Acta Montanistica Slovaca
ISSN 1335-1788
actamont.tuke.sk

Assessment of the environmental and economic impacts of mining and elimination of negative impacts of mining activities

Andrea SENOVA[1], Filip KUFFA[1], Lucia GROSOSOVA[1] and Ibrahim ALKHALAF[2]*

Authors' affiliations and addresses:
[1] Institute of Earth Resources, Faculty of Mining, Ecology, Process Control and Geotechnologies, Technical University of Košice, Letná 9, 042 00 Košice, Slovakia
e-mail: andrea.senova@tuke.sk
e-mail: filip.kuffa@tuke.sk
e-mail: lucia.grososova@tuke.sk

[2] Embrava, s.r.o. 040 11Košice, Slovakia
e-mail: alkhalaf.ibrahim@gmail.com

***Correspondence:**
Andrea Senova, Institute of Earth Resources, Faculty of Mining, Ecology, Process Control and Geotechnologies, Technical University of Košice, Letná 9, 042 00 Košice, Slovakia
Tel: +421556022985
e-mail: andrea.senova@tuke.sk

Acknowledgement:
The authors thank CRH (Slovensko) a.s. for providing data and technical support for our analyses (in years 2020-2021).

How to cite this article:
Senova, A., Kuffa, F., Grososova, L. and Alkhalaf, I. (2024). Assessment of the environmental and economic impacts of mining and elimination of negative impacts of mining activities. *Acta Montanistica Slovaca*, Volume 29 (4), 873-884

DOI:
https://doi.org/10.46544/AMS.v29i4.07

Abstract
The impact of mining activities is significant in several areas in Slovakia. Among the most serious negative impacts of mining activities on the environment is the disturbance of surface stability caused by the presence of open mined out areas underground, which can cause damage to construction objects, linear structures, risk of accidents and danger to life during the movement of people. The paper analyses the environmental impacts of gypsum mining and the establishment of the excavated area during mining activities. Attention was paid to a mining company that operates an anhydrite and gypsum mine, which is the second largest mine in Europe. The current methods of mining and proposals for new methods of foundation were presented. We have analysed the process of founding excavated spaces when mining is increased, with the financial impact and determination of the additional costs of founding the excavated space. We proposed the provision of a foundation with a financial assessment of the costliness of the process. The paper concludes with options for effectively eliminating negative impacts in mining operations.

Keywords
Extraction of gypsum, establishment of the excavated area, foundation material, environmental and financial impact of extraction.

Introduction

The extractive industry occupies a special position among other industries because its activities provide raw material resources to other industries in the national economy. It should not be forgotten that the extractive industries are also facing major changes that are expected to lead to climate neutrality in Europe by 2050 (Ulewicz et al., 2022). Most importantly, in the struggle for a green 27, the states must agree on concrete measures that each state will have to follow. The measures will affect all sectors of the economy and also the lives of ordinary people (Taušová et al., 2021). From an economic point of view, this is also closely related to the increase in employment and possibly the development of the mining region. However, like any industrial activity, in addition to profit, it also brings with it other concomitant manifestations that affect and reshape the original character of the exploited territory, impacting both abiotic and biotic components of the environment, not excluding the quality of life of the local population. Therefore, there is a growing interest in the analysis of ecosystem services in the assessment procedures of extractive activities (Assumma et al., 2022).

The impact of mining activities is significant and unnoticeable in several areas in Slovakia. The environmental footprint of the mineral extraction industry and measures to mitigate it are widely discussed in the global academic community (Mardonova et al., 2023). Mining is an industry for which public opinion is often unfavourable. This is due to, among other reasons, the significant interference of the mining sector in the natural environment, as well as the scale of the activities carried out. On the other hand, without access to the various extracted raw materials, the development of infrastructure on a micro- and macro-regional scale, which we benefit from on a daily basis (construction, road building, energy, etc.), would not be possible (Wozniak et al., 2018) (Wozniak et al., 2018). An important factor is the strong societal pressure for environmental protection and innovative activities in this area (Grebski and Mazur, 2022; Cernecky et al., 2015).

The most serious negative impacts of mining activities on the environment include the disturbance of surface stability caused by the presence of open mined out areas underground, which can cause damage to construction objects, linear structures, soil and forest cover, the risk of accidents and danger to life during the movement of people. The drainage effect of mine workings results in the dewatering of rock complexes, a reduction in the yield of exploited groundwater resources and the formation of concentrated discharges of mine water to the surface, the unnatural chemical composition of which adversely affects the quality of surface water. The accumulation of large amounts of residual materials containing contaminants on heaps or tailings and the associated pollution of surface and groundwater is also a residual of mining (Pactwa et al., 2020). In the case of mining and thermal processing of ore materials, vegetation cover and soil quality may also be affected by the immissions. The environmental impacts are physical, cognitive and emotional as they affect the actual life of people living near the mine (Suopajärvi et al., 2017).

Thus, assessing the environmental impacts of mining operations against the economic impacts is a necessity for maintaining the sustainable development of a particular site. Industry must also mitigate negative environmental impacts by reclaiming degraded landscapes and making creative use of unique landforms and habitats (Procházková et al., 2022). Mining activities can have significant environmental costs, making mining uneconomic due to the high cost of avoiding, reducing or offsetting environmental impacts (Badakhshan et al.,2023). Therefore, in the present paper, we have discussed the environmental impacts of gypsum mining and foundation excavation, analyzed the financial impact on the price of raw material when foundation excavation is initiated, and assessed the risk arising from this activity. A new perspective on mine waste management is then presented as a potential solution to the problem of sustainable mining. Such waste management should include planning for future material recovery and then managing the waste as a potential future resource (Lèbre et al., 2015). We also provide the specificities of the operation we studied, the geology of the deposit and the environmental impacts of gypsum mining on the community. We analyze the process of establishment under increased extraction with a financial calculation of the process and the additional costs of establishing the excavated area.

Material and Methods

The aim of the present paper is to analyze the environmental impacts of gypsum mining and the establishment of the mined-out area, to analyze the financial impact on the price of raw material when the implementation of the base mine starts and to evaluate the risks arising from mining activities. At the same time, it is necessary to propose options for the effective elimination of negative impacts in the implementation of mining activities.

We characterized the history and present of mineral raw materials mining in Slovakia, focusing on mineral raw materials, namely gypsum and anhydrite. Raw materials are of strategic importance to the manufacturing industry in the European Union, and therefore the European Commission has implemented various measures to secure the supply of raw materials, particularly minerals (Kivinen et al, 2020). We have also taken into account that the economic potential of the explored deposit must also guarantee the means necessary to eliminate adverse environmental impacts. We also examined the specific environmental impacts of the mining operation.

We analyzed the operation of a mining company and characterized the conditions of a mine on a deposit located in Slovakia, in the Rožňava district. The past and present financial data of the mine, the current mining methods and the proposed methods of mining of the mined out areas were observed. We analysed and proposed the process of foundation of mined-out areas at the assumed annual production with financial calculation of the process and additional costs for foundation of mined-out area. We have also proposed the provision of a baseline with a financial assessment of the costing of the process.

Theoretical background

We present the legislative framework of the Slovak Republic, which we had to take into account when designing the foundation of the excavated areas:

- Act No. 409/2011 Coll. on Certain Measures in the Field of Environmental Burden,
- Act No. 230/2022 Coll. amending Act No. 79/2015 Coll. on waste,
- Act No. 514/2008 Coll. on the management of waste from the extractive industry and Decree No. 255/2010 Coll. of the Ministry of the Environment of the Slovak Republic implementing Act No. 514/2008 Coll. on the management of waste from the extractive industry,
- Act No. 46/2021 amending Act No. 39/2013 Coll. on Integrated Pollution Prevention and Control,
- Act No. 58/1998 Coll. on Mining Activities, Explosives and State Mining Administration.

The deposit area focused on gypsum and anhydride mining is located on the border of the south-western part of the Slovak Karst between the towns of Rožňava and Rimavská Sobota. The deposit is part of the north-south ridge formed by the watershed of the Slaná and Muráňka rivers, about 1,5 km south of Gemerská Hôrka. The immediate vicinity of the deposit is an area of gently undulating hills with an elevation of 100-150 m above the valley of the Slaná River. No water source flows through the deposit itself. The deposit is bounded in the south by a narrow valley, and in the north by a watercourse flowing through an erosive gully. Rainfall in this area is approximately 700 mm per year.

The Rožňava Basin defines the northern boundary of the landscape unit of the geomorphological area of the Slovak Ore Mountains called the Slovak Karst, on the territory of which the Slovak Karst National Park was proclaimed on 13 February 2002. For the environmental impact assessment, it should be noted that the location of the deposit does not fall within the territory of the Slovak Karst National Park or its protection zone, and at the same time there are no protected natural or geological formations or other phenomena in the deposit area that would require special attention

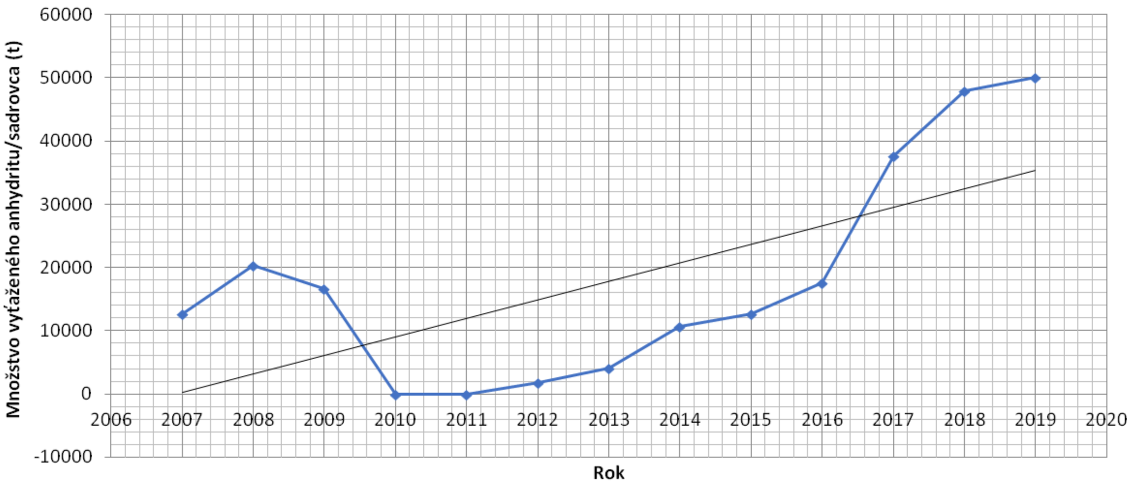

Fig. 1 Mine activity analysis - quantity of anhydrite/saggregate extracted . Source: (own elaboration by authors).

.

The main raw material of the deposit is anhydrite deposited approximately 50 to 160 m below the surface. In the central part, it is overlain by a layer of Neogene sediments of the gravel formation with a thickness of 1 to 50 m and a diameter of approximately 30 m.

The overlying spodotriassic complex in the southeastern and northwestern flank of the deposit is developed in cavernous limestone with positions of green calcareous shale. The sulphate position is in the underlying reddish purple and green clayey-sandy shale at a depth of 54 m from the surface. No boreholes have intersected the bedrock of the deposit.

The gypsum deposit is a hydrated crust of massive anhydrite position. The anhydrite is 100 m thick and is thought to be between 150 and 200 m thick. The thickness of the gypsum layer varies from 1 to 21 m with a diameter of 11.6 m. The general direction of the deposit horizon is SW-SE and it has a sub-horizontal bedding in the longitudinal direction. In the transverse direction, the bedding position falls slightly to the NW at an angle of 10-20°. Young fault tectonics plays a significant role in the construction of the deposit, with transverse faults dividing it into four tectonic crusts (Grecula et al., 1995).

As gypsum and anhydrite prices are not quoted on the world market, the acquirer of a deposit should not pay more than the cost of the land and machinery acquired in determining the profitability of extraction. A valuation of the deposit should therefore be carried out prior to the actual investment in the deposit. Mineral deposit valuation is a specific problem that is solved by classical means for efficient investment in productive enterprises and in their valuation (Shabbir et al., 2009).

The excavated area shall be founded with foundation material as the quarrying progresses until the last footbridge is cut

Disposal of the open space of the last footbridge will be carried out when the ceiling pillar and the interior pillars at this level are disposed of. The ceiling and intra-block piers will be drilled by hand or with a drilling rig in accordance with the developed drilling schematics. The ceiling shall be drilled to such a height that the excavated areas will be completely backfilled.

At the point of commencement of the disposal, a cut-off stack shall be formed to the full height of the ceiling pillar being disposed of. The cut-off chimney shall be extended by means of appendage bores to the full width of the block to be disposed of. The entire floor pillar will be divided into 16 m wide strips, with only the first strip of the disposal being 8 m wide from the inter-block pillar to the first row of intra-block pillars. Thereafter, the individual blasts will continue in the direction of the cutoff.

When the edge of the block is reached, move on to the next strip. This and the other strips to be disposed of will be the aforementioned 16 m wide, as a series of 8 m wide intra-block pillars will also be split.

For the other disposed mining belts, the same procedure as for the first disposed mining belt shall be followed. This procedure shall be followed until the entire overburden of the mined-out block has been disposed of.

The extraction of the raw material is carried out in several ways depending on the vertical level of extraction:

- Stripping of the material in the mining of the nil placer shall be done directly at the placer site using permitted mining trackless machines with internal combustion engine or electric drive or truck loaders, or other permitted mining trackless machines with internal combustion engine or electric drive will be used. From the loading site, the extracted material is transported by conveyor belt to the crusher at the surface of the mine.

- During the mining of the second and third gangways, the raw material may be transported from the spoil area by loaders to the designated dumping point on the zero gangway, where it is loaded and hauled as described in the previous point.

- When quarrying the higher benches at Site V-180, the spoil may be transported from the spoil site by loaders to the mining stacks. Through the chimneys, it will self-propel to the zero footbridge. Below the chimney, it is loaded by wheel loaders (wheel loaders also loaders in case of failure of wheel loaders) into trucks and transported as in the previous points.

- The loading of the mining material into the trucks can be carried out on site or on site by wheel loaders. This eliminates the transport of raw material to the mining stacks, which has a particular impact on fuel consumption. The entry of the extraction machinery into the block and the transport is via the passes from the traps. The method of transport is then the same as in the previous points.

- The extraction of the disconnected raw material, leaving several blasts behind and extracting them at once, will increase the dimensions of the excavated area to a maximum height of 8 m and a maximum length of 10 m.

As this is a substantial unlogged area, the condition for extraction and logging must be that the cycle time is as short as possible.

The primary landscape structure of the area of interest represents a set of natural systems - elements of the landscape system, i.e. rock environment, geomorphology, air and water. In terms of vegetation stages, the following vegetation stages are represented: oak, beech-oak, oak-beech, beech and fir-beech. As a result of human activity, in some places hornbeam or black pine, which are not native tree species of the Slovak Karst, are gaining predominance (Růžičková, 1996).

The secondary landscape structure of the area of interest represents a set of natural, man-made partially or completely altered dynamic systems or newly created artificial elements of the landscape system and their interconnections. It thus represents the structure of the landscape altered by human activity and is made up of landscape elements (forests, non-forest tree and shrub vegetation, meadows, pastures, non-usable and usable land, watercourses, water bodies and settlements).

There is no protected element or component of nature and no area with a declared protection regime in the area of the site under consideration or in its immediate vicinity. From what is known so far, there are no known animal or plant species on the site or in its wider vicinity for which a special protection regime has been established. However, conditions and restrictions may apply to animal species that use the site incidentally. Currently, any mining activity is required to operate in an ecologically managed manner, achieving efficient economic indicators in its individual processes, in such a way that there is no accumulation of the negative effects of mining on the surface (Bauer et al., 2005).

We started to look into the design of the conquest method with the establishment of the conquered space because of the numerous advantages it brings:

a) the overburden or bedrock is supported and the ore can be mined safely and without great losses,
b) prevent unnecessary contamination of the cuttings with tailings,
c) prevent unnecessary wind losses,
d) reduce the cost of maintenance of mining works,
e) enable mining in inter-chamber and ceiling pillars, also in safety pillars,
f) enable better and more systematic management of the mining blocks, thus reducing the loss of the payable component and extending the life of the mines,
g) they protect surface objects from subsidence and also protect mining works in a certain way from mountain tremors,
h) in the context of the working environment, increase its safety,
i) help tackle waste management,
j) enable economic extraction of deposits or parts of deposits that could not be extracted by other extraction methods.

As with other methods, quarrying methods with the establishment of a mined-out area have their drawbacks:

a) foundation mining is relatively costly, as it requires relatively large investments in equipment for the treatment of foundation material and in the foundation machinery and equipment itself, which is directly reflected in the costs of both the mining and the energy costs,
b) quarrying is much more demanding in terms of transport and organisation of operations,
c) The capacity of the base limits the workflow and the concentration of pores,
d) the base requires the preparation of the base material, i.e. crushing to the necessary lumpiness, or mixing of different types of materials,
e) the whole process requires a greater number of changes in the mine and on the surface than other mining methods.

The main feature of all quarrying methods with the foundation of the excavated area is the filling of the excavated area with foundation material in close continuity with the progress of the quarrying operations. According to the source of the foundation material, quarrying methods are divided into two groups:

a) *mining methods with own base* - the material is extracted directly at the quarry,
b) *extraction methods with foreign base* - material is imported from external sources, however, if possible, own base can be used, which saves part of the extraction and transport costs.

Mining with own base can be used at any deposit deviation. The main principle of this method is to handle the tailings as little as possible, which means that the size of the stockpile should only be so large that the volume of the spoil is equal to the volume of the foundation according to the formula:

$$m_p = \frac{m_z}{k-1} \tag{1}$$

Where: m_p is the power of the flange [m],
m_z is the power of the vein [m],
k is the humidity coefficient.

The advantages are:

- high quality of mined ore with little contamination,
- small quantities of ore transported,
- low sensitivity to changes in storage conditions,
- good ventilation conditions and a high degree of occupational safety.

The disadvantages are:

- complex organisation of work with low productivity,
- increased scope of drilling and blasting work,
- for valuable ores, it is often necessary to build floors in order to reduce ore losses in the base,
- high production costs.

It is possible to obtain the foundation material for your own foundation:

- from the side rock if the vein thickness is less than the minimum required working width (height) of the quarry,
- from the sorted tailings when the total extracted tonnage proves to be sufficient from a technological point of view, but the usable material is overgrown with tailings which are left in the cut area,
- from corridors cut into the bedrock or into the overburden of the quarry,
- it is possible to obtain base material from direct addition of side rocks when the deposit is of sufficient strength to be mined and the payable material is relatively pure, but it is not advisable to cut base passages into the sides of the deposit.

Foreign-base mining can be used for medium to very powerful deposits. Among the methods of foundation, it is worth mentioning the cast, blown, floated and placer foundation. Of these methods, the most widespread is the loose and floated foundation. Blown bedding is less common and cast bedding is the least common. This division is based on the different methods of foundation work. The basic requirements for the properties of the base, i.e. in particular the properties of the base materials, are also determined by the method of foundation. The deposition of mine waste as backfill material in underground mines is a common practice worldwide. The reasons for backfilling are related to geotechnical concerns, e.g. reducing landslide effects. In addition, backfill materials may also be of other origins (Mittelstädt et al., 2023).

All the different parts of the foundation process must depend on the mining technology itself, so it is actually the determining component of the entire mining process by these methods. The choice of a particular type of mining method and its parameters depends on a number of factors that will influence the suitability of its application in the conditions of a particular mining operation.

In the case of a mine operation, then, it is the zero-waste, ecological technology of the backfill base that appears to be the most advantageous. However, there are several technological issues that need to be addressed. Firstly, the method of transporting the material to the foundation site needs to be resolved. As the extraction will be carried out by trucks, it is then possible to deal with the removal of the foundation material by returning the truck from the rubble extraction, i.e. the truck will be loaded with rubble which it will take to the landfill site, unloaded here and loaded with foundation material which it will then take to the foundation site. In this way, a so-called closed mining cycle is created. For the efficiency of such extraction, the exact number of trucks needed needs to be calculated. The basis for the calculations is an annual mine output of 50 000 tonnes. The basic parameters of the deposit shows in Table 1.

Table 1 Basic bearing parameters.

Bearing parameters	Data
annual production - RŤ	50 000 [t]
number of working days per year - PD	252
net working time - t_p	6 hours
specific gravity of anhydride - ρ	2.95 [$t.m^{-3}$]
load capacity of the truck - M_a	12 [t]
volume of the bucket loader bucket - V_l	2 [m^3]
the total length of the truck route - L_c	3 [km]
average vehicle speed - v_s	15 [km/h]

Source: own elaboration by authors.

Results

We have found that one truck with a load capacity of 12 tonnes (maximum 15 tonnes) is not sufficient to achieve efficient extraction, and it would be optimal to use two trucks of the same type, in terms of providing a reserve in the event of a breakdown or maintenance of the truck, or lack of staff in the operation.

Choosing the right material for the foundation of the excavated areas will facilitate the whole process of foundation as well as the handling and storage of the foundation. From the calculations of the excavated quantity of anhydrite in tonnes, we have specified the quantity of foundation in m^3 to be calculated according to the following formula:

$$D\check{T} = \frac{D\check{T}}{\rho} \tag{2}$$

Table 2. Calculation of the amount of base material based on daily extraction in m^3

Annual production [t]	Daily extraction DŤ [t]	Specific gravity of anhydrite (ρ) [$t.m^{-3}$]	Conversion of daily production to quantity of base material [m^3]
50 000	198,4	2,95	67,25
60 000	238,1	2,95	80,71
70 000	277,8	2,95	94,17
80 000	317,5	2,95	107,63
90 000	357,1	2,95	121,05
95 000	377	2,95	127,8

Source: own elaboration by authors.

At the various annual harvesting rates, the daily production ranges from 67.25 m^3 to 127.8 m^3 of slash. The same amount is therefore to be replaced daily with foundation material during the foundation process. A small amount of foundation material is also produced by the operation itself in the form of mine tailings, which are extracted during the stamping of the main mine workings. In addition to the tailings, the material from other mining subsidiaries located in the vicinity of the mine under consideration can also be used. In this case, it is possible to count on low-grade cement, which is a suitable admixture in the foundation material because it improves the consolidation properties. In addition, it is also cost-effective to use construction and demolition waste within a radius of 100 km. The utilization of mine wastes is very important for many organizations involved in the mining industry (Kazmierczak et,al. 2019). Reduce negative environmental impacts, e.g. less reshaping of the landscape, taking up less landfill space (Fojtova et al., 2013).

Since in this case it is necessary to provide a sufficient amount of foundation material, we suggest approaching neighbouring municipalities in the framework of municipal waste management, industrial companies, companies dealing with recycling of waste materials or disposal of waste material. The only companies exempted are those dealing with hazardous waste, which must not be used due to the presence of groundwater in mining areas. The following construction waste may be placed on the paved concrete pad handling areas of the subject company:

- Concrete,
- Bricks,

- Tiles, tiles, ceramics,
- Mixture of concrete, bricks, tiles, tiles and ceramics,
- Bituminous mixtures,
- Soil and aggregate,
- Excavation soil,
- Gravel from the railway superstructure,
- Mixed waste from construction and demolition.

This waste will then be subsequently used for the foundation of the excavated areas of the mine under consideration. This is a win-win process from both an economic and an environmental point of view. Both municipalities and companies get rid of their unnecessary waste, thus contributing to saving and restoring the environment, and the mine operation receives free material for the foundation, because currently, according to the Waste Act, both the transport and the disposal of the waste are paid for by the waste producer.

It is therefore more than likely that a mine operation (Fig. 2) within a 100 km radius will obtain sufficient sources of cheap waste material to cover the need for stripping even with increased production.

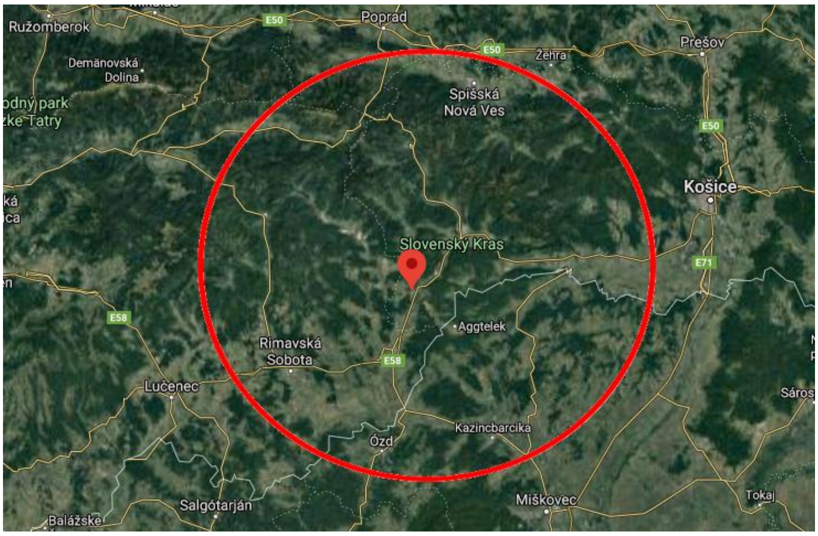

Fig. 2 Circumference in which foundation material can be profitably obtained . Source: (own elaboration by authors).

The recovered waste must be stored on the premises of the operation to allow continuous mining to continue. As we have indicated that the extraction varies between 50 000 and 95 000 tonnes during the year, the average extraction is approximately 70 000 tonnes. It is necessary for the mine to have at least one month's supply of foundation material, and possibly two months' supply, at the average rate of extraction. We have assumed an annual production (RŤ) of 70 000 t, a specific gravity of anhydrite (ρ) of 2,95 t/m^3 and calculated the necessary volume of the base stock according to the following formula 3. The annual volume of the base stock came out to be 23 728,81 m^3, the monthly volume of the base stock is 1977,44 m^3, but we will work with the rounding up for the case of increased production, i.e. with the figure of 2000 m^3. In Table 3, we show the amount of area required to store the material that will be used as foundation material.

$$V_{(year)} = \frac{R\check{T}}{\rho} \tag{3}$$

Table 3 Proposal for the size of the area required for the storage of foundation material

Characteristics of the Primary School	Period of one month	A period of two months
Volume [m^3]	2000	4000
Height of waste material [m]	2	2
Bearing area of material [m^2]	31,62	44,72

Source: own elaboration by authors.

Thus, an area of 35x35 m with a foundation height of 2 m is required for storing foundation material for one month, but due to the different volumes of excavated material during the year, we propose to increase this area to 50x50 m with a foundation height of 2 m.

As the volume of extraction varies throughout the year, the need for landfilling and transport of foundation material will vary and thus the cost of the entire foundation process will also vary. The cost of transporting the waste material is borne by the waste producer and the price is agreed between the mining company and the waste producer. The following Table 4 shows the calculation of the profitability of the process of founding mined-out areas with waste material.

Table 4 Required volume of base stock for a planned annual production of 70 000 t

Volume of the base	
Annual production (Yield) [t]	70000
specific gravity of anhydrite (ρ) [t/m^3]	2,95
required base volume (V) [m^3]	V = RŤ/ρ = 70000/2,95 = 23728,81 m^3

Source: own elaboration by authors.

In Table 5 we present a proposal of minimum requirements for transport, which will be continuously provided for the removal and import of the base material in volumes directly proportional to the production in the mining enterprise under study, including its economic evaluation.

Tab. 5 Draft minimum transport requirements.

Transport characteristics	**Input data**	**Calculation**
Truck bed area (P_{KNA}) [m^3]	6	
Collection daily (OD)		OD = OM/20 = 330/20≐ 17 turns
Collection monthly (OM)		OM = OR/12 = 3955/12≐ 330 turns
Removal per year (OR)		OR = V/ P_{KNA}= 23728,81/6≐ 3955 revs
Car speed [km/h]	12	
Load time [min]	3	
Distance [km]	1,25	
Collection time [min]	6,25	distance/speed of the car
Discharge time [min]	4	
Loss [min]	1	
Total time (FČ) [min]	14,25	
Total load time (CČ) [h]		CČ = FČ . OD = 14.25 . 17 = 242 min≐ 4.03 h
Transport price per hour [€]	25	
Transport price per day [€]		25 € . 4,03 h = 100,75 €
Transport price per month [€]		100,75 € . 20 days = 2015 €
Transport price per year [€]		2015 € . 12 months = 24 180 €

Source: own elaboration by authors.

In Table 6, we provide an assessment of the financial impact of the chosen method of establishment of excavated spaces.

Table 6 Economic evaluation

Economic evaluation of the benefit	
Price for waste treatment [€]	1,1
Price for waste treatment per year [€]	23 728,81 m^3 . 1,1€ = 26 101,70
Basic costs [€]	24 180
Profit [€]	1 921,70

Source: own elaboration by authors.

The calculation presented shows that at a price of €1.1 per 1m^3 of waste material removed, the whole process is cost-effective. However, the annual profit is not very high and therefore we do not recommend to reduce the price for landfilling of waste material. It is also questionable to increase the price, which must correspond to the development of prices on the market and to supply and demand in the area of the mine under consideration. In the post-reclamation period, the reclaimed object should not have a negative impact on environmental components, and at the same time it should have environmental efficiency (i.e., have a positive impact on environmental components), as well as bring economic profit to the owner of the object (Konovalov et al., 2018).

Nevertheless, it can be concluded that the process of establishing a mine by means of a fill foundation using available waste materials is economically and ecologically advantageous, both for the mining company and for the waste producers.

Conclusions

Years of mining activity leave visible traces on the terrain and landscape. Mining, treatment and processing affect mining regions and the surrounding environment. Mining activities are manifested in particular by the remains of mine spoil heaps, which are dumps of disconnected rocks, finely ground ores, often associated with chemicals used in mining and processing. Another clear consequence of mining activity is the excavated areas, which on the one hand visibly change the area, but on the other hand cause the surrounding soil and the soil above (in the case of underground mining) to change its behaviour significantly, threatening landslides, subsidence or intensification of weathering.

In an effort to eliminate the impacts of mining activities, new proposals are being put forward on how to eliminate these impacts in an efficient, cost-effective and, above all, environmentally friendly manner. Research and development of new technologies is an important way of promoting competitiveness and green credits play an important role (Chen, J. et al., 2024). One of the options that has been put forward is the establishment of mined-out areas, which we have also discussed in the case of the gypsum mine referred to above. This option for eliminating the impacts of mining activities is based on the fact that the excavated areas are founded with material that can take various forms. In the first instance, it can be founded with material that would manifest itself as a stockpile. Secondly, it is possible to deal with spoil by means of different materials suitable for spoil. The advantages of this approach are mainly the fact that the foundation supports the overburden, which improves safety and also eliminates the impact on the environment. This procedure also helps to address the waste management issue of eliminating spoil heaps and also the waste management of construction activities around the mining area. This solution has drawbacks in the form of potential costs, however, by efficiently establishing the excavated areas in a cost-effective and efficient manner, as in the proposed model for the mine, the establishment of the excavated areas can be carried out.

References

Act No. 409/2011 Coll. on Certain Measures in the Field of Environmental Burden and on Amendments and Additions to Certain Acts. [online] [cited 2024-04-03] Available at: <https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2011/409/>

Act No. 514/2008 Coll. on the management of waste from the extractive industry and on amendments and supplements to certain acts. [online] [cited 2024-04-03] Available at: <https://www.zakonypreludi.sk/zz/2008-514>

Act No. 39/2013 Coll. on Integrated Pollution Prevention and Control and on Amendments and Additions to Certain Acts. [online] [cited 2024-06-03] Available at: <https://www.zakonypreludi.sk/zz/2013-39>

Act No. 51/1988 Coll. on mining activities, explosives and state mining administration. [online] [cited 2024-06-03] Available at: >

Act No. 58/1998 Coll. amending and supplementing Act No. 51/1988 Coll. of the Slovak National Council on Mining Activities, Explosives and State Mining Administration, as amended, and Act No. 347/1990 Coll. of the Slovak National Council on the Organisation of Ministries and Other Central Bodies of State Administration of the Slovak Republic, as amended. [online] [cited 2024-06-03] Available at: <https://www.zakonypreludi.sk/zz/1998-58>

Assumma V, Bottero M, Caprioli C, Datola G, Mondini G. (2022). Evaluation of Ecosystem Services in Mining Basins: An Application in the Piedmont Region (Italy). Sustainability. 14 (2):872. https://doi.org/10.3390/su14020872

Bauer, V., Žiaran, V. (2005). Present and perspectives of development of decorative stones mining in Slovakia. In Acta Montanistica Slovaca, Volume 10, Issue 1, 25-28.

Cernecky, J., Valentova, K., Pivarciova, E., Bozek, P. (2015). Ionization impact on the air cleaning efficiency in the interior. In Measurement Science Review, Vol. 15, No. 4, online, pp. 156-166. DOI10.1515/jee2015-0008

Chen, J., Shang, H., Li, P., & Liu, J. (2024). Green Credit and Carbon Emission Reduction Technology R&D for Competitiveness. Journal of Competitiveness, 16(4), 242-256. https://doi.org/10.7441/joc.2024.04.12

Foitova, Pavla & Białecka, Barbara & Kurus, Krzysztof & Volgyi, Vojtech. (2013). Comparison of method about use mining waste in Czech republic and Poland. International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & Mining Ecology Management.

Collective of authors. (2011). Recycling of construction waste in Rožňava basin. Internal material of CRH.

Collective of authors. (2020). Plan of opening, preparation and mining of the exclusive deposit of gypsum - anhydrite in the Gemerská Hôrka mining area. 2020.Internal material of CRH.

Decree No. 255/2010 Coll. of the Ministry of the Environment of the Slovak Republic of 28 May 2010 implementing the Act on the management of waste from the extractive industry and on amendments and additions to certain acts. [online] [cited 2024-04-03] Available at: <https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2010/255/>

Grebski, M., & Mazur, M. (2022). Social climate of support for innovativeness. Production Engineering Archives, 28(1), 110-116. https://doi.org/10.30657/pea.2022.28.12

Grecula, P. et al. (1995). Mineral deposits of the Slovak Ore Mountains. Bratislava: Geokomplex, 1995, 829 p. ISBN 80-967018-2-7

Kaźmierczak U, Blachowski J, Górniak-Zimroz J. (2019). Multi-Criteria Analysis of Potential Applications of Waste from Rock Minerals Mining. Applied Sciences. 9 (3):441. https://doi.org/10.3390/app9030441.

Kivinen, S., Kotilainen, J. and Kumpula, T. (2020). Mining conflicts in the European Union: environmental and political perspectives. Fennia - International Journal of Geography. 198, 1-2 (Aug. 2020), 163-179. DOI:https://doi.org/10.11143/fennia.87223.

Konovalov V.E., Semyachkov A.I., Pochechun V.A. (2018). Concept of mining landscape rehabilitation. IOP Conf. Series: Materials Science and Engineering, 451, doi:10.1088/1757-899X/451/1/012208.

Lèbre É, Corder G. (2015). Integrating Industrial Ecology Thinking into the Management of Mining Waste. Resources. 4(4):765-786. https://doi.org/10.3390/resources4040765

Mardonova Mokhinabonu, Han Young-Soo. (2023). Environmental, hydrological, and social impacts of coal and nonmetallic minerals mining operations, Journal of Environmental Management, Volume 332, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2023.117387.

Mittelstädt P, Pollmann N, Karimzadeh L, Kories H, Klinger C. (2023). Waste in underground coal mines and its behaviour during mine water level rebound - a review. Minerals, 13 (12):1496.

Naser Badakhshan, Kourosh Shahriar, Sajjad Afraei, Ezzeddin Bakhtavar. (2023). Determining the environmental costs of mining projects: A comprehensive quantitative assessment. Volume 82, ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2023.103561.

Pactwa Katarzyna, Woźniak Justyna, Dudek Michał. (2020). Coal mining waste in Poland in reference to circular economy principles, Fuel, Volume 270, ISSN 0016-2361, https://doi.org/10.1016/j.fuel.2020.117493. (https://www.sciencedirect.com/science/article/pii/S0016236120304889)

Procházková, M., Vochozka, M. and Caha, Z. (2022). Age management in the mining industry. Acta Montanistica Slovaca, Volume 27 (4), 1028- 1039 DOI: https://doi.org/10.46544/AMS.v27i4.16

Ružičková, H. et al. (1996). Biotopes of Slovakia. Handbook for biotope mapping and catalogue of biotopes. Bratislava : ÚKE SAV, 192 p.

Shabbir Shahid, Mahmoud Abdelfattah, Ayman El-Saiy, (2009). Commercial Value Assessment of Newly Discovered Anhydrite Soil in the Coastal Lands of Abu Dhabi Emirate. European Journal of Scientific Research. 29. 36-46. 2009. Available online:

<https://www.biosaline.org/sites/default/files/publicationsfile/commercial_value_assessment_of_newly_discovered_anhydrite.pdf>.

Suopajärvi Leena, Ejdemo Thomas, Klyuchnikova Elena, Korchak Elena, Nygaard Vigdis, Poelzer Gregory. (2017). Social impacts of the "glocal" mining business: case studies from Northern Europe. Mineral Economics. 30. 10.1007/s13563-016-0092-5.

Taušová, M., Domaracká, L., Čulková, K., Matušková, S. Pena, N. and Mikita, M. (2021). European Climatic and Energy Strategy and its Goal Achieving in V4 Countries. Acta Montanistica Slovaca, Volume 26 (4), 825-833 DOI: https://doi.org/10.46544/AMS.v26i4.18

Ulewicz, R., Krstić, B. and Ingaldi, M. (2022). Mining Industry 4.0 - Opportunities and Barriers. Acta Montanistica Slovaca, Volume 27 (2), 291-305. DOI: https://doi.org/10.46544/AMS.v27i2.02

Woźniak J, Pactwa K. (2018). Overview of Polish Mining Wastes with Circular Economy Model and Its Comparison with Other Wastes. Sustainability. 10 (11):3994. https://doi.org/10.3390/su10113994