MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION

Rocznik Ochrona Środowiska

Volume 21. Year 2019 ISSN 1506-218X 14-28

Global Assessment of Industrial Expansion for Minimizing Environmental Impacts Utilizing the Principles of Mining and Logistics

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1. Introduction

The environmental aspects of mining and quarrying are a focus of experts worldwide. They are well aware of the need for compatibility between the extractive industries and the environment. Appropriate solutions and methods are sought to ensure a sufficient supply of raw materials, but there is also focus on the restoration and conservation of nature, natural resources and the environment.

The impacts of mining industry on the landscape are examined in the article "Experiences of voluntary early participation in Environmental Impact Assessments in Chilean mining" (Ocampo-Melgar et al. 2018).

The document "Knowledge coproduction in environmental impact assessment: Lessons from the mining industry in Panama" an explores issues related to the mining sector and environmental impact assessment for the proposed copper and gold mine in Panama (Mitchell & Leach 2019) and with the homogeneous production processes, simulation of production in manufacturing systems and approaches to their management deal authors Malindzak et al. 2017 and Trebuna et al. 2014.

The conference paper "Ensuring the Environmental and Industrial Safety in Solid Mineral Deposit Surface Mining" deals with the mining of raw materials in terms of safety and efficiency (Trubetskoy et al. 2017). A similar topic "The impact of mining changes on surrounding lands and ecosystem service value in the Southern Slope of Qilian Mountains" has been addressed by Qian et al. 2018.

The main environmental challenges of the gold mining sector in Colombia are the topic of "Gold mining as a potential driver of development in Colombia: Challenges and opportunities" (Betancur-Corredor et al. 2018).

Solutions to these issues are sought by Kozioł et al. 2016 in the study "Mining of aggregates in Poland – Opportunities and threats", Sajinkumar et al. 2014 examines the effect of quarrying in Banasuramala, and the expert Bergstrom in his paper "The curious case of Cuyuna: Re-Envisioning former extractive sites to stimulate local communities" focuses on ecological revitalization (Bergstrom 2017), and the natural process of revitalization following extraction is also examining by Gawałkiewicz 2018 and ecological innovation approach is examining by Loučanová & Olšiaková 2019.

Failure to maintain an ecological balance in an industry area is also the topic addressed by Pohrebennyk and Dzhumelia in the chapter of their book "Environmental assessment of the impact of tars on the territory of the Rozdil state mining and chemical enterprise "Sirka" (Pohrebennyk & Dzhumelia 2020).

Environmental impacts of raw materials are examined by the article "Temporally explicit life cycle assessment as an environmental performance decision making tool in rare earth project development" (Pell, Wall et al. 2019).

A further study on "A hybrid semi-quantitative approach for impact assessment of mining activities on sustainable development indexes" was prepared to develop a general impact assessment process for certain environmental indicators in mining (Amirshenava & Osanloo 2019).

The influence of mining on the environment was also of interest to Parviainen and Loukola-Ruskeenia in the article "Environmental impact of mineralised black shales" (Parviainen & Loukola-Ruskeeniemi 2019).

Reducing the negative environmental impact of mining activities is also the topic of "Energy storage in underground coal mines in NW Spain: Assessment of an underground lower water reservoir and preliminary energy balance" (Menéndez et al. 2019). Other interesting publications in this area are "Technical quality of fauna monitoring programs in the environmental impact assessments of large mining projects in south-eastern Brazil" (Dias et al. 2019) and "Evaluation of the environmental impact assessment (EIA) of Chinese EIA in Myanmar: Myitsone Dam, the Lappadaung Copper Mine and the Sino-Myanmar oil and gas pipelines" (Aung 2019).

The importance of planned and managed raw material extraction with regard to environmental protection is also addressed in the publication "Environmental optimisation of mine scheduling through life cycle assessment integration" (Pell, Tijsseling et al. 2019), while Polish experts focus on mining waste in their contribution "Screening Life Cycle Assessment of beneficiation processes for Rare Earth Elements recovery from secondary sources" (Grzesik et al. 2019), Czech specialists focus on raw materials evaluation criteria in their contribution "Determination of importance of ore raw materials evaluation criteria" (Haverland & Besta 2018, Vilamova et al. 2016).

The effects of mining on the health of the population were collated by experts Nkyekyer and Dannenberg in the report "Use and effectiveness of health impact assessment in the energy and natural resources sector in the United States, 2007–2016" (Nkyekyer & Dannenberg 2019) and in the contribution "Asbestos exposure and minimization of risks at its disposal by applying the principles of logistics" (Straka et al. 2016).

The case study "Environmental impact assessment studies for mining area in Goa, India, using the new approach" deals with human activities in mining, which have the most disruptive and catastrophic environmental impacts, while greatly affecting the environmental, economic and social elements of the area (Sarupria et al. 2019).

2. Theoretical base

2.1. Remediation as a means of environmental protection

For this article, remediation can be defined is a set of technical remedies designed to reduce or eliminate pollution of soil, rock, groundwater and surface water resulting from inappropriate disposal of waste from extraction, or to prevent the further spread of pollution or threats to human health.

Remediation ensures the removal or fixing of hazardous substances that leak or have the potential to leak into the environment outside the structure of the repository or to reduce their concentration to an acceptable level. Remediation is always where work is done to remove or reduce the contamination of the natural environment, including its safe and long-term isolation in a limited area.

It is important to define the significance of recultivation for this article. This term refers to the treatment of a site affected by a repository that allows the resumption of a satisfactory state with particular emphasis on soil quality, wild flora and fauna, natural habitats, freshwater ecosystems, landscapes and suitable land use.

It is necessary to realize the main difference between remediation and recultivation. The problems that are most often encountered in extractive industry need to be prevented by recultivation, but if they are already present, they need to be removed through remediation.

As we know recultivation technology must always be designed with regard to future land use. However, in our case, it is industrial activity in the mining sector and the extension of mining in the mining area Košice IV – Hradová, therefore we are dealing with a remediation process, as during the extraction processes problems have occurred which were not envisaged and therefore not addressed by the recultivation plan.

The location of the discussed area, the stone quarry in Košice IV – Hradová for the extraction of granodiorite building stone, is determined by the local

accumulation of mineral resources in sufficient quality and quantity for extraction. The projected maximum annual production capacity by 2021 is 290 000 tons/year.

The deposit is part of the resource base of the eastern edge of the Slovak Ore Mountains and its wider surroundings. Remediation of the steep slope above national road III/3390 is conditioned by the morphology of the terrain at the intersection of the Hornád River through "Black Mountain" and the route of the national road Košice-Sever to Kostoľany nad Hornádom, where the slopes of the granodiorite body of Hradová (the massif of the Black Mountain in the Vepor zone) are steep and unstable in terms of slope movements and rock rubble.

2.2. Defining the requirements of industrial activity

In 2011, an extraordinary situation was declared in Eastern Slovakia due to the active landslides on the Kostoľany road in Košice. The operation of the quarry located near the affected site ensured that the slope was remediated.

On the left side of the road there is a steep slope, which was strongly disturbed by landslides. Frequent slope landslides on the steep slope resulted in the rocks and rocky blocks falling from the highest and steepest slopes, weighing up to several tons.

We can ascribe the cause of these events to strong erosive activity, especially the intense alternation of positive and negative temperatures. The heavily eroded steep slope can cause direct threats to the health and life of passers-by. In order to increase safety, in 2012, traffic was reduced to only one lane controlled by traffic lights (Dilský 2012).

2.3. Defining environmental requirements

Important factors in terms of environmental requirements include safety, stability, biotope, logistics and the emissions factor. In terms of the further utilization of the quarry, the emissions factor is particularly important. The total annual emissions of the site under consideration are 4 167.6 kg or 2.0838 kg/h (Table 1).

3. Case study

3.1. Project to expand industrial activity in the particular region – capacity of deposit

The subject of the geological task was the verification of new deposits of building stone west of the existing area of extraction at Košice IV – Hradová. The goal of the geological task is to verify 5 million m^3 of building stone deposits.

Table 1. Emissions of pollutants from the quarry

Source	Pollutant	Emissions (kg/h)	
		Short-term	Long-term
Diesel mechanisms	CO	0.0413	0.0138
	NO_x	0.2583	0.0861
	SO_2	0.0517	0.0172
	PM (particulate matter)	0.0734	0.0245
	TOC (total organic compounds)	0.0059	0.0020
Stone extraction and processing	PM	2.0838	0.6946

The solution of the geological task did not result in permanent interference with the environment. Boreholes were made on existing forest roads. After geological mapping (Fig. 1), geophysical profiles with respect to borehole localization were also identified. Boreholes were made after the completion and operational evaluation of geophysical works. This ensured optimum deployment of the exploration boreholes. In order to demonstrate the quality of building stone, a survey is the only way to verify building stone deposits, with the exception of extraction (EUROVIA – Kameňolomy, s.r.o. Košice 2010).

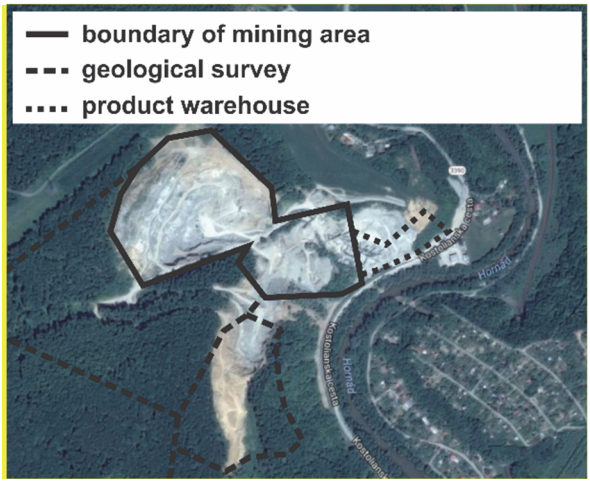

Fig. 1. Map of boundary of mining area and geological survey of Hradová quarry (EUROVIA – Kameňolomy, s.r.o. Košice 2017)

3.2. Possibilities of extending industrial activities – stabilization of deposits

The actual purpose of the activities under consideration is to expand the Košice IV – Hradová quarry and provide sufficient reserves of a mineral resource, namely granodiorite building stone, within the existing extraction area at Košice IV – Hradová, and especially outside it.

As mentioned earlier, for the expansion of extraction, it is necessary to focus on the proposal for stabilization of the slope, which consists of reducing the slope inclination by building terraces with a height of approx. 24 m on the slope at approx. 70°. The terraces are designed with a slope of 2.0% and a width of 23 to 40 m. A recultivation project has been prepared for this purpose. The work is being carried out in two stages.

In the first stage, the surface of the slope has been straightened so that it will be possible to build a protective barrier (Fig. 2), which is 2.0 m high, and will be able to capture loose boulders.

In the second stage, definitive recultivation of the slope will be performed, consisting of excavation work on the terraces from top to bottom. After the excavation is completed, recultivation will be carried out (Dilský 2012).

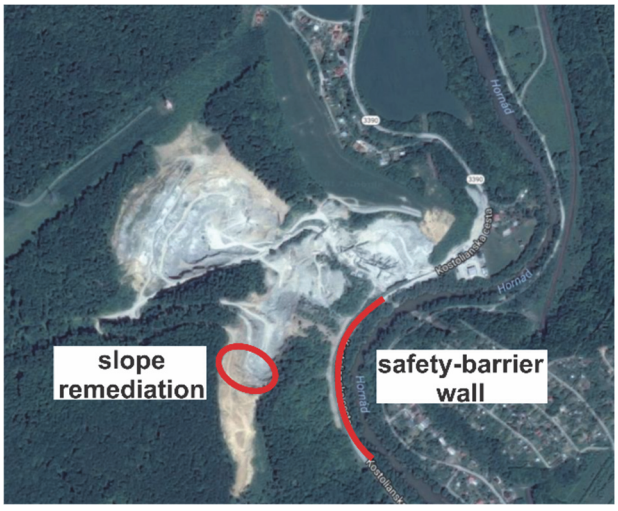

Fig. 2. Schematic representation of the slope remediation and safety-barrier wall (EUROVIA – Kameňolomy, s.r.o. Košice 2017)

Drainage on the site is solved with a single camber inclination towards the Hornád side of the road, as it is today. The plain was drained by the downward slope towards the Hornád River, then the area behind the protective-safety

barrier, which is closer to the slope, is drained along the compacted slope of the barrier to the nearest passage. Earthworks on the building site consist of:

- Removal of soil from the slope on which the remediation was carried out, however, it was first necessary to deforest the slope.
- Tipping of earth to form the safety barrier.
- Excavating the slope to the level of the terraces
- Adding soil to the terraces based on the recultivation project, recultivation will be carried out in the future.
- Waste arising during the remediation of the slope will be collected in the area of the Hradová quarry together with the waste generated during the operation of the quarry.

Upon completion of the remediation of the slope, recultivation will be carried out, which will include the following parts based on the recultivation project:

- Adding soil.
- Planting forest stands – trees.
- Caring for tree stands for 3 years.
- Planting more trees.
- Recultivation will be carried out in two stages, as will the slope remediation itself.
- Total land area for recultivation is 80 500 m^2.

3.3. The benefits of increasing production

Based on the geological survey, a total calculation of geological reserves, including overburden, was carried out in the explored area. In the area or areas where the geological survey of deposits was carried out, the body of the deposit was divided using 12 sections into vertical blocks, the volume of which was calculated by the product of the average content of the adjacent sections and their distance. If the sections were less than 10° between each other, the following relationship (1) was used to calculate the section distances.

$$v = (h1 + h2) / 2 \quad (1)$$

where:
h1, h2 – the lengths of the perpendiculars defined at the centre of gravity of the respective profiles.

The method of parallel cuts can be justified by the simple and precise construction of the surfaces of the block of reserves in individual sections, where the accuracy of the calculation is proportional to the density of cuts, which is in the range of 50 m.

Formulas used to calculate reserves:

$$Q = \frac{(P1+P2)}{2} \text{ x } V \text{ (m}^3\text{)} \quad (2)$$

$$Q = \frac{(\text{P1+P2+}\sqrt{(P1\ x\ P2)})}{3} \text{ x } V \text{ (m}^3\text{)} \quad (3)$$

$$Q = \frac{P1 \text{ x } V}{2} \text{ (m}^3\text{)} \quad (4)$$

where:
Q – volume (m^3),
P1, P2 – area of block in adjacent sections (m^2),
V – distance between sections (m).

The equation from (2) above is used when the sectional area difference is less than 40%, equation (3) is used if the difference in sectional area is greater than 40% and equation (4) is used if the bearing body is in a single line.

3.4. Overall results and evaluation of calculations of reserves in the exploration area

During the geological survey, after extensive calculations and evaluation of the area, a total of 28 501 850 m^3 of mineral resources were verified. The exploration area of raw material of quality category I (block I / area I) contains 21 539 703 m^3. The exploration area also contains lower quality raw material in category II (block II / area II) with 6 962 147 m^3 of reserves (Gallo et al. 2016).

4. Results and discussion

4.1. Impacts on the environment, including in terms of long-term and other possibilities of expansion and liquidation of activities

The quarry has a negative impact due to the relatively high dust content that exceeds limit values. Near the quarry there is an about 60 m wide belt of forest, lining the river Hornád. The forest acts as a filter against the spreading of dust, reducing it by more than 50%. That is why we can assume that the quarry has a reduced impact on the environment from dust.

The actual operation of the quarry is static source of noise, which is related to the performance of surface extraction of stone, namely blasting and granulometric treatment of stone in the quarry. A permanent source of operating noise is the stone crushing line located in the current mining area. Another source of noise is traffic from road I/68. However, it should be emphasized, in particular, that damage to the health of the population around the site due to excessive noise is not likely.

The operation of the quarry affects the well-being and quality of life especially for several houses in the north-eastern part and for the gardens in the south-eastern part on the other side of the Hornád. Fig. 3 illustrates the situation indicating the distance to settlements, including the gardens, from the nearest place of extraction.

Fig. 3. Distance of settlements from the nearest place of extraction (EUROVIA – Kameňolomy, s.r.o. Košice 2017)

The transport of aggregates is performed along the I/68 road, which is the largest source of air pollution in the vicinity of the quarry at present. It is assumed that 2/3 of the stone transport goes towards Košice and 1/3 towards Kostoľany nad Hornádom. A total of 3,327 cars passed through the Košice – okolie road section per year, which is part of the quarry underway. It follows from the above facts that the workers in the quarry and the population in the vicinity are not at risk of health damage from air pollution.

Harm to the health of the population around the activity under consideration due to water contamination is not likely.

Harm to the health of the population around the activity dues to soil contamination and the penetration of pollutants emitted from equipment into the food chain is not likely.

Harm to the health of residents around the proposed activity due to excessive noise from quarrying is not likely. Impulse noise due to detonations or blasting work is the impact most subjectively perceived by the population. However, blasting works are rare over time, and therefore, noise limits do not apply to this activity.

The area in question has quite varied natural conditions, the terrain is rugged with a rich representation of original and natural forest, meadow and

wetland communities, agricultural cultures and garden areas. There is also a variety of animal species (reptiles, mammals and birds). The quarry, plans to expand extraction of building stone adjacent to the existing extraction area. When assessing the effects on the natural environment, it is necessary to start with the species composition and structural properties of vegetation stands, which are high in the area concerned. The forests are of the highest biotic quality. The locations of existing local biocentres have lower levels of biotic quality. In the evaluated area, there are no endangered habitats of animals and plants that will be disturbed by the expansion of the quarry. The occurrence of protected species of plants and animals has not been recorded directly on the site. No significant negative impact on nature is expected.

The operation of the quarry or the extraction and treatment of stone (crushing, sorting) and handling of aggregates is a source of air pollution. The proposed activity is a medium source of air pollution. The operator of the air pollution source must comply with all the obligations arising from the applicable legislation in the field of air protection. In order to reduce dust in the quarry, crushed material is sprinkled with an aqueous film, the roads with a water cannon and vehicles leaving the quarry are cleaned in the washing plant to eliminate the effects on the quarry's surroundings as much as possible.

4.2. Evaluations and analysis of impacts by relevance

In order to ensure the ecological stability of the area, it is necessary to respect and protect the elements of the national network of protected areas. The solution of the Hradová quarry itself is located outside protected areas. For this reason, no impact on large-scale or small-scale protected areas or protective zones is expected. There is only one stage of effects on the individual components of the environment over the period of the proposed activity, the extension of the quarry. In this case it is the extraction stage, which is a continuation of the current activity. Table 2 summarizes the impacts of the quarry's operations.

Table 2. Overview of impacts related to quarry operations (EUROVIA – Kameňolomy, s.r.o. Košice 2017)

Impact type	Positive Impact	No change to current status	Negative impact	Type of impact
Landscape		X		The proposed activity is a continuation of the existing activity, and there will be no change from the landscape point of view
Flora and fauna		X		There will be no change in terms of flora and fauna

Table 2. cont.

Impact type	Positive Impact	No change to current status	Negative impact	Type of impact
Transport			X	In connection with the increase in mining capacity, the traffic burden will increase
Land		X		The proposed activity does not impose any demands on land use, no impact on the soil is expected
Air quality		X		New stationary technological sources of air pollution will not arise in connection with the proposed activity. Increased dustiness will occur with the passage of motor vehicles, we do not expect a significant change from the current state
Public health		X		There will be no significant changes to the current situation
Job opportunities	X			Positive impact on the creation of new jobs – about two employees
Noise		X		There will be no significant change compared to the current situation
Water		X		There will be no change compared to the current situation
Waste		X		An increase in waste compared to the current state is not expected

5. Conclusions

The recovery of free reserves in the quarry is irreversible over time, so it is necessary to consider expanding the quarry so that the demands of customers can be met in the future. Importing stone from a greater distance or opening a completely new quarry would not only be economically disadvantageous, but it would also place a greater burden on the environment. The expansion of the currently prepared and running quarry therefore appears to be the most advantageous solution.

Currently, during live quarrying the quarry undoubtedly has a disruptive effect on the function of the biocentre. The mentioned remediation of the steep slope above the Kostoľany road extends into the biocentre. However, the remediation is motivated by the protection of the life and health of road users on the Kostoľany road and therefore there is no alternative solution. In the medium and long term, the territory under consideration has the potential to be integrated into the natural area, or even to become a gene fund location.

Provided that all approved operational procedures and relevant legislative regulations are strictly adhered to on the basis of the public health impact assessment carried out, the expansion of mining operations of Hradová quarry can be objectively evaluated as acceptable on a whole society basis without serious impact on the health of workers and residents living in the area under consideration.

It is possible to envisage two interesting alternatives for the use of quarry operations for non-mining purposes:

- The first alternative is to use the quarry area under consideration as a cultural monument of open-cast mining. The proposal is based on the fact that near the quarry field there is a hiking trail which is part of the Vihorlat Protected Landscape Area and is slightly frequented. It is for this reason that this alternative would suitably fit into the environment. If this option were implemented, it would be necessary to propose a process of forest reclamation in combination with recreational reclamation.
- The second alternative is to use the quarry area as a waste repository. However, this is not the most appropriate way of land use from the environmental and ecological point of view. The advantage of this project is that it is the cheapest way to reclaim land. The disadvantage, however, is the level of soil contamination in the area and the possible contamination of surrounding waters. In this variant of land use, reclamation works take into account the protection of the surface against leakage of chemical elements from waste and the solution of the drainage system. In such a case, however, the revitalization work will not be subject to the liquidation and quarry operation plan.

The quarry does not affect protected areas and is not expected to have a direct negative impact on rare communities or protected areas in the wider area during quarry operations.

The assessed activity does not directly interfere with the urbanized area. The quarry is to be integrated into the forest land after extraction and recultivation. Freight traffic from the Hradová quarry is about 5% of the total traffic on the Kostoľany road, all predictions associated with dust and noise on the Kostoľany road, due to traffic on the Kostoľany road, are beyond the control of the proposer.

The submitted paper is a part of the project "Research and development of new smart solutions based on principles of the Industry 4.0, logistics, 3D modelling and simulation for production streamline in the mining and building industry." VEGA 1/0317/19.

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Abstract

This article addresses research into the effective expansion of industrial activity, taking into account environmental needs. The aim is to analyse and assess the possibilities for further development of industrial activity in a particular region of Slovakia. The objective of the geological task is to verify 5 million m^3 of building stone of category Z-2. In terms of environmental requirements important factors include safety, stability, habitat, logistics and the emissions factor. In terms of further utilization, the emissions factor is particularly important. The emissions factor for drilling, loading, unloading and for aggregate moisture of 0-0.5% is 9.4 g of PM per tonne of aggregate, which for extraction of 300 000 tons per year gives an output of 2 820 kg/year and 1.41 kg/h. The emission factor for primary and secondary aggregate processing with aggregate moisture of 2-3% with application of water spray is 14.6 g of PM per ton of aggregate, giving emissions of 657 kg of PM per year and 0.3285 kg of PM per hour. For the tertiary aggregate processing, at aggregate moisture of 2-3%, the emission factor is 230.2 g of PM per tonne of aggregate, giving emissions of 690.6 kg of PM per year and 0.3453 kg of PM per hour. The total annual emissions are 4 167.6 kg of PM, i.e. 2.0838 kg/h. In order to secure the ecological stability of the land area, it is necessary to respect and protect the elements of the national network of protected areas. The solution for the Hradová quarry is located outside of protected areas. For this reason, no impact on large-scale or small-scale protected areas or protective zones is expected.

Keywords:
ecological aspects, remediation-reinstating of slope, recultivation, emissions, environmental impacts, mining, logistics