UNIVERSITY OF PETROȘANI

DOCTORAL SCHOOL

DOCTORAL THESIS

RESEARCH ON REDUCING THE ENVIRONMENTAL IMPACT OF OPEN-PIT MINING OPERATIONS USING NUMERICAL METHODS TO ASSESS THE STABILITY OF TAILING DUMPS

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INTRODUCTION

Since ancient times, people have adopted various methods of exploiting nature to ensure their existence. The exploitation of mineral deposits has been one of the most important sectors for the development of society, with Romania being considered one of the richest countries in mineral resources.

Within the territory of Romania, the extraction and processing of solid raw materials has been known to occur since ancient times, and the importance and variety of mineral resources have made mining a traditional occupation. [15]

Out of the total energy production of the European Union in 2021, lignite accounted for 9%, with Romania being the sixth largest producer in the European Union, following Germany, Poland, the Czech Republic, Greece, and Bulgaria, according to data published by Eurostat. Romania accounts for 6% of the lignite production in the European Union, while Germany holds a share of 45%, Poland 16%, the Czech Republic 11%, Greece 10%, and Bulgaria 8%. Together, these six countries are responsible for 96% of the total lignite production in the European Union. [89]

For the past 2 years, there has been a significant reduction both in lignite production and in the proportion of energy produced from lignite, by approximately 26%.

In our country, the first coal mines were opened in Banat and Moldova in the 19th century, while systematic exploitation of lignite began in the 20th century, in Oltenia.

The contemporary exploitation of lignite has witnessed continuous development, which manifested not only within our country but also across Europe and globally. It is regarded that surface mining of useful mineral substances, particularly coal, offers several comparative advantages over underground mining, namely:

- lower operational losses compared to underground mining;
- labor productivity is significantly higher in surface mining;
- surface mining allows for mechanization throughout the technological process, utilizing high-capacity machinery;
- accessing and commencing exploitation in a surface mining operation is much quicker compared to an underground mine;
- the working conditions for surface mining operations are significantly better than those in underground mines;
- the risk of accidents is much higher in underground mines;

- the cost of coal extracted through surface mining is significantly lower compared to that obtained from underground mines;

Certainly, surface mining of mineral substances also presents numerous disadvantages, most of which relate to its environmental impact. Among these, we can mention:

- the influence of climatic factors on the normal course of production processes;
- removal of agricultural or forestry use and immobilization of large land areas;
- relocation of residences;
- high costs for restoring degraded lands to productive use;
- landslides;
- changes in landscape;
- presence of noise and vibrations;
- pollution of flowing waters, groundwater, and surface waters;
- alteration of air composition;
- destruction of flora and fauna in the area.

The Oltenia Mining Basin began production in 1957 in the counties of Gorj and Mehedinți. The quantity of coal extracted to date in the Oltenia Mining Basin is 1.6 billion tons, with 95.4% obtained in Gorj County and 4.6% in Mehedinți County. [32]

The Oltenia Mining Basin comprises the Motru Mining Basin, Rovinari, Mehedinţi, Jilţ, and Berbeşti.

The environment is a unified and complex system, consisting of a large number of elements and connections. It possesses a significant capacity for self-regulation, with human communities and their activities serving as the active factor within it. [15]

Mining activity affects the entire environmental cycle by polluting water, air, and soil, which are the main components of the environment. The impact of mining activity on the environment must be limited by adopting environmental strategies that impose the restoration of destroyed environmental components, ensuring that mineral extraction is carried out in harmony with environmental restoration.

In Romania, environmental protection is legislated through Law No. 137/1995, complemented by other laws, regulations, and government decisions regarding specific areas such as air quality, pollution control and risk management, ecological labeling, waste and hazardous substances management, nature conservation, biodiversity and biosecurity, water protection, environmental policies, atmospheric protection, and climate change. [43].

The Motru Mining Basin, with a history of 61 years, specializes in producing high-quality lignite for thermal and electric energy generation. Recently, the quantity of coal

produced has significantly declined due to high production costs and the depletion of exploitable reserves.

The Motru Mining Basin, along with the Rovinari mining basin, accounts for 85% of the total coal production in the Oltenia Mining Basin, with an annual production of 6.6 million tons of coal. The extracted coal is primarily directed to the Turceni, Rovinari, and Craiova Power Complexes. Gorj County provides approximately 36% of the national electricity output, placing it among the counties with the highest contribution to electricity production.[32]

Surface mining operations generate localized pollution that persists until the cessation of activity. This pollution must remain within acceptable limits to avoid impacting the populations in neighboring areas. If the maximum allowable values are exceeded, immediate measures must be taken to reduce them.

The legislation in our country uses the following instruments for assessing environmental impact:

- impact study;
- environmental balance sheet;
- environmental risk assessment;
- minimum acceptable environmental objectives;
- compliance program. [82]

All environmental factors are affected by surface mining operations, but the most devastating impact is on the soil. Soil is affected from the outset of mining operations due to the use of large machinery that disrupts its balance through uncovering, excavation, or waste dumping. After closure, efforts are needed to reintegrate the soil into agricultural use.

To protect the flora and fauna in the area, it is necessary to limit the emissions generated by the quarry and to properly manage the lands occupied by the surface mining operation.

Water is also affected by the technological flows of the quarries, changing the water regime of the waters in the area. In order to reduce the negative effects on the water, it is necessary to check the discharged water and prevent the discharge of dangerous substances.

Regarding the air quality near these mining operations, it is affected by dust emissions from belt conveyors and vehicular transportation. Planting trees is an optimal method to reduce air pollution, however, at the quarry level, appropriate operational procedures and emission control procedures need to be instituted.

The environmental impact resulting from mining operations persists throughout their duration, even after their closure. To mitigate this impact, measures need to be implemented to

restore fertile soil, reduce air, water, and soil pollution, rehabilitate affected areas, and reintegrate them into productive use.

A structured approach to mitigating and controlling the impact on the environment is recommended, respecting well-established environmental management procedures, in order to identify the sources of pollution, the ways of propagation of pollution and the receptors that suffer because of it. [72]

The doctoral thesis aims to analyze the environmental factors affected by surface lignite mining activity in order to improve their quality, to restore the affected areas, because everything that surrounds us must be unpolluted for the human health of the present and future generations.

The thesis consists of 9 chapters.

In the first chapter I presented the Motru Mining Basin and within it I focused on the description of the geology of the region, the origin of the lignite deposits, the coal layers present, the hydrogeology of the region, the climate in the respective area and the methods of lignite exploitation.

In the second chapter I described the situation of the mining activity carried out in the Motru Mining Basin, through the two surface mining operations, Lupoaia and Rosiuţa, the geographical location and the technological flow of the two mining perimeters.

In the third chapter, I pointed out the environmental impact of lignite mining, namely, the impact on air, water, soil, subsoil and on vegetation and fauna.

In the fourth chapter, I identified the sources and pollutants generated by the mining activity from the Lupoaia exploitation for each environmental factor, air, water, soil, subsoil, but also the noise level from the mobile and fixed sources of the exploitation, which generate noise pollution.

In the fifth chapter, I presented the impact on the environment of the Lupoaia exploitation, the impact seen to the air, water, soil, fauna, vegetation and the impact generated by vibrations and noise.

In the sixth chapter, I presented the research methods used for the global assessment of the environmental impact of lignite mining, the assessment matrix, the network method and the global impact assessment method.

In the seventh chapter, I proposed measures to reduce the environmental impact of lignite mining for each environmental factor, air, water, soil, vegetation, fauna, as well as measures to reduce the impact of noise and vibrations. Also, within this chapter, I have pointed

out the main mine closure and ecological rehabilitation works required after the cessation of activity.

During the thesis, I highlighted the importance of dump stability issues in the general framework of the environmental impact of surface exploitations, first of all by the fact that the risk and negative effects produced by instability (sliding) are not limited to the period when the tailings are deposited and geometrization procedures are done (levelling, slope), but extends to quite long periods of time after the end of the piling activity. Starting from these considerations, in chapter 8 I performed a stability analysis for a hypothetical slope, representative from a geometrical, dimensional point of view and the characteristics of the constituent material for the dumps (dump steps) in the Motru basin, using simulation on a numerical model, based on a new principle of analysis, namely the resistance reduction method.

In the last chapter, I presented the general conclusions of the thesis, personal contributions and future research directions.