



Impact of Open-Pit Mining on the Environment: Case Study of the Porphyry and Diabase Mines Company in Krzeszowice

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Abstract

Every mining activity harms the elements of the environment. It is minimized by several corrective actions or modern pro-environmental technological solutions. Porphyry and Diabase mines in Krzeszowice are an important element of the Polish mining sector, and the aggregates extracted there are widely used in road construction, railways, and construction. The article assesses the impact of the activities of Porphyry and Diabase Mines sp z o.o. on the environment in the following areas: landscape change, waste management, air pollution, noise and vibration, mining damage, as well as impact on water conditions and landslide hazards. The presented analysis showed that the impact on the environment was limited thanks to the implementation of numerous pro-ecological actions, such as the reclamation of post-mining areas, selective deposition of mining waste on the dump, reduction of dust emissions and a drainage system that does not have a negative impact on water conditions and groundwater quality. The actions taken by the Company support sustainable management of the open pit mine and minimise the impact on the environment.

Keywords: open pit mining, diabase, porphyry, environmental impact

Introduction

Mining activity, regardless of whether it is conducted open pit or underground, is inextricably linked to interference with the natural environment and anthropogenic objects, causing their transformations referred to as mining damage. It harms the elements of the natural environment: the lithosphere, hydrosphere, atmosphere, and biosphere. The lithosphere and hydrosphere are most exposed to negative changes [1]. The impact of mining on the elements of the environment can take place in the following ways [2]:

- direct (occupation of agricultural, forest, and recreational areas for mining plants and dumps of earth and rock masses),
- indirect (impact of mining operations: geomechanical transformations, degradation of soils, pollution of water and atmosphere).

Mining plants often border protected and naturally valuable areas, therefore after the completion of the process of exploitation of deposits, plants are obliged to reclaim degraded areas and ensure that the areas are restored to the environment in a form similar to that from before the exploitation [3].

The impact of mining activity on the lithosphere and the terrain is particularly visible in the case of open-pit mines, which significantly transform the Earth's surface. They cause in particular [4]: large-scale transformations of the landscape, creating concave forms (exploitation pits) and convex forms

(mining waste dumps), degradation of the soil cover, emission of dust pollutants into the atmosphere, seismic shocks, as well as changes in the relations between underground and surface waters in the case of drainage and reduced yields from agricultural land near the mine. Siting a mine near human settlements requires special care to comply with the standards of pollutant emissions into the environment.

Mining companies have a significant impact on environmental issues due to the specific nature of their operations. In connection with the above, they are obliged to limit the negative impact on the natural environment, i.e., the impact on biodiversity, soil, air and water pollution, dust and greenhouse gas emissions, landscape, and on humans (anthropoppression). Therefore, the basic goal of the proper functioning of industrial facilities, such as open-pit mines, is to maintain balance in the natural environment. Their impact on the environment is minimized through several corrective actions or the implementation of modern pro-environmental technological solutions [5]. By the currently applicable Sustainable Development Reporting (SDR) standards, companies are obliged to disclose their policies, activities, goals, and measures related to the impact exerted on the environment [6].

The main objective of the article is to assess the impact of the activities of the Porphyry and Diabase Mines Company in Krzeszowice on the environment. For this purpose, a detailed analysis of the issues identified in the following part was carried out. The analyzed Company consists of two open-



Rys. 1. Zdjęcie zwałowiska wewnętrznego Kopalni Niedźwiedzia Góra. Źródło: materiał udostępniony przez Kopalnię
 Fig. 1. Photo of the buried part of the Niedźwiedzia Góra Mine. Source: material provided by the Mine

pit mines: the Porphyry Mine Zalas in Frywałd and the Diabase Mine Niedźwiedzia Góra in Tenczynek. Rocks of volcanic origin are extracted and processed in the mines. Porphyry is extracted using the open-pit method, the longwall-and-scrap-er system. Mining is carried out on seven exploitation levels. There is a processing plant at the mine, which carries out mechanical processing of the mineral (crushing and screening), where grits, road and railway crushed stone, keystone, and unsorted rocks are produced. Diabase extraction is carried out in a five-level deep quarry. Diabase is processed to obtain crushed aggregate for road and construction purposes, including grits, stabilizing fines, mixtures, unsorted aggregates, and decorative gabion stone. Aggregates from both mines are widely used in road, railway, and construction engineering [7].

Environmental analysis and applicable regulations

Risk analysis and environmental analysis are interrelated processes that serve to assess potential threats related to human activity and their impact on people, property, and the natural environment. Risk analysis involves identifying threats, estimating the probability of their occurrence, and determining potential losses, which allows for assessing the scale of risk in the context of the project being implemented. Within the environmental analysis, particular emphasis is placed on identifying and assessing the impact of a given project on the natural environment, including water, air, climate, and the living conditions of local communities [8].

In the case of projects such as open pit mining, risk assessment and environmental analysis are inextricably linked. Risk assessment considers potential hazards resulting from the exploitation of the deposit, such as changes in the terrain structure or the risk of contamination, while environmental analysis provides detailed information on the impact on the natural and social environment. Both analyses are based on environmental protection laws, take into account geological and hydrogeological conditions, and help to determine measures to minimize the negative effects of exploitation. Together, they create a comprehensive picture of the hazards and their consequences, which allows for informed decision-making and the development of risk management strategies.

In Poland, the basic provisions on environmental protection and environmental impact assessment are contained in the following legal acts:

- Act of 3 October 2008 on the provision of information on the environment and its protection, public participation in environmental protection and environmental impact assessments (Journal of Laws No. 199, item 1227) – this act regulates the procedures

for assessing the impact on the environment, which may significantly affect the environment, including opencast mines [9].

- Act of 9 June 2011 – Geological and Mining Law (Journal of Laws 2011 No. 163 item 981) – specifies the principles for the exploration and exploitation of mineral resources and requirements related to environmental protection during mining activities [10].
- Act of 27 April 2001 – Environmental Protection Law (Journal of Laws 2001 No. 62 item 627) – provides a legal framework for environmental protection, including waste management, air and water protection [11].
- Regulation of the Council of Ministers of 10 September 2019 on projects that may have a significant impact on the environment (Journal of Laws of 2019, item 1839) [12].

The basis for conducting an environmental analysis in the context of mining activities is also cooperation with institutions responsible for environmental protection, as well as public participation in the environmental impact assessment process.

Surface Mining and Environmental Action Areas

An open pit mine is a type of mine in which mining operations take place on the surface, and the extraction process is carried out by discovering successive layers of raw materials. In open pit mining, the main factors influencing the environment are: the geology of the deposit, its surface, shape and useful mineral resources. However, the decisive indicator is the limiting depth of exploitation, which from a technological (but also economic) point of view decides which method is better to use for extraction – open pit or deep [14].

The impact of mining in a given area concerns not only natural, but also socio-economic elements. Open pit mining affects housing estates, industrial facilities, technical infrastructure, areas related to agriculture, forestry, water management and recreational facilities located within the boundaries of the mining plant. It is worth noting that areas of particularly high concentration of mines are the most transformed areas on our planet as a result of human activity.

The environmental analysis of the Porphyry and Diabase Mines focuses on assessing the impact of mining activities on the surrounding natural environment. In particular, it includes the analysis of the impact on: landscape change, waste generation, atmospheric air pollution, noise and vibration, the risk of mining damage, and changes in water conditions.



Rys. 2. Maszyna krusząco-sortująca. Źródło: [7]
Fig. 2. Crushing and sorting machine. Source: [7]

Changing the landscape and reclaiming post-mining areas

In the Porphyry and Diabase Mines, as a result of several decades of exploitation, a change in the shape of the terrain has occurred and is still ongoing in the form of the creation of concave forms, called workings, and convex forms, called dumps. The impact of the mine on the change of the landscape is inevitable. The response to the changes that have occurred is the reclamation of the area by the applicable requirements. The Krzeszowice City and Commune Office has established a forest and recreational direction for all post-mining land of the Zalas Porphyry Mine. The workings that constitute a concave form may constitute areas of recreation and water sports. On the other hand, for the Niedźwiedzia Góra Diabase Mine, a forest reclamation direction has been established. The basic phase of the reclamation of post-mining land in the workings is being carried out successively. Earth-rock masses originating from the development works carried out in the Zalas Porphyry Mine are deposited in the exploited part of the Niedźwiedzia Góra Diabase Mine excavation.

Detailed reclamation of areas related to mining activities, including the excavation and internal dump (Fig. 1), will be carried out after the deposit exploitation is completed.

Waste management

Mining waste in the Zalas Porphyry Mine is generated during the removal of overburden and exploitation of the mineral deposit. Overburden from the development works is selectively deposited on the mine's external dump, which is the object of mining waste disposal. In practice, this means that loose Quaternary overburden (loess, sands) is selected separately, and compact Jurassic overburden (limestone, marl, sandstone) is selected separately. Mining waste planned to be generated in the discussed Mine meets the criteria for classification as neutral waste, by current legal regulations.

Waste management in the Mines is conducted per the Mining Waste Act and the Waste Act. About the above, the Company has a mining waste management program approved by the Marshal of the Małopolska Province for each of the mines. Currently, the Zalas Porphyry Mine no longer produces processing waste, which in recent years constituted difficult-to-sell fractions (most often with a grain size of 0–20 mm), whereas today they are part of continuous-grained aggregates, including mixtures and unsorted aggregates, successfully used in construction and road construction.

In the Diabase Mine Niedźwiedzia Góra, in previous years, mining waste from removing the overburden lying above the diabase deposit was used to fill the exploited part of the excavation. Currently, the Diabase Mine Niedźwiedzia Góra

does not produce mining waste from development works, nor waste previously considered as difficult to sell fractions.

Atmospheric air pollution

Due to the mining activity, both the Niedźwiedzia Góra Diabase Mine and the Zalas Porphyry Mine experience unorganized emissions of dust pollution. The source of emissions into the air is the technological process in the excavation, technological transport, and, to a small extent, drilling work. Additionally, the Zalas Porphyry Mine also experiences organized emissions from the processing plant. The sources of emissions are crushers, screens, and belt conveyors (Fig. 3). The processing plant building is serviced by a set of dust removal devices equipped with cyclones and fabric filters that capture pollutants. In connection with the above, the mine has a permit to introduce dust from gases into the air for the mineral processing installation.

Due to the fact that the finished products contain very small amounts of dust and the dump is covered with greenery, secondary emissions are minimal. PM10 and PM 2.5 dust in the analyzed mine do not exceed the standards established for them.

In the Niedźwiedzia Góra Diabase Mine, dust and gas emissions come mainly from: the operation of mining and extraction machines and equipment, the operation of the processing plant, the transport of ore by technological vehicles and, to a lesser extent, from blasting operations. In order to reduce the nuisance associated with dust emissions into the environment, spray nozzles are used near the crushing and sorting equipment.

The analysis of the impact of the Niedźwiedzia Góra Diabase Mine on the air quality was included in the report on the impact of the project on the environment. The activity of the Niedźwiedzia Góra and Zalas Mining Plants does not constitute a new source of gas and dust pollution emissions into the air, therefore, no deterioration of air quality is expected in relation to the neighboring areas [15].

Noise and vibration

The location of the Niedźwiedzia Góra Diabase Mine (mainly a forest area) helps to reduce noise emissions to the environment. The sources of noise are: drilling and blasting operations, the operation of machinery involved in the operation of the mining plant, and the operation of the processing plant. The acoustic analysis carried out as part of the environmental impact report of the project showed that the emitted noise does not exceed the permissible standards for acoustically protected areas. There are no vibration phenomena in



Rys. 3. Maszyna krusząco-sortująca. Źródło: zdjęcie wykonane osobiście
Fig. 3. Crushing and sorting machine. Source: photo taken personally

the mine, which could be a source of potential impact on the environment. The main sources of noise in the Zalas Porphyry Mine are: the technological process in the excavation, blasting (between 1345-1415), road transport, and loading of aggregate. Thanks to soundproofing works carried out in the years 1996-2002, the mine significantly reduced noise emissions to the environment [15].

Removing damage caused by mining activities

Mining damage is a negative change in the environment caused by mining activities. In the mine's operations, three types of hazards can be distinguished related to the occurrence of potential mining damage, which may occur as a result of, for example, blasting operations, i.e. the scattering of rock fragments or the effect of harmful seismic vibrations. For preventive purposes, a zone of scattering rock fragments is designated, marked in the area with warning signs and, in special cases, with safety posts or road barriers. During blasting operations, seismic vibrations are generated, the range of which is minimized by the use of delayed fuses and limiting the number of charges in the series and for the delay. Although the Zalas Porphyry Mine is located in the dense development of three villages: Zalas, Sanka and Frywałd, no mining damage has been reported in the surrounding buildings for over 30 years [15].

In the Niedźwiedzia Góra Diabase Mine, no damage caused by blasting has been reported to date. Mining prevention in the scope of deposit mining consists of conducting blasting in such a way that no damage continues to occur to the indicated objects. To reduce the range of the harmful impact of the seismic wave, millisecond fuses are used during blasting, and the maximum charges in the series are limited, thanks to which the amplitude of vibrations is relatively small, and thus there is no charge accumulation, causing its intensification. Because the mine is located in a forest area, outside built-up areas, there is no need to apply special construction prevention within the range of mining operations. Moreover, the plant buildings located in the zone of rock fragments scattering have structures resistant to penetration by fragments [15].

Impact of the mine on water conditions

Concerning mining works, based on the current recognition of hydrogeological conditions and the results of measurements and observations in this area, no changes in water conditions have been observed. Drainage of the Niedźwiedzia Góra Diabase Mine affects the hydrogeological conditions of surface streams to which unpolluted mine water is discharged. Due to the very good quality of water from drainage,

its discharge has a positive effect on water quality parameters. The current observations show that the drainage of the deposit remains neutral to the environment, which is confirmed by the vegetation growing near it. As part of preventive measures in the area of impact on water conditions, it is planned to continue the current hydrogeological measurements and observations. The measurement and observation program will include measurement of the amount of water inflow to the excavation, the amount of water discharged to the stream, measurement of the position of the water surface in the mine sump, observation of the slopes and the floor of the excavation, as well as tracking possible water leaks and measurement of the amount of atmospheric precipitation.

In the Zalas Porphyry Mine, pumping water out of the excavation causes the underground water level to drop and a depression cone to form. In the 1980s, observation holes were drilled around the mine excavation, in which filters were built in, enabling measurements of the formation of the groundwater level. As a result of the measurements and hydrological observations, it was established that the current exploitation of the deposit has no impact on the intake of underground water for municipal purposes of the local population. In the annual analyses of water conditions, no decreases in the groundwater level were found in individual aquifers, which could be attributed to the mining activity of the mine. However, it was found that the environment in the area of the Zalas Porphyry Mine shows a very strong dependence on the amount of atmospheric precipitation. Individual aquifers react very quickly to the occurrence of precipitation, which results in increased expenditure of sources and an increase in the amount of water flowing into the sump of the Zalas Porphyry Mine (Fig. 4). At the same time, the scale of impacts is relatively small, which results from geological conditions such as poor rock permeability. The mine drainage system does not induce any adverse phenomena and processes on crop reduction, soil drying, or a decline in the condition of vegetation, because mine drainage concerns Permian layers, isolated from Quaternary formations, from which plants take up water. For the purpose of control, hydrological measurements and observations are carried out at established points, within the scope and frequency established by the plant operations manager, based on the opinion of a hydrogeologist [15].

Landslide and rock fall hazards

Landslides may occur in the parts of the hard overburden that are being removed, but no threats have been identified at present. Due to the possibility of such threats, a landslide monitoring method is used, recommending appropriate geo-



Rys. 4. Rząpie i wkop udostępniający w Kopalni Porfiru Zalas. Źródło: [7]

Fig. 4. Lake in the sump of the Zalas Mine. Source: [7]

detic and observational measurements. In addition, the geological surveying service periodically checks the condition of the slopes and escarpments in terms of their stability and the possible occurrence of natural hazards. The hazard zones associated with landslides will be secured with warning signs and, if necessary, also fenced off.

As for the risk of rock falls, which occur mainly in the upper parts of the exploitation walls after blasting and especially on the wall joints, the inclination of which exceeds 90° , as well as at the overburden level. Mining supervisors are obliged to check the condition of the sidewalls at the beginning of each work shift to ensure maximum safety conditions for people and equipment, which will be recorded in the sidewall inspection book. If a hazard is identified, it is the duty to remove it. To limit the amount of rock overhangs, drilling and blasting methods will be used that will allow the smallest possible wall area to be obtained after blasting.

Summary

Currently, a major problem for the development of open-cast mining is the negative perception of mining activity by society, which is mainly associated with soil degradation, changes in the landscape, or water pollution. The presented analysis of the impact of the Porphyry and Diabase Mines on the environment showed that the impact on the environ-

ment was limited thanks to the implementation of numerous pro-ecological measures, such as the reclamation of post-mining areas, selective deposition of mining waste, monitoring the quality of mine waters, and reducing dust emissions. Dust emissions are limited, among others, by dust removal devices, while the generated noise was reduced after the modernization of the plant, which is evidence of a responsible approach to environmental protection. The drainage system in the Zalas Porphyry Mine does not hurt water conditions and groundwater quality, which is crucial for the protection of the surrounding vegetation.

The Porphyry and Diabase Mines in Krzeszowice are an important element of the Polish mining sector. Thanks to effective management, advanced technology, and environmental responsibility, these plants have the potential to further develop and strengthen their market position. However, in the context of decreasing diabase resources and increasing environmental requirements, it is necessary to develop a long-term strategy that will ensure the stability and competitiveness of the company in the future and thus support the sustainable management of the open pit mine.

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Wpływ działalności kopalń odkrywkowych na środowisko: studium przypadku Spółki Kopalnie Porfiru i Diabazu w Krzeszowicach

Każda działalność górnicza oddziałuje w sposób negatywny na elementy środowiska. Jest on minimalizowany poprzez szereg działań naprawczych czy wdrażanie nowoczesnych prośrodowiskowych rozwiązań technologicznych. Kopalnie Porfiru i Diabazu w Zalasiu są istotnym elementem polskiego sektora wydobywczego. A wydobywane tam kruszywa znajdują szerokie zastosowanie w drogownictwie, kolejnictwie i budownictwie. W artykule przeprowadzono ocenę wpływu działalności Spółki Kopalnie Porfiru i Diabazu na środowisko w następujących obszarach: zmiana krajobrazu, gospodarka odpadami, zanieczyszczenie powietrza, hałas i wibracje, szkody górnicze a także zanieczyszczenie powietrza, oddziaływanie na stosunki wodne oraz zagrożenia osuwiskowe. Przedstawiona analiza pokazała, że wpływ na środowisko został ograniczony dzięki wdrożeniu licznych działań proekologicznych, takich jak rekultywacja terenów pogórnich, selektywne składowanie odpadów oraz zmniejszenie emisji pyłów, a stosowany system odwadniania nie wywiera negatywnego wpływu na stosunki wodne i jakość wód gruntowych. Podejmowane przez Spółkę działania wspomagają zrównoważone zarządzanie kopalnią odkrywkową i minimalizują wpływ na środowisko.

Słowa kluczowe: kopalnie odkrywkowe, diabaz, porfir, oddziaływanie na środowisko