UNIVERSITY OF PETROSANI
DOCTORAL SCHOOL
DOCTORAL FIELD: MINE, PETROL AND GASES

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PHD THESIS

RESEARCHES ON THE IMPACT ASSESSMENT GENERATED BY THE ADJACENT MINING ACTIVITIES CET-ROVINARI, WITH SPECIAL REFERENCE ON THE STABILITY OF THE AFFERENT LANDS

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Petroșani, 2020

CONTENT

Synthesis of the doctoral thesis

The doctoral thesis entitled Research on assessing the impact of adjacent mining activities CET-Rovinari, with special reference to the stability of the land structured in seven chapters, highlights the issue of assessing the geotechnical and environmental impacts generated by energy activities in the Rovinari perimeter on land on the location and on those related to the Rovinari thermal power plant.

The Introduction shows the importance of taking such an approach for the safe operation of the energy sector in this area.

Also presented here are the purpose, objectives and research methods that were the basis for the approach to establish the geotechnical and environmental risks generated by such activities and to counteract them.

Chapter I ***The general presentation of the studied area*** has as objective the Rovinari mining basin, formed by the quarries Tismana, Roșia, Pinoasa, Peşteana and Rovinari being represented by a flat relief towards the hill, but also hilly parts with strongly fragmented slopes, so a safe premise for the state of instability of inclined surfaces and for functioning as important mobile sources.

The lignite deposit is found here close to the surface and thus, there have been and are, conditions for its exploitation through quarries. The average thickness of a layer varies between 4.0m - 8.0m, with an inclination of up to 5^0 presenting corrugations in several directions being developed unevenly. The rocks in the roof and the bed of the lignite layers are generally weakly consolidated, showing extensive erosion or non-sedimentary surfaces. They consist of topsoil in a proportion of 5 - 20%, clays and marls 50 - 70% and sands 5 - 20%.

The physical-geographical conditions of the Rovinari Basin are favorable for the accumulation of significant reserves of groundwater and their permanent renewal. The structure of the hydrographic network is a dentritic, complex, water-bearing one, the water resources being confined in the rivers that have their springs or transit the region. Permanent watercourses have their origin in the mountains, have a high frequency and a periodic torrential course. Secondary watercourses have a non-permanent regime.

From a hydrogeological point of view, the groundwater in the Rovinari Mining Basin is divided into two main categories: groundwater with free level (groundwater) and groundwater under pressure, with ascending level or artesian level.

The Rovinari mining basin is part of the climate group of hills and plateaus, with a temperate-continental climate, benefiting from a sheltered climate with mild winters and moderate summers.
For most of the year it is under the influence of southern, southwestern and western air masses. In the case of the studied area, the air temperature, as a multiannual average, is around 10.1^0C, the absolute maximum temperature is + 40.6^0C, and the absolute minimum temperature is -31^0C, with some differences in the hill area where temperatures decrease by $1{,}5^0$C. The highest average monthly temperature is in July exceeding the value of 20^0C, and the lowest being in February 5^0C. Summers are moderate and winters mild, with sufficient rainfall, but unevenly distributed: abundant in spring, autumn and winter and deficient in summer. Between November and March, the activity in the quarries is carried out in difficult or difficult conditions.

The winds are almost non-existent due to the sheltered climate of this area, the most dominant being the northern ones. The predominant wind direction is northwest, its average speed being 3.2m /s.

From the seismic point of view, the Rovinari administrative territory falls in the seismicity zone E (ag = 0.12g, Tc = 1) with seismic degree 7.

In the analyzed area, the flora and fauna are varied, arranged in floors, in close correlation with the morphological factors. From a floristic point of view, this area falls into:

- vegetation area of deciduous forests (consists of over 2000 species of sub-Mediterranean, Pontic, Balkan and Balkan-Dacian plants);

- azonal vegetation occurring along river valleys and in human settlements (blue grass meadows - Molinia caerulea, Medicago falcata, Alopecurus pratense, Agrostis stolonifera and black alder groves, Populus nigra, Populus alba, Salix alba, Salix frag purple etc).

The characteristic fauna of this area is represented by: deer, squirrel, rabbit, fox, wild boar, some rodents, horned viper, scorpion, hazel, rooster, thrush, blackbird, nightingale, woodpecker, sitar, etc., as well as ubiquitous species such as they are: the sparrow, the crow and the dove.

The aquatic fauna of the rivers in the region falls into two major areas: the grayling and moioage area, at higher altitudes and the barbel area, at lower altitudes. In wetlands (ponds) there are reptiles and gastropods specific to these biotopes

Mining works carried out in the area led to the uncovering of hundreds of hectares, which had the effect of destroying the natural flora and strongly influencing the surrounding areas. The consequence of this situation is the accentuated reduction of the floristic diversity on the analyzed territory.

Chapter II ***The current situation of the energy sector in the Rovinari Mining Basin*** performs, at the beginning, a SWOT analysis for establishing the Mining Strategy of Romania 2017 - 2035 on lignite resources, after which we move on to the detailed presentation of energy activity in the Rovinari Basin represented by CET Rovinari and the operating quarries of this basin.

Rovinari Mining Basin, formed by quarries belonging to E.M.C. Roșia - Rovinari, is divided into four distinct areas as landforms: the meadow area of the Jiu River, the meadow area of the Tismana creek, the eastern hilly area and the western hilly area. The central part is represented by the alluvial plain of the Jiu, with altitudes varying between +168 m and +135 m to the south.

The quarries belonging to this basin are presented in detail below (location, opening, working technology, transport, dumps): Tismana, Rovinari, Roșia de Jiu and Peșteana

The Rovinari thermal power plant is located about 2 km northwest of the city of Rovinari and about 25 km S-V of the municipality of Tg-Jiu, in the immediate vicinity of mining operations in the Rovinari mining basin: the Rovinari, Tismana and Pinoasa quarries. The access inside the power plant is made from the national road DN 66.

Currently CET Rovinari has 4 energy groups / blocks of 330 MW each powered by a single boiler, designed to operate on lignite with gas support, each group having electrostatic dedusting plant, dense sludge plant, flue gas desulphurization plant. The 4 energy blocks are connected to 2 chimneys (two to one chimney), 220 m high, with an outlet diameter of 8.7 m.

The surface of the CET Rovinari enclosure is 826,555.84m2, being occupied by: constructions, municipal technological networks, transport routes and free land.

From the point of view of the infrastructure, on the CET Rovinari site there are the following equipment and installations: steam boilers (4 x 1 035 t / h) with the attached installations; steam turbines (330 MW) with ancillary installations; pipeline installations; electrical and automation installations; hydrotechnical installations; chemical water treatment plant; compressed air installation; fuel households; coal deposit; the slag and ash deposit to which, in the thesis, a short presentation was made.

Chapter III ***The impact of energy activities in the Rovinari Mining Basin on the environment*** is approached from two points of view: from the one generated by the lignite exploitation activities in this basin and from the one related to the production of electricity and heat after burning this lignite in thermal power plants. Thus, this dual approach outlined an overview of the assessment of the impact generated by energy activities in this area on the environmental components and allowed to find solutions to improve them in order to improve the quality of the environment.

The pollution generated by the mining activities in the Rovinari Mining Basin is generated by the lignite extraction process from this mining basin, producing a multitude of negative effects on the environment, the most significant being: the degradation / modification of the landscape; land degradation; the hydrodynamic imbalance of groundwater, as well as the pollution of surface runoff and groundwater; negative influences on environmental components; widespread noises and vibrations in the environment, which cause discomfort and negative influences on health; displacement of households from exploitation areas.

In chap. III, paragraphs III.1.1- III.5. pollution of the following environmental components is analyzed in detail: land / soil, air, surface and groundwater, noise pollution and biodiversity.

The pollution generated by CET Rovinari has at hand multiple possibilities to minimize the negative impact on the immediate environment, while the exploitation of the deposit raises major problems, both landscape and pollution of all environmental factors, problems that can not be solved immediate.

Despite this minimization of the direct negative impact on the source, the activity of the thermal power plant, by burning fossil fuels, is the activity with the most significant share of environmental degradation, compared to the exploitation of the deposit, if this activity does not comply with the conditions imposed by law. the field of environmental protection.

The main sources of pollution of the Rovinari thermal power plant are: chimneys of thermal power plants, wastewater and ash deposits.

In chap. III, paragraphs III.2.1- III.2. the pollution of the following components of the environment is analyzed in detail: land / soil, air, cooling and wastewater, noise pollution and biodiversity.

Chapter IV ***Environmental impact assessment of environmental activities in the Rovinari Mining Basin*** is essential for the process of ecological remediation and reconstruction in order to ensure the safety of the population in the area, being an important tool in the decision-making process. imposed by the competent authorities.

In the evaluation of the impact generated by the energy activity in the Rovinari basin, two methods from the specialized literature were used, namely: the Matrix method of Rapid Impact Assessment (MERI) and the Method of integrated quantitative assessment of the impact and risk of pollution of environmental components (EIRM). According to the Rapid Impact Assessment Matrix (MERI) method, the mining activities in the Rovinari basin have a moderate negative impact, caused mainly by the removal from the economic circuit of significant land areas and drying works, which influence the groundwater level with repercussions on the supply. with drinking water of some localities.

According to the Integrated Quantitative Impact and Risk of Pollution (EIRM) method, the mining activities in the Rovinari basin generate an environment subject to the effects of industrial / human activities within permissible limits with minor risks to be monitored.

In the case of CET Rovinari, according to the MERI method, the activities of the thermal power plant create a negative impact, and according to the EIRM method medium subject to the effects of industrial / human activities causing discomfort with medium risks at an acceptable level, which require prevention and monitoring.

Based on the analysis made by the two methods on the impact of the energy sector in the Rovinari basin, the general conclusion can be revealed that the activity of this sector does not lead to the identification of significant negative effects strictly associated with it.

Chapter V ***The geotechnical study of the lands related to CET Rovinari*** represents the first stage of the construction or consolidation process of an objective, which includes information about the consistency and structure of the soil, the level of the groundwater table and recommendations for the technical project.

The paper analyzes two important and defining areas for determining the degree of stability of the lands related to CET Rovinari as required by the topic of the doctoral thesis:

- thermal power plant - enclosure;
- Gârla slag and ash deposit;

The geotechnical study involved: the execution of several drillings on the lands on which the objectives are located; sampling rock / earth and water; laboratory analysis of these samples; stability calculations of the objectives located on these lands.

In order to answer the topic of the thesis, it was necessary to know, from a geotechnical point of view, the lands on which the objectives under study are located. Such an approach involves time (several years), but especially high costs necessary for the geotechnical investigation of the land (drilling, sampling, laboratory determinations, etc.). Of all these conditions, the execution of drilling by a specialized unit is not within the reach of a doctoral student, both physically and financially.

Therefore, in order to respond to the topic of the doctoral thesis, we used the data provided in the Geotechnical Study of the lands related to CET Rovinari carried out by S.C. Institute for Scientific Research, Engineering and Design of Mines on Lignite - S.A. Craiova, which included the works of geotechnical exploration of the land afferent to the Rovinari thermal power plant. It is stated that the geotechnical drilling was carried out by S.C. Institute of Energy Studies and Designs S.A. Bucharest with FSC 2.5 drilling rig at depths between 15m and 30m.

The drilling positions were established according to the proposed location for the important constructions, and the drilling depth according to the development of these constructions both in plan and vertically. The study was carried out in two stages: stage Ia on the right bank of the Jiu River (the lands on which the constructions related to the thermal power plant and the lands related to the coal depot are located) (fig. nr.V.2) and stage II on the left bank of the Jiu River (Cicani - Beterega - Gârla slag and ash deposit).

The geotechnical investigation works aimed at establishing: the stratification of the site land, the physical-mechanical characteristics of the lands encountered, the hydrostatic level and the chemical characteristics of the waters in the subsoil of these lands. In establishing in the laboratories I.C.S.I.P.M.L-Craiova the physical and mechanical properties of the rocks (presented in detail in the thesis) I also participated in the actual testing stage and in the calculation of these properties (2017).

The following is a summary, based on personal processing, of the data from this study. Following the analysis of the stability of the lands on which the constructions inside the Rovinari CHP are located, the following conclusions were obtained:

Conventional pressures, p_{conv}., determined according to STAS 3300/2 - 1985 and the Norm for the design of direct foundation structures - NP 112/2014, were calculated taking into account the basic values by categories of layers, corresponding to foundations with the width of the sole B = 1m and B = 2.5m and depth D = 2m and D = 3.5m both for cohesive soils - as a function of plasticity (I_p), consistency (I_c) and

porosity (pore index *e*), and for non-cohesive soils - as a function of degree of compaction (I_d) and humidity (*W*).
In general, the conventional pressure exceeded 250-300kPa, small values, up to 200kPa, highlighting both in depth and close to the surface, in layers of clay, soft plastic dusty clay, soft plastic dusty sand, soft plastic clay sand.

- *Permissible pressures at the deformation limit state (fundamental loads)* p_{pl}, have the minimum values p_{pl}, min = 92kPa for continuous foundations with the small side of the foundation base B = 0.6 m and the foundation depth D = 0.8 m and maximum $p_{pl,max}$ = 287kPa for foundations with maximum dimensions of B = 2.5m and D = 3.5m.

Because the average effective pressure at the base of the foundations is pef, med = 81kPa for foundations with dimensions of D = 0.8m and B = 0.6m and of pef, med = 259kPa for those with dimensions D = 3.5m and B = 2.5m pressures lower than the limit pressure values calculated for the two extreme dimensions of the existing foundations at CET Rovinari (see table no. V.10) it can be confirmed that the condition imposed in relation V.5 is met, *ie the land foundation under constructions placed on direct foundations is stable.*

- *Absolute probable settlements, s, minimum* s_{min} *= 13mm and maximum* s_{max} *= 54mm* corresponding to an average net unit effort p_{net} = 280kPa on the foundation base, fall within the permissible limits for constructions (permissible values for any type of construction are higher than 80mm).
- *Permissible pressures at the load-bearing capacity limit state (special loads),* $R_{d,,}$ have the minimum values $R_{d,\ min}$ = 122kN / m for continuous foundations with the small side of the foundation base B = 0.6m and the foundation depth D = 0.8m and maximum of Rd, max = 1196 kN/m for foundations with maximum dimensions of B = 2.5 m and D = 3.5 m.

Taking into account that the calculation values of the vertical actions are Vd = 107kN/m for foundations with dimensions of D = 0.8m and B = 0.6m and Vd = 1058kN / m for those with dimensions D = 3.5m and B = 2.5m values lower than the minimum of the pressures at the limit capacity of load-bearing capacity (see table no. V.11) it is found that the condition imposed in relation V.9 is met, ie *the foundation ground under the constructions placed on the foundations direct is stable.*

In case of indirect foundation (on piles) of the constructions inside CET Rovinari (chimneys, gas duct supports) the ultimate load-bearing capacity of a pilot ($R_{c;d}$ = 379kN) is higher than the calculation value of the axial compression load on of a pilot corresponding to the ultimate limit state is ($F_{c;d}$ = 224.5kN), which ensures the stability of these constructions.

Following the analysis of the stability of the Gârla slag and ash deposit, the conclusions are as follows:

- *In order to establish the geotechnical characteristics of the basic terrain*, the company SC GEOCONSULTING SRL carried out 6 geotechnical drillings (F1-F6), and three dynamic penetrations (P1-P3), up to a depth of 6.00 m.

From the point of view of landslides, although the studied area falls within areas with high potential for landslides, the location of the deposit, being in a former quarry, does not present any risk.

- The slag and ash deposit falls into geotechnical category 3 with major geotechnical risk.
- The basic value for the conventional basic p_{conv} pressure taken into account in the calculation of the foundation ground will be 250 kPa for fundamental loads, the width of the foundation base B = 1.00 m and the depth D = 2.00 m, which for the given conditions will be the conventional calculation pressure p_{conv} calculation.
- The site terrain does not require improvements or consolidations because the actual pressures exerted by the dams on the filler material are much lower than conventional calculation ones.
- The calculation of the general stability of the Gârla slag depot (for the designed structure) was performed with the specialized program SLOPE W-Version 3, of the Canadian company GEOSLOPE International Limited using the methods Fellenius and Bishop, which evaluates the safety factor based on moments and Janbu, which assesses the force-based safety factor. The geotechnical parameters taken into account for the final deposit quota of 192.00 mdMN are given in table no. V. 15, and the results of the calculation of the safety factors by the three methods, for different values of the range / safety guarantee are given in table no. V. 16.
- From the analysis of the results of the calculations of the stability factors results the need to keep permanently in storage the dimensions of the beach / safety berm of at least 60 m to obtain permissible safety factors for the situation of an earthquake equal to the one taken into account ($K_h = a_g$ = 0,15g).

Chapter VI. ***Land stabilization and rehabilitation solutions*** include a series of measures that must be taken in order to reduce the impact generated by the activities of the energy sector in the Rovinari basin on the related lands as well as on the environment. Achieving physical stability removes the phenomena to which the ground is exposed (erosion, landslides, freeze-thaw phenomena) and consists in improving the foundation ground through various processes. The works are diversified according to the problems identified following the geotechnical and geomorphological analyzes:

- works with the role of restoring (completing) in the soil the moisture deficit (irrigations);
- works that have the role of preventing or eliminating the excess water from the soil, from its surface (regularization of watercourses, irrigation, drainage and drainage);
- works that have the role of protecting the soil against the mechanical action of water and wind (works to prevent and combat / control soil erosion);
- works for water accumulations necessary in agriculture, industry, leisure etc. These works consider the following:
- control of slope erosion, including stability;
- control of floods and riverbed processes;
- irrigation and drainage;
- arrangement of accumulation lakes.

The main effect of stabilizing the foundation ground is to increase the shear strength of the earth, which leads to a higher load-bearing capacity, respectively to the possibility of supporting higher loads. In addition to increasing the resistance, the stabilization process also has effects on the permeability of the soil in the sense of its decrease, which means a stabilization of volume variations. As the permeability decreases, so does the degree of compressibility of the soil, thus providing greater safety to buildings located on such land.

The stabilization process consists of introducing and mixing additives (stabilizing agents) into the soil, in powder or suspension form, in order to improve the volume stability, strength, permeability and durability of the soil.

Due to the fact that the stabilization of the foundation ground is a complex process, it is necessary that the stabilization works be monitored both during the execution and during the entire operation.

Cement stabilization is effective for clay soils and less effective for organic or highly plastic soils. However, in the latter case it is possible to obtain increases in strength by the addition of an additional source of calcium, which provides an additional amount of calcium ions necessary for the chemical reaction to take place.

Lime stabilization is quite effective especially in clay soils. In the case of granular soils or those with small clay fractions, the efficiency of the method is quite low. In general, lime is effective for soils whose plasticity limit is between 10% and 50%.

Where the use of cement or lime does not lead to the desired strengths, these materials can be mixed with others to obtain the desired properties. The composition of the stabilizing agent will be made only after knowing the initial geotechnical characteristics of the earth.

In recent years, land stabilization procedures have developed more and more, now it is possible to stabilize the land to great depths (45 m), and, under special conditions, even to greater depths. The stabilization of the foundation lands by means of the columns with stabilizing agents has a double role, with effects on the improvement of the geotechnical characteristics of the surrounding land, as well as with the role of resistance piles for the respective construction.

The stabilization process must be chosen according to the geotechnical characteristics of the site, the economic conditions as well as the execution conditions (existence and location of the execution equipment).

Taking into account the conclusions presented in Chapter V, §V.6.1.4 on the foundation conditions ***for the area of buildings and equipment inside the Rovinari thermal power plant***, it is considered that the foundation systems to ensure their stabilization are:

- in the case of equipment (tanks, silos, etc.) with a large bearing surface the solution: direct foundation on a general eraser executed on a compact ballast cushion;

- in the area of the chimneys: screed of minimum 3-4m thickness and piles with a plug of sufficient length to enter the terrace formation;

In the case of the Gârla slag and ash deposit, it is considered that:

- the basic land on the site does not require improvements or consolidations;

- in order to achieve the stability of the deposit (contour dams) it is necessary to permanently maintain in the deposit the dimensions of the beach / safety guarantee of at least 60 m in order to obtain permissible safety factors for the event of an earthquake equal to the one taken into account ($K_h = a_g = 0.15g$).

The ecological reconstruction of the lands affected by the activity of the energy sector requires the remediation and rehabilitation (improvement) of the degraded lands following the development of the activities in the energy sector related to this basin, given that during the coal mining operations soil mixtures with sterile rock and other materials , as well as the improper movement and storage of the dumped material and last but not least, numerous phenomena of instability due to the massive drying or overloading of the loads of the sites and equipment necessary for the technological processes in this sector.

Land rehabilitation will be achieved by agricultural cultivation and forestry cultivation of different species suitable for the area, depending on the pedological studies and economic calculations of production obtained by planting agricultural and forestry areas.

In the case of the Rovinari mining basin, for the restoration of the lands degraded by the exploitation activities, it was found that the cultivation of Miscanthus Giganteus and Paulownia is suitable for the soils here.

The cleared land surfaces are also covered by mature trees, which include the following species: beech, sessile oak, acacia, maple hornbeam, sky and oak.

In the area of CET Rovinari, fruit trees and poplars were planted to achieve the stability of the lands related to the activities of the thermal power plant.

The following measures have been taken to protect the environment against contamination with ash or substances contained therein:

• in the execution periods of the uplift dams made of slag and ash, due to the specific earthworks (excavations, fillings, compaction), concentrations of dusty dust appear in the air. In order to avoid environmental pollution, during the works the surface of the work areas is watered using the specially provided spraying installation;

• in order to protect the surface waters, the total recirculation of the hydrotransport water was provided;

• mounting around the overflow wells some pipe floats that have the role of retaining the floating ash, thus avoiding its penetration in the hydro circuit of the power plant;

• for the protection against pollution of the Jiu River, a concrete veil embedded in the bedrock was made;

• for the protection of the groundwater in the area, the pit was covered in order to seal with clay on the ends of the groundwater layer.

Another problem is the follow-up in time of all the constructions related to the development of the activities in the energy sector and the intervention of their consolidation when it is needed.

Chapter VII ***General conclusions and own contributions*** make a synthesis of my entire approach to solve the given topic and end with a timely presentation of my own contributions to the research conducted to meet the desired goal.

I consider that ***the main contributions*** I have made to solving the topic of my doctoral thesis can be summarized as follows:

➢ studying and analyzing the location conditions (geographical, geomorphological, climatic, biodiversity, neighboring human settlements and the current stage of works) of the energy sector in the Rovinari Mining Basin;

➢ centralization of the materials encountered in the drillings made in the studied area;

➢ realization, verification and centralization of all physical and mechanical characteristics made in the area under study;

➢ participation in the laboratory determination of the geotechnical characteristics of the materials that form the basis of the construction foundation on the CET Rovinari site and of the Gârla slag and ash deposit;

➢ assessment of the impact of energy activities in the Rovinari Mining Basin on the environment;

➢ determining the stability of the land on the CET Rovinari site;

➢ determining the stability of the Gârla slag and ash deposit using the SLOPE / W program - 2007 version;

➢ proposing solutions for stabilization and rehabilitation of the lands in the analyzed area.