AN INTEGRATED APPROACH TO RECYCLING OF WASTE ROCK FROM COAL MINE DUMPS

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The coal mining industry plays an important role in the energy sector of many countries, as coal is one of the main sources of energy [1, p. 2]. Hard coal is used to generate electricity, in the metallurgical, chemical and construction industries, and for heating infrastructure, especially in regions with a cold climate. Although renewable energy sources have been on the rise in recent decades, coal remains an important resource in the global energy sector, especially in countries with developing economies and a high dependence on fossil fuels. However, in addition to the important economic role of this energy resource, its mining and processing is characterized by significant waste generation: waste rock dumps from mining operations and tailings dumps for storing finely-dispersed beneficiation products are formed on the earth’s surface, which pollute the adjacent soil and water resources and often occupy valuable land areas [2, p. 129; 3, p. 148].

To minimize the harmful impact of the coal mining industry, a number of “green technologies” are used, such as increasing the volume of energy production from alternative sources [4, p. 346], using waste to backfill the mined-out space of mines [5, p. 1], waste recycling and reuse [6, p. 767], as well as other low-waste technologies.

In Ukraine, over the years of its independence, the functioning of coal mining complex has led to the formation of about 1200 waste rock dumps in the Donetsk and Lviv-Volyn coal mining basins, and only a small part of them has been reclaimed. Numerous studies by both global and Ukrainian scientists have proven that the accumulated waste rock is a valuable source of a wide variety of mineral resources, which are technogenic deposits of the future. However, as of today, this significant potential of technogenic mineral-raw materials has been significantly lost due to the military aggression of the russian federation in 2014 and 2022, as a result of which a significant territory of the Donetsk Coal Basin is occupied. There are about 25 mines left on the government-controlled territory, including those of PJSC DTEK Pavlohradvuhillia, SE Lvivvuhillia, SE Dobropilliavuhillia-Vydobutok, and

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PJSC Mine Administration Pokrovske. Such an enterprise as PJSC DTEK Pavlohradvuhillia provides 60-70% of the volume of coal mining in Ukraine and is closest to the war zone [7, p. 2; 8, p. 1574].

From the list of existing approaches to "green technologies" in the coal mining sector, waste recycling and reuse are most likely to be suitable for Ukraine's conditions with a developing economy. The well-known researches on the processing of waste rock from coal mine dumps are usually characterized by the study of a certain valuable resource: extraction of coal concentrate, use of raw materials for the construction industry, road construction or fertilizers for agriculture. However, there are few publications devoted to the complete complex recycling of dump waste rock mass, obtaining a wide range of resources and completely liberation of the land area.

In the context of the future post-war reconstruction of the heavily damaged infrastructure of Donbas, the waste rock dumps of PJSC DTEK Pavlohradvuhillia mines can be an ideal source of the necessary mineral-raw materials. To use the Donbas waste dumps for infrastructure reconstruction, it will take some time to study their chemical and mineralogical composition and effective beneficiation methods. Therefore, these studies can already be conducted at PJSC DTEK Pavlohradvuhillia dumps today. The close proximity of PJSC DTEK Pavlohradvuhillia waste dumps to Donetsk Oblast and the existing logistics routes are indicators of the attractiveness of possible investment projects on the part of the state and private business.

As of 2023, the state register identifies 9 waste rock dumps of PJSC DTEK Pavlohradvuhillia coal mines in Western Donbas as waste disposal sites: Yuvileina mine (1 dump), Stepova mine (2 dumps), Dniprovska mine (1 dump), Zakhidno-Donbaska mine (1 dump), Stashkova mine (1 dump, the mine was closed in 2020), Ternivska mine (1 dump), Samarska mine (1 dump), Pershotravneva mine (1 dump, the mine is inactive).

In 2026-2027, due to the depletion of industrial reserves, it is planned to close the Stepova mine, which, together with the Yuvileina mine, is the closest to Donetsk Oblast. There are two waste rock dumps in the Stepova mine allotment: Block No. 1 and Block No. 2. The waste rock dump of Block No. 1, which was closed in 2014, has the largest resource capacity.

The source of waste rock formation is the technological processes of conducting stripping and preparatory mine workings. Tunnelling machines break the coal-rock mass as the drifting face of the extraction seam drift advances according to a mixed scheme. As a result, the mixed waste rock flow, entering the waste rock dump, contains coal fractions. The share of coal in the drifting face is within 10-20%. The rocks of the mined seam immediate roof are represented by argillite and siltstone ($f = 2\text{-}4$) and sandstone ($f = 5$). The main roof is represented by an interlayer of argillite and siltstone with sandstone lenses. Thus, the main mineral-raw material component of the waste rock flow moving from the drifting face to the surface waste rock dump is represented by coal, argillite, siltstone and sandstone.

The tunneling machine's operating member breaks the coal-rock mass within the fractional composition of 0...150 mm, so part of the broken mass has finely-dispersed particles. Given that the rocks consist of argillite and siltstone, which are clayey rocks, as well as sandstone, the content of sand and clay fractions in the dump waste rock mass, which are also valuable construction components, is likely to be high. This is evidenced by our mineralogical studies using the X-ray phase analysis method. For example, the main minerals of the Stepova mine waste rocks are quartz, kaolinite, magnetite and illite. The presence of kaolinite and illite form the clay base of the main rock types, such as argillite and siltstone, and quartz – the main sandstone mineral.

Thus, in our opinion, the generalized conceptual scheme for recycling of dump waste rocks at Stepova mine should have the form illustrated in Figure 1 (image of coal waste recycling plant taken from source [9, p. 286]). The waste rock dump of Stepova mine Block No. 1 has the shape of a truncated pyramid, occupies an area of 23.1 hectares, and is 75 m high, while an accumulated rock volume within these geometric parameters is 7400 thousand m^3 or 16.5 million tons.

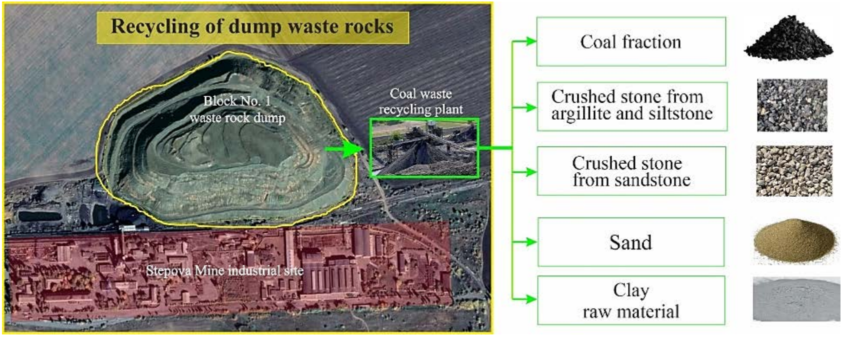

Figure 1. Generalized conceptual scheme for producing the main resources during the recycling of waste rock from the Stepova mine dump

Given the identified complex of valuable resources (Fig. 1) and the accumulated rock volume, it can be argued that the waste rock dump of Block No. 1 is a valuable source of energy and construction resources. The use of a set of gravity beneficiation methods should form the basis of a technological scheme for recycling dump waste rock. Coal fractions can be used for re-combustion of coal in thermal power plants or combined heat and power plants; rock crushed stone can be profitably used as aggregates for light and heavy concrete or other construction mixtures, in road construction, etc.; the sand fraction is in high demand in various construction mortars; clay raw materials can be rationally used in the production of bricks, cement and ceramics. Technological lines of the waste rock mass recycling complex should be adjusted and equipped with appropriate beneficiation equipment precisely for obtaining the above-mentioned resource components.

This large-scale integrated recycling of waste rock from dumps will make it possible to obtain valuable products that can be used in energy, construction, industry and agriculture. This not only contributes to waste management and environmental improvement, but will also bring economic benefits as an alternative source of raw materials for various industries, especially for the post-war reconstruction of the infrastructure in Donetsk region.

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References:

1. Jasansky S., Lieber M., Giljum S., Maus V. (2023) An open database on global coal and metal mine production. *Scientific Data*, vol. 10(1). DOI: https://doi.org/10.1038/s41597-023-01965-y

2. Popovych V., Bosak P., Petlovanyi M., Telak O., Karabyn V., Pinder V. (2021) Environmental safety of phytogenic fields formation on coal mines tailings. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, vol. 2(446), pp. 129–136. DOI: https://doi.org/10.32014/2021.2518-170x.44

3. Petlovanyi M. V., Haidai O. A. (2017). Analysis of stocking, systematization and perspectives of development of rock dumps of coal mines. *Geotechnical Mechanics*, vol. 136, pp. 147–158.

4. Majeed Y., Khan M. U., Waseem M., Zahid U., Mahmood F., Majeed F., Sultan M., Raza A. (2023) Renewable energy as an alternative source for energy management in agriculture. *Energy Reports*, vol. 10, pp. 344–359. DOI: https://doi.org/10.1016/j.egyr.2023.06.032

5. Bo L., Yang S., Liu Y., Zhang Z., Wang Y., Wang Y. (2023). Coal mine solid waste backfill process in china: current status and challenges. *Sustainability*, vol. 15(18), 13489. DOI: https://doi.org/10.3390/su151813489

6. Petlovanyi M. V., Malashkevych D. S., Sai K. S. (2020) The new approach to creating progressive and low-waste mining technology for thin coal seams. *Journal of Geology, Geography and Geoecology*, vol. 29(4), pp. 765–775. DOI: https://doi.org/10.15421/112069

7. Bondarenko V., Salieiev I., Kovalevska I., Chervatiuk V., Malashkevych D., Shyshov M., Chernyak V. (2023) A new concept for complex mining of mineral raw material resources from DTEK coal mines based on sustainable development and ESG strategy. *Mining of Mineral Deposits*, vol. 17(1), pp. 1–16. DOI: https://doi.org/ 10.33271/ mining17.01.001

8. Petlovanyi M, Medianyk V., Sai K., Malashkevych D., Popovych V. (2021) Geomechanical substantiation of the parameters for coal auger mining in the protecting pillars of mine workings during thin seams development. *ARPN Journal of Engineering and Applied Sciences*, vol. 16(15), pp. 1572–1582.

9. Gawor Ł. (2014) Coal mining waste dumps as secondary deposits – examples from the Upper Silesian Coal Basin and the Lublin Coal Basin. *Geology, Geophysics & Environment*, vol. 40(3), 285. DOI: https://doi.org/10.7494/geol.2014.40.3.285