Specifics and practical examples of low-hazard industrial waste utilization for filling technogenic cavities

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Abstract.
The presented research focuses on the pressing issues of restoration of land areas disturbed by mining operations. The paper studies legislative peculiarities of industrial waste utilization for the purpose of reclamation of disturbed lands in Ukraine. Real practical examples of using low-hazard industrial waste for reclamation of land areas disturbed by quarrying and failure zones are analyzed. It is noted that, provided that all legal and sanitary requirements are met, low-hazard class IV waste can be used at the mining-technical stage of quarry reclamation. Aspects of the prospects for restoring the earth’s surface level are clarified based on the development of directions for the backfill mass formation in technogenic cavities, which will provide stability and geomechanical reliability of the earth’s surface.

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Anthropogenic activities related to mining of minerals result in significant environmental impacts. The earth’s surface is particularly affected. Thus, as a result of mining by open-pit and underground methods, the following types of disturbances are formed: quarry cavities, zones of shear and the earth’s surface failure, large-tonnage accumulations over significant areas. The specified earth’s surface disturbances cause contamination of surface and underground water resources, changes in their hydrological regime, contamination and erosion of fertile soils, as well as dust pollution of the atmosphere. In addition to the environment, there is a negative social-economic impact of the mentioned forms of disturbances: the potential of land areas is not used, depressive technogenic landscapes are created, and the population is resettled with the liquidation of settlements, followed by the destruction of industrial and civil infrastructure [1-4].

As of 2021, on the territory of Ukraine, the land areas occupied by open-pit mining, quarries and mines, peat mining with related facilities and buildings is 52.73 thousand hectares. The leaders are Dnipropetrovsk Oblast – 23.57 thousand hectares, Donetsk Oblast – 5.83 thousand hectares, Zhytomyr Oblast – 4.22 thousand hectares, which is, a total of 52.73 hectares [5]. In addition, there are significant areas used for industrial waste disposal outside the mining and land allotments of mining and processing enterprises.

An effective measure for preventing and restoring disturbed lands during underground mining of deposits of valuable types of minerals is the use of the technology for backfilling mined-out area [6-8]. The formation of the backfill mass helps to prevent the earth’s surface subsidence, the utilization of large-tonnage industrial waste accumulations. These activities are particularly important if the regions have extensive industrial and civil infrastructure. Mines and quarries that do not use backfilling of the mined-out area form zones of shear and significant failures on the earth’s surface, which creates a technogenic hazard and reduces the land potential of the territories [9, 10]. In open-pit mining operations, not
enough attention is paid to the activities of backfilling mined-out quarry cavities. Usually, reclamation measures are used to restore disturbed lands, consisting of mining-technical and biological stages [11, 12].

Land areas disturbed by mining operations should be restored as close as possible to the natural state, both in terms of social-economic aspects and legislative ones. Thus, in accordance with Article 166 of the Land Code of Ukraine, after the completion of the quarry operation, the territory that has undergone changes as a result of mining operations is subject to reclamation [13]. Restoration of disturbed lands is ensured by carrying out of technical and biological stages of reclamation.

Due to the fact that usually when planning the reclamation of areas disturbed by quarrying, the volumes of overburden rocks are not enough to completely fill the mined-out spaces of quarries due to the withdrawal of the volume of minerals. Therefore, recreational, water management and forestry management directions of reclamation are most often adopted. If, however, the earth’s surface disturbances occur on the lands occupied by industry, there is a loss of their economic potential due to the adoption of the above-mentioned reclamation directions.

It is possible to achieve success in the development of the construction and agricultural directions of reclamation of land areas disturbed by mining operations under the conditions of restoring the earth’s surface by using accumulated industrial waste as a reclamation material when filling technogenic cavities. This is especially reasonable if the disturbed lands are located in mining areas, where various industries are widely developed and, accordingly, there are large-tonnage industrial waste accumulations.

According to the new Law of Ukraine “On Waste Management”, the concept of “backfilling” is defined. This is a restoration operation in which waste suitable for this, which is not hazardous and/or inert, is used to fill mine workings (cavities), reclamation of depleted mining facilities, other landscape works, while replacing non-waste materials [14]. That is, if industrial waste, when filling cavities in the subsoil, does not pose a danger to the environment and public
health, it can be treated as reclamation or backfill material. According to Article 48 of the Law of Ukraine “On Environmental Protection”, incentives may be provided in the environmental protection system for enterprises and organizations that generate waste [15]. Thus, when they introduce low-waste, energy-, resource-saving technologies and implement other effective measures aimed at improving the natural environment protection, tax incentives are provided.

In addition, filling in the mined-out spaces of depleted quarries in order to restore the earth’s surface and lands in accordance with the Resolution of the Cabinet of Ministers of Ukraine dated September 17, 1996 No. 1147 refers to the nature protection type of activity (items 27, 33, 74-1) [16]. Of great importance is also the fact that, in accordance with Article 240, item 5 of the Tax Code of Ukraine, business entities are not taxpayers for waste placed on their own territories (objects), including waste as secondary raw materials [17]. Backfilling and mining-technical reclamation, according to the current legislation norms, is the utilization (reuse) of waste, which is not subject to payment of environmental tax.

It is of scientific and practical interest to analyze the existing experience of using industrial waste for the purpose of filling technogenic cavities (quarries and failures) on the territory of Ukraine. The conducted analysis of scientific and informational sources makes it possible to identify a number of theoretical and practical examples of filling the resulting technogenic cavities with various types of low-hazard industrial waste.

Due to the decommissioning of the Smolinska mine (in 2025), which produces uranium ores, it is also planned to close the existing sand quarry (Smolinske mining enterprise). The facility is shown in Fig. 1a. The mentioned enterprises are part of the SE VostGOK. The sand quarry was built with the aim of extracting sand as a raw material for backfilling the mined-out space at uranium mine. A project has been developed for the sand quarry reclamation of the Smolinske sand deposit, where measures are taken to restore the earth’s surface level by filling the mined-out space with low-hazard mining waste [18]. Thus, the area of the disturbed territory
from the quarry operation subject to reclamation, is 50.0 hectares, while the volume of the mined-out space at the time of the quarry closure will be 6.35 million m³. Attention is drawn to reclamation measures that provide for gobbing of mined-out space in a quarry with a complex of mining waste: waste rock from mine workings, neutralized bulk leaching waste, waste from the ore beneficiation plant, materials from dismantling of buildings and structures, as well as reclamation of the mine area and covering its surface with natural soils (loam and fertile soil).

Figure 1
An illustration of technogenic cavities, where their backfilling with industrial waste is conducted or planned: (a) sand quarry at Smolinska mine, SE VostGOK; (b) quarry No. 2 PJSC Central GOK; (c) quarry Tsentralnyi, Pobuzhskyi Ferronickel Plant LLC; (d) failure zones at Kozatska mine, PJSC Kryvbaszalizrudkom
All types of waste correspond to hazard class IV (low-hazard). According to the project calculations, 10.99 million tons of materials will be placed in the quarry to completely fill the mined-out space during the reclamation period. The reclamation project was developed by the Ukrainian Research and Design Institute for Industrial Technology (SE “Ukr R&D Institute for IndTech”) in 2019.

Another example of filling of mined-out quarry cavities is quarry No. 2 PJSC Central GOK (Velyka Hleiuvatka iron-ore field), where the mining-technical reclamation stage is carried out (Fig. 1b). Overburden or waste rock from the operating quarry No. 1 PJSC Central GOK is used as reclamation material. This type of waste corresponds to hazard class IV (low-hazard). Annually, 1.5–1.7 million m$^3$ of overburden or 4.0–4.5 million m$^3$ of waste rocks are backfilled into the mined-out space [19]. The volume of the mined-out quarry space is more than 70 million m$^3$. The filling degree is 50–60%. After backfilling with rocks to the earth’s surface level, a land plot of 80 hectares will be cleared and will be used to form a new external dump and prevent the alienation of new land areas. The reclamation project was developed by the SE State Institute for Design of mining enterprises Kryvbasproekt in 2014.

To backfill the mined-out space in the closed quarry Centralny, where nickel ores are mined (Dereniukhivsko-Lypovenkivsk zone), shown in Fig. 1c, Pobuzhskyi Ferronickel Plant LLC uses electric furnace slag from ferronickel production for the purpose of reclamation. This slag is recognized as an environmentally neutral material, thus avoiding impact on the composition of groundwater. This type of waste corresponds to hazard class IV (low-hazard). Every year, 0.7–1.0 million tons of ferronickel production slags are utilized as reclamation material in the mined-out quarry. As a result of backfilling the mined-out quarry space, it is planned to restore a land plot with an area of 45.3 hectares. The reclamation project was developed by the SE State Institute for Design of mining enterprises Kryvbasproekt in 2004.

Attention is drawn to the backfilling of zones of shear and the earth’s surface failure during the underground mining
of iron ores, which takes place in the Kryvyi Rih iron ore region. Mining operations in almost all mines have resulted in the formation of failure zones. Thus, in the mining allotment of the Kozatska mine (formerly Hvardiiska mine), PJSC Kryvbaszalizrudkom, mining-technical reclamation of failure zones is performed by backfilling them with mine dump rocks formed during mining operations (Fig. 1d) [19]. This type of waste corresponds to hazard class IV (low-hazard). Annually, 0.135 million m$^3$ or 0.350 million tons of waste rocks are utilized in the mine failure zone. After backfilling with rocks to the earth’s surface level, it will be possible to clear a land plot of 80 hectares.

Noteworthy are the theoretical developments on the reclamation of quarry cavities at the Illich Iron and Steel Works, OJSC in Mariupol. On request of the plant, the technical specifications TU U 08.1-00191158-002:2020, created in 2020, have been developed and approved by the relevant state institutions that regulate the use of metallurgical slags of the plant as backfill mixtures for the technical reclamation of mined-out quarry areas. In 2023, it was planned to develop a project for the reclamation of quarry No. 2 of the Karansk granite deposit by forming a backfill mass based on metallurgical slags. According to preliminary calculations, it was planned to restore 50 hectares of valuable land, dispose of 22 million tons of metallurgical slag within 11 years and prevent the formation of a new slag dump [20].

It should be noted that when backfilling quarry cavities with hazard class IV waste, special attention is paid to preventing soil and groundwater contamination. A prerequisite for the measures is the engineering-geological protection of the quarry bottom, which isolates and seals the probable contact of quarry waters with the disposed waste. At the base of the quarry, it is recommended to lay overburden and waste rocks that have a similar chemical and radionuclide composition with natural rocks of the quarry base, thereby not creating pollution.

A promising method of restoring the earth’s surface can be to develop the directions for the formation of a backfill mass in the resulting technogenic cavities, which will provide
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stability and geomechanical reliability of the earth’s surface, unlike the usual backfilling. The formation of a backfill mass can be effective in terms of ecology, optimal use of the restored earth’s surface and economic benefits, promoting infrastructure development and attracting investments to the industrial region. To develop directions, a spatial analysis of the location of industrial waste accumulations and formed technogenic cavities on the territory of Ukraine is required, since the presence of sufficient reserves of backfill material near technogenic cavities is of great importance.

Thus, from the analysis of the existing practical experience in backfilling technogenic cavities, it is obvious that, provided that all legal and sanitary requirements are met, low-hazard class IV waste can be used for the mining-technical stage of reclamation of quarry and failure cavities. Mining-technical reclamation can be performed by backfilling waste into the mined-out area or forming a stable backfill mass in the mined-out space for the multi-purpose industrial use of the restored areas.

References:


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