mln m^3 (2507 mln t). Area: 849 ha /1187 ha
	Open pit "Hannivskyi"	Capacity: 965 mln m^3. Area: 991.6 ha /1346.5 ha
	Tailing dam	Capacity: 978.5 mln t (631.29 mln m^3). Area: 1410 ha /1837.49 ha
JSC Inhyletskyi GZK	Inhuletskyi open pit	Hp = 650 m, Sp = 577.2 ha
	Open pit "# 1"	Capacity: 280756.0 thous. t Area: 164.3 ha /300 ha /350 ha (considering SPZ)
	Open pit "# 2"	Capacity: 529 022 500 m^3. Area: 438.5 ha / 577.0 ha
	Open pit "# 3"	On the open pit wall (its revomal is planned for the wall reactivation) Capacity: 192186.0 thous. t. Area: 147.3 ha
	Open pit "# 5"	Designing. Designed volume 543.7 mln m, designed base area 670.6 ha
	Tailing dam	Capacity: 1180690 thous. t. Area: 977.5 ha.
JSC Central GZK	Hleiuvatskyi open pit	Hp = 500 m, Sp = 480 ha
	Petrovskyi open pit	Hp =300 m, Sp = 104 ha
	Artemovskyi open pit	Hp =500 m, Sp = 336 ha
	Internal open pit	Designed volume – 60 mln m^3, designed base area – 50 ha
	Open pit "Southern-Western"	Capacity: 39.43 mln t. Area: 49.6 ha/ 152.7 ha/52.4 ha
	Open pit "# 5"	Inactive. Capacity: 28 mln m^3. Area: 78 ha /140 ha /188 ha.
	Open pit "# 6"	Capacity: 11 mln m^3. Area: 50.2 ha/101.7 ha / 90.9 ha.
	Open pit "Northern"	Designed volume – 100 mln m^3, designed base area – 210 ha
	Open pit "Eastern "	Designed volume – 22 mln m^3, designed base area – 80 ha
	Open pit "Western"	Designed volume – 50 mln m^3, designed base area – 170 ha
	Open pit # 2	Designed volume – 44 mln m^3, designed base area – 102 ha
	Open pit # 3	Designed volume – 93 mln m^3, designed base area – 255 ha
	Tailing dam	Capacity: 688.00 mln t. Area: 1705.8 ha /5356.22 ha /1959.6 ha

Note: *no information
SPZ – sanitary-protective zone
Hp – open pit depth, Sp – open pit area on the day surface

According to the orders at the level of local self-government authorities, technical and technological parameters of the iron-ore mining and processing technology are being constantly monitored along with the control of industrial waste distribution [3, 4]. These data have made it possible to accumulate the data concerning dynamics of waste accumulation, discharge volumes and location of the industrial wastes of the mining industry of Kryvyi Rih Region within the period of 2019-2021. The results are represented in Table 2.

Table 2 – Dynamics of the accumulation, discharge, and location of the wastes of mining enterprises of Kryvyi Rih iron-ore basin within the period of 2019-2021 according to data [3, 4, 7]

##	Enterprise	Gross discharge, thous. t	Discharged contaminated return water without treatment, thous. m^3.	Wastes generated factually at the enterprise, t	Wastes accumulated at the end of 2020, t
		2019/ 2020/ 2021	2019/ 2020/ 2021	2020	
1	PJSC "Arcelor Mittal Kryvyi Rih"	230.8/ 209.0/ 211.2	918.9/ 812.1/ 1283.0	Overburden (gangue) rock 9 278 134.5 Concentration tailings 14 950 568.1	837 198 800.0 618 958 989.4
2	JSC Southern GZK	23.28/ 1.22/ 1.308	*/ */ *	Wastes of the overburden rock 7752734.288 Slurry of the iron ore concentration 16094466.0	808135148.0 570240697.9
3	JSC Northern GZK	6.8/ 5.11/ 5.893	*/ */ *	*	*
4	JSC Inhuletskyi GZK	1.615/ 1.520/ *	107.8/ 108.1/ 106.8	Iron ore wastes (DMS) 744409.0 Wastes of iron-ore open pit mining 568164.0 Slurry and tails after concentration 18288815.0	14371398.0 1274645100.0 843414905.0
5	JSC Central GZK	2.527/ 2.507/ *	927.5/ 913.1/ 1390.4	*	*

Note: *No statistic information
DMS – dry magnetic separation

Analysis of the data in Table 2 helps make conclusions as for the objects of technogenic load on the environment, their parameters, and dynamics of the industrial waste accumulation. We have considered only the largest enterprises of the industry that are located in the region. Other enterprises intensify the effect, and situation worsens due to the additional environmental loads.

The influence of the Kryvbas enterprises on the atmospheric air can be analyzed by means of gross discharge of the contaminating substances. On average, more than 235.62 thous. t/year enter the air with the dust.

Dust emission influences the quality of water and land resources as these are the substance particles that deposit on the reservoir surfaces and ground with its following intermediate influence on the flora and fauna. That also favours eutrophication resulting in changing species variety, damaged agricultural crops, forests, and plants by reducing their growing rate. In 2021, mining enterprises of Dnipropetrovsk Region emitted into the air 26.4 % of harmful substances of the total regional emissions [3].

Direct influence of mining industry on hydrogeology can be studied on the example of return water discharged into the Inhulets River intake. The matter is that the technogenic water is discharged without proper treatment but only after water precipitation that affects the water quality. As a result, unfortunately, water mineralization is not reduced. Thus, the largest mining enterprises of Kryvyi Rih Region discharge on average 2296.8 thous. m^3/year of the contaminated water. In turn, due to changed water motion and drainage of mine workings, ground water reserves experience their reduction along with the disturbed hydrogeological and consequent hydrological regimes.

Tailing dams of Southern, Inhuletskyi, and Central GZK are located along the Inhulets River; they increase the river mineralization due to the influence of highly mineralized drainage water. When oxides of calcium and silicium, aluminium, iron, manganese, magnesium enter from the waste dumps into the ground water and then into other water-bearing levels, that may result in changing ratio of these substances in the water-bearing levels of the waste dump base and the Inhulets River.

In 2020, mineral mining with the intense water handling, discharge, disposal of the contaminated industrial waste and mine water within the zone of Kryvbas GZK activities influences local contaminations of ground water within the territory of Dnipropetrovsk Region [3].

The existence of a great number of technogenic objects within the mining area has negative influence on the natural hydrogeological processes.

In terms of Kryvyi Rih, almost overall drainage of the quaternary water-bearing level is observed. It is replaced by local formation of a technogenic water-bearing level through slurrying, numerous hydrotechnical facilities built in the ravines, expansion of the available tailing dams, and dumping. All combined, it has resulted in the formation of a joint water-bearing level of ground water formed by means of infiltration of atmospheric precipitations and strong technogenic leakages affecting a hydrological network of the adjacent territory and region. Further environmental influence is manifested in the reduced level of ground water that depreciates fertile lands.

In paper [8], power dependence of the accumulation of Ukrainian mining wastes in terms of time factor is established. These studies demonstrate that each 10 years, on average, 2.4 bln tons of industrial wastes are accumulated in Ukraine alone. Thus, a share of some enterprises of Kryvyi Rih iron-ore basin, which apply open-pit mining of iron ore (according to the total data of Table 2, column 5), accounts for about 40%.

Land areas, which surface is disturbed due to mineral mining apart from other factors belong to the degraded lands.

GZKs are the main enterprises of Dnipropetrovsk Region which disturb its land at open-pit and underground mining. During the years of 2021, 37.9500 thous. ha of land are disturbed, 6.0300 thous. ha are mined out, and in 2019 4.65 thous. ha are reclaimed [3].

Processes of natural restoration of vegetation surfaces, soils, and reliefs of the disturbed land are rather slow or even do not happen at all. Different reclamation methods and techniques are applied to restore natural lands.

3. Results and discussion

Certain measures are considered in Table 3 to reduce environmental impact on the land and water resources at open-pit mining.

Table 3 – Measures to reduce impact on the land and water resources at open-pit mining

Environmental component	Measures to reduce impacts		
	in terms of open pits	in terms of waste dumps	in terms of tailing dams
Land resources	- dust control while mining; - timely land reclamation; - improvement of the technological schemes for the formation of technogenic landscape in terms of different movement directions of mining areas	- not to plan additional land allotment for dumping; - dust control while rock loading, transporting, and unloading on a waste dump along with the workplace moistening; - dust control of the waste dump surfaces and constant control of dust generation and soil condition around a waste dump; - planned reclamation of the waste dump surface	- use of the depositing site systems, in terms of which practically all tailing dam area will be covered with water; that will minimize the discharge of dry fine sands; - use of sulfate soap solution for dry “beaches”; - water spraying of the workplaces, tailing dam surfaces and dam slopes; - constant control of soil contamination within the operation zones; - set of operations to restore the inactive tailing dams
Water resources	- systematic daily control of water level in the emergency reservoirs; - implementation of a network with the necessary number of dewatering wells; - reconstruction and implementation of the surface drainage for the open pits; - replacement of the water supply networks (if they are outdated);	- together with others (waste dumps and tailing dams located within the area), formation of a linear series with the required number of dewatering wells; - decreasing volume of filtration water leakage into a drainage system from the active tailing dams; - implementation of the required number of regime observation wells; - processing of the water accumulated in the tailing dams; - implementation of the mechanisms to stimulate development of environmentally friendly technologies and a process of transferring to wasteless production	

continuation of table 1

	- systematic monitoring of the level and intensity of water inflow into an open pit;- advanced domestic waste water treatment; - minimization of water consumption, implementation of proper environmental protection systems; - implementation of effective technologies to provide reduced level of water mineralization before its discharging into the water objects; - total prohibition to discharge untreated and insufficiently treated water immediately into the water objects; - clear and timely monitoring of discharges, strengthening of the responsibility for not following the requirements and intensification of the water-protection measures by the contaminating enterprises	

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ДОСЛІДЖЕННЯ ВПЛИВУ ВІДКРИТИХ ГІРНИЧИХ РОБІТ НА ЗЕМЕЛЬНІ ТА ВОДНІ РЕСУРСИ В КРИВБАСІ

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Анотація. Розглянуто основний вплив та наслідки на земельні та водні ресурси під час розробки родовищ. Встановлено, що інтенсивна розробка родовищ корисних копалин відкритим та підземним способом призвела до заміни природних ландшафтів новими техногенними об’єктами, які в свою чергу вплинули та змінили геоморфологічну і гідрологічну будову регіону. Визначено сучасний стан порушених земельних та водних ресурсів на прикладі Криворізького залізорудного басейну. Аналіз показав, що внаслідок гірничотехнічної діяльності в Кривбасі порушено не менше 15-20 млн га земель, з них 59 % площі використано під різні гірничі виробки, 38 % – під відвали пустої породи або відходи збагачення, 3 % – місця осідання, провалів і інших порушень поверхні, пов'язаних з підземними розробками. Також щорічно близько 1 км^3 дренажних вод виймається при видобутку корисних копалин. Таким чином відбулася заміна природних ландшафтів новими техногенними об’єктами, які в свою чергу вплинули та змінили геоморфологічному і гідрологічну будову регіону. Досліджені основні техногенні об’єкти та їх параметри від найбільших підприємств добувної галузі Кривбасу. Наведена динаміка накопичення викидів, скидів, розміщення відходів підприємствами добувної галузі залізорудного Криворізького басейну. Встановлено, що через валовий викид забруднюючих речовин в середньому у повітря потрапляє з пилом біля 235,62 тис. т/рік. Також визначено, що найбільшими гірничодобувними підприємствами Криворіжжя скидається в річку в середньому біля 2296,8 тис. м^3/рік. Запропоновано заходи, які сприятимуть зниженню негативного впливу спричиненого відкритою розробкою родовищ на зазначені компоненти середовища. Вони спрямовані на дотримування та впроваджування ресурсозберігаючих технологій та вдосконалення рекультивації техногенних об’єктів.

Ключові слова: гірничі роботи, вплив, техногенні об'єкти, відвал, земельні ресурси, водні ресурси.

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