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COMPLEX CLASSIFICATION, CHEMICAL AND GEOMECHANICAL STUDY OF SOME OPHIOLYTIC ROCKS, FOR THEIR USE IN CONSTRUCTIOS

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Abstract: *Abstract: The use of rocks in construction is governed by standards that require a series of chemical criteria, mineralogical-petrographical and physical-mechanical that they must meet. The execution of various works is permitted only if they fall within certain quality criteria. In this context, the geo-mechanical properties were determined for Căzănești gabbro and Căzănești diabase, which were compared with the conditions of admissibility imposed by current standards, for use in different areas. To get a more detailed view of geo-mechanical properties of the ophiolitic rocks it was required a classification based on three criteria: chemical, geological and geo-mechanical. The chemical criterion of rock classification is based on the content of SiO2 and alkali-aggregate reaction. From the geological point of view, there were chosen for classification purposes those features that could provide information on strength and deformation behavior. The geo-mechanical classification criterion employed in this paper was in accordance with standards widely used today, trying to characterize the analyzed ophiolitic rocks in terms of physical characteristics, strength and deformation.*

Keywords: *gabbro, diabase, aggregate, chemical, geological, strength, classification.*

1. INTRODUCTION

The rocks have been used as building materials since antiquity. Over time, their use in various forms, all over the world, has become more widespread, varying according to culture and time [1].

On the Romanian territory, the useful rocks have a wide spread in the vorland structures, but especially in the Carpathian structures. They have multiple uses in construction, as well as in various other industries. Thus, in addition to the use in the form of raw stone in constructions, roads and other engineering works, they can also be

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used in ornamental-decorative works, depending on the physical-mechanical and aesthetic characteristics.

This wide range of uses today places in an important place the interest for the knowledge of the areas that contain deposits that are not in exploitation, but whose reserves allow the exploitation in a close perspective.

The construction, rehabilitation and maintenance of infrastructure in the road and rail sectors involves the use of significant quantities of materials, of which natural aggregates have the largest share. Thus, the rigorous determination of the quality of the rocks from which the aggregates used in the mentioned sectors come is strictly necessary and with well-established periodicities [2].

The use of rocks in the execution of various works is allowed only if they meet certain quality criteria. In this context, the present study aims to establish the chemical, mineralogical and geomechanical parameters of some ophiolites (gabbros and diabases) in the Mures Corridor, in order to capitalize on them in the field of construction, rehabilitation and maintenance of infrastructures in the road and railway sectors. The results obtained will be classified and compared with the limit values imposed by the standards in force.

2. METHODS AND RESULTS

2.1. Chemical characteristics

The alkali-aggregate reaction highlights the reactivity and potential harmfulness of aggregates containing one or more forms of low crystallization silicon dioxide (opal, chalcedony, tridymite, cristobalite) and volcanic bottles rich in silicon dioxide [16].

Based on the verification of the alkali-aggregate reaction, the possibility of using the aggregates together with cements to attenuate or annihilate the reactivity and harmfulness is established. This determination is necessary in the case of aggregates used to make concrete that come into permanent or alternative contact with water or a humid environment [16]. The results obtained from the analyzes are presented in table 1.

Table 1. The average values for the alkali-aggregate reaction

Sampling location/ Rock type	**Silicon dioxide concentration, Sc [mmol/dm^3]**	**Reduction of sodium hydroxide concentration, Rc [mmol/dm^3]**
Gabbro/Căzănești	7.3	19.8
Diabase/ Căzănești	6.7	20.5

The chemical analyzes performed for the two types of ophiolitic rocks aimed at determining the main oxides. The results of the chemical analysis are presented in table 2.

Table 2. Chemical composition of the ophiolites [1].

Chemical composition					
Oxides	**Sampling location/ Rock type**		Oxides	**Sampling location/ Rock type**	
	Gabbro/ Căzănești	**Diabase/ Căzănești**		**Gabbro/ Căzănești**	**Diabase/ Căzănești**
	%	%		%	%
SiO_2	42,4	41,0	As_2O_3	0,0260	-
Al_2O_3	13,7	10,9	SrO	0,106	0,0190
Fe_2O_3	17,2	26,5	CeO_2	0,093	0,193
MnO	0,308	0,712	Tb_4O_7	0,181	0,130
MgO	5,89	5,54	Cl	0,0615	-
CaO	16,3	9,35	Yb_2O_3	-	0,0337
Na_2O	0,608	0,877	Er_2O_3	-	0,0181
K_2O	1,03	0,224	La_2O_3	-	0,0785
TiO_2	0,953	2,79	CuO	-	0,0231
P_2O_5	0,141	0,227	Ga_2O_3	-	0,0265
SO_3	0,557	0,804	Rb_2O	-	0,0126
V_2O_5	0,114	0,0488	Ag_2O	-	0,127
Cr_2O_3	0,195	-	CdO	-	0,0881
NiO	0,0662	-	Sm_2O_3	-	0,0233
ZnO	0,0331	-	Gd_2O_3	-	0,0263
GeO_2	0,0346	-	ReO_2	-	0,204

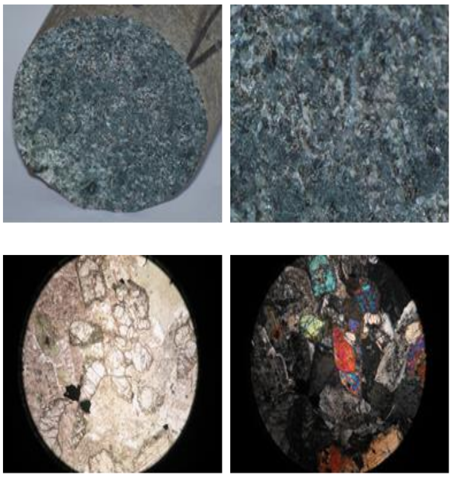
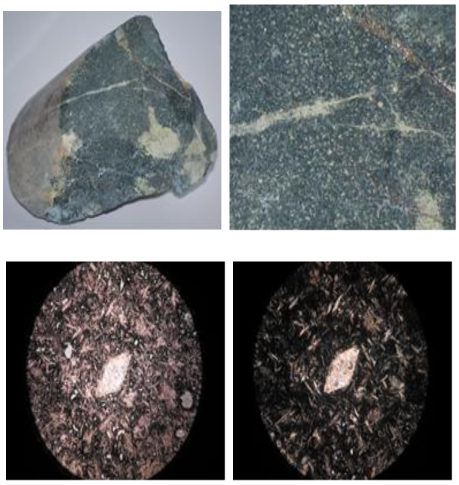
2.2. Mineralogical and petrographic characteristics

Ophiolitic rocks were previously analyzed both macroscopically and microscopically to determine the mineralogical-petrographic characteristics (Table 3).

The mineralogical-petrographic study was based on the analysis of thin sections using the polarizing microscope. Following a macroscopic and microscopic examination, a detailed description of these rocks was obtained.

Table 3. Mineralogical and petrographic analysis [1].

Gabbro/Căzănești	**Diabase/ Căzănești**
ALPINE OPHIOLITIC ERUPTIVISM (INITIAL) **MACROSCOPIC ANALYSIS** **ROCK TYPE**: magmatic, plutonic, basic; **STRUCTURE:** holocrystalline, hypidiomorphic and allotriomorphic; **TEXTURE:** massive (unoriented), compact; **COLOR:** dark gray, black-green; **MINERALOGICAL COMPOSITION**: basic plagioclase feldspar, augite, olivine, oxide minerals, secondary minerals; **REACTION TO ACIDS:** no mineral component reacts with diluted hydrochloric acid (HCl). **MICROSCOPIC ANALYSIS** **STRUCTURE:** holocrystalline, hypidiomorphic and allotriomorphic; **TEXTURE:** massive (unoriented), compact; **MINERALOGICAL COMPOSITION:** basic plagioclase feldspar, olivine, augite, opaque minerals, saussurite. ***Basic plagioclase feldspar (55 %)***, consists of the series labrador - bytownit - anorthite with 65% An. It is medium and widely developed (0.3 / 0.2 - 4.3 / 2.3 mm) and has various stages of saussuritization, i.e. its transformation into a fine aggregate, consisting of zoisite, clinozoite, epidote, bleached, zeolites, sericit. ***Olivine (20%)*** is represented by hypidiomorphic, idiomorphic and allotriomorphic crystals, with dimensions between 1.5 / 0.5 mm and 0.5 / 0.1 mm. It is quite fresh and only the olivine without its own contour shows on the contour and cracks some opacitizations and serpentinizations. ***Augite (8%)*** consists of hypidiomorphic and allotriomorphic crystals whose dimensions do not exceed 1 mm. The cleavage is unidirectional in the case of sections parallel to the “z” crystallographic axis and bidirectional (89 °) in the sections perpendicular to the same axis. ***Opaque minerals*** are finely crystallized and	**OPHIOLITIC ERUPTIVISM (INITIAL), STAGE I** **MACROSCOPIC ANALYSIS** **ROCK TYPE**: magmatic, effusive, paleovolcanic; **STRUCTURE:** medio - ophitic; **TEXTURE:** massive (unoriented), compact. The rock has a system of millimeter cracks, clogged with carbonates and pyrite; **COLOR:** light greenish gray; **MINERALOGICAL COMPOSITION**: plagioclase feldspar, pyroxene, carbonates, pyrite, secondary minerals, dolomitic limestone enclaves; **REACTION TO ACIDS:** calcium carbonate ($CaCO_3$), reacts strongly with diluted hydrochloric acid (HCl) **MICROSCOPIC ANALYSIS** **STRUCTURE:** medio - ophitic; **TEXTURE:** massive (unoriented), compact; **MINERALOGICAL COMPOSITION:** plagioclase feldspar, augite, olivine, calcite, dolomite, pyrite, chlorite, serpentine. ***Basic plagioclase feldspar (58,5%)***, initially basic (anortitic), partially and in most cases albitic, it is represented by idiomorphic and hypidiomorphic crystals with dimensions between 0.2 / 0.09 mm and 0.05 / 0.03 mm. The plagioclase in the fundamental mass of the rock is totally transformed into kaolinite, calcium carbonate and magnesium. ***Augite and olivine (22%)***, consist of submillimetric allotriomorphic crystals developed at the interstices between intersected prismatic plagioclases. They are, in most cases, transformed into chlorite, bastite and serpentine minerals. ***Calcite, dolomite and pyrite (15%)*** are minerals of hydrothermal origin, very finely crystallized, subsequently deposited

unevenly dispersed in the rock mass.	on the contraction cracks of diabasic lava.
 Gabbro with olivine and slightly mineralized augite	 Partially altered and mineralized medio-ophitic diabase

The geomechanical characterization of rocks implies the understanding of those phenomena that occur when rocks are subjected to various actions, under the influence of internal and external factors, on a macroscopic, mesoscopic or microscopic scale.

In order to elucidate the geomechanical behavior of rocks (quantitatively and qualitatively) some features ought to be known, like: physical properties, strength and deformation characteristics.

2.3. Physical characteristics

Knowing the physical condition of the rock can be helpful when making a quantitative description and estimate the influence on the strength and deformation characteristics. This can only be done by determining the physical characteristics.

The determination of the physical properties was performed in accordance with the effective norms (STAS, SR EN, EN), with the recommendations of the International Bureau of Rock Mechanics (BIMR) and those of the International Rock Mechanics Society (SIMR). The methods of determination and the calculation relations are found in various specialized works [1, 7, 11, 12, 13].

By determining the physical parameters, according to the standards in force and the specific procedures, the following average values were registered for the analyzed samples (Table 4-5)

Table 4. Average values of physical characteristics of ophiolites

Rock type/Sampling location	Physical characteristics					
	Specific density (real) ρ x 10^4 [N/m^3]	Apparent density (volumetric) ρ_a x 10^4 [N/m^3]	Apparent porosity n_a [%]	Total porosity n [%]	Pore number e	Compactness c [%]
Gabbro/Căzănești	2,8887	2,8449	0,8106	1,5162	0,0153	98,4837
Diabase/ Căzănești	2,7852	2,7499	0,7102	1,2673	0,0127	98,7326

Table 5. Average values of physical characteristics of ophiolites

Rock type/ Sampling location	**Physical characteristics**			
	Water absorption		Saturation coefficient s	Natural humidity W [%]
	At normal pressure [%]	By boiling [%]		
Gabbro/Căzănești	0,4274	0,5406	0,7902	0,2271
Diabase/ Căzănești	0,6951	0,7324	0,9486	0,3922

2.4. Strength and deformation characteristics

According to the pursued objective, the following strength and deformation characteristics of the rocks were determined: compressive strength, frost-thaw resistance, static modulus of elasticity, Poisson's ratio, continuity index, residual deformation coefficient and heterogeneity coefficient, according to tables 6-9.

The methods of determination and the calculation relations used are in accordance with the effective STAS, the recommendations of the International Bureau of Rock Mechanics and of the International Society of Rock Mechanics, and some of them can be found in the specialized literature [1, 7, 11, 12, 13, 19, 20].

Table 6. Average values of resistance characteristics of ophiolites.

Rock type/Sampling location	**Strength characteristics**				
	Uniaxial compressive breaking strength σ_{rc} [MPa]; [N/mm^2]			Softening coefficient after saturation η_s [%]	Coefficient of softening after freeze-thaw η_g [%]
	Specimen status				
	Dry	Saturation	Freeze-thaw		
Gabbro/Căzănești	150,173	131,375	124,644	12,483	16,942
Diabase/ Căzănești	161,117	138,883	129,017	13,757	19,882

Table 7. Average values of resistance characteristics of ophiolites.

Rock type/Sampling location	**Strength characteristics**		
	Freeze-thaw resistance		
	Number of specimens with obvious damage	Coefficient of gelivity μ_g	Decreasing elasticity modulus after 25 freeze-thaw cycles Δ [%]
Gabbro/Căzănești	0	0,022	6,240
Diabase/ Căzănești	0	0,033	8,361

Table 8. Average values of resistance characteristics of ophiolites

Rock type/Sampling location	**Strength characteristics**			
	Wearing resistance			Resistance to breakage by shock in dry state, R_c [%]
	LOS ANGELES, LA [%]	DEVAL, R_{uz} [%]	Quality coefficient, C	
Gabbro/Căzănești	12,204	2,525	15,844	95,083
Diabase/ Căzănești	15,815	3,049	13,133	93,760

Table 9. Average values of deformation characteristics of ophiolites

Rock type/Sampling location	**Deformation coefficients**				
	Static elasticity modulus, E_s [MPa]	Static Poisson coefficient, μ	Continuity index, I_c [%]	Remaining deformation coefficient, C_r	Heterogeneity coefficient of, C_{df}
Gabbro/Căzănești	26976,97	0,234	91,458	0,007282	0,8
Diabase/ Căzănești	20730,50	0,243	72,960	0,005376	0,7272

2.5. Classification criteria

For the efficiency and success of a classification system usage, this must be simple, easy to understand and apply, taking into account only the significant and intrinsic parameters of the rock, which are most relevant in engineering [9].

In this paper a classification of ophiolitic rocks (gabbro and diabase) was performed based on the literature [1, 3, 4, 5, 6, 8, 9, 10, 13, 14, 16, 18] according to the chemical, geological and geomechanical criteria, considering all the characteristics that have a significant influence.

Depending on the chemical criterion, the classification of the rocks was made according to the chemical composition and the alkali-aggregate reaction, two very important criteria in the qualitative characterization of the rock.

Table 10. Classification of rocks according to chemical criteria

Classification of rocks according to CHEMICAL CRITERIA	Rock type/Sampling location	
	Gabbro/Căzăneşti	Diabase/Căzăneşti
SiO_2 content	Alkaline	Alkaline
Alkali-aggregate reaction	Unreactive	Unreactive

From a geological point of view, the rocks were classified taking into account the origin, deposit conditions, structure and texture.

Table 11. Classification of rocks according to geologic criteria

Classification of rocks according to GEOLOGIC CRITERIA	Rock type/Sampling location	
	Gabbro/Căzăneşti	Diabase/Căzăneşti
Genesis (origin)	Magmatic	Magmatic
Deposit conditions	Plutonic	Vulcanic (Effusive)
Structure	Holocrystalline, Hipidiomorph and Allotriomorph	Medio-ophitic
Texture	Massive (Unoriented), Compact	Massive (Unoriented), Compact

The classification of ophiolitic rocks (gabbro and diabase) according to the geomechanical criterion was made according to the criteria used today on a large scale, trying to characterize the rocks from a physical point of view, of resistance and deformation.

Taking into account the geomechanical criterion, the analyzed gabbros and diabases were classified according to the properties in table 12.

Table 12. Classification of rocks according to geomechanical criteria

Classification of rocks according to GEOMECHANICAL CRITERIA			Rock type/Sampling location			
			Gabbro/Căzăneşti		Diabase/Căzăneşti	
Characteristics	Feature	Classification Value	Obtained value	Rock characterization	Obtained value	Rock characterization
Physical	Volumetric density	2,251 - 3,000	2,8449	- heavy	2,7499	- heavy
	Porosity	1,0 – 5,0	1,5162	- slightly porous	1,2673	- slightly porous
	Water absorbtion at normal pressure	< 0,50 0,50-3,00	0,4274	- slightly absorbant	0,6951	- slightly absorbant

Resistance	Compression breaking strength Panet (1993)	60-200	150,173	- high resistance	161,117	- high resistance
	Compression breaking strength used in Romania	120-200	150,173	- high resistance	161,117	- high resistance
	Quality coefficient (Deval method)	> 15 13-15	15,844	- excellent	13,133	- very good
	Freeze-thaw behavior	0 < 0,3 < 25	0 0,022 16,942	- resistant	0 0,033 19,882	- resistant
	Weather resistance	0 80 - 100	0 87,5	- fresh	0 86,2	- fresh
Deformation	Static elastic modulus	20000 - 50000	26976,97	- rigid	20730,50	- rigid
	Poisson coefficient	0,2 - 0,3	0,234	- average	0,243	- average
	Deformation behavior	0,001 – 1 0 – 3,125	0,0079 0,8	- elastic behavior	0,0053 0,727	- elastic behavior
	Continuity index	90-10 50-75	91,458	- zero - very good	72,960	- average - average
Resistance and deformation	Deere and Miller					
	Uniaxial compression breaking strength	100-200	150,173	- high resistance	161,117	- high resistance
	Es/σc (Modulus ratio)	< 200	179,639	- low	128,667	- low
	Ramamurthy and Arora					
	Uniaxial compression breaking strength	110 - 250	150,173	- high resistance	161,117	- high resistance
	Es/σc (Modulus ratio)	100 - 200	179,639	- average	128,667	- average

Based on the average values of the main physical-mechanical characteristics obtained for the analyzed rocks and compared with the admissibility conditions, gabbros and diabases are classified in one of the 5 admissibility classes (Tab. 13).

Table 13. Admissibility conditions of the rocks used for rail and road works

Characteristic	Rock Class						
	A	B	C	D	E	A	A
	Admissibility conditions					**Rock type/Sampling location**	
						Gabbro/Căzănești	Diabase/Căzănești
Apparent porosity at normal pressure, %, max.	1	3	5	8	10	0,8106	0,7102
Compression strength, dry N/mm^2, min.	160	140	120	100	80	150,173	161,117
Wear using Los Angeles method, %, max.	16	18	22	25	30	12,204	15,815
Resistance to breakage by compression in dry state, %, min.	70	67	65	60	50	77,326	75,338
Freeze-thaw resistance: - gelivity coefficient (μ_{25}), %, max.	3					0,022	0,033
- freezing sensibility (η_{d25}), %, max.	25					16,942	19,882

3. DISCUSSIONS AND CONCLUSIONS

After determining the geomechanical characteristics, the classification and comparison of the rocks, the following conclusions can be drawn regarding the analyzed samples:

- The analyzed ophiolitic rocks are compact, having a high density, which results from the comparison of specific densities and apparent densities;
- Compression breaking strength of the analyzed ophiolites is quite high, being between 150 - 162 MPa, with an admissibility class A;
- The wear resistance has low values, and the resistance to crushing by compression in dry state registers values over the one imposed to the admissibility class A, thus recommending these rocks for railway and road works;

- Depending on the values obtained for the gelivity coefficient and the softening coefficient after freeze-thaw cycles, it is considered that these rocks are resistant to freeze-thaw;
- Following the comparison of the obtained results with the admissibility conditions, the analyzed ophiolitic rocks can be classified in the admissibility class A;
- Due to the resistance to weather and wear, as well as the high polishing capacity, the analyzed ophiolites can be used in constructions, as a decorative stone for interior and exterior plywood, for monumental works;
- Ophiolitic rocks (gabbro and diabase) can also be crushed to make different types of aggregates used in road and railway works, asphalt and road concrete;
- In large-scale projects, diabase can be used as a structural element. The edges made of diabase are more durable than those made of concrete and much more decorative;
- Lately, due to the intensification of acid rain (due to pollution), diabase and gabbro have started to replace more and more marble in ornamental works, because they are much more durable.

Gabbro is a very good material for construction and road works. Due to its physical-mechanical characteristics, it can be used to make aggregates that are part of road and asphalt concrete. Due to the beautiful color (black-green), Căzăneşti gabbro constitutes an excellent material for ornamental-decorative works. Through processing, gabbro acquires a color contrast, and can be used in relief works and applied ornaments.

Diabase, based on the physical-mechanical characteristics obtained in the laboratory and compared with the admissibility criteria (high density, low porosity, low water absorption, high compressive strength, wear resistance, high weather resistance, high crushing strength and crushing) is recommended for road works (constituting an excellent material for asphalt mixtures), railways, hydrotechnical concretes, retaining walls, foundations, aggregates for concrete.

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RESEARCH REGARDING THE RECOVERY OF COPPER FROM ROMANIAN SETTLEMENT PONDS IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Abstract: *As the demand for copper on national and international markets is growing and the opening and exploitation of new deposits is increasingly difficult (both financially and in terms of environmental protection requirements), the recovery of this metal from tailings ponds is of increasing interest. The paper presents the research undertaken in order to recover the copper from the Valea Șesei tailings pond, Roșia Poieni, a pond that stores 100 milions square meters of waste, with an area of approximately 260 ha. Laboratory research conducted for the recovery of copper, the only element that may be of economic interest, focused on the method of concentration by flotation, testing three technological variants, in different working conditions, the results obtained making it possible to advance Another possible method of recovering copper from this industrial waste is by bacterial solubilization, a process that takes place anyway due to the action of heterotrophic bacteria of the genus Thiobacillus, nitrifying bacteria, sulfur-oxidizing bacteria and sulfate-reducing bacteria.*

Keywords: *tailings ponds, copper deposits, copper content, flotation, bacterial solubilization*

1. INTRODUCTION

Currently, in the U.E. and worldwide, the demand for mining products, especially in the non-energy sector is growing, the same being manifested in Romania.

The European Commission's initiative on raw materials is essential for the sustainable functioning of modern society. Ensuring a viable and constant access to raw materials is an increasingly important factor for the competitiveness of the EU. and therefore an essential element for economic growth. Sectors such as construction, the metallurgical industry, the chemical industry, the automotive industry, the aerospace industry, the electronics industry and energy production are completely dependent on access to certain raw materials.

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In the current economic context, the U.E. decided to promote a policy of economic growth, through regulations regarding non - energy raw materials. The Raw Materials Initiative (RMI) was launched in 2008 to identify Europe's needs and the mineral resources of its component countries. In 2010, the European Innovation Partnership on Raw Materials (EIP) was formed with 22 Euromines partner countries, with the main objective of identifying and ensuring the needs of mineral resources for the sustainable development of the economy and society [1].

Copper is one of the most important metals, with many uses, from heavy industry to pharmaceutical industry. According to the latest data (USGS, 2013), the amount of copper mined worldwide amounts to about 700 million tons, and the identified deposits still contain about 2.1 billion tons of copper, which brings the total amount of copper discovered to 2.8 billion tons. It is also estimated that undiscovered resources contain about 3.5 billion tonnes of copper, which would mean that there are about 6.3 billion tonnes of copper on Earth. Resources are much higher and short-term supply limits, which often lead to rising price trends, act as an incentive to explore new deposits [1].

The exploitation of copper ore deposits significantly affects the environment, which is the reason that rises the issue of its recovery, the use of mining waste for various purposes and the return to the economic circuit of degraded land. Over time, all over the world, copper mining and exploitation technologies have undergone several stages of evolution, these being perfected in order to obtain as large quantities of metal as possible from the raw ore. This means that there are older dumps and tailings ponds, which contain concentrations of copper that make it profitable to recover it with the help of innovative technologies.

Another reason for a detailed analysis of the possibilities of recovering copper from landfills is that current environmental legislation that imposes very strict rules for the management of solid, liquid and gaseous waste, resulting from industrial activities in both Europe and in the whole world.

Regarding the technologies used in mining activities, access to resources solutions must be approached by improving the efficiency throughout the life cycle of mineral resources starting with their exploration, development, exploitation and processing. It is necessary to continue the development of new processing technologies for a better extraction and use of minerals and metals. On the other hand, it is important to continue the development of new technologies for the recovery of secondary resources and industrial waste, thus reducing the loss of these resources for the economy and sustainable development of our society. (Romania's mining strategy 2017-2035) [2],[21],[22],[26].

On the Romanian territory, the copper ore was exploited both underground and in the quarry, the most well-known deposits being those from Roşia Poieni, Moldova Nouă, Sasca Montană, Baia Mare, Altîn Tepe, Bălan, resulting from the exploitation of significant quantities of sterile. Currently, copper ore is still mined in the Roşia Poieni quarry, by Cupru Min S.A. and in the Oraviţa area by small private companies. Considering the presented items, in order to find viable solutions for the recovery of copper from the tailings ponds, the Valea Şesei pond was chosen as a case study, which belongs to the Roşia Poieni quarry [10],[13].

2. MATERIALS AND METHODS

The copper ore deposit from Roşia Poieni is located in Transylvania, in the Apuseni Carpathians, 70 km away from the city of Deva. It is one of the largest copper deposits in Europe and has been exploited since 1978. The Roșia Poieni deposit is located in the area of Poieni, Vârşi, Curmătura peaks, the level of reserves approved so far is 320 million m3. The exploitation of the copper ore from Roșia Poieni is done in the quarry [19]. The porphyry sulfur copper ores contained in this deposit contain 0.2 - 2% Cu and 0.008 - 0.1% Mo, have high impregnations of copper minerals or high concretions with molybdenite, pyrite in the gangue, as well as intimate associations of copper with molybdenite and pyrite.

Figure 1. Location of the Valea Şesei tailings pond at Rosia Poieni

At Roşia Poieni the ore contains pyrite, magnetite, chalcopyrite, marcasite, chalcocin, coveline, molybdenite in quartz gangue, sericites, clay minerals.

The ore is processed by classical processes, obtaining a chalcopyrite concentrate which is subsequently recovered pyrometallurgically [8],.

The tailings from flotation are stored in the tailings pond Valea Şesei which was designed for a total capacity of 100 million square meters, with a final area of 260 ha.

The principle underlying the processing of a sample, in order to determine the physical, chemical, particle size, mineralogical characteristics, whatever its origin and size, is to maintain the representativeness of the sample material in the process of reducing its mass. At the same time, it must be taken into account that the processing of the sample should be carried out in the shortest possible time and with the lowest possible costs. Therefore, such a process is usually performed in two or more stages, at the end of each stage proceed to a certain number of reductions in the mass of the sample resulting from the previous stage [15].

In order to maintain the representativeness of the sample, as its quantitative reduction is required, it is necessary that any reduction procedure be preceded by a process of shredding the sample.

The minimum quantity of sample allowed after the reduction, depending on the maximum size of the granules resulting from the crushing of the sample is also regulated in the INTERNATIONAL STANDARD ISO / TC 27 N 1422 [9].

Sampling of non-ferrous ores and concentrates is regulated by STAS 6922-90. This standard explains in detail how the elemental samples are taken, their number according to the amount of material tested and the amount of sample to be taken depending on the size of the granules and how the representative sample is formed from the elementary samples.

2.1. Chemical characteristics determination

Chemical analysis is performed by processes that are specific to each component to be analyzed and that must meet requirements related to precision, accuracy, repeatability / reproducibility, selectivity and sensitivity. In connection with these characteristics, it should be noted that for each chemical element there are different methods of analysis for different concentration ranges, for the existence of interfering elements in the sample, etc. These processes are based on chemical methods, also known as stoichiometric methods, which measures quantities or volumes of reactants or reaction products, being direct methods. In the case of low concentrations of the component to be analyzed, instrumental methods of analysis are used, which are based on the measurement of a physical quantity that is associated by a calibration curve with the concentration of the constituent in the sample.

Chemical analyzes were performed according to STAS 1269 / 1-82 - Ores and concentrates of copper, lead, zinc, bismuth, molybdenum, pyrite and complex sulfides. STAS 1269 / 2-88 -Ores and concentrates of copper, lead, zinc, bismuth, molybdenum, pyrite and complex sulfides. Determination of copper content;

For the characterization of waste and soils there is the standard SR EN 15309: 2007 Characterization of waste and soils, determination of the elementary composition by X-ray fluorescence.

2.2. Particle size characteristics determination

The granulometric composition is determined with the help of granulometric analyzes according to STAS 1913 / 5-85, which can be:

- site analyzes - for materials with granules larger than 0.04 mm;
- laser analysis - for materials with dimensions between 0.0005 - 0.3 mm;
- sedimentometric analyzes (of dust) - for materials with granulation between 0.05-0.005 mm;
- microscopic analysis - for ultrafine particles.

Site analyzes are the most used to determine the particle size composition of the mineral raw materials subjected to the preparation and most of the products obtained in various phases of the technological process [6].

2.3. Mineralogical composition determination

The mineralogical analysis showed that the sample contains as main useful minerals chalcopyrite and secondary copper sulfides in a weight of over 85%, the pyrite content is about 2% and the magnetite content of approx. 1%.

3. RESULTS AND DISCUSSIONS

Table 1 shows the chemical composition of the sterile sludge sample taken from the Valea Șesei tailings pond.

Table 1. Chemical composition of sterile sludge

Element	***U.M.***	***Content***
Cu	%	0.213
Zn	%	0.02
Pb	%	0.01
S	%	1.48
SiO_2	%	61.62
Fe	%	4.84
Al_2O_3	%	15.42
CaO	%	1.18
MgO	%	2.44
K_2O	%	3.15
Na_2O	%	2.74
TiO_2	%	0.56
P_2O_5	%	0.21
P.C.	%	4.03
MnO	%	0.07
Mo	%	0.01
Au	g/t	0.15
Ag	g/t	3.05

In figure 2 is presented the granulometric analysis of the tailings sample taken from the Valea Şesei tailings pond.

The particle size analysis showed that the largest share (39.40%) has the particle size class -0.03 mm and the particle size class 0.10-0.15 mm (37.12%), therefore none of the classes granulometric cannot be removed from the study.

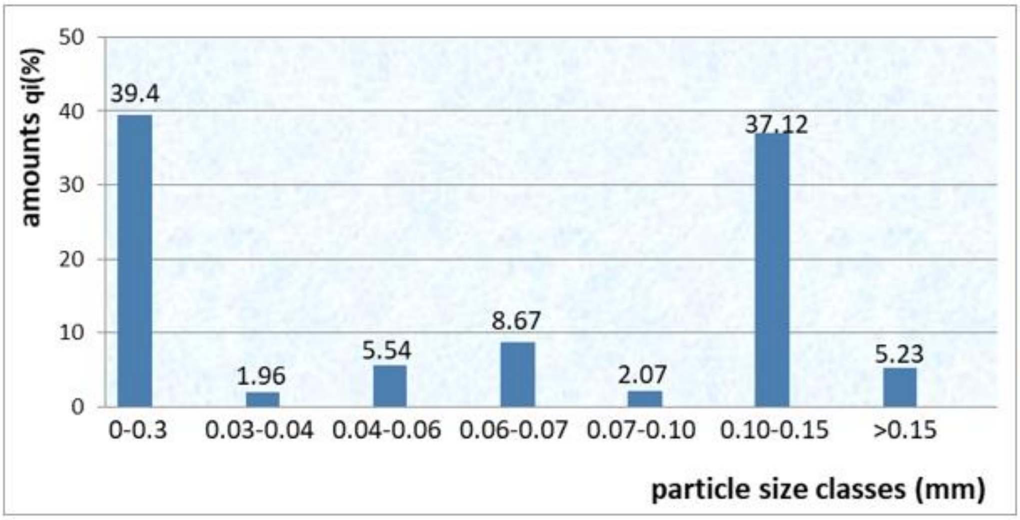

Figure 2. Particle size analysis of the tailings sample

In table no. 2 shows the mineralogical analysis of the sterile sludge sample.

Table 2. Mineralogical analysis of the sterile sludge sample

Mineral	Formula	Content (%)
Pyrites	FeS_2	2.0
Chalcopyrite	$CuFeS_2$	0.5
Bornite	Cu_5FeS_4	0.05-0.1
Chalcocite	Cu_2S	
Covellite	CuS	
Oxidic Cu minerals	-	0.05
Molybdenum	MoS_2	0.01
Blend	ZnS	0.05
Galena	PbS	
Magnetite	Fe_3O_4	1.0
Goethite	FeOOH	0.05
Feldspar		35-40.0
Quartz	SiO_2	25 - 30.0
Amphibole		4.0 – 5.0
Biotite		
Chlorine		
Sericite		25 – 30.0
Illite		
Miscellaneous (apatite, Ti oxides, etc.)		0.5 – 1.0

The mineralogical characteristics of the tailings sample show that the useful minerals and mainly chalcopyrite come both in the form of free granules, with dimensions ranging from 3 - 5µ to 0.1 - 0.2 mm, and overgrown with gangue. The degree of oxidation in the ore deposit is accentuated both in terms of quantity and especially by the superficial reactions that the minerals undergo under the conditions of stagnation in the tailings pond.

The volumetric weight varies between 1.55 -1.80 t / m3, at a depth of 10 m, the porosity varies from 54.2% at the surface to 48-50% towards the depth, the humidity varies between 0.76-1.0 at the surface, decreasing in depth and the grinding fineness is 90% class -0.074mm.

3.1. Research on the possibilities of capitalizing on sterile sludge by flotation

Flotation of copper sulfide ores generally takes place in an alkaline medium at pH-8.0-12.0, very rarely using a neutral or acidic medium. When the ore contains iron sulfides, the alkaline medium, formed with lime, is preferred, because lime is the depressant reagent for pyrite [16].

The reagent regime for the flotation of copper, lead, zinc, iron, nickel, cobalt, noble metals and oxides of these metals varies depending on the shape of the ore, the mode of association with other sulfides or tailings, the degree of oxidation, etc.[14].

Rational analysis of the material in the representative sample revealed the presence - in varying proportions - of copper sulphides and oxide compounds, copper sulphate and carbonate.

Taking into account the mentioned characteristics, the researches focused on the recovery of copper, the only chemical element of interest, these being oriented on the concentration by flotation in:

- strongly alkaline environment;
- weakly alkaline environment;
- acid environment.

3.1.1. Direct primary flotation in a strongly alkaline environment

The flotation tests were performed with a Denver pneumatic-mechanical flotation cell, the turbidity density of 1195 g/l, similar to that applied in the Roșia Poieni processing plant. The direct selective flotation scheme was applied to obtain a copper concentrate. As flotation reagents were used: as a collecting reagent - ethyl xanthate and isobutyl xanthate, foaming reagent - Dowfroth, to achieve pH - lime and as a depressant reagent for gangue minerals - sodium silicate. The technological scheme shown in Figure 3 comprises a primary flotation of Cu, two enrichment flotations and a cleaning flotation in order to recover the metal losses in the tailings.

The results obtained are presented in table 3.

Table 3. Results obtained from flotation in a strongly alkaline environment

Product	***weightextraction (%)***	***Content (%)***		***Metal extraction (%)***	
		Cu	***S***	***Cu***	***S***
Cu concentrate	0.68	17.85	24.5	58.37	13.89
Enrichment flotation intermediate product II- P.I.2	0.12	7.08	24.36	4.09	2.43
Enrichment flotation intermediate product I- P.I.1	0.44	1.81	25.0	3.85	9.17
Cu- cleaning intermediate product P.I.3	0.29	1.04	17.74	1.44	4.29
Final sterile	98.47	0.068	0.86	32.25	70.23
Feeding	100	0.208	1.20	100.0	100.0

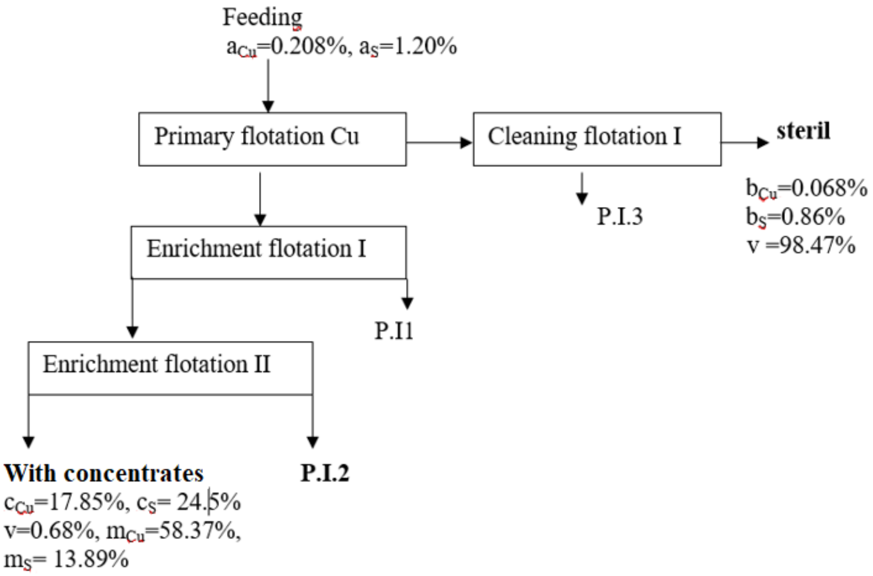

Figure 3. Flotation technological scheme in strongly alkaline environment

a- metal content in the feeding (%)
b- metal content in tailings (%)
c- metal content in concentrate (%)
v- weight extraction (%)
m- metal extraction in concentrate (%)
P.I.-intermediate product

It is observed that, after two enrichment flotation operations and a cleaning flotation, it is possible to obtain from the flotation material, a copper concentrate with an extraction by weight of approx. 0.68%, containing 17.85% Cu and 24.5% S, with metal extractions of 58.37% Cu and 13.89% S.

3.1.2. Direct primary flotation in a weakly alkaline environment with pyrite depression

The technological flow is similar to the one presented above, the difference being that, in the primary flotation, a lower consumption of lime is used, in order to achieve a pH of 7.5, the pyrite depression being carried out mainly by cyanide, used in the grinding. This technological variant involves only one re-floating step, obtaining concentrates with 19.09% Cu, with recoveries of 62.73% Cu and 15.10% S, at a weight extraction of 0.71% and a tailings with a content of 0,071% Cu and 0,92% S.

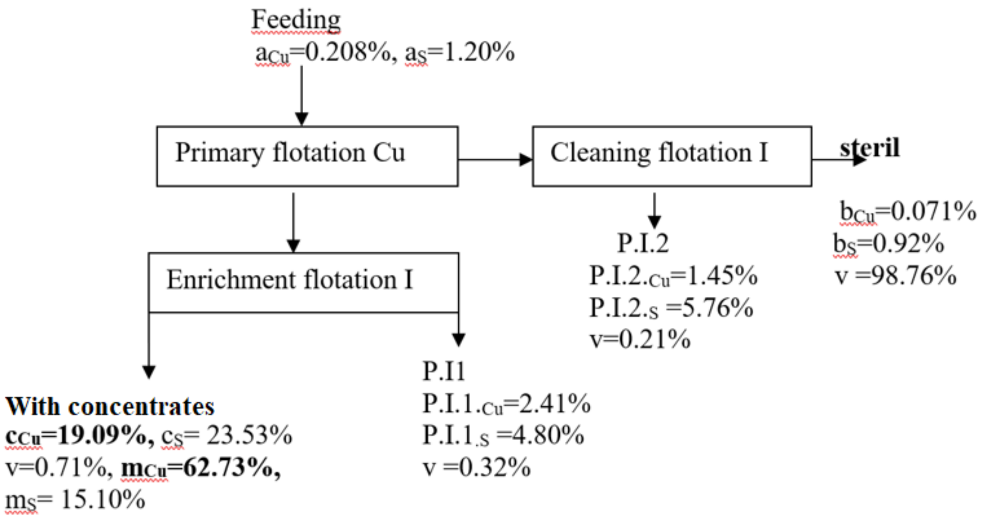

Figure 3. Flotation technological scheme in low alkaline environment

It is found that the results are superior to those obtained by using a strongly alkaline environment, both in terms of the quality of concentrates and copper recoveries. The application of this variant requires a careful monitoring of the pH, which must be maintained strictly in the range 7 - 7.8, at a higher pH value, cyanide strongly depressing and chalcopyrite, thus reducing the extraction of copper in the concentrate.

Table 4. Results obtained from flotation in a weakly alkaline environment

Product	***Weight extraction (%)***	***Conent (%)***		***Metal extraction (%)***	
		Cu	***S***	***Cu***	***S***
Cu concentrate	0.71	19.09	23.53	62.73	15.10
Internal product. Reflotation	0.32	2.41	4.80	3.57	1.39
Cu cleaning concentrate	0.21	1.45	5.76	1.39	1.09
Final sterile	98.76	0.071	0.92	32.31	82.42
Feeding	100.0	0.216	1.107	100.0	100.0

3.1.3. Primary flotation in acid medium

The technology involves a collective flotation of copper sulfides and pyrite. (Figure 5).

By applying this technological variant, a pyrite concentrate is also obtained. The quality of the copper concentrate is much lower (15.82% Cu) at a metal extraction of 65% Cu and 18.5% S.

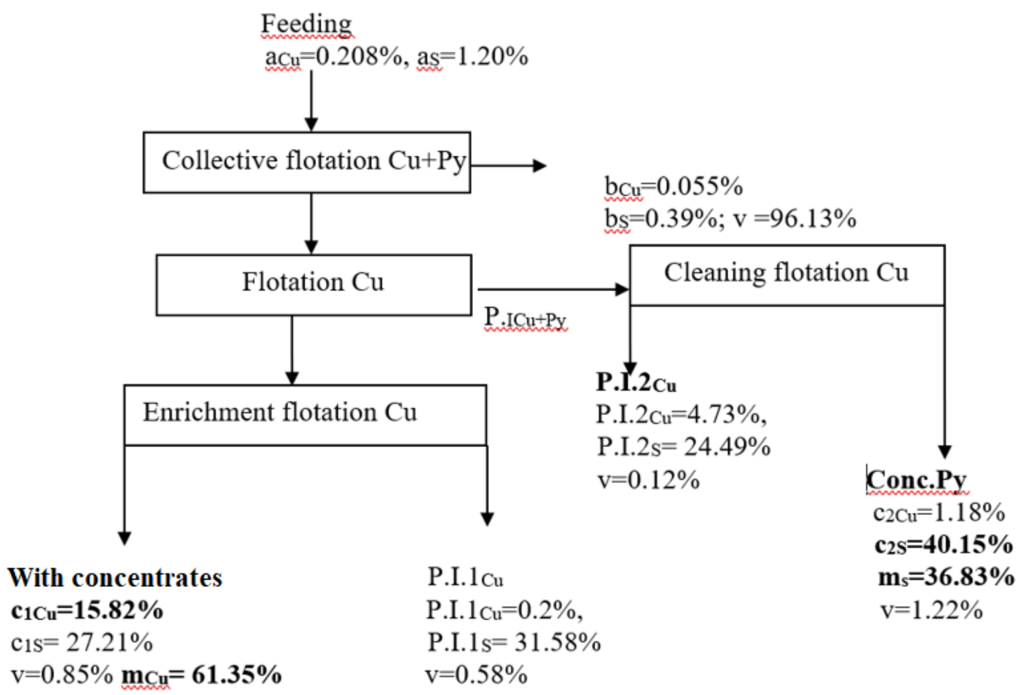

Figure 5. Technological scheme of flotation in an acid environment

3.2. Research on the possibilities of capitalizing on sterile material by bacterial leaching

The natural, chemical and bacterial phenomena of oxidation of sulfides in mining and preparation tailings cause massive solubilizations of the metals contained, especially Fe, Cu and Zn and the acidification of the solutions that pass through them. The analyzes show that in recent years, the phenomena of metal solubilization and water acidification have been accelerated, which causes the aggravation of the situation in the area.

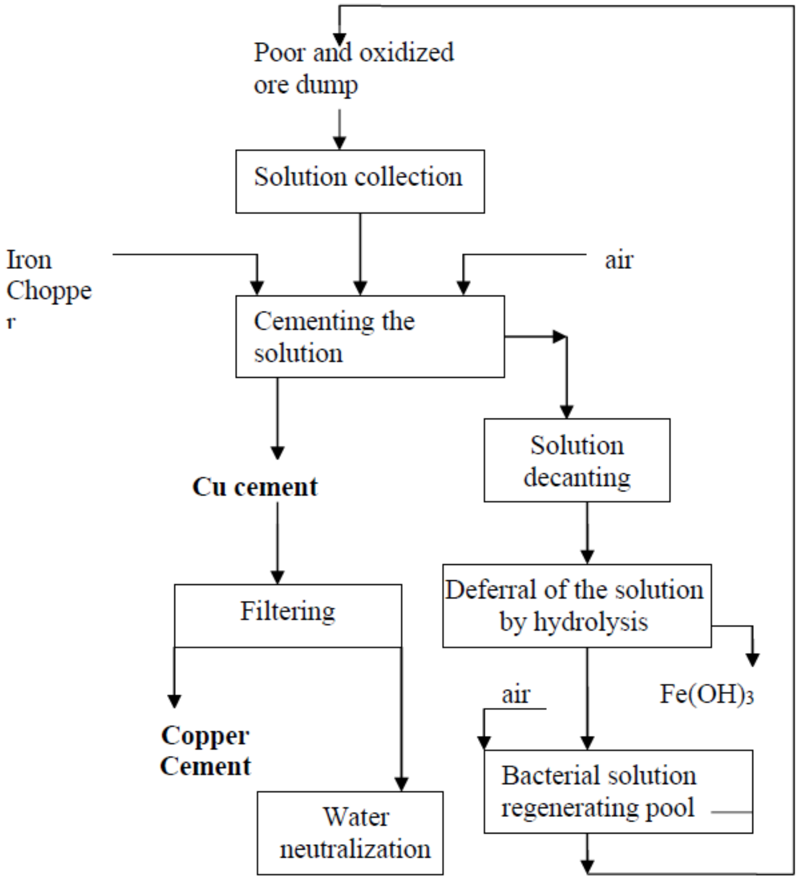

Figure 6. Technological scheme of bacterial leaching from Roşia Poieni, Romania

The tailings pond, due to the intense biosolubilization process due to the upstream waters of the Valea Şesei pond, which washes the Geamăna dump, which for a while stays in the pond and then is evacuated through the evacuation systems in the Şesei brook and from here in the Arieş river, are polluted with a rich microbial flora. There are both groups of microorganisms involved in the biosolubilization processes of metals and groups of microorganisms that could be used for bioaccumulation or biofixation of solubilized metal ions. The presence of bacteria with a role in biodesulfurization causes a decrease in water pH and an increase in the concentration of various metal ions [3],[5].

The microbiological analyzes performed on water samples, taken from the Valea Şesei tailings pond, revealed heterotrophic bacteria: aerobic, facultative aerobic, iron-oxidizing bacteria, of the genus Thiobacillus, nitrifying bacteria, sulfur-oxidizing bacteria, sulfate-reducing bacteria. Along with bacteria, another group of microorganisms that was identified in water samples were microscopic fungi such as Aspergilius and Penicillium [12],[17]. For the extraction of copper from this material, bacterial leaching research was performed on samples from different horizons of the deposit, both in the laboratory phase and in the semi-industrial phase.

Figure 6 shows the technological scheme of bacterial leaching of oxidized copper ore with low copper content from Roşia Poieni, Romania.

4. CONCLUSIONS

The chemical and mineralogical analyzes showed that the copper minerals are predominantly in the form of sulfides, the copper content of the representative sample taken from the tailings pond being 0.213%.

Due to the fact that the contents of the other chemical elements in the sample are well below the minimum exploitable content, the research focused only on the recovery of copper.

The concentration method applied was flotation, using different reagent regimes, the response function being the metal content in the concentrate, respectively the extraction of metal in the concentrate.

The best results were obtained by applying the method of concentration by flotation in a low alkaline environment, resulting a concentrate with a copper content of 19.09%, respectively an extraction of copper in concentrate of 62.73%.

Another method of recovering the copper from the tailings resulting from the processing of the ore from the Roșia Poieni processing plant is by bacterial solubilization (fig.6).

We consider that the results obtained from the research undertaken make it possible to recover copper, in conditions of economic efficiency, taking into account the results obtained and the global economic situation.

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THE USE OF BIOTECHNOLOGIES IN THE PROCESSING OF SILICATES AND ALUMINOSILICATES

CAMELIA BĂDULESCU[1]

Abstract: *The paper presents techniques and technologies for chemical-bacterial solubilization of silicates, aluminosilicates as well as the recovery of some chemical elements from the ash of the power plant. The degradation of silicates and aluminosilicates is achieved by various bacteria, algae, fungi and lichens, the most important being silicate bacteria of the genus Bacillus.Biological degradation can lead to the creation of an acidic, alkaline or complex environment. The research focused on bacterial leaching of bauxite by silicate bacteria that perform a selective extraction of SiO2, bioleaching of aluminosilicates, for aluminum extraction, solubilization of power plant ash in the presence of Bacillus bacteria.*

Keywords: *silicates, aluminosilicates, silicate bacteria, SiO2, aluminum*

1. INTRODUCTION

Silicates and aluminosilicates have the widest distribution in the earth's crust, accounting for about 90% of the earth's crust. The first data on the degradation of silicates and aluminosilicates in the soil and the causes leading to this phenomenon have been described by Darwin.

The degradation of silicates is a biochemical process, the action of microorganisms being channeled on:

- extraction of silicon with the help of silicate bacteria that destroy the crystalline network of silica and transform it into an amorphous mass;
- extraction of unwanted impurities from silicates and aluminosilicates.

The application of biotechnologies for the recovery of aluminum from low quality bauxites and aluminosilicates aims at:

- obtaining a solid residue, enriched in alumina, as a result of the selective solubilization of the silicate components;
- selective solubilization of aluminum.

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2. THE MECHANISM OF BACTERIAL SOLUBILIZATION OF SILICATES AND ALUMINOSILICATES

2.1. Characteristics of silicate bacteria

The most important silicate bacteria are those of the genus Bacillus, the microorganisms able to interact with silicates and aluminosilicates being: Bacillus circulans, Bacillus mucilaginosus or species of Micrococcus luteas, Pseudomonas extorquens, Pseudomonas fluorescens and Pseudomonas oxiliticus.

Silicate bacteria are heterotrophic microorganisms, which obtain their energy by degrading organic substances. In a weather-free environment, bacteria are much more efficient at biodegrading aluminosilicates and silicates than microscopic fungi.

The microscopic fungi characteristic of the biodegradation of silicates and aluminosilicates are:

-Aspergillus niger - is chemolithotrophic, rich in enzymes, being used in industry for the production of organic acids;

- Actinomycetes - are filamentous bacteria, able to multiply by spores.

The diameter of the filaments varies between 0.5-2.0μm. These attributes fall into the category of fungi, but the prokaryotic organization of cells, their metabolism, their response to antibiotics fall into the family of bacteria.

Bacteria in this category are gram-positive, aerobic, except for the Actinomyceteae family - which can be anaerobic. Some species are resistant to alcohol and acid and only some species are pathogenic.

These microorganisms participate in the degradation of silicate minerals and aluminosilicates with the help of enzymes and the products of their metabolism (organic and inorganic acids). They are not only active in certain climatic zones, they are active even in the Arctic, withstanding temperatures above 95° C and depths of 5000m.

The degradation of silicates and aluminosilicates is achieved by various bacteria, algae, fungi and lichens, resulting in chemical elements that migrate into the biosphere and lithosphere. There are also differences between these microorganisms in terms of the biodegradation mechanism, the transport of products and their storage process.Biological degradation can lead to the creation of an acidic, alkaline or complex environment.

2.2. Microbiological leaching resulting in acidic environment

This is a process in which a proton of an acid, which is a metabolite of microorganisms, releases a metal from the mineral, as follows:

M-mineral + HX→H-mineral + MX
where:
M – metal;

X- anions: SO_4^{2-}, NO_3^-, HCO_3^-, $RCOO^-$;

By microbiological oxidation of sulfates, elemental sulfides, inorganic compounds, the acids they come in contact with make them very weak complexes or not at all. The most used acids are: sulfuric, nitric, carbonic, lactic, gluconic.

The degradation of minerals by the metabolites of microorganisms begins with the tetrahedral structure Si-O, where Si is substituted by Al. The dissociated acid protons enter the chemical structure of the mineral and they bombard oxygen from the Si-O-Al covalent bond, forming a weaker Si-OH-Al bond. Breaking the chemical bonds, the structure disintegrates to form hydroxides: $Al(OH)_3$, $Si(OH)_4$.

The degradation of plagioclase by microorganisms is 3-10 times more intense than in their absence and intensifies with increasing anorthite content. The rate of destruction of plagioclase is influenced by the type of acids produced by microorganisms.

Citric acid> salicylic acid> acetic acid

The products resulting from the microbiological degradation of silicates and aluminosilicates are viscous gels, consisting of hydrated oxides of silicon and aluminum and ions adsorbed by potassium, sodium and calcium. Among aluminosilicates, talc is the strongest:

Talc <montmorillonite < kaolin <muscovite

The most common product of aluminosilicate erosion is kaolinite. The action of microorganisms is more effective in the case of minerals with perfect crystalline structures than imperfect ones. Acids such as formic, acetic, butyl, lactic, transfer calcium and potassium ions in solution, while aluminum and iron remain in the solid residue. Calcite-containing rocks are disturbed by the *chemolithotrophic nitrifying bacterium* which, in a neutral or weakly acidic environment, oxidizes ammonia to nitrites and then to nitrates, with the help of bacteria of the genus *Nitrobacter*.

$$NH_4^+ + O_2 + 4H_2O \rightarrow NO_2^- + 4H^+ + 4H_2O + 2e^-$$
$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

The nitric acid that forms dissolves carbonates. In the presence of NH^{4+} nitrifying bacteria can destroy some rocks, even granite. They are aerobic, they live on the surface of rocks. Under favorable conditions, the annual production of nitric acid produced by this bacterium can be 30g / m^2 of rock.

2.3. Microbiological leaching with the creation of an alkaline environment

Under anaerobic conditions, in the presence of organic substances, the action of heterotrophic microorganisms such as: *Bacterium denitrificans, Bacillus nitroxus*, causes the reduction of nitrogen compounds to nitrites, nitrogen and ammonia.

Sodium carbonate is formed from sodium salts, resulting in an increase in pH to 8.6. This pH value is optimal for the dissolution of silicon from silicates and aluminosilicates, by the action of ammonia produced by the bacterium *Sarcina urea*. For most minerals, this process is not an effective degradation process.

Heterotrophic bacteria - *Pseudomonas* or *Bacillus circulans* and microscopic fungi - *Aspergilus niger, Penicillium simplicissium*, achieve a significant degradation of clay minerals and produce oxalic and citric acids. The amount of aluminum extracted from these minerals depends on the concentration of acids produced. Minerals such as kaolinite, illite and montmorillonite are much more stable to the action of microorganisms than minerals without clay, such as those in the serpentine group.

The stability of clay minerals to the action of microorganisms increases as follows:

kaolinit> illit> montmorillonit

Among the microscopic fungi, the one that performs the largest clay extraction is *Aspergillus niger* which, during the biodegradation process produces oxalic acid, citric acid, gallic acid, gluconic acid. Heterotrophic bacteria *Alcaligenes, Bacillus, Escherichia, Microccocus* and *Pseudomonas* produce various amino acids during the biodegradation process.

Biodegradation of clay by silicate bacteria is faster than in the presence of fungi. Leaching products are different metabolites, citric acid being a product that does not predominate as in the case of biodegradation in the presence of microscopic fungi.

Amino acids resulting from bacterial leaching have variable compositions, there is no correlation between the type and amount of acid resulting and the leaching rate, the rate of extraction of metals being directly proportional to the growth rate of bacteria and their number in the leaching system.

3. RESEARCH ON THE RECOVERY OF CHEMICAL ELEMENTS BY BACTERIAL SOLUBILIZATION

Bauxite is the most important ore from which aluminum is obtained. Bacterial leaching of bauxite leads to a selective extraction of SiO_2 by the silicate bacterium.

The tests for bioleaching of aluminosilicates took place in 5 bioreactors with a capacity of 5 liters. Bauxite, mixed with the leaching solution containing mineral salts and 1% glucose, is transferred to the leaching tanks within 5-7 days. Solutions with a 63.9% Al_2O_3 content were obtained compared to flotation concentrates with a 43.4% Al_2O_3 content.

In addition to bauxite, another source of aluminum is clay sediments, altered volcanic rocks (15-25% Al_2O_3). During their leaching, microorganisms produce organic substances that extract aluminum and other chemicals from the mineral mass. Most often, the solution used in the leaching process is a solution obtained by a controlled cultivation of *Aspergillus niger*.

The leaching solution, with a high content of citric and oxalic acid, is used for bioleaching at high pressure. Applying a high temperature pretreatment can lead to an increase in metal (Al) extraction. Under optimal leaching conditions, within 3-5 hours, 90-95% Al was extracted from all samples of clay minerals and rocks rich in aluminum.

The presence of iron oxides in clay minerals is undesirable because they interact with complexes resulting from bacterial activity.

The rate of microbial leaching of iron minerals decreases as follows:

Hematite <limonite <goethite

Aspergillus and *Penicilinum molds* are most active during iron leaching. At the industrial level, the following technology has been developed:

- Stage I - cultivation of Aspergillus niger, at 30° C, in a molasses medium;
- Stage II - leaching medium, enriched in fermentation products, is used for leaching under strict acidity conditions.

The obtained results revealed the fact that the Fe content decreased considerably, improving other properties such as: white degree, fire resistance, etc.

Biotechnologies can also be used in the case of industrial extraction of several chemical elements present in different rocks. Thus, the microbiological leaching of potassium was experimented in order to establish the optimal technology for biological leaching of huge deposits of volcanic rocks rich in potassium, from central Italy as well as finding an alternative solution to the import of potassium salts, bacteria that contributed to the process leaching being *Penicillium Scopulariopsis.*

Lithium and beryllium from the pegmatites of eastern Siberia also have a good behavior in bioleaching, this process being carried out in the presence of *microscopic fungi*, *sulfur bacteria* and *nitrifying bacteria*.

In the Czech Republic, silicate bacteria have been used successfully in the leaching process of bentonites, kaolin and kieselguhr, this process leading to the production of bentonites, located in western Bohemia, of the highest quality.

Bacterial leaching tests, laboratory phase, were also performed on three types of power plant ash. The bacterium used was of the genus *Bacillus*.

The results of bacterial leaching of thermal power plant ash resulting from the burning of brown coal are presented in Tables 1, 2, 3. In the presence of Bacillus bacteria, after a leaching time of 30 days, it was found that the highest percentage of metal extraction, was recorded for Ti and Fe.

Table 1. Results of biological leaching for power plant ash with the *genus Bacillus*

Leaching time, (days)	**The solid phase content of somechemicalelements, afterleaching**				
Chemical element	**Al**	**Si**	**Ti**	**Fe**	**Ca**
0	100	100	100	100	100
30	92,1	92.5	33,9	65,1	89,6

Table 2. Results of biological leaching for power plant ash with *Aspergillus niger*

Leaching time, (days) Chemical element	**The solid phase content of somechemicalelements, afterleaching**				
	Al	**Si**	**Ti**	**Fe**	**Ca**
0	100	100	100	100	100
14	79,0	87,2	45,8	41,8	50,0

Table 3. Results of biological leaching for power plant ash with *Actinomycetes*

Leaching time, (days) Chemical element	**The solid phase content of somechemicalelements, afterleaching**				
	Al	Si	Ti	Fe	Ca
0	100	100	100	100	100
40	96,1	100	57,8	98,7	57,0

Figure 1 shows the technological scheme of bauxite processing with bacterial leaching of the silicate component.

This process is effective in the case of treating lower quality bauxite and involves grinding and peeling at 0.03 mm, the coarse fraction being subjected to magnetic separation in two stages, the non-magnetic fraction representing the Al concentrate with a content of 48.3% Al_2O_3.

The fraction - 0.03 mm is subjected to bacterial leaching, the leaching time being 9 days, during which time 22% of the material is solubilized, the residue obtained after leaching representing an Al concentrate with 49% Al_2O_3 and 7% SiO_2. Part of the alumina is also dissolved in the leaching solution, obtaining a complex solution containing both silicon dioxide and aluminum oxide and in a small weight dissolved iron.Various extraction methods can be used to remove silica and iron from the solution. Zeolites can be used for the extraction of aluminum, with their subsequent regeneration.

Figure 2 shows the technological scheme of bioleaching of aluminosilicates, for the extraction of aluminum. This process can be used for various raw materials based on aluminosilicates (clays, kaolin), in order to capitalize on the aluminum in them. In order to increase the susceptibility of aluminosilicates to processing by bioleaching, a thermal pretreatment is performed at 600-650° C, for 1-2 hours, thus removing water from the crystalline structure of the clays, which become amorphous.

The processing of aluminosilicates involves treating the material with a solution rich in organic acids, produced by microorganisms. The leaching solution is made by fermenting with a culture of Aspergillus niger a solution rich in sugars (molasses, cane juice, starch), the sugar concentration being 10-20%. The fermentation solution thus obtained contains 200 g / l organic acids, mainly oxalic acid and citric acid. The pH of the medium must be 0.5, which is achieved with a mixture of mineral acids: sulfuric acid, hydrochloric acid and phosphoric acid, in a ratio of 2: 1: 1.

The solubilization of aluminum from the ore is performed in reactors, resistant to acids, under mechanical stirring, continuously or batchwise, at a temperature of 90-100°C. After the leaching time has elapsed (5 hours), the solution containing 90-95% aluminum is separated from the solid residue by filtration.

The aluminum-enriched solution contains various impurities (iron, silica) which are separated from it by precipitation at different pH values. The recovery of aluminum from the solution can be done by different methods:

- as precipitated aluminum hydroxide, by increasing the pH of the solution. By calcination of Al hydroxide the final product alumina is obtained;

- as potassium sulphate and aluminum (alum) which is obtained by the addition of potassium sulphate and sulfuric acid, at a temperature of 90 ° C;

- as precipitated $AlCl_3 \cdot 6H_2O$, by saturating the solution enriched with hydrochloric acid. The precipitate is separated by filtration and then enriched by redissolution in 20% HCl and reprecipitated by saturating the solution with hydrochloric acid. The product can be treated by calcination to obtain alumina;

- by retention on zeolites, with their regeneration and then precipitation of aluminum hydroxide and its calcination.

4. CONCLUSIONS

The application of biotechnologies for the recovery of aluminum from low quality bauxites and aluminosilicates aims at:

- obtaining a solid residue, enriched in alumina, as a result of the selective solubilization of the silicate components;

-selective solubilization of aluminum

The tests of bioleaching of aluminosilicates were performed with leaching solutions containing mineral salts and 1% glucose, the solubilization time being 5-7 days. Solutions with a 63.9% Al_2O_3 content were obtained.

The results of the bacterial leaching of the power plant ash resulting from the burning of brown coals, in the presence of *Bacillus bacteria*, after a leaching time of 30 days, it was found that the highest percentage of metal extraction was recorded for Ti and Fe.

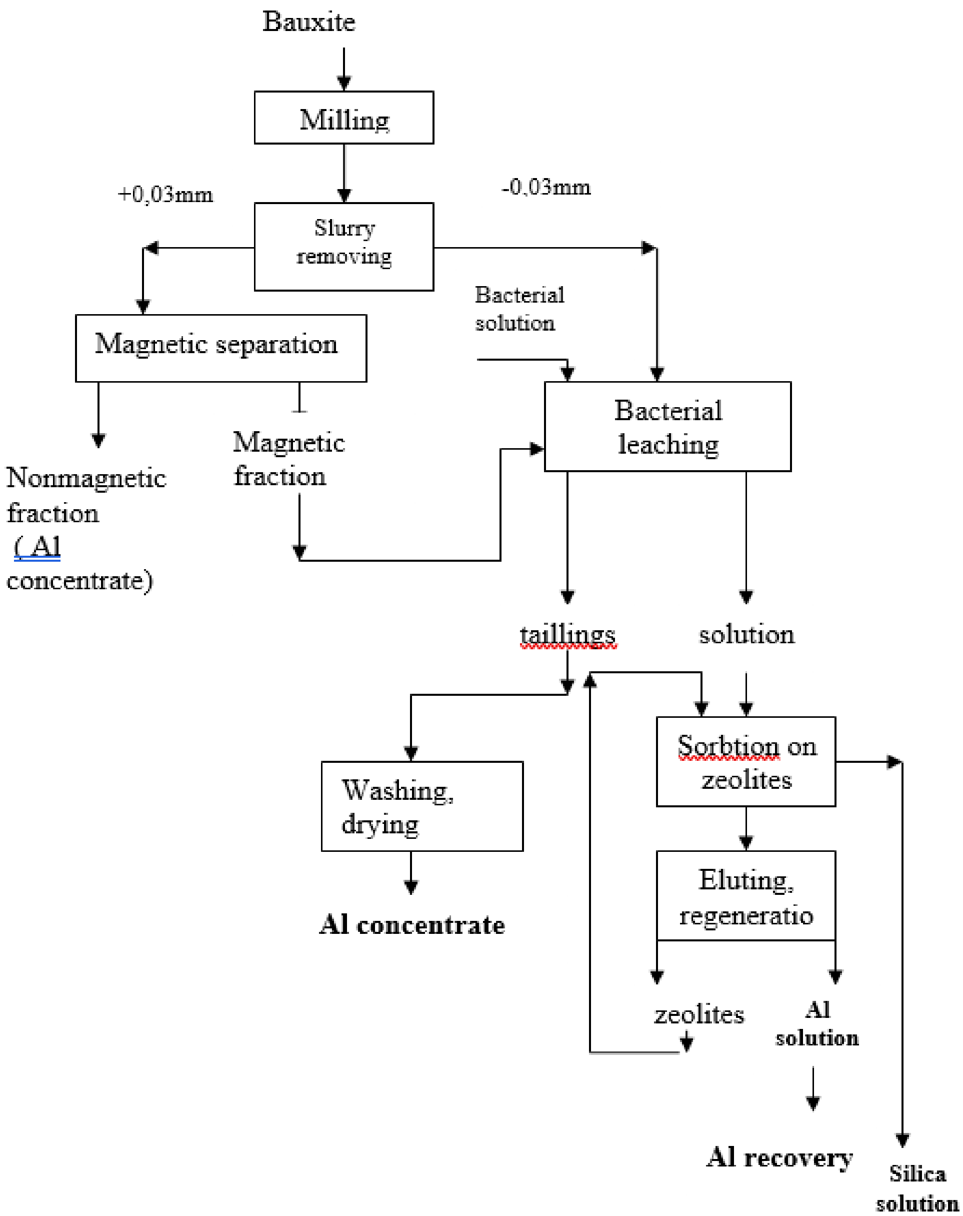

Figure 1. Technological scheme of bauxite processing, with bacterial leaching of the silicate component

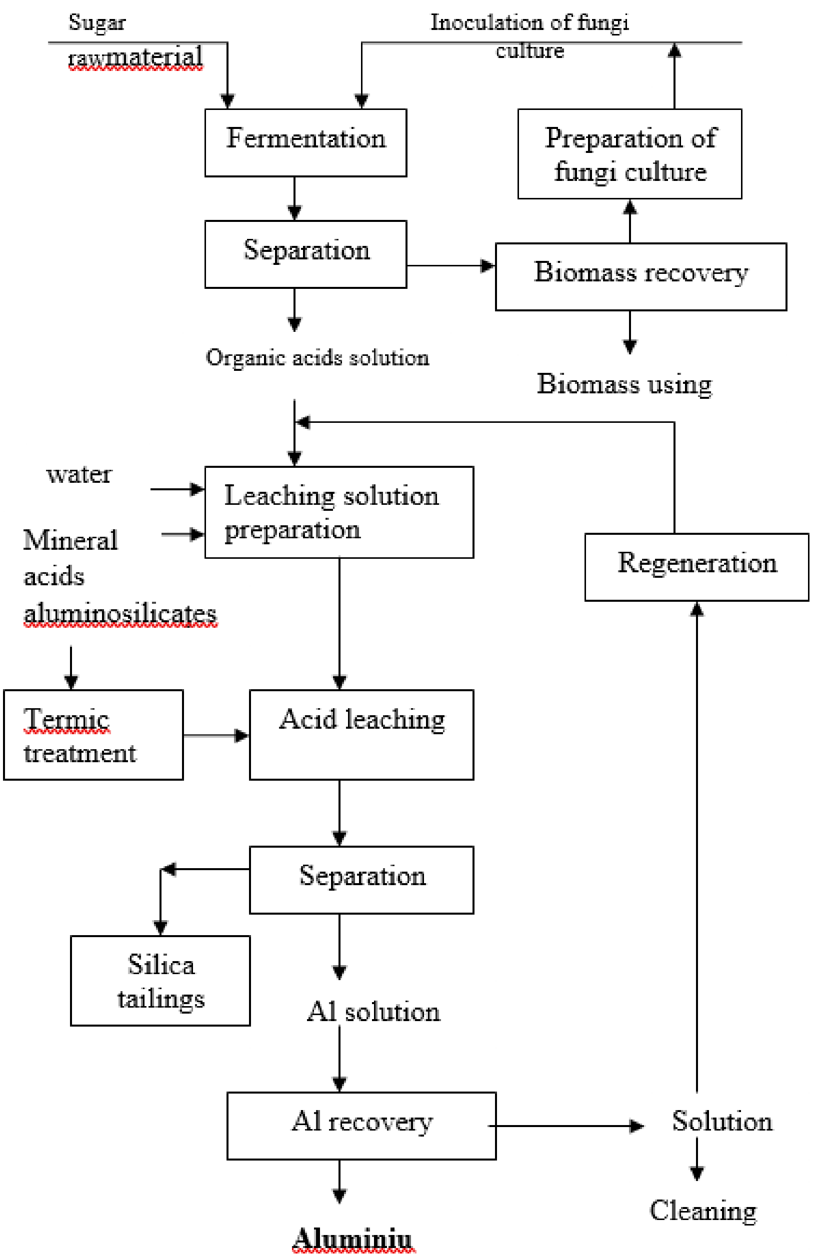

Figure 2. Technological scheme of aluminium and aluminosolicates biotechnological recover

The technological scheme for processing bauxite with bacterial leaching of the silicate component is efficient in the case of treating lower quality bauxites, obtaining an Al concentrate with a content of 48.3% Al_2O_3.

The technological scheme of bioleaching of aluminosilicates, for the extraction of aluminum (fig.2) supposes a thermal pretreatment of them at 600-650°C, for 1-2 hours, thus achieving the elimination of water from the crystalline structure of the clays, these becoming amorphous. The leaching solution is made by fermenting with a culture of *Aspergillus niger* a solution rich in sugars (molasses, cane juice, starch). The solution containing 90-95% aluminum is separated from the solid residue by filtration.

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RESEARCH FOR THE DESTABILIZATION OF ARGILLACEOUS SUSPENSIONS FROM THE WASTEWATER RESULTED AFTER COAL WASHING

CAMELIA BĂDULESCU[1]

Abstract: *Mining industry uses and returns into the environment great quantities of water resulted both during coal mining and processing. The most important water polluting sources are the coal processing plants. This fact imposes the existence of a complex water circulation process. The reagents used by coal mining industry for waste water cleaning may be divided in three classes: electrolytes or chemical salts; natural polymers and synthetic polymers. Because the waste water quality exceeds the legal limits and the tested reagents regimes did not prove their efficiency this study analyses separately the two processes involved in water cleaning: coagulation and flocculation using trivalent electrolytes: ferric chloride and aluminum sulphate.*

Keywords: *wastewater, destabilization, coal washing, argillaceous suspensions*

1. INTRODUCTION

The most important water pollution sources are the coal processing plants. From raw coal processing operations, 14-18 % represents sludge with particles in size less than 0.5 mm that is found entirely in the processing water.

This fact imposes the existence of a complex processing water circulation. Processing water quality and waste water flowed in emissary; characteristics depend on a good water circulation management.

Physical – chemical characteristics of waste water are shown in table 1 [9].

Table 1. Physical-chemical characteristics of wastewater

Characteristics	U.M.	Value	Admissible value
Hardness	˚ Hardness	3.95-5.44	-
Oxygen dissolved	mg/dm^3	5.8-8.3	4 min.
Oxygen chemical demand	mg/dm^3	23.2-45.5	25 max.
Oxygen biological demand	mg/dm^3	0.6-2.0	12 max.
Cl^-	mg/dm^3	17.5-35.2	1.0 max.

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Fe^{2+}	mg/dm^3	0	0.5 max.
CN^-	mg/dm^3	0	0.5 max.
Suspension	mg/dm^3	450-13.000	80 max.
pH	pH units	7.1-8.4	6.5 – 8.5

The following conclusions are driven from presented data in table 1:

- BOD value is under the admissible values in class III for ground water (maximal 12 mg/dm3). This fact shows that organic water does not represent a proper pollutant for Jiu water;
- COD has relatively high values due to countryside farms placed at the extremities of coal field.
- Solid particles present excessive high values. These values are because of coal processing plants and Paroşeni power station also. The content of argillaceous and coal-bearing particles in suspension is very high;
- High amount of fine grade argillaceous particles (montmorillonite) – material containing particles under 10µm, represent 60% of suspension in refuse;
- High amount of humic acids, represents 3 – 5 g/l;
- Low amount of salts in water – approximately 100 mg/l – undesirable influence on settling processing;
- Electro-kinetic potential is between -40 and -200 mV, which confers high stability to waste waters. The low the electro-kinetic potential value is the high the stability of wastewater is, this leading to low sedimentation velocity.

In conclusion it can be stated that coal mining industry is responsible for water pollution with solid suspensions and organic matter in a lower grade.

2. EXPERIMENTAL STUDY REGARDING EFFICIENT IMPROVEMENT OF WASTE WATER TREATMENT

Argillaceous and coal-bearing particles in suspension resulted from mining industry are ranged from granulometric point of view in colloidal or semicolloidal domain [4].

The treatment of such a wastewater involves important aspects:

a) Waste water treatment by destabilization of argillaceous colloidal suspension;
b) Drying and storage of sterile sludge resulted after waste water treatment.

2.1. Cleaning technology tested for wastewater with solid suspensions

The reagents used by coal mining industry for waste water treatment may be divided in three classes:

- electrolytes or chemical salts;
- natural polymers;
- synthetic polymers.

These reagents are used separate or mixed. The clarifying reagents tested were: plaster, lime, ferric chloride, sodium chloride, calcium chloride, ferrous sulphate, aluminum sulphate, zetag-with specific consumption of 100-600 g/m3; caustified starch with specific consumption of 30-100 g/m3, polyacrylamide, polias 330, solacril, magnafloc, separam, polifin with specific consumption of 1-6 g/m3[1], [2].

Based on tests made with the clarifying reagents mentioned before the following conclusions were drawn:

-for the first class substances (plaster, lime, $FeCl_3$, NaCl, $CaCl_2$, $Al_2(SO_4)_3$) the following characteristics were obtained: very low turbidity and solid particles content of 0.01-0.3 g/dm3, very low sedimentation velocity of 0.2-0.4 m/h and a low rate of sludge settling;

-for the second class substances (starch derivates) provide the flocculation of coal slurries together with a part of colloidal clay. Good sedimentation velocity between 0.6-1.5 m/h but clarified water turbidity is slightly high (>1g/l) are obtained during cleaning tests made with caustificated starch;

-for third class substances (polyacrilamide, polifin, etc.) the clarifying process the following characteristics were obtained: high sedimentation velocitie, clarified water has a very high content of solid particles (>3g/l) because reagent act mainly on coal particles, surface, clay being very little affected. Sludge obtained is well settled.

In this research a systematic study to analyze separately the two processes involved in water cleaning: coagulation and flocculation using trivalent electrolytes, was proposed. The tested electrolytes are: ferric chloride and aluminum sulphate.

Comparing these two electrolytes the following conclusions were drawn:

- ferric chloride forms flocules with greater density than aluminum sulphate:
- aluminum sulphate form hydrolysis products just in a limited pH domain and do not hydrolyses at temperatures less that 10˚C;
- ferric chlorides formed products more insoluble than aluminum sulphate;
- aluminum sulphate is not colored an excess the water as ferric chloride colored water in yellow.

2.2. Coagulant and flocculant concentration influence on clarified water turbidity

In the first part of the research there has been used only coagulation reagent, but the obtained results were not conclusive.

It was noted that cleaned water turbidity decreased when coagulant reagent concentration was increased and sludge settlement was decreased. Coagulant reagent concentration increasing over a critical concentration will reduce the sedimentation velocity but the clarified water quality remained the same.

Sludge settlement depends on coagulant reagent concentration just in the measure that affects cleaned water transparency.

Flocculent reagent concentration is not involved directly in parameters that described the cleaning process.

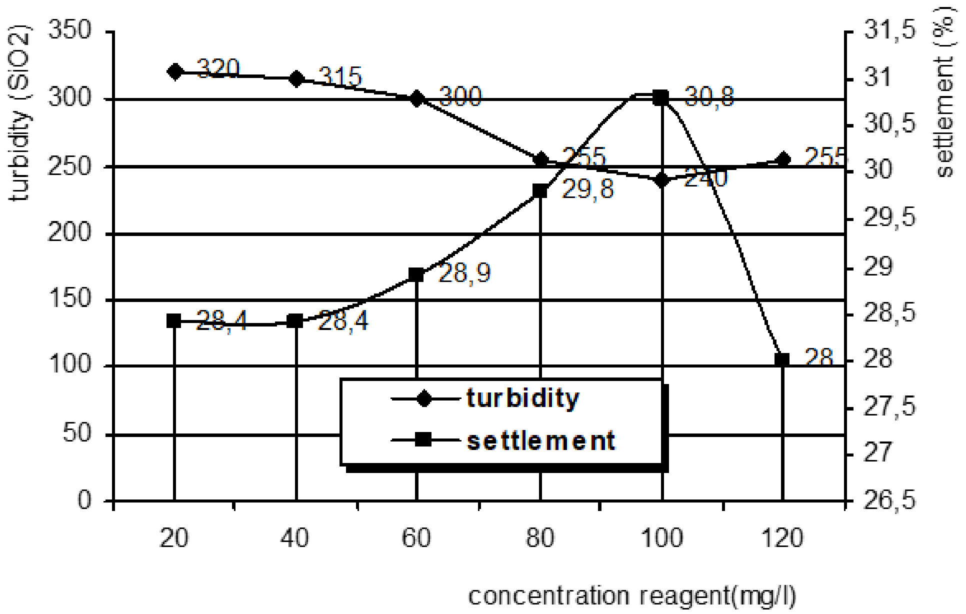

Figure 1. Reagent coagulation concentration influence on clarified water turbidity

Floculant reagent concentration effect on clarified water turbidity is show in figure 2.

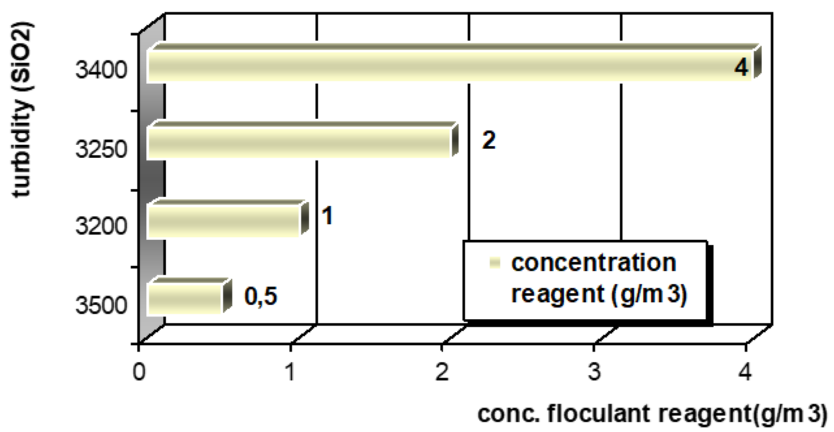

Figure 2. Clarified water turbidity at different flocculant reagent concentrations

The turbidity increase at high concentration of flocculant reagent because particles surfaces covering rate by polymer molecules increase and in this way they are not other possibility to create bridges between them.

At a flocculant concentration slightly high the sedimentation process stops the water volume being entirely jellified. Because these two clarifying reagents are used together it is very important to evaluate the cumulative action on clarified water turbidity and sludge settlement. Figure 3 present the dependence of clarified water turbidity at different flocculant reagent concentration respectively the dependence of clarified water turbidity at different coagulant reagent concentration.

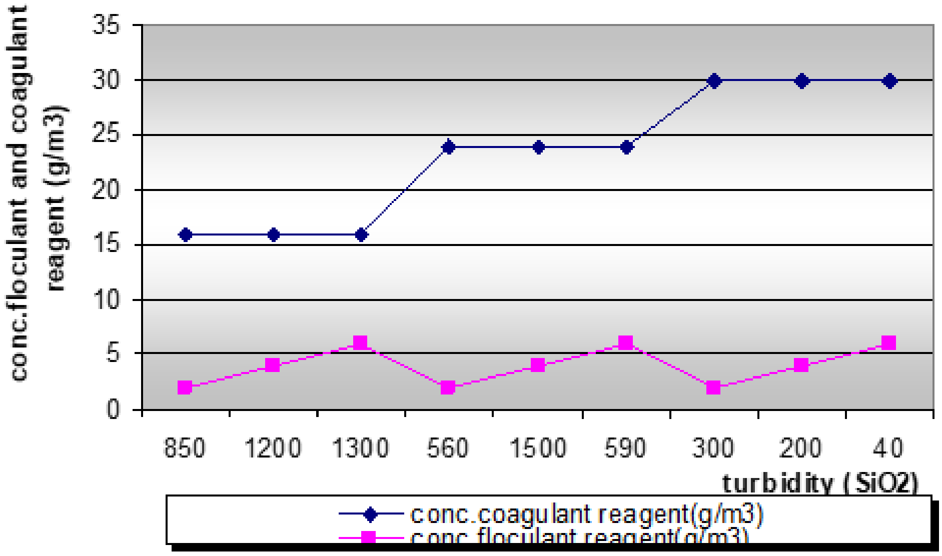

Figure 3. Flocculant and coagulant concentration influence on clarified water turbidity

The coagulant reagent concentration increase has the effect of decreasing the clarified water turbidity regardless of the flocculant reagent concentration. On the other hand flocculant reagent concentration increase has different effects depending on coagulant reagent concentration. These facts prove that flocculation depends strongly on coagulation.

2.3. Solid particles concentration and electro-kinetic potential influence on sedimentation velocity

The treatment of waste water resulting from the washing of coal in processing plants, has an important issue: the variation of solid particles concentration.

Table 2 and figure 4 present solid phase concentration influence on sedimentation velocity.

From data presented in table 2 and figure 4 it was observed that the optimum reagent concentration (determined above 32 g/l) it is not influenced by solid suspension concentration. This fact can be explicated if taking into account the fact that electro-kinetic potential depends first of all on electrolytes concentration. By this reason, even if solid phase concentrations differ, at the same electro kinetic potential optimum coagulation concentration will be the same.

Table 2. Solid phase concentration influence on sedimentation velocity

Suspensions (g/dm³)	Reagent coagulant (mg/l)	Reagent flocculant (mg/l)	Sedimentation velocity.(m/h)
20	30	6	2.41
40	30	6	1.15
60	30	6	0.73
200	30	6	1.10

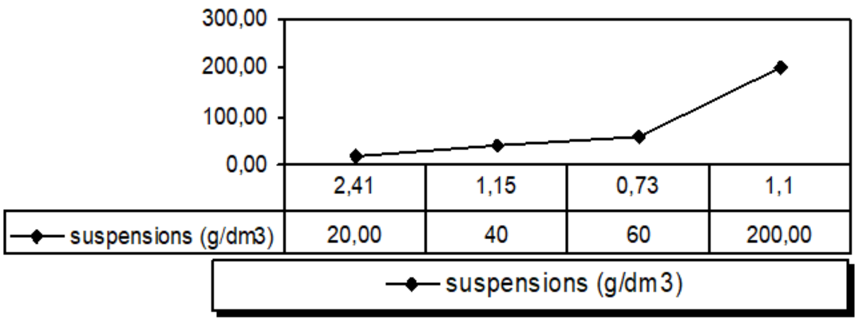

Figure 4. Solid phase concentration influence on sedimentation velocity

In the case of flocculant reagent, besides optimum concentration it is necessary to provide the requested amount of reagent that will be adsorbed to the particle surfaces in order to create floccules bridges. For this reason its concentration depends on solid particles concentration also.

Table 3 is shows the electro-kinetic potential zeta influence on clarifying reagent consumption.

Table 3. Electro-kinetic potential influence on cleaning reagent consumption

Electro-kinetic potential ξ (mV)	Reagent coagulant (mg/dm³)	Reagent flocculant (mg/dm³)	Sedimentation velocity (m/h)
40	100	20	0.73
60	40	4	1.80
140	32	2	2.50
200	16	6	2.93

From data presented in table 3 it is observed that to lower potential is necessary a higher coagulant consumption, fact that seems to be in contradiction with expected results.

Ferric ions adsorption is controlled by zeta potential. A higher electro-kinetic potential a easier adsorption process [3].

The dependence of optimum coagulation reagent consumption by electro-kinetic potential is exponential (1):

$$C_{coagulation\ reagent} = 2374 \cdot \xi^{-0,95} \quad (1)$$

The optimal flocculant concentration increases with electro-kinetic potential decreasing too. This dependence is exponential also:

$$C_{floculant\ reagent} = 190 \cdot \xi^{-0,78} \quad (2)$$

The relations presented above aim to compute the reagents regimes correlated with suspension nature respectively the souses of processed coal.

3. EXPERIMENTAL STUDY ON WASTE WATER TREATMENT IN ELECTRICAL FIELD

In the second part of the research is studied the possibility of replacing coagulant reagent with electrocoagulation process, using for this purpose an electrifier. It consists of a pair of plate-shaped electrodes (58 x 95 x 0.5 mm) made of aluminum and connected to low voltage DC.

The first set of tests was carried out on slurry with the solid phase concentration of 60 g/l, for different feed rates of the treatment circuit [7], [8].

Table 4. Sedimentation velocities at flocculant consumption 7.4 ml/l and electrifier volume 0.6l

Working voltage (V)	**Intensity (A)**	**Power (x 10^{-3} kW)**	**Flow (m^3/h)**	**Sedimentation velocity v(m/h)**	**Treatment Time (h)**	**Consumed energy (x 10^{-5} kWh)**	**Concentration of clarified water (g/l) Observations**
5	0.04	0.2	0.0462	1.77	0.0129	0.258	0.65 big floccules
5	0.03	0.15	0.0194	2.02	0.0309	0.463	0.65 big floccules
10	0.11	1.10	0.0669	0.87	0.0089	0.979	0.50 small floccules
15	0.21	3.15	0.0256	2.21	0.0234	7.37	0.65 very big floccules
20	0.32	6.40	0.0530	0.92	0.0113	7.23	0.50 small floccules
24	0.36	9.00	0.0850	0.78	0.0070	6.30	0.50 small floccules

Feeding flow is a technological parameter that influences the clarifying process. It is quite difficult to control in practice therefore is accepted variations within certain limits. The flow is conditioning the action time of electric current on the slurry or otherwise the transit time of the slurry through electrifier.

The correlation between feeding flow and sedimentation velocity was based on data from table 4 in presented in figure 5. As expected increase feeding flow decreases the sedimentation velocity, emphasizing the importance of residence time of the slurry in the electrifier.

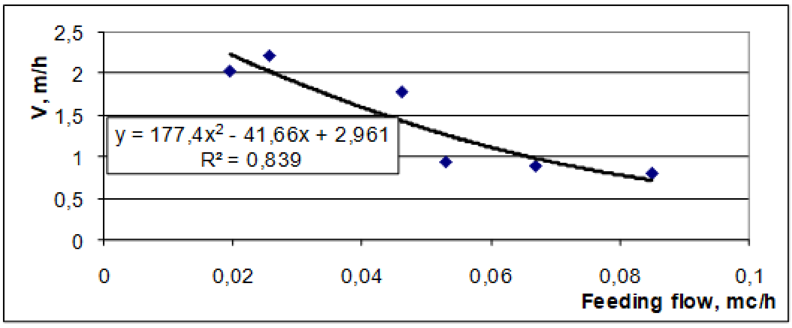

Figure 5. Corelation between feeding flow and sedimentation velocity

The correlation between working voltage and sedimentation velocity is of lower intensity (R = 0.59), meaning that the lower working voltages are more suitable in the process. (fig.6)

Energy consumption W is an important parameter and connects the four other process parameters

$$W = P.t = U.I.t = U.I\ .V\ /\ Q \quad [kWh], \tag{3}$$

In which:

P – power, W; U – voltage,V; I – intensity, A; T – transit time,h; V– electrifier volume, m^3; Q – feeding flow, m^3.

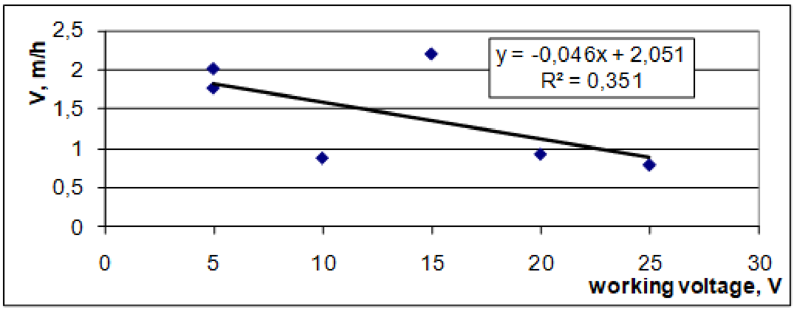

Figure 6. Correlation between working voltage and sedimentation velocity

Overlapping the diagrams v = f(Q); v = f(U) and v = f(W), where v is the sedimentation velocity, two variation domains are obtained: W Є (0 ÷ 1.10^{-5}) kWh in which Q and U have low values and W Є (6 ÷ 8.10^{-7}) kWh in which Q and U have high values. This fact illustrates the bondage between feeding flow and working voltage having R = 0.65, (fig. 7). If R Є (0 ÷ 0.3) the bondage between those parameters is wick, if R Є (0.3 ÷ 0.7) the bondage between those parameters is medium, and if R Є (0,7 ÷ 1) the bondage between those parameters is strong.

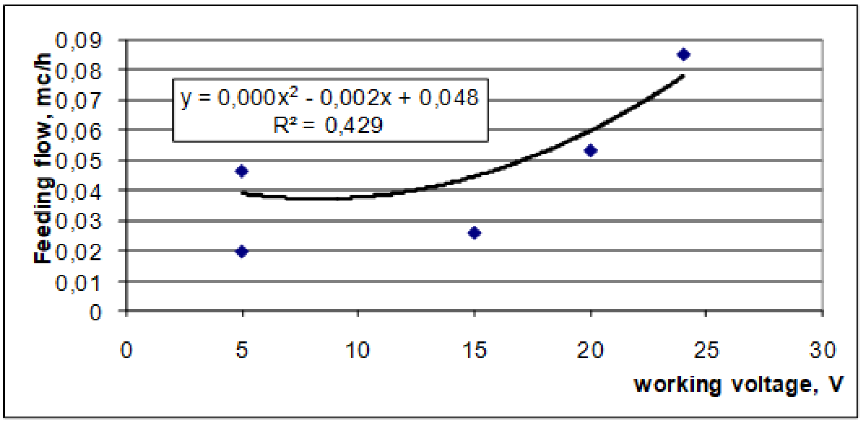

Figure 7. Correlation between working voltage and sedimentation velocity

Regarding these facts the following experiment was conducted for the same solid phase concentration, same flocculants reagent consumption and working voltage U= 24 V.

4. CONCLUSION

It is noted that increasing the energy value above 4 $x10^{-5}$ kWh, meaning higher power longer residence time, was futile.

In order to transpose the experimental result at industrial scale, the following working scheme is recommended:

- Working voltage, 24 V;
- Consumed power, 4.08 x 10^{-3} kW;
- Specific electrical energy consume, 0.047 kWh/m^3;
- Electrode current density, 0.18 A/m^2;
- Anode specific aluminum consumption, 41 g / month;
- Sedimentation velocity, 1.67 m/h;
- Solid phase concentration in clarified water, 0.65 g/l.

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EVENT-BASED ANALYSIS OF ACCIDENTOGENIC SCENARIOS FOR EXPLOSIVE DEPOSITS

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Abstract: *The paper summarizes the results of the application of the Event Tree Analysis to the development of explosion scenarios in explosives depots in order to optimize applicable safety measures. An exhaustive analysis of the possibilities of the initiating events that could lead to a potential explosion, materialized by detonation, by explosion or by the combination of these two types of explosive phenomena, was performed. The applicable safety barriers to prevent the occurrence of the identified initiating event were analyzed. Next, the accidentogenic sequences were grouped into classes in which the sequences in a branch result in the same consequences. The development of the scenarios will serve, in a future stage of the research to calculate the frequency of occurrence of each scenario and, by corroborating the frequency with the severity of the consequences will determine the value of the explosion risk level, according to a methodology developed and adapted in order to ensure a clearer classification of risk levels.*

Keywords: *explosive deposit, Seveso, Event Tree, explosion scenario, trigger, safety barrier.*

1. INTRODUCTION

Industrial sites where explosives are stored have always been considered as major risk areas for industrial, public and occupational safety and security, due to the possibility of major accidents occurrence, both due to the nature of the explosive substances stored and due to the serious consequences of which can generate a possible explosion phenomenon produced on these sites [1], [12], [18]. Consequently, for sites where various activities are carried out involving explosive substances [22] and which are subject to the so-called SEVESO Directive [13], both the assessment of the security of the systems and, implicitly, the manner in which the activities are carried out on those sites, as well as risk management, are mandatory objectives for both industrial units and competent authorities. [2], [3], [19].

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Over time, several types of initiating events have been identified that have been the basis for detonation events - uncontrolled explosion of explosive substances, as well as safety measures whose application can prevent the occurrence of these events [23]. Initiating events and appropriate measures to prevent and protect against explosion phenomena can be grouped into several categories [4], [5]: i) Shock waves; ii) Mechanical energy; iii) Thermal energy; iv) Chemical energy; v) Electromagnetic radiation.

Generic sequences of accidents (scenarios) were developed using ***Event Tree*** type diagrams, the analysis being adapted to site-specific conditions and protection measures and ranked in terms of explosion risk reduction. Quantitative risk assessment (QRA) methods have been widely used over the last 20 years as a framework for informed decision-making on risky industrial installations and sites, but are not frequently used for systems that concern activities involving the production, handling, transport and storage of explosive substances [6], [7], [8], [9], [10]

Tree-specific applications for QRA in installations involving explosives have been reported by Hauptmanns [14] and Papazoglou et al. [20], [21]. The general structure of a quantitative risk assessment method (QRA) includes three stages: 1. Analysis of event trees and their frequency of occurrence; 2. Assessing the consequences of event trees (explosions); 3. Risk integration.

2. RESEARCH METHODOLOGY

This paper details the first stage, namely the Event Tree Analysis (ETA), with an emphasis on how the results of this stage can be used to adopt additional safety measures for explosives depots.

The first stage of the quantified risk assessment for explosives depots requires a complete analysis of all the possibilities of the initiating events that could lead to a potential explosion, materialized ***either*** by detonation ***or*** by explosion ***or*** the combination of these two types of explosive phenomena. Next, the safety measures that could be adopted are analyzed, by installing ***technical safety barriers*** or by applying other ***organizational*** or other measures, so as to aim at preventing any possibility of the initiating event already identified. Accidental sequences are ***delimited***, consisting of an initiating event, failures or specific successes of the functionality of the protection measures, including here the human responses (operator intervention). Next, the accidentogenic sequences are grouped into classes (branches of the event tree) in which the sequences in a branch result in the same consequences. Finally, the frequency of each injury sequence (scenario) is calculated. From a qualitative point of view, the first phase of this stage consists in analyzing the system, to identify possible components that could be sources of explosion (intrinsic hazard), assessing the plant's responses to these scenarios that would lead to the elimination of intrinsic hazard of the installation [21].

From a quantitative point of view, the frequency of occurrence of each type of potential scenario identified is analyzed. In fact, the risk assessment methodology involves the delimitation of possible accident scenarios in installations and locations where explosives are used, the quantification of these frequencies being used for their ranking and subsequently for the adoption of additional safety measures. Quantification involves both the possibility of failure of various components of the system and the likelihood of human error. If specific probabilities are not available for the equipment at the site analyzed, generic values may be used. If they are not available either, their subjective assessment can provide a basis for comparing alternative safety measures and procedures that could be adopted.

We will demonstrate how this approach can be used to support competent authorities in assessing the relative level of safety and to highlight the importance of introducing additional safety measures in installations and industrial sites where explosives are used and which are subject to the Seveso Directive. The research approach we have undertaken involves the description of the main logical diagram, in order to include all types of sources for initiating events; inventory and systematization of applicable safety measures; graphic presentation of accident scenarios / sequences; analysis and evaluation of specific trees; synthesis of the obtained results and formulation of conclusions.

3. SYSTEMATIC IDENTIFICATION OF THE DIRECT CAUSES OF IGNITION AND EXPLOSION

The direct causes (initiating events) that may underlie the explosion-type events on the sites where operations with explosives are carried out, identified based on the literature as well as the analysis of events produced in Romania, were organized as a block scheme. This kind of graphical representation is a logic diagram similar to ETA (Event Tree Analysis), without including the specific ETA mathematical formalism. The graphical representation begins with a peak event and breaks down into simpler contributing events as shown in Figure 1.

In this logic scheme, six general ways for igniting / exploding explosive materials were identified and retained, as follows: i) Shock wave; ii) Mechanical energy; iii) Thermal energy; iv) Electricity; v) Chemical instability / reactivity; vi) Electromagnetic radiation. The events located at the base of the tree represent direct causes of the explosion / ignition type event and can be materialized in installations or processes in specific forms, being considered as initiating events of explosions (triggering risk factors).

4. DEVELOPING AN ACCIDENTOGENIC SEQUENCES LOGICAL MODEL

In order to be able to assess the probability of an explosion occurring in an installation, the possible sources for initiating the event and the safety measures are combined in a ***logical model***, in the form of sequences of events.

A sequence of events is composed of the initial source of the event and specific safety measures, including possible human errors.

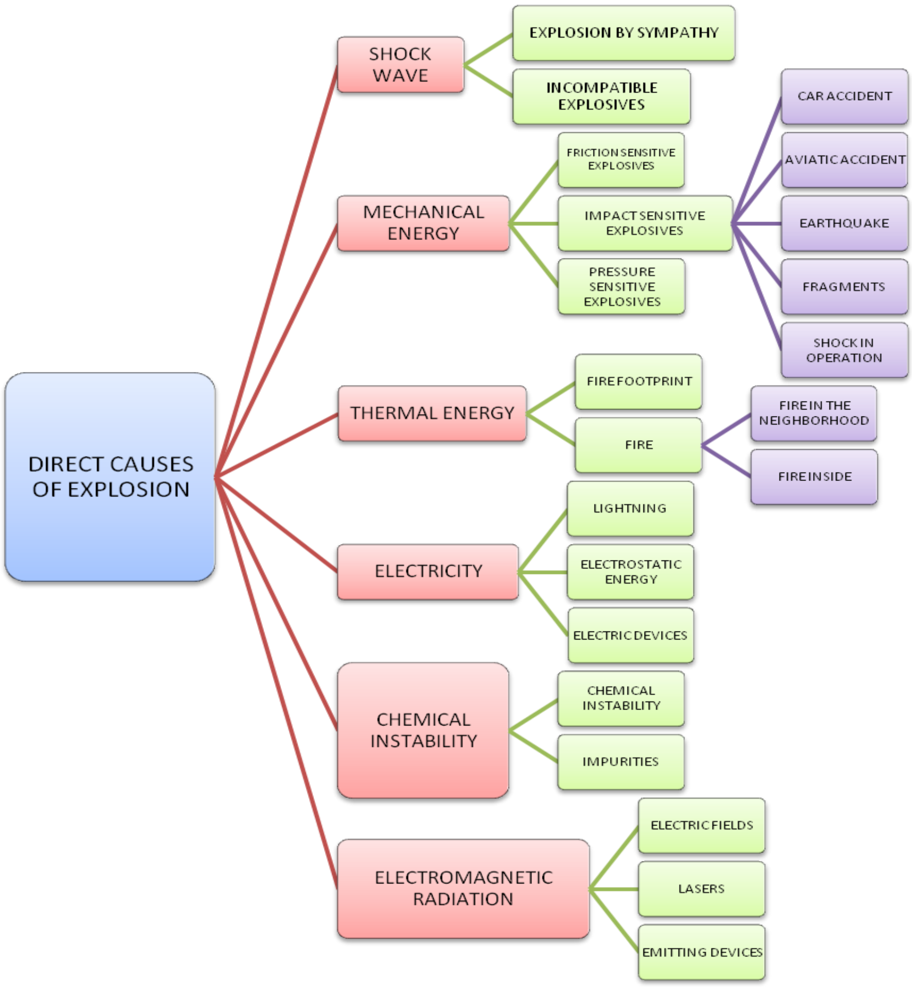

Figure 1. Classification of explosion initiation direct causes

The end result of a sequence of events may be the elimination of the possibility of an explosion, or, if not, the occurrence of the event in the form of an explosion of explosives. An event sequence in which the result is negative, in this case by the occurrence of the explosion is called an accident sequence and can provide qualitative and quantitative information on the safety level or risk level of the installation. From a qualitative point of view, the information generated by an accident sequence is represented by the identification of specific combinations of factors that can lead to an explosion. Quantitatively, the information provided is represented by the relative frequency of occurrence of each sequence. The initial events that may evolve into a direct cause of an explosion are shown in Table 1.

Table 1. Initial sources of risk (Triggers-D) for explosives depots

Symbol	Description
D1	Incompatible explosives
D2	Car accident inside the warehouse
D3	Plane crash
D4	Earthquake
D5	Explosions in the neighborhood
D6	Impact sensitive explosives
D7	Friction sensitive explosives
D8	Atmospheric surges, lightning
D9	Sparks from malfunction of electrical equipment
D10	Sparks due to static electricity
D11	Chemically unstable explosives
D12	Impurities in the composition of explosives
D13	Electro-explosive devices
D14	Outdoor fires
D15	Indoor fires

Preventive measures are adopted and implemented in order to prevent the occurrence of explosions, but also if the risk factor cannot be completely eliminated, in order to limit its evolution, so that it does not end up initiating an explosion. The safety measures resulting from the analysis of the specialized literature and from the practice are further systematized, corresponding to the previously identified risk factors [11], [15], [16], [17].

The technical safety measures adopted for each of the initial sources of risk of the events are presented in Table 2. Some of the safety measures presented in Table 2 apply to the prevention of several sources of risk.

Table 2. Technical safety measures (T) for explosives deposits

Symbol	Description
T1	Constructive protection of the deposit (building) - the type of deposit
T2	Arrangement of separate rooms for the storage of incompatible explosives
T3	Protective barriers between storage rooms
T4	Shock resistant equipment
T5	Racks and shelves arranged so that the impact energy is less than the ignition energy
T6	Storage of explosives on shelves and racks in packing boxes so as to avoid friction and / or frictional energy to be is less than the ignition energy
T7	Lightning protection devices
T8	Grounding of electrical equipment and protection of personnel
T9	Explosive distribution flow adapted to reduce storage time

T10	Prevention of contact with impurities - Maintenance and cleanliness of storage spaces
T11	Explosion-proof encapsulation of electrical equipment
T12	Elimination of electrical sources
T13	Dispersion currents with energy lower than the ignition energy
T14	Elimination of laser radiation sources
T15	Elimination of radio wave sources
T16	Elimination of mobile phone radiation sources
T17	Outdoor and indoor fire detectors
T18	Operators trained in fire detection and operational intervention
T19	Water tanks, water wells or connection of the reservoir to the water network, fire hydrants
T20	Availability of high pressure pumps, diesel or electric pumps
T21	Availability of sprinklers
T22	ADR authorized vehicles, protected against fires
T23	Fire extinguishers
T24	Barricades, fences, earth waves for the protection of the deposit

Proper construction of deposits (T1), concrete protective barriers (T3) and fencing of deposits with protective barricades, earth waves (T24) are also applied to prevent explosions in case of car accident (D2), shocks caused by earthquakes (D4) and to prevent the spread of any other explosions produced in the vicinity (D16), but also in all cases where it is possible to initiate the stored explosive, to stop / decrease the propagation of the effects of the explosion outside the deposit, implicitly in its vicinity. Fire prevention and control measures (T17-T23) have common applicability both for outdoor fires, for example vegetation fires in the vicinity of deposits (D14), and for fires inside the storage facility (D15).

Another category of measures, in particular of an organizational nature, may complement the technical measures presented in Table 2. These type of measures are set out below in Table 3.

Table 3. Organizational safety measures (T) for explosives deposits

Symbol	Description
O1	Procedures to avoid joint storage of incompatible explosives
O2	Procedures for labeling explosives by compatibility groups
O3	Procedures for licensing motor vehicles and drivers for the transport of dangerous goods (ADR)
O4	Procedures for limiting vehicles speed of transporting explosives inside the site
O5	Procedures for ensuring the maintenance and cleaning of the vegetation inside the deposit
O6	Operating / maintenance procedures to avoid impact shocks
O7	Handling, loading / unloading and transport procedures to avoid shocks caused by impact
O8	Procedures for choosing equipment for impact reduction, shock absorption
O9	Handling, transport and storage procedures to prevent and reduce contact and

	friction between stored explosives
O10	Checking equipment according to ATEX procedures
O11	Procedures for performing explosives stability tests
O12	Procedures for adapting the storage flow of explosives to shorten storage times
O13	Quality control
O14	Production control
O15	Procedures for space maintenance and cleaning
O16	Procedures and checks for measuring electromagnetic fields
O17	Procedures for the prevention of laser radiation

These measures of an organizational nature complement the technical measures, creating links that influence the probability of occurrence of the event. For example, the measure on the adoption of procedures of preventing joint storage of incompatible explosives (O1) and the measure on the labeling of explosives by compatibility groups (O2) lead to a more rigorous application of the technical measure for the storage of incompatible explosives in separate rooms (T2), implicitly reducing the probability of an explosion-type event caused by incompatible explosives (D1).
The logical models used for the development of accident sequences are the Event Tree type. A logical model of this type allows the quantitative analysis of risks, but also the qualitative analysis of safety measures. Event tree analysis (ETA) involves determining the events that result from the failure of a component or part of the system. Starting from an initiating event or a fault of origin, the analysis through the event tree allows the estimation of the system deviation, systematically considering the operation or failure of the detection, alarm, prevention, protection or intervention devices. These safety barriers can be both *technical* and *human* means (intervention of operators) or *organizational* (application of procedures).

5. IDENTIFICATION OF EXPLOSION SCENARIOS AND GRAPHIC DEVELOPMENT OF EVENT TREES

In this stage, the accident sequences and the event trees were elaborated for each of the 15 triggering factors presented in table 1, for each of these scenarios being identified and presented the safety barriers that can be applied (technical and / or organizational measures). The development and graphical presentation of the event trees was performed in the Star UML application. For each of the possible triggers of an explosion, in the first phase were identified the technical and organizational measures that lead to reducing the risk of explosion, thus constituting prevention measures, after which were identified the measures that, in the event of explosion, lead to limit its effects as well as the area in which these effects may occur.

Thus, we can exemplify, according to figure no. 2 and table 4 the tree of events and sequences of accidents corresponding to the ***trigger factor type D1 - Joint storage of incompatible explosives***, where prevention measures are represented by the development and implementation of procedures O2 and O1, which involve the labeling of explosives by groups of compatibility and avoidance of storage of incompatible explosives in the same room. After these initial organizational measures, technical prevention measures of type T2 are provided, which are related to the arrangement of separate rooms for the storage of incompatible explosives.

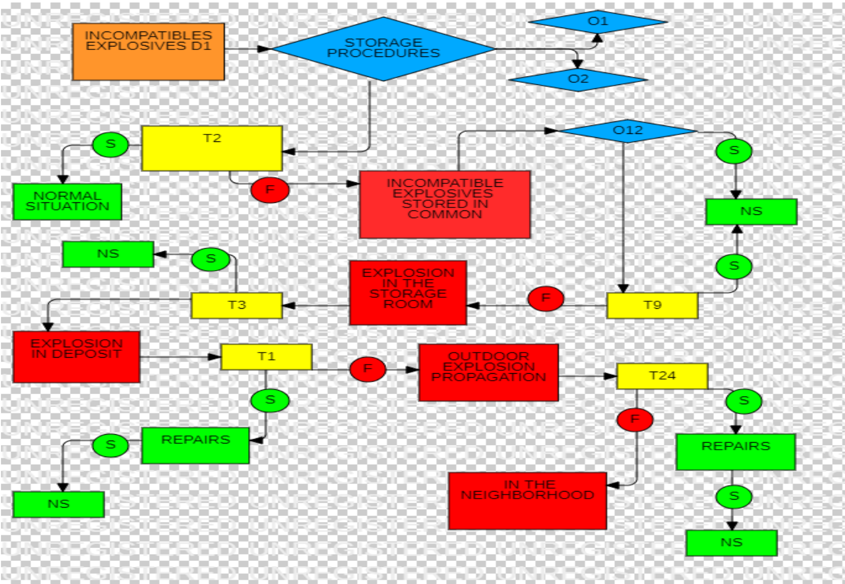

Figure 2. Event tree developed for D1 triggering factor - Incompatible explosives

Table 4. Accident sequences for trigger D1 - Incompatible explosives (r-success; e-failure)

D1*O2e*O1e*O12e*T2e*T9e*T3e*T1e*T24e
D1 D1*O2e*O1e* O12e *T2e*T9e*T3e*T1e*T24r
D1*O2e*O1e* O12e *T2e*T9e*T3e*T1r*T24r
D1*O2e*O1e* O12e *T2e*T9e*T3e*T1r
D1*O2e*O1e* O12e **T2e*T9e*T3r*T1r*T24r
D1*O2e*O1e *O12e **T2e*T9e*T3r*T1r
D1*O2e*O1e* O12e *T2e*T9e*T3r
D1*O2e*O1e* O12e *T2e*T9r
D1*O2e*O1e* O12e *T2r*T9r
D1*O2e*O1e*T2r
D1*O2r*O1r*T2r

If these measures are not sufficient and yet there are incompatibilities (although in practice this situation should be impossible and unacceptable) these measures are followed by a complex of technical and organizational measures (T9 and O12) which involve the creation of a flow of use and distribution of explosives which ensures the shortening of storage times, thus reducing the probability of an event. Furthermore, assuming that after taking all measures to prevent the explosion, however, it occurs at the level of one of the storage rooms, the technical measures to limit the effects of the explosion produced intervene, thus:

- Concrete protection barriers between storage rooms (T3) - these measures are mandatory to be taken from the construction phase of the storage facility. By successfully applying this measure the effects of the explosion are limited to the room where it occurred, so that, after performing the necessary repairs, the activity can return to normal parameters. In case of failure of the measure, the effects can be transmitted throughout the deposit and could lead to the explosion of the entire amount of explosives in the facility.
- In this case, technical measures of type T1 intervene, which are given by the constructive type of the deposit (Ex - underground deposit, with covering rock layer, or surface deposit with rooms arranged on the hillside), through which the effects of the explosion could be limited to the storage facility level.
- The next applicable technical measure is the protection of the entire deposit by fencing with earth waves (T24), with the dimensions established by law, which lead to either limiting the effects of the explosion on the fenced enclosure or reducing these effects on the environment, buildings and communities in the vicinity of the deposit.

Similarly, in Table 5 and fig. 3 are shown the accident sequences and - respectively - the event tree corresponding to the ***trigger factor type D1 – Car accident in the deposit***.

Table 5. Accident sequences for trigger factor D2 - Vehicle accident inside the deposit, (r-success; e-failure)

D2 *O3e*O4e*T22e*T18e*T23e*T19e*T20e*T1e*T24e
D2 *O3e*O4e*T22e*T18e*T23e*T19e*T20e *T1e*T24r
D2 *O3e*O4e*T22e*T18e*T23e*T19e*T20e *T1r
D2 *O3e*O4e*T22e*T18e*T23e*T19r
D2 *O3e*O4e*T22e*T18e*T23r
D2 *O3e*O4e*T22e*T18r
D2 *O3e*O4e*T22r*T23r
D2 *O3e*O4e*T22r*T18r*T23r*T19r
D2 *O3e*O4r*T22r*T18r*T23r*T19r
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D2 *O3r*O4r*T22e* T18e*T23e*T19e*T1e*T24r
D2 *O3r*O4r*T22e* T18e*T23e*T19e*T1r
D2 *O3r*O4r*T22e* T18e*T23e*T19r
D2 *O3r*O4r*T22e* T18e*T23r
D2 *O3r*O4r*T22e* T18r*T23r
D2 *O3r*O4r*T22r
D2 *O3r*O4r

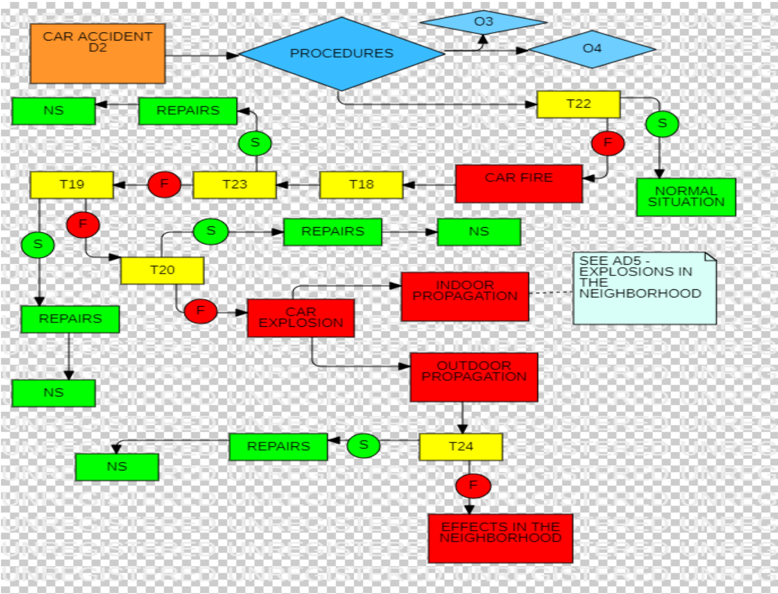

Figure 3. Event tree for trigger factor D2 - Car accident in the deposit

6. CONCLUSIONS

The paper presented the methodological stages for the construction of accident sequences in the systems in which explosive materials are stored. A main logic diagram was developed from a comprehensive list of triggers that can underlie the occurrence of an explosion and analyzed up to specific events. Also, the technical and organizational safety measures that can be implemented in these systems have been inventoried and systematized. For each of the initiating events identified, in order to increase the level of safety and security, additional safety measures and / or support measures have been systematized that can be introduced in the system. For each accident sequence, the safety measures that can be considered to be introduced or not in the system to be analyzed were hierarchized, thus providing a system of trees specific to the accident sequences. The evenimential analysis of accident scenarios for explosive depots can be used to assess the possibility of an explosion occurrence at the storage site, by identifying all possible triggering risk factors and associated safety measures. Accident sequences for a hypothetical "complete" location involve the generation of event trees for each possible trigger of the event. Moreover, the frequency of occurrence of the initial events and the failure of the safety measures can be modified to reflect the specific conditions, the event-specific trees being quantifiable. However, this approach does not take into account the possible consequences of an explosion, so we will develop the research based on the evaluation of the risk levels determined in the matrix form "frequency / consequences".

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SELF-HEATING COAL STOCKPILE IN OPEN PIT COAL MINING

TUDOR GOLDAN[1]

Abstract: *Coal naturally oxidizes over time. The paper analyzes the possibility of coal self-heating and, finally, the appearance of spontaneous combustion when storing coal for a long period of time. During self-heating, progressive changes occur in the coal's chemical and physical properties that have undesirable consequences, such as loss of cooking properties, a reduction in liquefaction yield, and a reduction in solvent extraction. In addition to self-heating, secondary mechanisms for mass and calorific loss include, partial or total coal combustion, removal of small coal particles due to wind and rain, and incomplete recovery of the pile during removal.*

Keywords: *open pit, coal, mining, self-heating.*

1. INTRODUCTION

Coal is stable underground, but the exposure of coal to air during and after mining can result in reactions and oxidation which, in turn, result in self-heating and, in extreme cases, spontaneous combustion.

When storing coal for a long period of time, attention must be paid to the possibility of spontaneous combustion. The temperature inside a stockpile immediately after the piling is approximately 30°C to 50°C, but it rises gradually due to the heat generated by low-temperature oxidation of the coal. The temperature of a stockpile is determined by the type of coal, particle size, oxygen concentration of the air, balance of the heat of coal oxidation, moisture content of the coal, the latent heat of water evaporation and the heat dissipated from the stockpile by air flow. It is considered that the temperature continues to rise at a spot where heat generation domination, which eventually leads to spontaneous combustion. When considering the spontaneous combustion characteristics of coal in storage, the effect of external factors, such as the particle size distribution and the filling state of the coal, the amount of the sprinkled/precipitated water and ambient temperature, must also be taken into account.

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2. AIR FLOW IN COAL STOCKPILE

In the open pits located in the area are used three types of stockpiles: open pit stockpiles; intermediary stockpiles and final stockpiles, from where the lignite is delivered to the beneficiaries (figure 1).

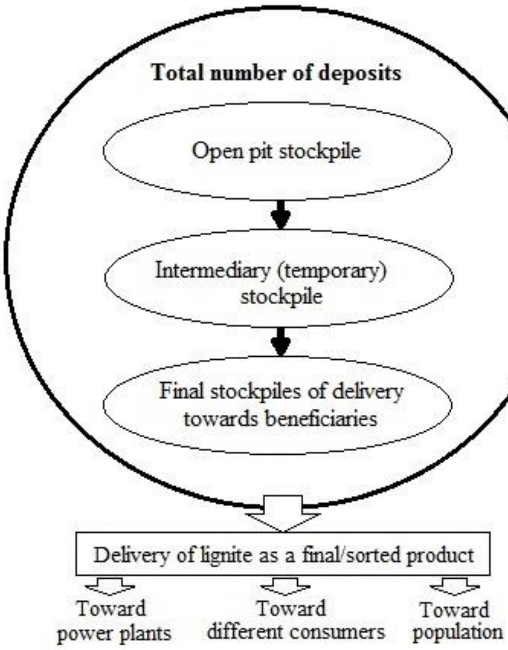

Figure 1. Distribution of coal from the stockpiles.

In a stockpile, air flow by the natural convection is associated with heat generation. Roughly speaking, the air flow is caused by warmed air rising up inside the pile and escaping outside, while fresh air is being supplied from outside. A stockpile is an accumulation of coal granules having a size distribution. Thus, in order to reproduce the air flow, the pressure drop inside the pile must be assessed and the flow conditions of the air must be determined. In addition, a stockpile consists of coal granules with a wide size distribution, resulting in different degrees of breathability, depending on the location within the pile. For example, the breathability is increased at the foot of a pile, because when coal is piled, coal granules with large sizes tend to roll and to be segregated at the foot.

The air flow and pressures around the coal will affect the movement of the newly released gases from the exposed coal surface. If the differential pressure is low then the gases will remain at the coal surface, deprived somewhat of oxygen and therefore less likely to ignite. At high differential pressure the heat from oxidation is removed effectively and this also reduces the likelihood of an incident. There is a ‘sweet point’ of pressure and air flow which can create the perfect conditions for spontaneous combustion and this must be avoided.

Having a greater surface area, the fine particle of coal can absorb much more oxygen and this causes a rise in temperature, favorable conditions for further absorption and for chemical action between the oxygen and the constituents of the coal.

A spontaneous increase in coal temperature with a possible transition into fires represents a direct hazard to coal storage and transportation.

The self-oxidation reaction is a slow process that can take from several hours to days or weeks; passing through thermal decomposition and oxidation steps when the material is exposed to the oxygen present in the air. At ambient temperature this reaction is thermodynamically spontaneous, which means that it does not need an external source of energy to progress. Compared with a conventional combustion, this is a series of parallel endothermic and exothermic reactions developed between 20°C to 80°C, releasing some heavy volatiles as well as H_2O, CH_4 and CO, without the presence of a visible flame. However, if the exothermic reactions outweigh the endothermic reactions, the rate of heating can increase considerably and release higher amounts of CO_2 and water.

The reaction takes place between the oxygen-reactive sites in the coal material and molecular oxygen in the surrounding atmosphere under ambient conditions. The products are CO, CO_2 and H_2O and oxygen-containing functional groups in the coal material. The chemical mechanisms generally proposed for coal oxidation include the following sequence of free radical reactions:

$$RH + O_2 \rightarrow R^- + HOO^- \tag{1}$$

$$R^- + O_2 \rightarrow ROO^- \tag{2}$$

$$ROO^- + RH \rightarrow ROOR + H^- \tag{3}$$

$$ROO^- + RH \rightarrow ROOH + R^- \tag{4}$$

$$ROOR \rightarrow 2RO^- \tag{5}$$

$$ROOH \rightarrow RO^- + {}^-OH \tag{6}$$

$$HOO^- + H^- \rightarrow HOOH \tag{7}$$

$$HOOH \rightarrow 2HO^- \tag{8}$$

$$RO^- \rightarrow products \tag{9}$$

$$HO^- \rightarrow products \tag{10}$$

$$coal + O_2 \rightarrow oxidized\,coal + CO + CO_2 + H_2O \tag{11}$$

Since coal consists of various types of organic structures with different reactivities towards oxygen, new types of reactions emerge as the temperature increases. Decarboxylation reactions gain significance around 80ºC generating additional heat due to their exothermic nature.

Self-heating (spontaneous heating) and autoignition (selfignition or spontaneous ignition) are the precursors of spontaneous combustion. All coals self-heat to some extent, both in mines and storage; but only if the conditions are favourable they may autoignite.

3. STOPPING THE INCREASE OF COAL SELF-HEATING

Should self-heating reach a stage where the stockpile needs to be cooled, water can be applied. However, this increases the water content of the coal and reduces its heating value. It should be noted that when stckpiled coal is exposed to water, whether through rain or the application of a water spray, some organic and inorganic matter, such as calcium, magnesium and sulphur, leach out. This may cause a small decrease in the calorific and weight value of the coal, but it also produces an environmental hazard. Since self-heating can increase the local temperature inside a stockpile to above 80°C, the application of a water spray to reduce localized self-heating results in hot water running through the stockpile, which increase leaching.

Coal fires also produce a high impact on human health, especially for local residents close to the burning sites. The long-term exposure to the emission of noxious gases such as H_2S and SO_2 has direct relation to lung cancer and damage to the respiratory system. Also, the prolonged exposure to a range of volatile organic species emitted from these fires, including xylene, toluene and benzene, could be another cause of respiratory diseases. Recently, nanomaterials released from fires have been identified, which could be potentially hazardous; however, the impact of these substances on human health is currently unknown.

Moisture plays an important role on behavior of coals in stockpiles. The amount of water contained by coal for a given value of relative humidity is described by its adsorption and desorption isotherm. The interaction between water and coal can be exothermic or endothermic depending on whether the water condenses or evaporates. In sufficient quantities, water suppresses self-heating by blocking access of oxygen to active sites and by taking up the heat released by oxidation as it occurs. However, if the moisture content of the coal is lowered, it may be expected that these moderating effects will become less effective and a significantly greater level of self-heating will occur. In addition, it has been reported that low rank coals undergo the highest heating rate when their moisture content is reduced to about one-third of the original as-received moisture content.

The efficiency of the storage and extraction operations of lignite from the stockpiles is influenced by the shape of the stockpiles and by the existing equipment, in conditions of limited investments in the mining sector.

As a result of the fact that the lignite layers have different calorific value (figure 2) in order to ensure a consistent quality of the product (lignite), it is necessary to maintain the homogeneity of the coal from the stockpiles. Following studies conducted in this regard, Chevron storage method was replaced by the Windrow method. In this method, the stacker moving on rails spills the school in parallel rows along the silo's length by changing the boom angle from the ground level, which allows the reconfiguration of the stockpile so as to facilitate input-output operations and maintain a consistent quality of coal which will be distributed to consumers.

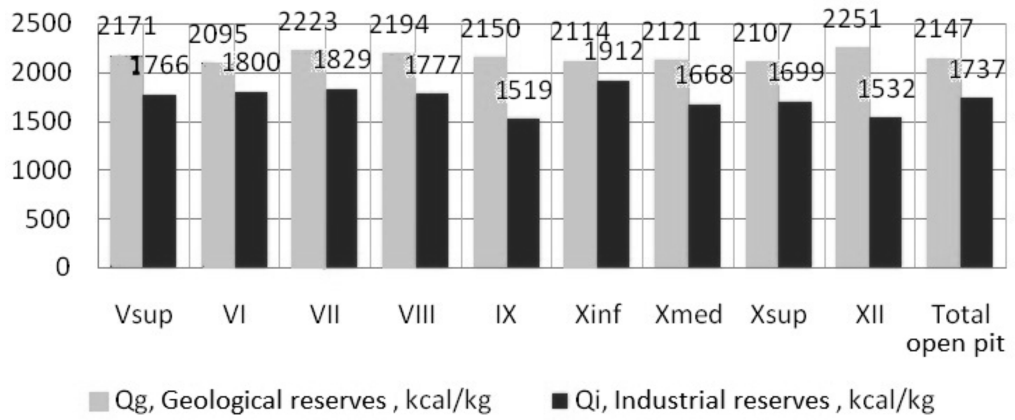

Figure 2. The quality of the coal.

4. CONCLUSIONS

Storage of coal in the stockpile is necessary to take care of any disriptions in the transport system or in coal mines due to which coal cannot be received at the power plant on such days. The general practice is to provide a 7-15 days stockpile in case of a pit head power plant depending on the reliability of the mines and the conveying system. In case the power plant is far away from the coal mines, coal stock of 30 days requirement will be provided.

Self-heating can be minimized if the heat generating capacity of coal is reduced by establishing high heat losses. A variety of measures have been tried to reduce self-heating, including: minimizing the angle of the slopes of the stockpile, compaction of the pile, protection of the coal pile through covering it with an inert material, making the atmosphere inert, and the use of natural or artificial wind barriers around the perimeter of stockpile.

Compaction of the stockpile reduces the pore volume between coal particles, which decreases air ventilation through the stockpile, and is an effective way to reduce permeation af air. A loosely stored pile may have a voidage of 25% or 30%. This may be reduced to 10% through compacting with mechanical means. Compaction also reduces the permeation of water into the pile, and changes the thermal conductivity of pile.

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MONITORING AND PROGNOSIS OF SURFACE SUBSIDENCE FROM THE OLD MINES – SLĂNIC SALINE

ILIE ONICA[1], DACIAN-PAUL MARIAN[2], OVIDIU MARINA[3]

Abstract: *The underground mining of the rock salt deposit from Slănic started in 1665, with the help of bell shape-type chambers and continued between 1831-1971, with the extraction in large trapezoidal chambers in the Sistematica, Carol, Mihai and Unirea mines. In total, a volume of over 5.5 million m^3 of rock salt was extracted from the Old Mines. This article presents, in summary, the study of surface displacement measurements and the prediction of the ground surface subsidence above the Old Mines. Also, the main factors that contributed to the deformation of the ground surface are described, namely: the dimensions of the underground cavities, the mining depth, the geomechanical characteristics, the tectonics of the deposit, the hydrogeology, the mining method and the explosives detonation effect.*

Keywords: *rock salt, subsidence, salt mine, trapezoidal chambers, pillars, monitoring, prognosis*

1. THE EVOLUTION OF THE UNDERGROUND MINING OF THE ROCK SALT DEPOSIT FROM SLĂNIC

The beginnings of rock salt extraction at Slănic are mentioned for the first time in documents that authenticate the purchase of the "Slănic estate" by Mihail Cantacuzino, in 1665 and 1669. Between 1689-1691 he opened the mines from Baia Baciului. These old mines, being close to the surface, collapsed, leading to the creation of excavations / pits in which were formed the following salt lakes: Baia Verde, Baia Baciului, Lacul Mare, Grota Miresei and Baia Porcilor [4] (Fig.1).

The extraction of salt at Băile Verzi and Grota Miresei, between the years 1800-1854, was carried out in bell shape-type chambers, on their entire section. The opening of the chambers was done through a shaft, dug from the surface to the salt deposit, from where the salt was extracted downwards, by manual carving, resulting in an excavation in the shape of a "bell". Today, these mines are partially silted. Ocna din Vale was mined between 1819-1865, and Ocna din Deal, between 1838 and 1865, then they were reopened for extraction between 1875 and 1881. Ocna din Vale reached a

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depth of 145 m, with a diameter of 75 m, at an excavated volume of 171 941 m^3, and Ocna din Deal had a depth of 96 m, with a diameter of 68 m, resulting in an excavated volume of 94 516.8 m^3.

Rock salt extraction in the Sistematica Mine, during the years 1865-1875, represented an evolution in rock salt extraction, when the rudimentary extraction of salt in bell shape-type chambers was abandoned and a "systematic, multi-chamber" method of extraction was adopted. Sistematica Mine was closed in 1875 due to the low quality of the rock salt produced in this mine and, especially, due to the presence of water in the mining workings.

In addition to the mines presented above, the following mines also operated in the central area of the deposit: the Mine of Principatele Unite or Carol, between 1831-1935; 23 August Mine or Mihai, between 1912-1943; Unirea Mine, in the period 1947-1971 [4].

In 1881, the Carol mine was officially opened, through four horizontal mining workings, with the extraction shaft positioned in the central part. The extraction was carried out downward, starting from these preparatory mining workings, resulting at the end of the extraction, in 1935, an excavation with an ogival shape profile, with a height of 97 m and an opening at the bottom of 48 m. The surface at the base of the Carol mine is 24 672 m^2, with an excavated volume of 1 703 396 m^3.

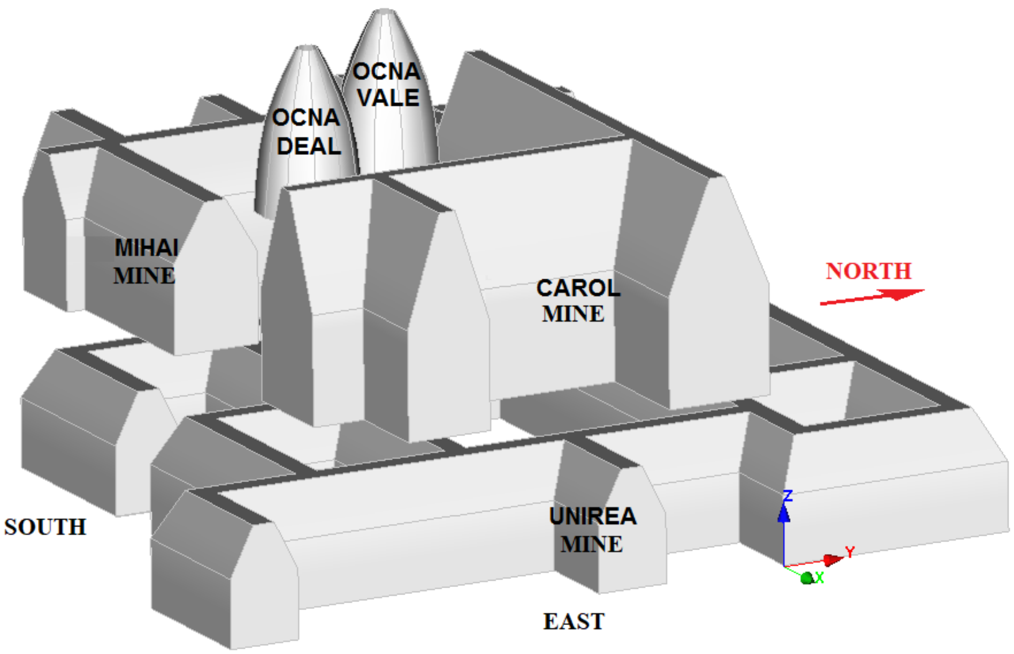


Figure 1. 3D overview of the Ocna din Deal and Ocna din Vale, and of the Carol, Mihai and Unirea Mines

In 1912, the Mihai mine was opened and started, which mined simultaneously with the Carol mine. The underground mining rooms have a trapezoidal-rectangular profile, with sizes of 12 m, opening to the ceiling, with walls inclined at 60°, a length of 30 m, a height of 66 m and an opening at the base of 37 m. The operation was completed in 1942, resulting in an excavated volume of 462 332 m^3, at a base area of 12 500 m^2.

Under the two Carol and Mihai mines, which are positioned on the same level, under a safety crown pillar of 28-31 m of thickness, the Unirea mine develops in depth, opened and mined between 1942 and 1970. Unirea mine is a set of rooms with a trapezoidal profile, arranged around a central pillar. The rooms have an opening to the ceiling of 10 m, inclined walls at 60°, a length of 30 m, an opening to the bottom of 35 m and a height of 56 m. The rooms of the Unirea mine have a base area of 78 360 m^2 and a total volume of excavated salt of 2 903 131m^3. After the mining stopped, the Unirea mine operates as a tourist attraction.

Until 1970, a volume of rock salt of over 5.5 million m^3 was extracted from the Old Mines (see Figure 1).

Starting with 1970, the Victoria Mine was opened, where was applied the mining method with small rooms and square pillars, with multi-storey levels. Until 1993, a volume of 7 379 128 m^3 was extracted from this mine.

South of the Old Mines, in 1993 started the extraction of rock salt at the Cantacuzino Mine, where the same mining method was applied, with which, until 1999, a volume of rock salt of approx. 2 362 324 m^3. Furthermore, the extraction takes place with the same mining method, at the New Mine Slănic, under a leveling crown pillar of 40 m of thickness, constituted under the Victoria mine, the Old mines and the Cantacuzino mine.

2. GENERALITIES REGARDING THE SURFACE SUBSIDENCE IN THE OLD MINES PERIMETER

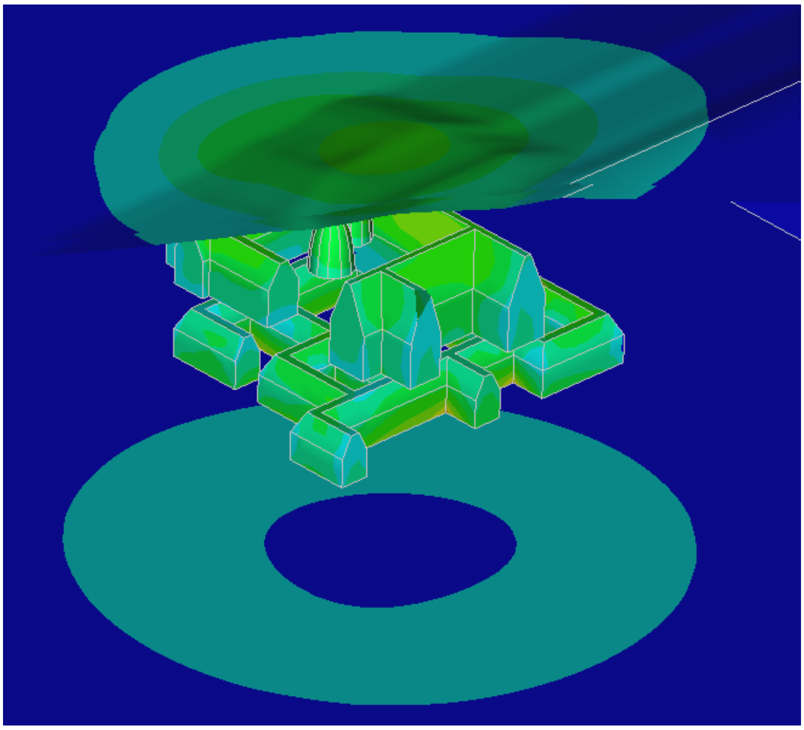
Among other things, the surface subsidence is a consequence of the underground mining of mineral resources, including rock salt, as a result of the change in the natural state of stress, by removing a certain volume of the earth's crust. Under specific geo-mining conditions, continuous and discontinuous subsidence troughs can occur.

Discontinuous troughs are characterized by significant surface displacements and the formation of discontinuities in the surface profile. In the conditions of underground mining of the rock salt deposit from Slănic Prahova, it can be defined as a discontinuous deformation or subsidence of the ground surface, the collapse of the rocks after a sinkhole near the Carol shaft, due to dissolution voids on the rock salt body ridge. Also, this category may include the collapse of the bell shape-type rooms, as a result of the collapse of the crown safety pillar, which led to the formation of surface pits, respectively salt lakes Baia Verde, Baia Baciului, Lacul Mare, Grota

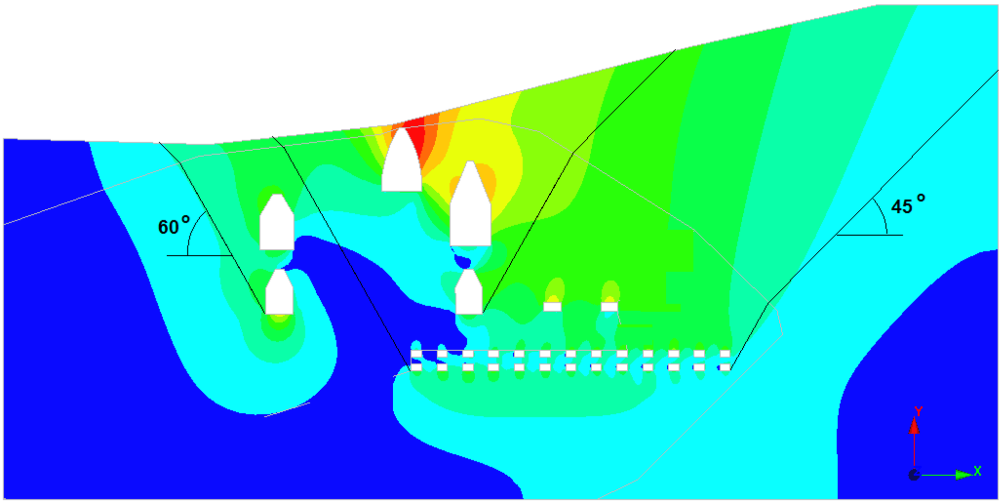
Miresei and Baia Porcilor. In general, all dissolution voids can lead to the sudden dislocation of rocks after such sinkholes.

Continuous subsidence troughs include those deformations of the surface which form an extended profile of the subsidence trough and which develop progressively as the extracted surface expands. These results from the underground mining of the coal seams by longwall mining or the extraction of other deposits of useful mineral substances, such as sulfur or evaporite deposits, enclosed in sedimentary deposits - as is the case with rock salt deposits [1].

According to Brauner [2], continuous subsidence occurs at each point of the subsidence trough, being characterized by five important sizes: vertical displacement (subsidence), horizontal displacement, inclination and curvature of the diving bed and horizontal compression and tensile strain [8, 10]. Each influencing factor induces different types of surface destruction, within the limits of an area of influence, bordered by subsidence planes inclined with some angles of subsidence. For the geo-mining conditions from the Slănic rock salt mine, the following values of the subsidence and influence angles were used: 60º, for the rock salt massif; 45º, for the surrounding rocks. These values were used to delimit the areas of influence of the underground mining of the deposit and to draw the main safety pillars (Fig.2).



a)



b)

Figure 2. Scalar distribution of the total displacement vector d_{uvw} [5]
a) 3D modelling with finite elements; b) 2D modelling with finite elements – correlation with subsidence angles (future situation, after the extraction of levels +145m and +129m) for a representative cross section through the Old Mines

Analyzing the graphical representations of the total displacements shown in Figure 2.b, it can be seen that the limit planes of influence, inclined with subsidence angles of 60°, for the rock salt massif and 45°, for the surrounding rocks, very well frame the areas of influence of the underground excavations, where rock movements are observed. This conclusion validates both the results obtained by numerical modeling [7] and the angles adopted from field observations and used to design the main safety pillars and the influence areas of the underground mining excavations.

3. ANALYSIS OF THE MEASUREMENTS OF SURFACE SUBSIDENCE UNDER THE INFLUENCE OF THE OLD MINES

At the surface of the Slănic rock salt mine, in the areas of influence of the Old Mines, 36 topographic landmarks were placed, on 5 alignments, on which were performed measurements of surface subsidence, at intervals of approx. one year, starting in 1994, until now. These landmarks were mounted either on the ground or on the foundation of the buildings. The values of the vertical displacements, measured by precision leveling and the values of the subsidence speeds of each landmark were stored in tabular and graphical form.

In the case of the Old Mines, the landmarks used to monitor the surface deformation were placed on the following alignments: 123-Shaft S, S1n-S6new, G1-G8, L2-M3 *, N1-N2v. From each alignment were selected the landmarks with the highest subsidence, between 149.2 mm (landmark H5v) and 1965.6 mm (landmark N2), with subsidence speeds of 1.5 mm / month, respectively 73.4 mm / month. The subsidence and subsidence speed prognosis functions, for the selected landmarks, are shown in Figures 3 and 4, Table 1 and 2. For both subsidence and subsidence speed prognosis, the functions with the best approximation were the linear and logarithmic that highlights a very diverse behavior of the phenomena of the surface deformation. Based on these functions, the evolution over time of subsidence and subsidence speeds was predicted, over a period of 50 years, summarized in Table no. 3.

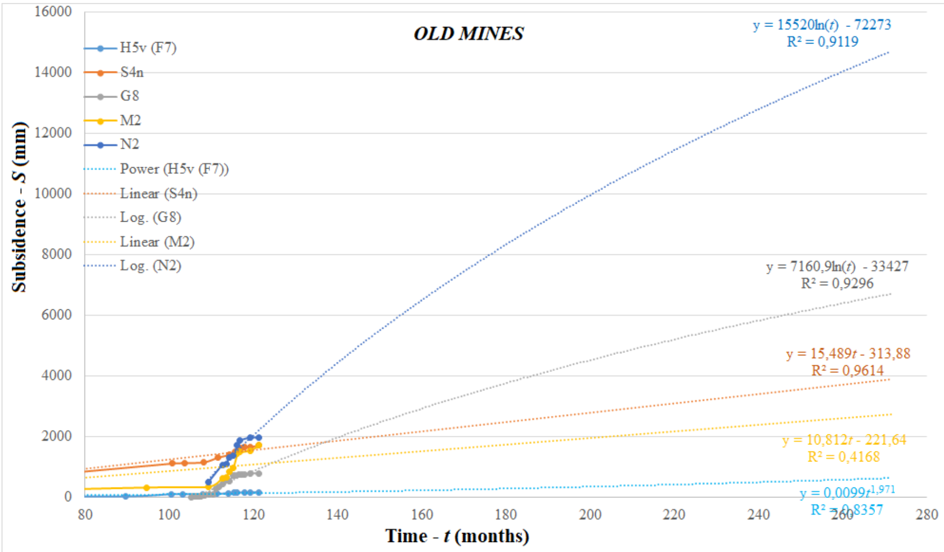


Figure 3. Subsidence prognosis for the surface landmarks – Old Mines [5]

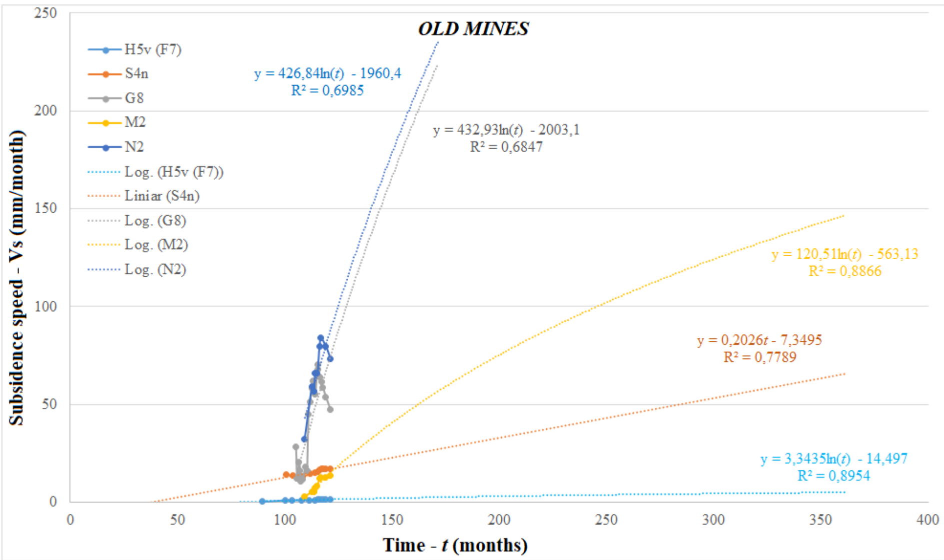


Figure 4. Subsidence speed prognosis for the surface landmarks – Old Mines [5]

Table 1. Prediction functions of the subsidence phenomena for the landmarks with the highest subsidence, from the Old Mines (including Unirea Mine) [5]

Land-mark	Alignment	Approx. law	Approximation formula of the subsidence, $S_{(t)}$ mm	Coeff., R^2	Last subsidence speed, mm/month	Total measured subsidence, mm
H5v (F7)	123-Shaft S	*power*	$S^U_{H5v(t)} = 0{,}0099 \cdot t^{1{,}971}$	0,8357	1,4964	149,2
S4n	S1n-S6new	*linear*	$S^U_{S4n(t)} = 15{,}489 \cdot t - 313{,}88$	0,9614	17,0758	1697,5
G8	G1-G8	*logarithmic*	$S^U_{G8(t)} = 7160{,}9 \cdot \ln(t) - 33427$	0,9296	47,4683	773,5
M2	L2-M3*	*linear*	$S^U_{M2(t)} = 10{,}812 \cdot t - 221{,}64$	0,4168	13,9956	1699,2
N2	N1-N2v	*logarithmic*	$S^U_{M2(t)} = 15520 \cdot \ln(t) - 72273$	0,9119	73,3792	1965,6

Table 2. Approximation of the subsidence speed for the landmarks with the highest subsidence, from the Old Mines (including Unirea Mine) [5]

Land-mark	Alignment	Approx. law	Approximation formula of the subsidence speed $V_{S(t)}$, mm/month	Coeff., R^2	Last subsidence speed, mm/month	Total measured subsidence, mm
H5v (F7)	123-Shaft S	*power*	$V^U_{H5v(t)} = 3{,}3435 \cdot \ln(t) - 14{,}497$	0,8954	1,4964	149,2
S4n	S1n-S6new	*linear*	$V^U_{S4n(t)} = 0{,}2026 \cdot t - 7{,}3495$	0,7789	17,0758	1697,5
G8	G1-G8	*logarithmic*	$V^U_{G8(t)} = 432{,}93 \cdot \ln(t) - 2003{,}1$	0,6847	47,4683	773,5
M2	L2-M3*	*logarithmic*	$V^U_{M2(t)} = 120{,}51 \cdot \ln(t) - 563{,}13$	0,8866	13,9956	1699,2
N2	N1-N2v	*logarithmic*	$V^U_{N2(t)} = 426{,}84 \cdot \ln(t) - 190{,}4$	0,6985	73,3792	1965,6

Table 3. **S**ubsidence and subsidence speed values predicted in time for the landmarks with the highest subsidence on the alignment, from the Old Mines (including Unirea Mine) [5]

Land-mark	Parameter	Time									
		5 years	*10 years*	*15 years*	*20 years*	*25 years*	*30 years*	*35 years*	*40 years*	*45 years*	*50 years*
		60 months	**120 months**	**180 months**	**240 months**	**300 months**	**360 months**	**420 months**	**480 months**	**540 months**	**600 months**
H5v (F7)	$S_{(t)}$, mm	280	492	762	1090	1475	1918	2418	2974	3587	4257
	$V_{S(t)}$, mm/ month	2,89174	3,84710	4,58927	5,19626	5,70980	6,15486	6,54758	6,89898	7,21694	7,50727
S4n	$S_{(t)}$, mm	2496	3425	4355	5284	6213	7143	8072	9001	9931	10860
	$V_{S(t)}$, mm/ month	29,4041	41,5601	53,7161	65,8721	78,0281	90,1841	102,3401	114,4961	126,6521	138,8081
G8	$S_{(t)}$, mm	3815	5861	7451	8751	9851	10804	11645	12398	13079	13700
	$V_{S(t)}$, mm/ month	248,4645	372,1687	468,2683	546,8632	613,3583	670,9869	721,8379	767,3388	808,5092	846,1021

M2	**$S_{(t)}$, mm**	1740	2388	3037	3686	4335	4983	5632	6281	6930	7578
	$V_{S(t)}$, mm/ month	63,6134	98,0476	124,7978	146,6754	165,1849	181,2264	195,3812	208,0468	219,5070	229,9713
N2	**$S_{(t)}$, mm**	8443	12877	16322	19140	21524	23590	25413	27044	28520	29867
	$V_{S(t)}$, mm/ month	259,4919	381,4560	476,2037	553,6930	619,2527	676,0707	726,2063	771,0672	811,6585	848,7226

For the values of subsidence and subsidence speed in the area of the Unirea mine, after the measurements performed on 11.06.2019, the scalar maps from Figures 5 and 6 were elaborated by interpolation.

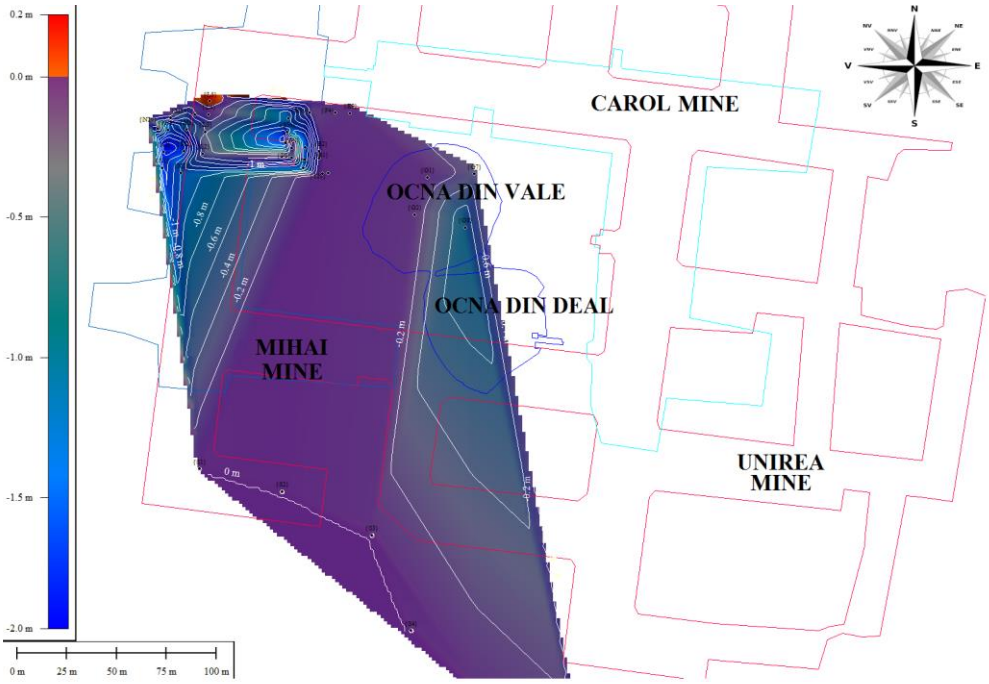
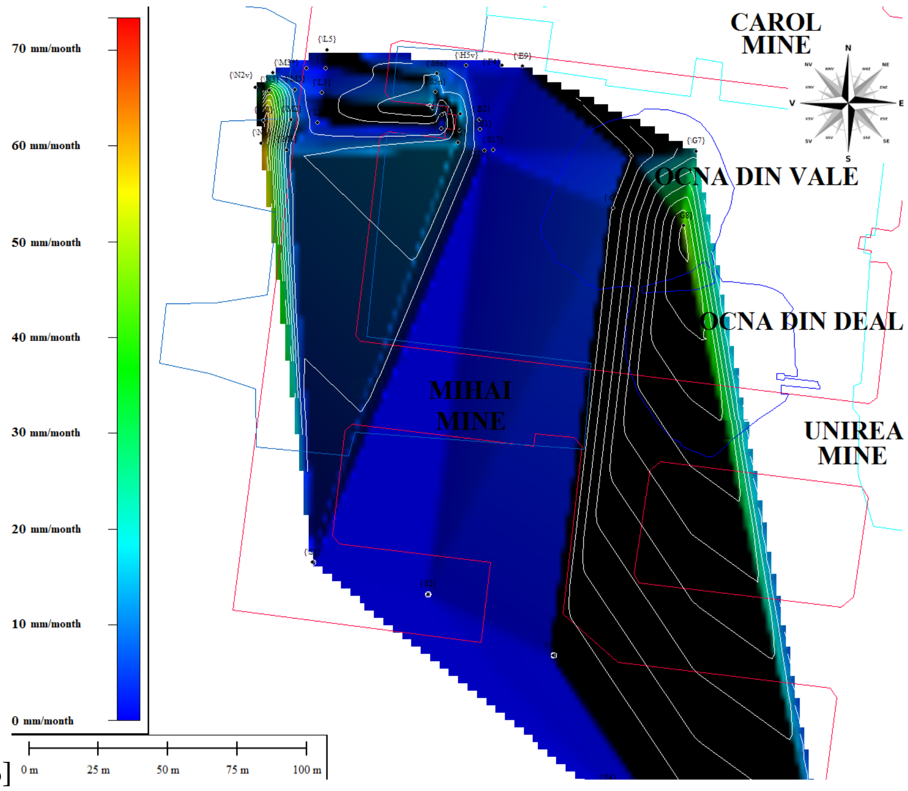


Figure 5. Scalar representation of subsidence measured at the surface until 05.02.2019, in the area of influence of the Old Mines (including Unirea Mine) [5]

If in the case of the ceilings subsidence, a critical subsidence can be considered, which would be an indicator of the appearance of the collapse of a ceiling, in the case of ground surface subsidence this principle cannot be used. The phenomena of ground surface subsidence, under the influence of underground mining excavations, are very complex and depend on several factors, especially on the thickness of the rock mass above the excavations (which sums up the crown pillar/ marginal pillar of rock salt from the roof, where adds the thickness of the useless covering rocks) and the size of the mining excavations. Moreover, the visible subsidence phenomena that have occurred in the areas of influence of the mines are both subsidence generated by the presence of mining excavations and produced by dissolution voids, deformation phenomena that are interrelated.



[5]

Figure 6. Scalar representation of subsidence speed, determined on 05.02.2019, in the area of influence of the Old Mines (including Unirea Mine) [5]

More precisely, the deformations of the ground surface, caused by the mining excavations can reach some critical values that could cause the fracturing of the covering rocks and the rock salt crown pillar. These fractures are ways of water infiltration into the rock salt deposit, which produce local dissolutions and thus voids in the earth's crust. Around the opening mining workings with access to the surface, water infiltrations have produced and will produce even more accentuated dissolutions. Finally, when the total collapse of the mines from the Slănic Prahova rock salt mine will occur, this phenomenon will be one generated by the association of the mining subsidence with the dissolutions of the rock salt massif. Therefore, permanent active measures to combat water infiltration into the deposit are very important to extend the stability of the mines from the Slănic Saline.

For the landmarks with the highest value of total subsidence, cumulated at the date of the last measurement, have been developed prognosis functions both in terms of the evolution of subsidence and the evolution of subsidence speed. The maximum values of subsidence and subsidence speeds for each mine from the Slănic Prahova Saline are presented graphically and tabularly, for the next 50 years.

The prognosis equations elaborated for estimating the evolution in time of the subsidence at the level of the most affected landmarks, are linear, logarithmic and of power type (table no. 1), which highlights once again the complexity of the surface deformation phenomena located in the area of influence of the Old Mines (including the Unirea mine). The prognosis in time of the subsidence values during the next 50 years, made with the functions contained in Table no. 1, is summarized in Table no. 4. In the case of this mine there are landmarks with the highest values of subsidence reported at the level of the Slănic Prahova Saline. These values are explained both by the near surface positioning of the Old Mines and by the very large volume of the mining chambers.

Table 4. The values of subsidence predicted in time for the landmarks with the highest subsidence, from the Old Mines (including Unirea Mine) [5]

Landmark	**Scufundarea prognozată $S_{(t)}$, mm**									
	5 years	***10 years***	***15 years***	***20 years***	***25 years***	***30 years***	***35 years***	***40 years***	***45 years***	***50 years***
	60 months	**120 months**	**180 months**	**240 months**	**300 months**	**360 months**	**420 months**	**480 months**	**540 months**	**600 months**
H5v (F7)	280	492	762	1090	1475	1918	2418	2974	3587	4257
S4n	2496	3425	4355	5284	6213	7143	8072	9001	9931	10860
G8	3815	5861	7451	8751	9851	10804	11645	12398	13079	13700
M2	1740	2388	3037	3686	4335	4983	5632	6281	6930	7578
N2	8443	12877	16322	19140	21524	23590	25413	27044	28520	29867

4. FACTORS THAT DETERMINED THE OCCURRENCE OF SUBSIDENCE PHENOMENA FROM THE SURFACE OF THE OLD MINES – SLĂNIC SALINE

4.1. The geometry and volume of the voids resulted from underground mining

The spatial sizes (height, width and length) for the Old Mines, including the Unirea Mine, their relative arrangement to each other and the shape of the voids in the rock salt massif have a decisive influence on the distribution and amplitude of the deformation values transmitted to the surface (with the location of the voids in relation to the surface) – Figure 7 and Table no. 5.

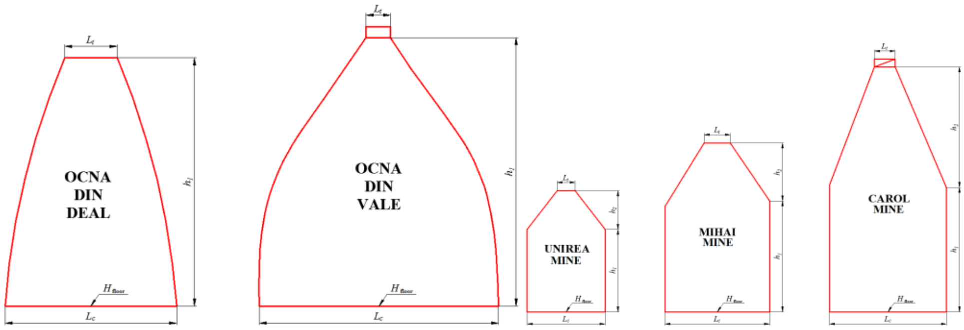


Figure 7. Cross sections through the Old Mines

Table 5. The main geometric features of the excavations of the Old Mines

Mine	Floor elevation, [m]	Surface elevation, [m]		Width, [m]		Room height, [m]	
	H_{floor}	H_{max}	H_{min}	L_c	L_t	h_1	h_2
Ocna din Deal	+337	417,00	402,00	47,6	14,5	68,9	-
Ocna din Vale	+315	406,00	401,00	66,4	6,8	74,5	-
Carol Mine	+276	448,00	401,00	44,7	8,0	47,9	46,4
Mihai Mine	+270	409,00	395,00	40,0	10,0	42,7	22,3
Unirea Mine	+198	467,00	395,00	29,8	7,0	31,8	14,9

The irregular distribution of displacements in the area of influence of the voids is specific to the excavations in the area of Unirea Mine, which were mined by bell shape chambers or large trapezoidal-rectangular chambers, going until the collapse of the bell shape chambers (Ocna din Deal and Ocna din Vale).

The high amplitude of displacements generated by the important sizes of the mining excavations is evident in the case of bell shape chambers and large trapezoidal-rectangular shape chambers, by reducing their volume due to convergence.

4.2. The depth of the deposit

The depths of the excavations from the Old Mines (Ocna din Deal, Ocna din Vale, Carol, Mihai and Unirea) have values between 65 and 269 m.

Taking into account the rheological behavior of the rock salt from Slănic [4], 3 creep zones were identified, for which were defined the states of long-term stability, the relative stability and instability of the rock salt (Fig. 8):

Zone I: for the depth $H < 267$ m, elastic behavior of the rock salt massif - unlimited stability;

Zone II: for the depth H = 267 - 476 m, elastic-plastic behavior of the rock salt massif - of relative stability;

Zone III, for the depth $H > 476$ m, plastic and visco-plastic behavior of the rock salt massif - of instability.

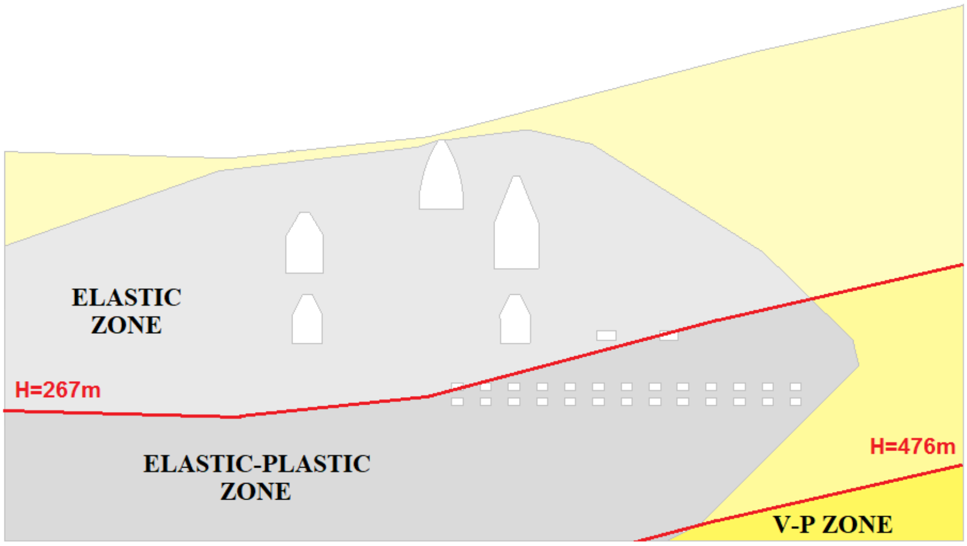


Figure 8. In-depth representation of the areas with elastic, elastic-plastic and visco-elastic behavior, in a representative cross section through the Old Mines – New Mine Slanic [5]

If the deposit and the surrounding rocks were perfectly elastic, then the deformation following the geostatic stresses would have been in this field, theoretically considered reversible, by the cessation of stresses (which in reality is an impossible situation).

The increase of the loads on the resistance structures (pillars, crown pillars) makes the loadings developed into the massif to exceed the elastic limit of the geological formations (especially of the rock salt), causing the appearance of irreversible phenomena in the rock salt massif and in the surrounding rocks (plastic deformations, opening of natural cracks and the appearance of induced cracks and fractures, etc.). All these phenomena determine a convergence of the mining excavations and implicitly a reduction of their volume with impact on the deformation of the massif from the area of influence of the excavations and their progressive transmission to the ground surface. These phenomena are evident in finite element models, in which the surface configuration is variable and in which the most strained pillars are located at a greater depth from the surface.

Associated with depth is the natural state of stress [3]. The horizontal natural stresses calculated according to the Poisson's ratio have the value of approx. 39-40% of vertical geostatic stresses. However, the analysis of the stability phenomena at the Slănic Prahova salt mine proves that the horizontal stresses, even in the conditions of the lack of in situ measurements, can be estimated as being at least equal to the vertical ones. In conclusion, among other causes, the high value of horizontal stresses can be considered a main factor that contributed to the amplification of instability phenomena at the Slănic Prahova Saline.

4.3. The geomechanical properties of the rock salt deposit and of the surrounding rocks

Regarding the dependencies between the surface deformation and the physical-mechanical, elastic and rheological properties, the most important are those geomechanical characteristics that determine the reduction / convergence of the volume of the underground mining excavations. First, we mention the elastic characteristics of the rock salt, for the elastic zone, namely the modulus of elasticity and the Poisson's ratio, then the creep deformation characteristics and the rheological characteristics, for the elastic-plastic area of the deposit. The natural cracking, dislocations and inhomogeneities in the salt massif can significantly contribute to the intensification of the expend phenomenon and implicitly to the deformation of the resistance structures and the convergence of the excavations.

All the geomechanical properties [6, 9], mentioned above, determine a higher compressibility of the rock salt massif under the action of the stress developed in the massif, the vertical deformation of the pillars, the rooms convergence, transmitted to the surface in the form of the subsidence phenomenon.

4.4. The tectonic of the deposit

From the tectonic point of view, the deposits within the Slănic perimeter are located in a large Miocene syncline. The lower and middle Miocene formations are framed between two major fractures: the Audia line and the Cosminele fault. The rock salt that appears in the middle of the syncline is intensely folded, due to the pressure that manifested from the direction of the Homorâciu spur. Due to the lateral pressures to which the deposit was subjected, a tendency of salt diapirism is observed in the central-northern area.

From the above synthesis, regarding the tectonics of the deposit, the following conclusions can be drawn: the distribution of geostatic and hereditary stresses in the massif is uneven; due to the lateral pressures during the genesis of the deposit, it is possible that the natural state of stresses to be characterized by some horizontal stresses that tend to at least equal the value of the vertical stresses in the massif; the base of the syncline is marked by a concentration of hereditary stresses in this area; the major faults Audia and Cosminele, following the deformations of the massif generated by the underground mining can be factors of destabilization of the rock masses and of non-uniform transmission of the deformations to the surface.

4.5. The hydrogeology of the deposit

In general, in the case of underground mining, the hydrological factor is taken into account only in terms of the risk of flooding of underground mining workings. In the case of rock salt mines, in addition to this danger, water infiltration into the deposit and in underground mining excavations generates a significant risk due to the action of dissolving the rock salt massif and compromising the stability of underground resistance structures. Water infiltrations in the subsoil occur on natural fractures or induced by the underground mining [11].

Moreover, by dissolving the rock salt from the marginal safety pillars, voids are formed, larger or smaller, which themselves lead to local or more extensive phenomena of surface instability and which overlap with the phenomena of subsidence generated by the underground mining of rock salt. Hence the complexity of the phenomenon of surface deformation, sometimes combined with landslides.

The main factors whose interdependence influences the hydrogeology of the deposit are: geological (petrography of the deposit, water solubility of useful rock, tectonics of the deposit), hydrological and hydrogeological (hydrographic network, character of aquifers, precipitation) and anthropogenic (mining workings).

Through the changes they bring to the land morphology, especially through the appearance of longitudinal and transverse cracks, permeable and impermeable deposits allow the infiltration of precipitation waters and their accumulation in the depressed sectors on the back of the rock salt deposit and, hence, their infiltration into the underground mining workings.

The existence of old mining workings (bell shape chambers), partly unknown, from the area "Baia Verde" and "La Noroaie" make possible the infiltration of water in them and, from here, to the current mining area and represents the main water infiltration area to the rock salt massif.

The three lakes known as the Băile Verzi were born by accumulating water in the voids created by the collapse of the crown pillars of some old bell shape mines. The depths of the three lakes are the following: Baia Verde 1, 33 m; Baia Verde 2, 13 m; Baia Verde 3, 41 m.

In the area of the marginal pillar there is a particular situation, due to the presence of salt lakes on the alignment "La Noroaie - Baia Verde". The anthropo-saline ponor "La Noroaie" represents the main area of water infiltration towards the rock salt massif.

Among the geomorphological and geologic-dynamic factors, with implications on the hydrogeology of the deposit, landslides and karst phenomena are important.

In the Slănic Prahova perimeter, landslides are very frequent, especially in the slopes of the Tulburea, Baia Verde and Malul Roşu streams. From a hydrogeological point of view, the landslides and the ravines that are created determine the release, at certain points, of the rock salt massif and the production of favorable conditions for the penetration and circulation of water on the back of the rock salt deposit and, subsequently, their infiltration inside the rock salt massif and into the underground mining workings.

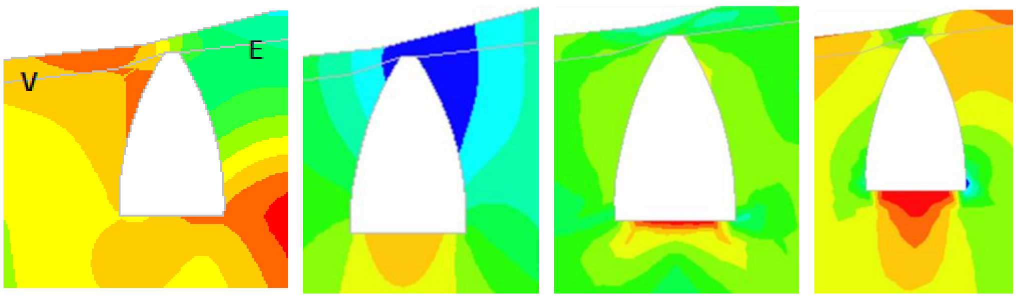
The action of the dissolving agents Baia Verde - La Noroaie gave rise to specific forms of saliferous karst, natural and anthropological-natural, both in rock salt and in the waste rocks that cover the rock salt deposit. The karst forms listed above represent ways of infiltration and circulation of water on the back of the rock salt deposit, from where the waters migrate through fractures into the underground mining workings.

4.6. The mining method and technology

The extraction of the Slănic deposit started at the end of the 17th century, in “bell shape” rooms (in Baia Verde Mine, Baia Baciului, Dorobăneşti, Grota Bârsei, Grota Miresei, Ocna din Vale and Ocna din Deal).

Although both the ogival shape of the chamber, which generated a favorable distribution of the mining pressure on the contour of the excavation, and the cutting of the rock salt without inducing cracks into the massif, would have determined a very good stability over time however, their proximity to the surface led to the collapse of the overlying rocks. Following the collapse of the rocks from the ceiling of the mines, the following salt lakes were formed: Baia Verde, Baia Baciului, Lacul Mare, Grota Miresei and Baia Porcilor. At the collapse of the ceiling of these mines have contributed both the thickness of the crown pillars and the low resistance of the rocks, as well as the infiltrations of water on the natural cracks and fissures and those induced by the state of stress in the ceiling of the rooms.

The lakes already formed on the ground surface and the presence, above and in the center of the deposit, of the other mines (Ocna din Vale and Ocna din Deal) and the access shafts to them, favored the infiltrations of water from the surface, towards the rock salt ridge and in the underground mining excavations, accentuating the rock salt dissolving phenomena, forming voids that contributed to the accentuation of the phenomena of ground surface deformation.



a) b) c) d)

Figure 9. 2D finite element model [5]:
Horizontal displacements (a), vertical displacements (b), maximum main stresses (c), minimum main stresses (d), developed around Ocna din Deal mine

The extraction of the rock salt from the bell shape chambers was done manually, which together with the adequate geometry of the mining pressure distribution on their contour, gave them a very good long-term stability (see Fig. 9). The only factor that contributed to the collapse of these rooms was the proximity of the ceiling to a few tens of meters from the surface, the collapse being facilitated by water infiltrations on cracks and fissures in the ceiling pillar.

Further extraction, in depth, under Ocna din Vale and Ocna din Deal, starting with the first half of the 19th century, of the Carol, Mihai and Unirea mines, by the mining method with large chambers with ogival transversal profile (Carol mine) and trapezoidal-rectangular profile (Mihai and Unirea mines), was a first leap in the technical evolution of the extraction of rock salt deposits, which allowed a better organization of the mining process.

The ogival and trapezoidal shape of the large rooms with a 60^{o} inclination on the ceiling is favorable regarding their stability. However, their proximity to the surface, the opening of 48 m and the height of 97 m, in the case of the Carol Mine, the width of 37 m and the height of 66 m, in the case of the Mihai Mine caused the loss of stability over time for these mines (Fig. 10). In addition to the state of stress developed around the excavations, the proximity of the two mines and the access wells, the low resistance of the rock salt massif, the waste rock intercalations and the micro tectonics, the water infiltrations into the mining workings and on the fractures with connection to the surface and the long-term effect of seismic waves have contributed to the production of instability in the case of these mines.

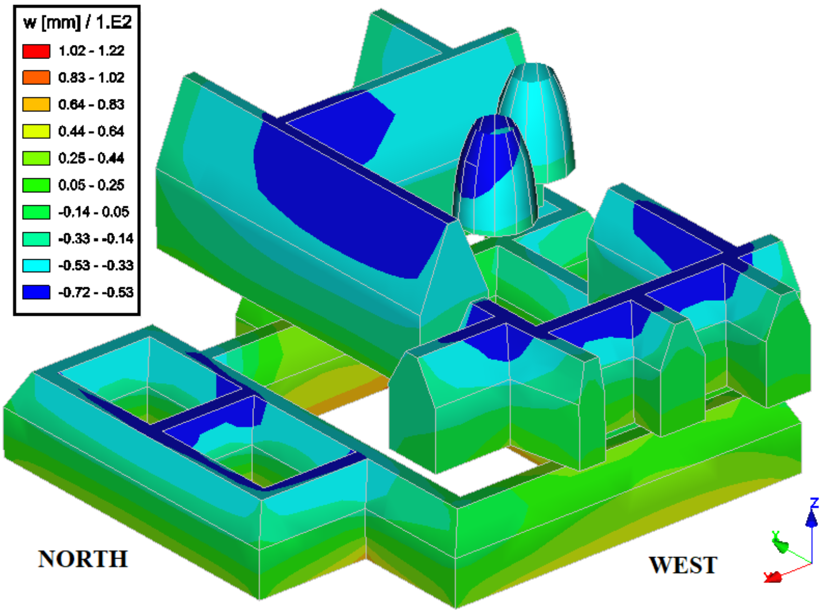


Figure 10. Development of the vertical displacements on the Old Mines (3D finite element modelling) [5]

4.7. The explosives detonating effect on the stability of the excavations and underground structures

The increase of the mining depth of the salt mines in Romania, and implicitly of the extraction level from the Slănic Prahova Salt Mine at over 300 m obviously determines an amplification of the state of stresses and strains, accentuated around the underground mining excavations. These phenomena are amplified by the repeated effects of seismic waves generated by systematic detonation, of approx. twice a day, of over 200 kg of explosive - induced seismic phenomenon, equivalent to a natural earthquake of 4-5 degrees on the Richter scale. As a singular effect, these seismic phenomena could be appreciated as insignificant, but their cumulative effect, over the years and even decades, is a very important one, destroying the integrity of the resistance structures on a depth appreciated at more than 0.6-1.0 m. The only effective solution available to solve the stability problems, highlighted above, is the abandonment of the use of explosives for the extraction of rock salt from the massif, in favor of mechanical cutting with the aid of roadheaders.

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THE INFLUENCE OF HYDROMETEOROLOGICAL CONDITIONS ON THE STABILITY OF SLOPES FROM ALUNU MINING PERIMETER

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Abstract: *Alunu lignite open pit, part of Berbești Mining Basin (Vâlcea County), is located in a hilly area, whose morphology, structure as well as the geological and tectonic conditions favor the periodic triggering (especially in periods characterized by heavy rainfall) of landslides, variable in size, volume of material involved and velocity. Obviously, on this natural background that favors the formation of landslides, in areas where human activity affects the integrity of existing geological formations, (in this case in areas of open pit mining of lignite deposits) the occurrence risk of such phenomena is amplified. Thus, in conditions of rainfall amounts well above the multiannual averages in a relatively short period of time (high intensity rainfall), on 23.05.2019, in the perimeter of Alunu open pit there was a large landslide, judging by the volume of rocks involved. The landslide had a violent character and a rapid extension in the upper steps and on the slope. The phenomenon began with local subsidence in the structure of the rocks in the slope, which were followed by the actual landslide. In this context, this paper analyzes the conditions and causes that led to the landslide, focusing on the influence of excessive rainfall in the area in the period preceding the event.*

Keywords: *Alunu open pit, hydrometeorological conditions, landslide, slope stability*

1. INTRODUCTION

The Getic subcarpathians, are framed from a morpho-structural point of view in the hilly floor with a high morpho-dynamic potential, where accentuated modeling

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processes and a great capacity of land degradation takes place [12]. It is an area where frequent landslides of progressive or regressive type occur, depending on the favorable factors, as well as subsidence or rock fall phenomena [1, 3]. The presence of landslides has been recorded over the years and is materialized through the presence of stabilized landslides and the existence of new or reactivated ones [1 – 4, 6].

From this point of view, the studies and investigations undertaken by different expert groups show very clearly that the geological structure of the region is totally unfavorable to ensure the stability of the slopes [1, 12]. The presence of the alternation of clayey-marly and clayey-dusty rocks with sandy or sandy-clayey formations or intercalations, with inclinations concordant with the inclination of the slopes and the existence of anticline or synclinal flanks on certain alignments, are structural elements that favored and favor the production of morpho-functional changes by landslides or subsidence (fig. 1) [2, 7]. The contact surfaces between sandy and clayey formations or between diluvial formations and bedrock are the most favorable surfaces for landslides, especially in conditions of increased humidity or water saturation of sandy rocks, when colloidal or dusty clays tend to liquefy in the area of contact plans [13].

Figure 1. Complex instability phenomena on natural lands (unaffected by human activity)

It has been found that most landslides occur during periods of heavy rainfall (most often in spring after melting snow or in autumn during periods of heavy rainfall following periods of drought), when the amount of water infiltrated into soil and subsoil is increased, which causes a decrease in rock strength, an increase in volumetric weight, the manifestation of water pressure in the pores and hydrodynamic pressure, all with an unfavorable influence on the stability of natural or artificial slopes (of engineering earthworks) [1, 3, 6]. To these are added the phenomena of freeze-thaw, temperature variations and especially drought, when there are additional ways of water penetration along the path of cracks and fissures, which can later become surfaces of detachment or slipping of rock masses [12, 13].

In the areas where the identified lignite reserves, located in the Dacian deposits, are extracted through open pit mining works, the natural predisposition to landslides of the slopes is amplified by the imbalances that appear in rock mass due to the excavation works [1, 3, 4]. In turn, these imbalances associated with mining activity can lead to the loss of the stability reserve of the excavated massif when the elements stipulated by the technical projects for the execution of mining works and the exploitation programs are not strictly respected [11] (the designed geometric elements, the gap between machines, speed and direction of advance in the work fronts, etc.).

2. DESCRIPTION OF THE LANDSLIDE

Following the observations made in the field, the analysis of the available video and photo materials and the discussions with the technical staff, the research team established that it was a deep landslide, of regressive type, with fast deployment, very dangerous and with catastrophic consequences.

The dislocation of the earth mass took place over a length of approx. 60 m and a width of approx. 20 m as well as a level difference of approx. 40 m, the dynamics of this landslide involving three main successive phases:

1. The detachment and collapse of the rocks from the slope of the work front, when a first imbalance of the rocks from the massif takes place by reducing the support forces;
2. The extension of the phenomenon in the upper steps and on the slope (fig. 2), when the actual slide occurs, and the mass of moving rocks creates an additional pushing force;

Figure 2. The upper left side of the landslide (detachment area)

3. Stabilization of the slide by rebalancing the active forces from the massif with the passive forces (of support) of the slipped rocks in a non-uniform geometry (fig. 3).

a

b

Figure 3. The uneven geometry of the stabilized landslide (a – left side of the landslide, b – frontal view of the landslide)

Also, there was identified an area in which a post-slide dejection cone (alluvial fan) was formed and where flows of the fertile upper layer to the affected area were observed. Such lower amplitude flows were also reported in other areas, on the contour at the top of the slide (fig. 4).

Further analyzing the causes that led to the landslide from 23.05.2019, the members of the research team concluded that this was a complex phenomenon, influenced by multiple factors, both natural and anthropogenic, but with a predominant role of those related to geomining conditions and hydrometeorological conditions.

a

b

Figure 4. Flows of the fertile upper layer (a – through the post-slide dejection cone, b - on the contour of the slide)

Thus, the land morphology, geology and hydrogeology of the region, the mineralogical composition of the rocks in the slope, their granulometry, the geometry of the slope, the large amounts of precipitation (104.8 l/m^2 in only 22 days) and their intensity corroborated with the predisposition of the rocks in the composition of the slope to allow water infiltration and storage have converged to a greater or lesser extent in triggering the landslide.

In view of the above, following, in the paper, stability studies are presented for two sections materialized in the area of landslide. It is very important that these sections were made based on the topographic surveys performed on 22.05.2019, one day before the landslide (practically we had an exact situation of the slope geometry before the landslide).

The stability analyzes took into account the average values of the geotechnical characteristics (volumetric weight, cohesion and internal friction angle) provided by the operator [17] (after a verification of their correctness by means of laboratory tests performed on the samples taken during the two field trips) and for lignite these characteristics were determined in the laboratory and compared with data from the literature and specialized studies for validation [5, 14].

3. FAVORING AND TRIGGERING FACTORS

3.1. Conditions characterizing the deposit

Pliocene age formations participate in the geological composition of the Alunu mining perimeter. The coal layers are cantoned in Dacian formations, represented by an alternation of clay-sandy rocks, in which clays, sands and different combinations of them predominate, with accentuated variations of lithological or granulometric facies, both vertically and horizontally [6 - 8].

In the bed and roof of the coal layers, clay rocks predominate, with frequent intercalations of sand, of various granulometric structures, characteristic of sandy clays and clayey sands, more or less compact and consolidated.

The upper sedimentary deposits belonging to the Romanian and Quaternary, consisting of weakly cohesive and non-cohesive rocks, trapped in a sandy-clay material, over which clays and sandy clays with metric thicknesses were deposited. There is also the existence of alluvial terraces along watercourses, dejection cones, diluvial deposits and, especially, areas with landslides that are periodically reactivated due to the influence of hydrometeorological and climatic factors [9, 10].

The lithological structure of the Dacian, Romanian and Quaternary formations allows the infiltration and storage of water in the rock mass and the formation of aquifer layers and horizons. As a result, conditions of saturation of clay rocks are created, which determines the modification (in the sense of worsening) of their resistance characteristics. The supply source of aquifers and horizons is represented by atmospheric precipitation and infiltrations from the hydrographic network [6].

Coal layers, with exploitable thicknesses from 1 to approx. 4 m, have a complex structure, being composed of several lignite banks, and separated by sterile intercalations. Such a structure creates difficulties in the technological process of extraction, due to the need for selective excavation, while affecting the geometry of the excavation fronts [9, 10]. Moreover, the presence of ripples in the layers and their inclination of 2 - 5º from N to S and from W to E, forces the excavation in the bed for the horizontalization of the bottom of the open pit [4], which represents another difficulty in the extraction process with high capacity bucketwheel excavators [11].

Tectonically, the Amaradia-Tărâia lignite deposit, of which the Alunu mining perimeter is part, is weakly affected by disturbances. The coal complex is contained in a wide monocline, oriented W - E, with inclinations of 5 - 10º to the south [9, 10]. Locally, there are small ripples and some stratigraphic gaps, which are not highlighted precisely enough, given the 200 x 200 m exploration network (with boreholes) [17]. The existence of such a network does not detail the investigation of the deposit from a structural and tectonic point of view, being possible the existence of micro-faults or fracture lines at the level of the layers.

3.2. Morphological conditions

From a morphological point of view, the Alunu mining area belongs to the hilly areas in the northwest of Oltenia, which develops south of the Târgu Jiu - Râmnicu Vâlcea depression. It includes a hilly area with altitudes between 320 and 450 m, which decrease to the southeast, being crossed by the valleys of the rivers Amaradia, Olteţ and Tărâia and by the valleys of their tributaries. The valleys fragment the geological formations within the perimeter up to minimum elevations of approx. 360 - 310 m [8]. The fragmentation of the covering rock mass led to the existence of slopes, where the stratigraphic structure, but especially the nature of the rocks (weakly cohesive and non-cohesive) facilitated the production of natural landslides, stabilized over time, but which can be reactivated by adverse weather conditions or excavations in the roof of the deposit [1, 3].

From a geotechnical point of view, the Amaradia hills are classified as high risk areas, according to Law 575/2001, Annex V - regarding landslide risks [16]. Superficial natural landslides are also reported on the slopes of the Alunu open pit perimeter. Their occurence and reactivation in the southeastern part of the perimeter required the dismantling of the T-750 conveyor from the site arranged on the slopes in this area. The T-750 conveyor ensures the transport of sterile rocks from the upper steps of the open pit to the exterior waste dump [17].

It is worth mentioning that the landslide from 23.05.2019 occurred in an active area from this point of view, in unfavorable weather conditions, to which also contributed the concordance between the direction of the level curves of the slope from elevations 350 - 420 m and the direction of the slope itself. The existence of the active area is also highlighted by the allure of the level curves 330 - 340 m, which enter towards the slope, without preserving the linearity between them and the direction of the lateral slope.

The fragmentations and possible displacements of the rocks can also be related to the historical erosions of the Olteţ river [8, 9], located at approx. 400 m distance from the work front, highlighting in this sense the non-interception of layers III and IV of lignite in the exploration drilling no. 61792, but found about 100 m to the east in the excavation works for arranging the embankments of the conveyor belts near the SO-6 transformation station at elevation 305 m [17].

3.3. Hydrometeorological conditions

Regarding the hydrometeorological conditions from May 2019, data were requested on the precipitation recorded at the weather station closest to the Alunu open pit, respectively the Polovragi weather station (located at a distance of about 20 km from the Alunu open pit). It should be mentioned that at the request of the operator, the Oltenia Regional Meteorological Center provided rainfall data from the Râmnicu Vâlcea meteorological station (located about 60 km from the Alunu open pit), data that are not considered relevant for the studied area. As a result, the research team obtained the daily precipitation sheet from the Polovragi weather station, and the data are presented in the diagram in figure 5.

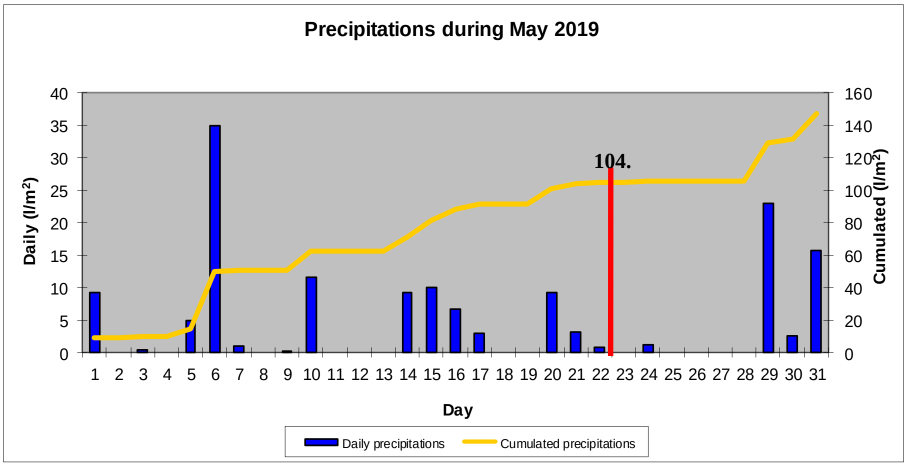

Figure 5. Precipitations recorded at Polovragi weather station between 1 and 31.05.2019

Analyzing the diagram in figure 5, it is found that May 2019 was characterized by abundant rainfall, totaling 147.3 l/m^2. It is observed that most of these precipitations (104.8 l/m^2) were registered in the first three weeks of May (1 - 22.05.2019), before the occurrence of the investigated landslide.

It can be added that the peak of precipitation, recorded on May 6, was followed by repeated precipitation, lower in quantity. However, there is a time lag between the moment of precipitation and the accumulation of water in the soil and subsoil.

The permeability of sandy rocks and the hydrophilic properties of clays favored both the infiltration and the accumulation of water from precipitation in the subsoil, in the form of free and physically bound water [12]. These processes have had unfavorable effects on the strength characteristics of the rocks, in the sense of increasing the weight of the rock mass by water supply and reducing the shear strength (by decreasing the cohesion and internal friction angle of clayey and clayey-sandy rocks) [13].

4. ANALYSIS OF SLOPE STABILITY UNDER NORMAL CONDITIONS (NATURAL HUMIDITY)

As a first step, the stability analyzes performed aim to determine the technical condition of the slope before the landslide occurs. The results of the stability analyzes allow the assessment of the stability reserve and the conditions for the safe execution of the excavation works.

In order to perform the stability analyzes, samples were taken, both from the sterile cover and intercalations, and from the second layer of lignite, samples on which laboratory tests were performed. The results obtained confirmed the average values of volumetric weight, cohesion and friction angle presented in the existing documentation. It is mentioned that the coal samples were subjected to compressive and tensile breaking tests, through which the specific characteristics of the shear strength were determined. Analyzing the literature and specialized studies [5, 14] that contain values of physical and mechanical properties of lignite from Oltenia and corroborating these values with those obtained in the laboratory, the average values used in the stability analysis were established (table 1).

It is specified that when establishing the calculation values, the proportions of the main types of rocks (sand, clay, dust) present in the cover and the sterile intercalations within the slope structure were taken into account.

Table 1. Physical and mechanical properties of the rocks at natural humidity

Parameter / Rock type	Volumetric weight γ [kN/m^3]	Cohesion c [daN/cm^2]	Internal friction angle φ [degree]
Sterile rocks	19.80	0.40	19
Lignite	12.00	3.40	49

The stability was analyzed using the specialized software SLOPE, taking into account the stratigraphy and the type of rocks, the sliding mechanism, as well as the geometric configuration of the slope. The calculations were performed using the methods of Fellenius, Bishop, Simplified Janbu and Bell. All these methods are based on the limit equilibrium theory, and the sliding surface was considered cylindrical-circular, a shape that is characteristic of the type of rocks that make up the slope.

The two sections were modeled with the help of SLOPE software, respecting the geometry of the slope before sliding, according to the situation plan. After running the calculation program, the results presented in table 2, respectively in figures 6 and 7 were obtained.

Table 2. Results of the stability analyses at natural humidity

Section	Stability coefficient, s			
	Fellenius	**Bishop**	**Janbu**	**Bell**
P2	1.15	1.16	1.34	1.18
P3	1.20	1.22	1.27	1.28

It is stated that only the figures illustrating the results obtained by the Fellenius method were included, because it is the method that leads to the lowest values of the stability coefficient. From the figures shown, it is observed that a possible slip would cross the rock formations present in the working front and would move a relatively large volume of material.

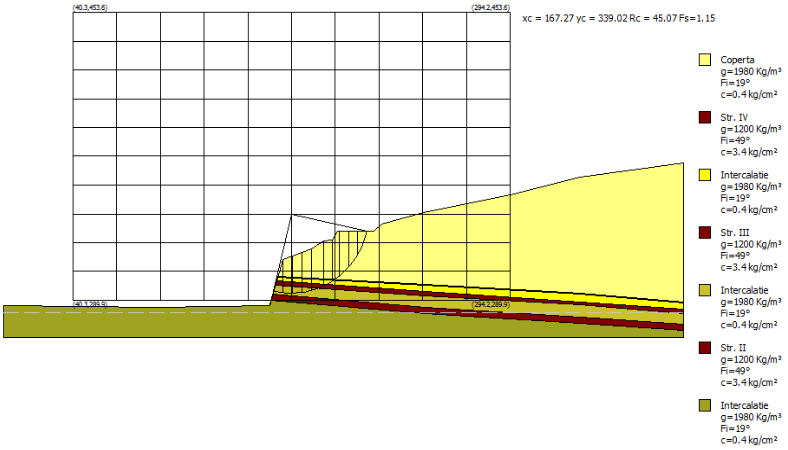

Figure 6. Cross section P2 (natural humidity)

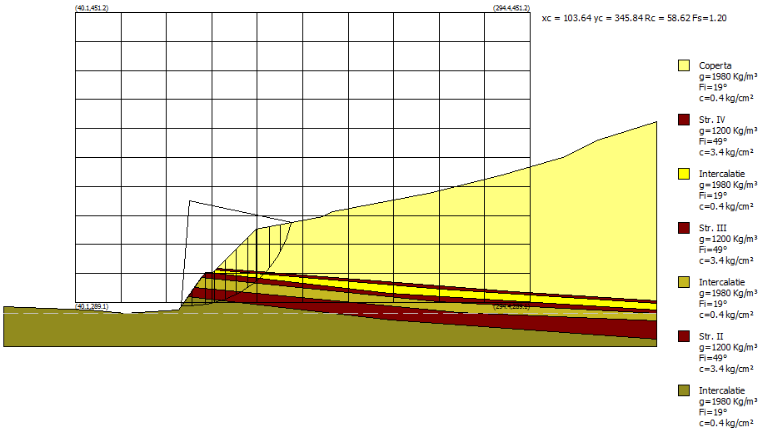

Figure 7. Cross section P3 (natural humidity)

The results of the stability analysis (for natural humidity conditions) show the following:

- the values of the stability coefficient are higher in section P3 due to a more favorable geometry;
- in both sections, under conditions of natural humidity, superunitary values of the stability coefficient have resulted from all the methods used, which indicates that the slope is stable;
- the lowest stability reserve (s = 1.15) is found in section P2, being obtained by the Fellenius method;
- given that the slope of the working front is one with a short residence time, according to the literature [13, 15], a stability reserve corresponding to a coefficient between 1.1 and 1.2 can be considered as sufficient.

5. THE INFLUENCE OF EXCESSIVE PRECIPITATION ON THE STABILITY OF THE SLOPE

In the context in which the precipitations registered in the area exceeded the meteorological norms (multiannual averages) corresponding to May (see paragraph 3.3), it was considered that by infiltrating the water in the subsoil, the rocks reached the saturation limit.

As a result, using the software option to analyze the stability under saturation conditions (respectively the corresponding reduction of the mechanical strength characteristics of the rocks), the stability analyzes were redone, the results being presented in figures 8 and 9 and in table 3. As in the case of rocks with natural humidity, the analyzed sections were P2 and P3, and the inserted graphical representations are those resulting from the application of the Fellenius method.

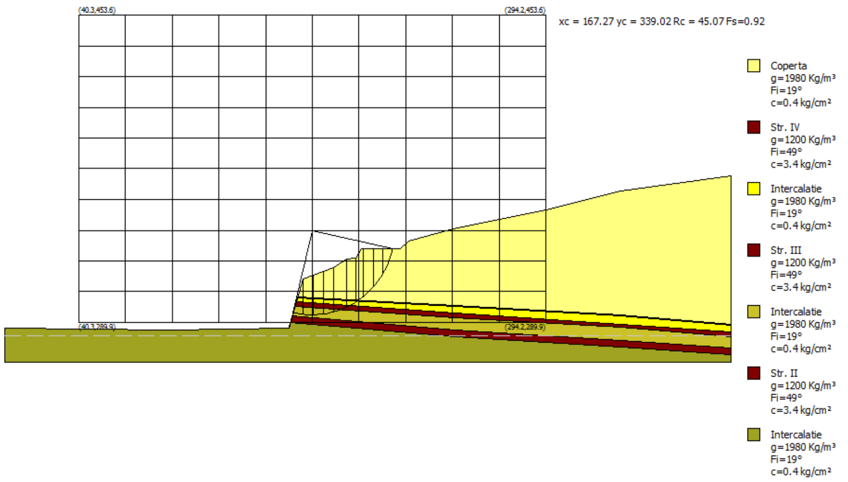

Figure 8. Cross section P2 (saturated rocks)

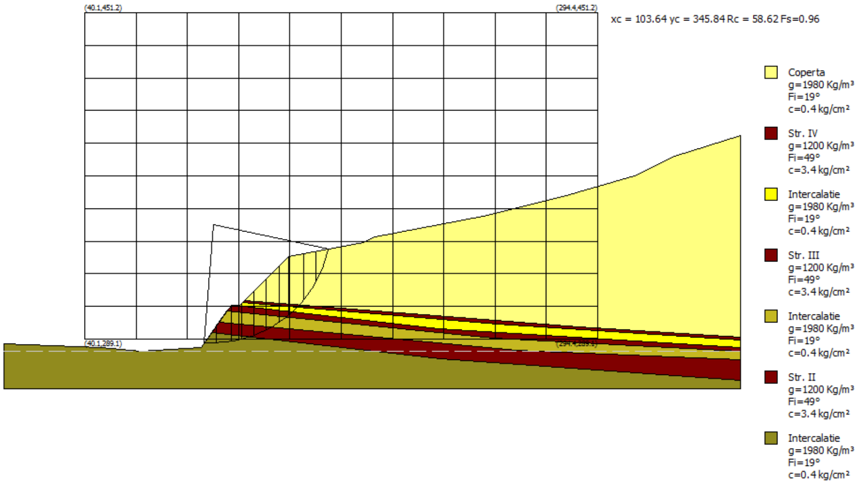

Figure 9. Cross section P3 (saturated rocks)

Table 3. Results of the stability analyses at saturation

Section	Stability coefficient, s			
	Fellenius	**Bishop**	**Janbu**	**Bell**
P2	0.92	0.93	1.07	0.95
P3	0.96	0.98	1.02	1.02

Analyzing the results in table 3, the following conclusions can be drawn in saturation conditions of the rocks:

- for section P2, three of the four methods used indicate the loss of stability of the working front slope (stability coefficients are subunitary), only the Simplified Janbu method indicates a superunitary stability limit (s = 1.07);
- for section P3, two of the analysis methods used lead to subunitary values of the stability coefficient (Fellenius and Bishop), and the other two (Simplified Janbu and Bell) indicate a superunitary stability limit (s = 1.02);
- the reduction of the stability reserve in case of saturated rocks is around 20%;
- the critical sliding surface affects the slope on the entire height, and the sliding phenomenon puts into move a large volume of rocks.

6. CONCLUSIONS

The landslide from the morning of 23.05.2019 occurred on the slope of the work front, having a violent character and a rapid extension in the upper steps and on the slope. The phenomenon began with local subsidence in the structure of the rocks in the slope, which were followed by the actual landslide. The landslide involved a large volume of rocks, and occurred rapidly, without signals or precursors and without the existence of a slow phase.

In order to perform the stability analysis, the sections on the situation plan dated on 22.05.2019 considered to be relevant were modeled in a specialized software, taking into account the stratigraphy, and 4 methods of analysis based on the theory of limit equilibrium were used.

In the first situation, considering the rocks at natural humidity, the analyzes indicate that the slope (both sections), taking into account the short period of time in which they in place, is stable, with a stability reserve between 15 and 20%. (in accordance with the recommendations in the literature).

Given those presented in the paper regarding the amount and intensity of precipitation in May, in the second stage of the stability analysis, we considered that the drainage capacity of the rocks in the slope was exceeded and under these conditions they reached the saturation limit.

By running the software under these conditions (keeping the slope geometry but reducing the values of the mechanical strength characteristics of the rocks accordingly) unsatisfactory stability coefficient values were obtained: for section P2, three of the four methods used indicate loss of slope stability of the working front (stability coefficients are subunitary), only the Simplified Janbu method indicates a superunitary stability limit (s = 1.07); for section P3, two of the analysis methods used lead to subunitary values of the coefficient of stability (Fellenius and Bishop), and the other two (Simplified Janbu and Bell) indicate a stability limit (s = 1.02) superunitary, but at the very limit of equilibrium.

In other words, all the methods of analysis used (in saturated conditions) show either that the slope is unstable or that the stability reserve is below the 10% limit recommended by the literature.

The reduction of the stability reserve in the case of saturated rocks is around 20%, and the critical sliding surface affects the slope on the entire height, the sliding phenomenon moving a large volume of rocks which is in full accordance with those observed in the field.

As a general conclusion, it can be stated that the abundant and intense precipitations had a major contribution in triggering the landslide analyzed through the phenomenon of saturation of the rocks in the slope (having as effect the increase of their volumetric weight and the reduction of shear strength characteristics: cohesion and internal friction angle).

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POSSIBILITIES TO CONSOLIDATE THE UNDERGROUND MINING EXCAVATIONS MARKED BY INSTABILITY AT THE SLANIC PRAHOVA SALT MINE

DACIAN-PAUL MARIAN [1], ILIE ONICA[2]

Abstract: *The underground mining from the Slănic rock salt deposit of a volume of over 15.5 million m^3, in a period of over 350 years, led to the appearance of some phenomena of loss of the stability of the underground excavations, until their collapse, and the surface deformation. Over time, a number of less effective temporary local measures have been taken against these destructive phenomena. In this article, starting from the existing and perspective situations of the Slănic salt mine, two main categories of consolidation of mining excavations marked by instability are proposed, namely: consolidation of salt structures (pillars and ceilings) affected by instability by using cablebolts; and filling underground voids with backfill paste.*

Keywords: *rock salt, consolidation, rooms, pillars, ceilings, cablebolt, backfill paste*

1. GENERAL INFORMATIONS ON THE INSTABILITY OF THE RESISTANCE STRUCTURES AND OF THE SURFACE FROM THE SLANIC PRAHOVA SALT MINE

The underground mining of the rock salt deposit from Slănic Prahova started in 1668, over 350 years ago, in a bell-shaped room, located close to the surface. Then, in 1865, the mining method with large trapezoidal-rectangular rooms was introduced, and in 1970 the mining method with small room and square pillars was adopted, a method used until today. With this last method, the levels, with a height of 16 m, from the Victoria and Cantacuzino mines were mined. The 30 x 30 m network, on which the mine structure was designed, was adapted in depth, starting from rooms with an opening of 15 m and square pillars with a side of 15 m, up to the first level below the leveling pillar from the level +145 m, from the New Mine Slănic. From here, the rooms were designed at an opening of 12 m, and the pillars at a width of 18 m [3].

After more than 300 years, from the beginning of the operation of the "bell shape" rooms, the crown pillars above the rooms collapsed, and the collapse spread to

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the surface, leading to the formation of salt lakes: Baia Verde, Baia Baciului, Lacul Mare, Grota Miresei and the Baia Porcilor.

Also, the Carol and Mihai mines and the 12 levels of the Victoria mine became inaccessible as a result of the collapses that took place, over time, inside the rooms.

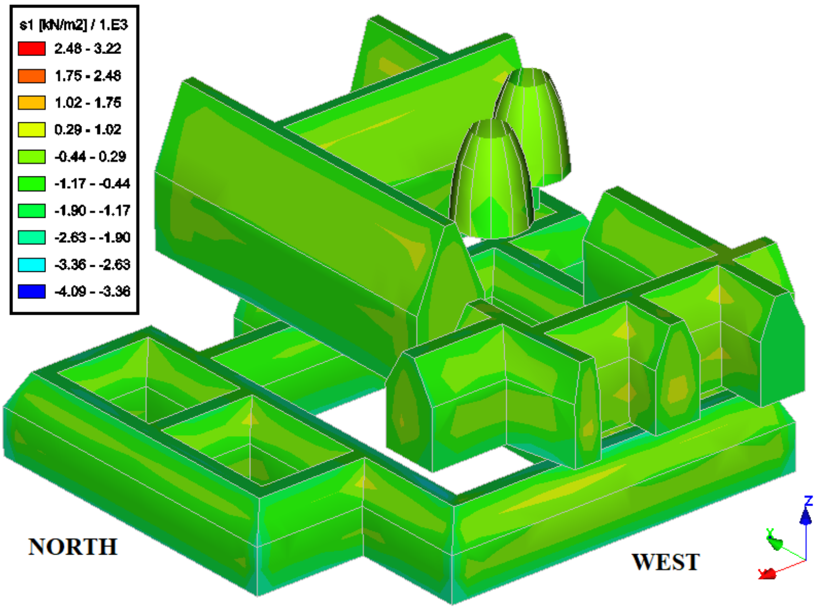
The Cantacuzino mine was opened in 1992 and continued to operate on 7 levels (from level V to level XI).

As the rock salt mining progressed, in the ceilings between the levels, cracks / fractures appeared approximately parallel to the eastern marginal pillar. The fractures have a development on the whole eastern opening of the level, on a strip of about 50-60 m, starting from the floor and the ceiling, from negligible amplitudes, up to a few meters, towards the interior of the ceilings. These fractures have caused the stability of the levels to be more or less affected, the phenomenon being in continuous development, over time. Due to the structural defects, also highlighted by the electrometric measurements [1, 9], the vertical displacement / subsidence of the ceilings was accentuated in the areas affected by cracks, as they were highlighted by topographic mapping and monitoring. Currently, the only levels that can be used safely are levels X and XI.

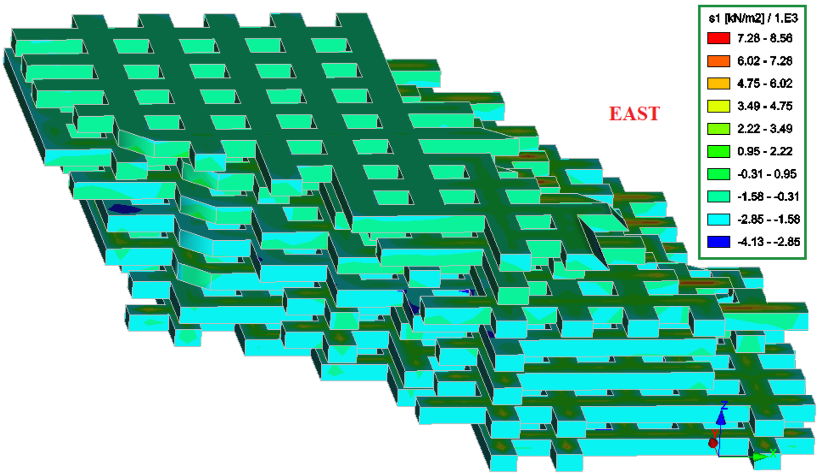
To a greater or lesser extent, the stability of the surface was also affected (subsidence, landslides, etc.) and implicitly of the industrial and civil buildings, located in their area of influence. The monitoring of the deformation of the surface and of the constructions located in the affected areas was performed by topographic measurement of subsidence and displacement of landmarks located on the foundation of buildings, in the area of influence of underground excavations [6].

We appreciate that, so far, a reserve of over 32 million tons has been extracted from the Slănic Prahova salt mine, which has led to a volume of excavations in the rock salt massif of over 15.5 million m^3. Without further scientific analysis of stability, only by taking into account the huge volume of voids created in the salt massif and taking into account the increase of the mining depth at over 300 m, we can anticipate the phenomena of instability that have developed since over almost 350 years of underground mining (Fig.1).

In order to counteract the damage caused by the instability of the resistance structures at Slănic salt mine, a series of measures have been practiced over time in order to maintain the stability of underground mining excavations and the stability of the ground surface and surface buildings, in acceptable security conditions. Of these, we mention the following more important measures: drainage of surface water and discharge of water infiltrated underground; filling with concrete or waste rocks from the surface of some mining workings; injection of concrete around some mining works; waterproofing of some watercourses, etc. Unfortunately, these measures were effective only in the short term, and in the long term there was a continuous degradation of the underground mining excavations, sometimes to the point of collapse, as summarized above.



a)



b)

Figure 1. The distribution of maximum principal stresses, in kN/m^2 – 3D modelling with finite element [6]: a) Overview of the Old Mines; b) Overview of the Cantacuzino mine

In general, the technical measures that were effective worldwide, in conditions similar to those existing at the Slănic Prahova salt mine, were the following: 1) the consolidation of the rock mass in the support structures (pillars, ceilings, contours of the excavations), with the aid of cablebolts; 2) filling the dissolution voids and those resulted from the underground mining with backfill material.

2. THE CONSOLIDATION OF THE ROCK SALT MASSIF BY CABLEBOLTING

In general, the supports of the excavations used in the field of mining and civil engineering fall into two main categories: a) load-bearing supports; b) consolidation supports. If the first category is based on the principle of generating by the artificial or natural support structure of a reaction, which is opposed to the stresses developed by the massif (due to the imbalance of rock masses), the second category is based on the principle of strengthening the resistance characteristics of the rock massif.

If the mass of rocks (here, the rock salt) can take over relatively efficiently the compressive stresses, having much lower tensile and shear strength, most collapse phenomena have occurred due to the exceeding of these strength limits. In general, taking into account that the resistance properties of the rock salt massif according to the planes of cracks and fissures existing into the massif are the lowest, the cablebolts that cross these planes of minimum resistance can take over these stresses, thus maintaining the continuity of the massif and avoiding a potential collapse.

The role of the cablebolts inserted into the massif is precisely to take over the tensile and shear stresses, developed into the massif. In this context, the effects produced by the anchored support and the support with cablebolts on the mass in which they are introduced are the following: a) the suspension effect; b) the beam effect; c) the consolidation effect. The first effect refers to the suspension of the blocks from the rock massifs traversed by the fracture sets, which delimit the articulated blocks. The second effect is generated by the cablebolts inserted approximately perpendicularly in a bundle of layered rocks, by increasing their bending rigidity. The last effect is the consolidation one, in which case both the massif and the steel cablebolts participate united in taking over the stresses developed into the massif. However, in practice, these effects are present in all cases of use of bolted support systems, however there is a predominant effect, of the three listed, generated by the presence of bolts in a certain location [10].

The first use of cablebolts in the mining industry, in generalized form, took place in the 1970's, at the cut-and-fill stoping underground mining method [4], but their first uses seem to have taken place in Canada [5] and in 1964 in South Africa. Since then, the use of cablebolts has exploded in popularity, being introduced in all mining countries (Canada, Sweden, Finland, South Africa, etc.) [2].

Towards the end of the 1970s, the use of cablebolts for cut-and-fill stoping underground mining was common practice and well mastered. Due to market price pressures, the mining industry has had to move towards more productive mining methods, such as open-pit or underground mining with large chambers and long holes blasting. Under the conditions of these methods, the cablebolts were used to increase the stability of the surrounding rocks and the preparatory workings. Thus, the application of cablebolts to all types of mining methods has become widespread [2].

From the outset, we consider that, in general, classical anchors/bolts are not effective for consolidating the rock salt masses both because of their operating principle (especially those with point mechanical grip and those with friction) and because of their relatively short length.

For the conditions of the rock salt mines from Romania, we propose the use of fully grouted cablebolts both for the consolidation of the ceilings between the levels, and for the consolidation of the pillars and, in general, of the underground excavations executed in the rock salt massifs.

To strengthen the ceilings between the levels, the cablebolts must be mounted in boreholes that cross the fracture/fissure planes. At least in the case of the Cantacuzino mine, the boreholes must be drilled diagonally to the fracture planes.

Regarding the consolidation of the "small square" pillars (from the Cantacuzino mine or, in the future, from the New Mine Slănic) with the aid of the cablebolting, a horizontal arrangement of the cables on the whole width of the pillars is preferred, by fixing their ends with stretching devices (not necessarily with pretension which, in the case of cables, do not have too much efficiency) and grouting along the entire length of the cable (with cement paste or synthetic resins). The cable network is placed in pillars according to a scheme that must take into account the value and orientation of the maximum deformations of the pillars.

In the case of strengthening the walls of the large chambers (from the Unirea mine) or opening mining works, cables must be of sufficient length to allow them to be fixed in an area of the massif with acceptable deformations. They will be inserted in the probe holes, at the wall level, and cemented according to a scheme adapted to each location.

Due to the high heights at which the drilling rigs must operate, beyond their technical possibilities, it can be studied an inclined arrangement of the network of cablebolts, in order to facilitate their execution at the level of the floor of the chambers / rooms.

The costs of strengthening the support structures with the aid of cablebolting (which are recovered used materials) are not prohibitive, and their advantages using these procedures are considerable. The cost is mainly determined by the execution of the boreholes and of the value of the binder, especially in the case of the use of synthetic resins. If cement paste is used for fixing the cables, then the cost decreases exponentially.

Several authors have tested various types of cables, as well as different types of cement paste/slurry, but there is a consensus in the mining industry to use a single cable with 7 steel wires of 15.2 mm in diameter [13], fixed with a Portland cement paste in a ratio of 0.3-0.4 water / cement. It has also been established that the maximum value of the pull-out strength of the cablebolting is a function of the properties of the rock mass, of the cement and the state of stresses.

The installation of a cablebolting is carried out as follows: after drilling a hole with a diameter of 51 mm, with a given length (for upward drilled holes, the maximum length is about 20 m, because at longer lengths, the mass of the cable becomes very large and difficult to handle) cement paste is injected into the hole. Cement paste/slurry is injected according to the following three methods [12]:

1) The injector tube is attached to the cable, the ends of the cable and the tube being connected together. The assembly is pushed to the bottom of the hole and the cement slurry is pumped filling the hole, from the bottom to the mouth of the hole;

2) An air exhaust pipe is attached to the cable, the assembly being inserted to the bottom of the hole. The injector tube is installed at the mouth of the hole, which is sealed. The cement slurry is injected until it is removed through the exhaust pipe;

3) An injector tube is placed at the bottom of the hole. The hole is filled with cement slurry, gradually withdrawing the injection tube and the cable is thus installed.

In the conditions of the Slănic Prahova rock salt mines, and of other salt mines from Romania, the only type of support that can ensure the consolidation of the resistance structures (ceilings and pillars) are the supports with cablebolts. However, supports with grouted anchors/bolts can also be effective in the case of opening mining workings excavated in rock salt, such as the inclined workings for trucks access and shafts, in areas where there is an intensification of their deformation.

Cablebolts can be used to strengthen the resistance structures in the active areas of the mines where the mining activity has ceased, but continue to be in operation, such as: levels X and XI of the Cantacuzino mine, where the processing plant is located; the large trapezoidal-rectangular rooms at the Unirea mine, which are maintained for tourist purposes; the pillars between the rooms and the ceiling between the levels +145 m and +129 m, from the New Mine Slănic, where the rock salt mining will continue in the future and will ensure the entire production capacity of the Slănic-Prahova saline.

The schemes for mounting the cablebolts will be adapted and designed to the local conditions of each structure which needs to be strengthened. In the case of salt deposits, in order to be effective, the cablebolts must be located in the areas with the greatest deformations and be oriented according to the vector of maximum displacements, in order to effectively take over the pull-out efforts developed from the massif. In the conditions of a fractured structure (pillar or ceiling), the cables must efficiently take over the shear stresses and, therefore, will be placed in boreholes that cross the planes of minimum resistance, at an angle as close as possible to 90^{o} (technically possible).

Although each cable anchoring system must be designed for the specific conditions of each case, the following are some examples of boreholes arranging schemes for cablebolts, namely: a) for strengthening the ceiling between levels and of a square pillar crossed by a family of fractures; b) for the consolidation of the square pillar with large horizontal deformations; c) for consolidating the wall of a large trapezoidal-rectangular room.

Figure 2 shows an example of reinforcement with three rows of anchoring cables of the fractured ceiling between level IX and X, for the second row of rooms from the east part of the Cantacuzino mine, between rows of pillars I40 and J40. The boreholes are drilled in such a way as to intersect the fracture sets, in order to prevent the movement of the salt blocks detached from the ceiling, according to the fracture planes. In this case, the cablebolts are mainly subjected to shear stresses, but they also take over the tensile stresses developed as a result of the complex bending of the ceiling, thus helping to reduce its subsidence.

The reinforcement using anchoring cables of the square pillars is exemplified in figures 3 and 4. In the example from figure 3 is represented a safety pillar from the level +129 m, from the New Mine Slanic, taking into account the distribution of the safety coefficient. In this case, the layout of the anchor cables took into account the maximum horizontal displacements of the pillars (the expansion from the middle of the pillars), due to the fact that they are subjected to compressive stresses. To prevent this phenomenon, with the best possible efficiency, the anchoring cables were placed in the middle of the pillars, on three symmetrical parallel rows, at equal distances of 2m, 4m and 6m, so that they will be subjected mainly to tensile stresses. Note that the location of the cables is identical on the two pairs of vertical surfaces of the pillars, with certain gaps, to avoid the intersection of the boreholes.

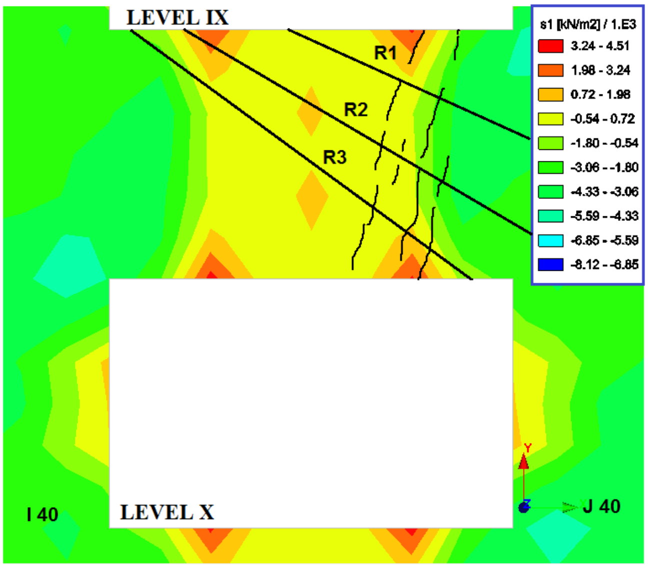


Figure 2. The reinforcement with three rows of anchor cables (R1, R2 and R3) of the fractured ceiling between levels IX and X, for the second row of rooms from the east, between the rows of pillars I40 and J40, the Cantacuzino mine (scalar representation of the maximum principal stresses, în kN/m^2 – 2D finite element modelling) [6]

For drilling the rows of boreholes at a height of 4 m and 6 m from the floor, it is necessary to purchase drills that can perform drilling operations at this level. Accordingly, the layout of the cablebolts can be adapted to the technical and operational characteristics of the drilling rigs existing at the Slănic salt mine. In this sense, figure 4 shows an example of reinforcement of the row of pillars G40, level IX, from the Cantacuzino mine, with inclined cablebolts, drilled from two parallel surfaces. If necessary, the inclination of the cables can be correlated with the inclination of the sets of fractures that affect the body of the pillars. The drilling operation can be designed by piercing the pillar on both parallel surfaces, when it is possible to prestress the cables or they can be made with a length less than the inclined distance between the two free surfaces of the pillars.

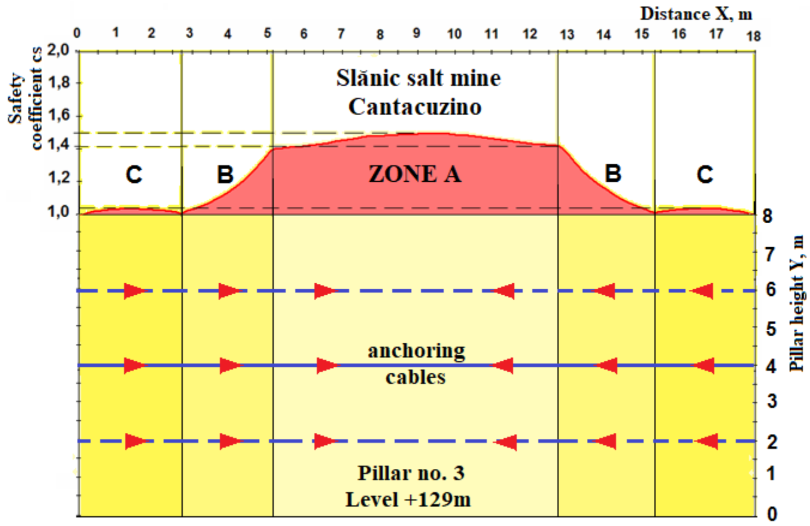


Figure 3. Mounting the anchor cables in a pillat at the Slanic salt mine, taking into account the safety coefficient calculated for a horizontal section from level +133m (halfway up the pillar), New Mine Slanic [6]

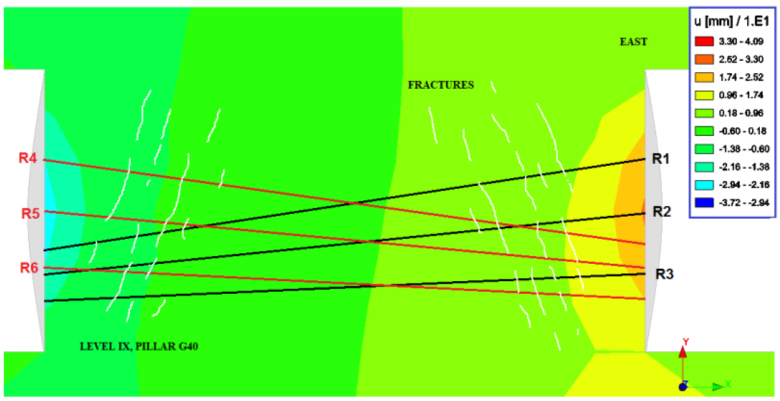


Figure 4. Reinforcement with inclined anchor cables of the G40 pillar, level IX, from the Cantacuzino mine -R1, …, R6–rows of cablebolts (scalar representation of the horizontal displacements–*u* in mm–2D finite element modelling) [6]

The rooms at the Unirea mine are kept in operation for the tourist activity and because their degradation was found, starting from the level of the walls, in the example from figure 5 a scheme of inclined location of the boreholes is presented, taking into account the technical possibilities of drilling of the boreholes. The boreholes were located in the areas where the walls of the chambers show the most important tendency of plastic deformation and where a series of fractures developed approximately parallel to the surface of the walls. In this case, the cablebolts are subjected both by tensile stresses (to take over the expansion of the walls) and by shearing stresses, according to the fracturing planes.

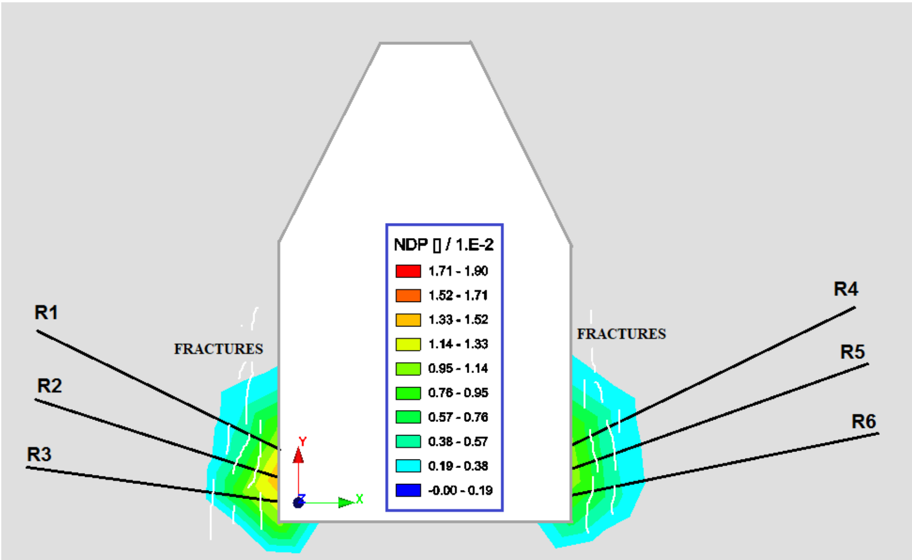


Figure 5. Reinforcement with cablebolts of the walls of the western chamber/room, from Unirea mine, taking into account the areas of rock salt plasticization and salt fractures (scalar representation of the plastic deformation norm – 2D finite element modelling) [6]

In the case of using the support technology with cablebolting, the equipment strictly necessary for the implementation of this support technology consists of a drilling rig with a length of 15-20m and a diameter of 51-52mm and a cement slurry/paste injection plant at several atmospheres, with the possibility of vertical transport over a distance of at least 20 m.

The economic calculation of the rock salt massif consolidation system is adapted to each particular case, defined by the layout of the anchor cables (supporting monograph) and the technology of implementation of the support with anchor cables.

The support technology with anchoring cables includes the time staggering of the following complexes of operations: 1) drilling in the rock salt massif of the boreholes with a diameter of approx. 45-50 mm (mounting the installation at the level of the borehole and actual drilling of the borehole); 2) cleaning the detritus from the borehole with the help of a compressed air hose; 3) inserting the cablebolt, the cement slurry/paste injection pipe and the air outlet hose into the borehole; 4) mounting the fastening systems at the ends of the anchoring cable (tensioning or, if necessary, pre-tensioning); 5) tensioning or pre-tensioning the anchoring cable with the aid of a hydraulic device; 6) injection of cement slurry/paste into the boreholes.

The equipment and devices used in the implementation of the consolidation system with anchoring cables are the following: drilling rig that can make boreholes with a diameter of 45-50 mm and a minimum length of 20m; compressor; lifting installation with platform; installation for injecting cement paste into the boreholes; hydraulic device for tensioning or pre-tensioning the cablebolts.

The items for calculating the cost of the anchor cable consolidation system are the following: a) Materials: cablebolts (strands of used cable from the shafts hoist, etc.), cement, water, drilling tools, devices for fixing the cablebolt ends, plastic pipes; b) Electricity and fuel; c) Capital depreciation; d) Workmanship. Following an estimated calculation, taking into account these items of expenses, an average specific cost of making a meter of anchoring cable of about 50-70RON was established.

3. THE CONSOLIDATION OF THE UNDERGROUND EXCAVATIONS BY FILLING THE VOIDS WITH BACKFILL PASTE

First used in the 1980's at the Grund mine in Germany, the backfill paste is uniform, has low permeability, generally consisting of a mixture of high-density solids with a content of approx. 15% fine particles below 45 μm. Due to compaction, these particles do not separate from the suspension at a zero flow of the backfill operation, forming a ring around the coarse particles, thus reducing friction with the pipe walls and thus the resistance to movement of the backfill material [7, 8].

The only efficient measure to increase on long term the stability of excavations and of the resistance structures from the underground and the ground surface stability, in the conditions of the Slănic Prahova rock salt mine, is the backfilling with solid materials of the underground voids resulted by underground mining of rock salt or appeared as a result of dissolving process of the rock salt. Among the backfilling processes used in the mining field, the only efficient process is that of hydraulic backfilling, and if possible, with backfill with cemented properties. However, this process was excluded from use in saline conditions, due to the large amounts of water needed to transport the solid material into underground.

Recently, the process of filling the mining voids with backfill paste has been experimented worldwide in mining industry, which has the following main advantages: the backfill is transported without excess water, water that is consumed almost entirely in cementation reactions; after hardening, depending on the composition, a backfill mass with a resistance of over 100 daN/cm^2 can be obtained [7, 8].

The order of backfilling of the underground voids (mined levels) must be made in such a way that the backfill material does not load with its own weight the resistance structures and in particular the ceilings between the levels. Therefore, the backfilling operation must start at the lowest level and continue upwards, vertically.

The technological scheme of the backfill system is conditioned by the location of the processing and mixing station of the backfill, on the surface or underground. The location of the station underground is used in the conditions in which the backfill material comes from the excavation of the mining workings located into waste rocks, which is not the case in the conditions of the Slănic rock salt mine. Therefore, in the case of the Slănic saline, the only possible option is the one with the location of the backfill preparation station to the surface, in the area closest to the backfill supply point of the underground voids.

After preparation, the backfill paste can be introduced underground in three ways [6]: a) from the surface, through boreholes drilled from the surface, directly into the underground cavities (Figures 6 and 7) b) through pipelines located in underground mining works, up to the underground voids (Figures 6 and 8); c) through mining workings and through boreholes drilled underground, up to the backfilled voids.

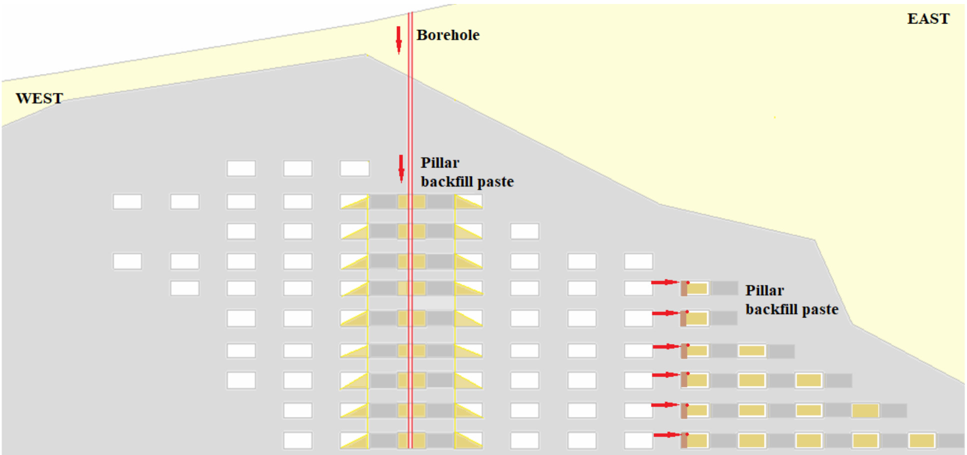


Figure 6. Vertical section through the Cantacuzino mine, with the introduction of the backfill paste from the surface through vertical boreholes and underground mining workings [6]

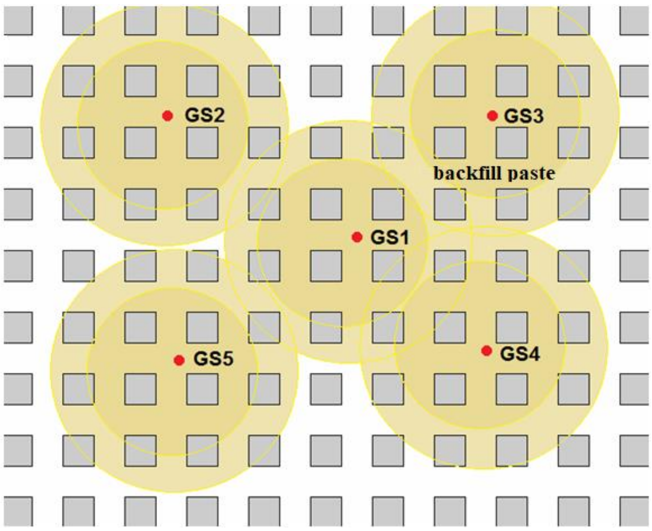


Figure 7. Plan projection of a level from Victoria mine with the introduction of the backfill paste through boreholes from surface [6]

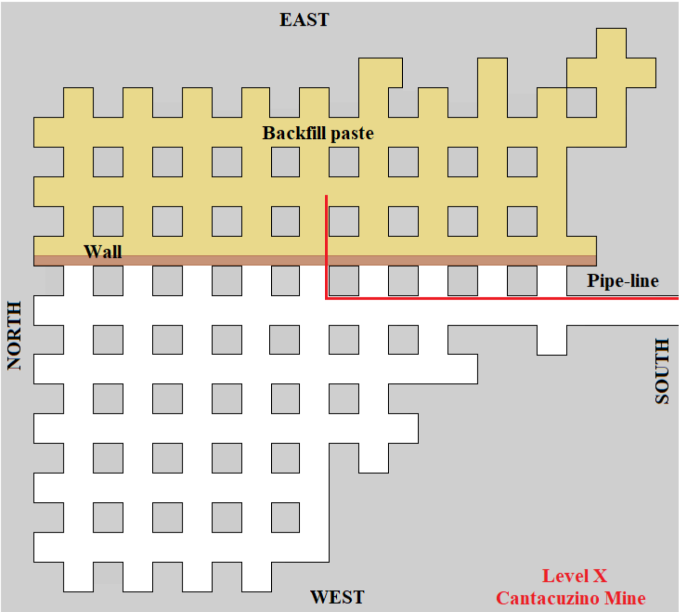


Figure 8. Plan projection of the level X, Cantacuzino mine with the construction under the roof of a backfill paste pillar [6]

a) In the first case, the boreholes, with diameters of approx. 150-200 mm, are drilled from the surface to the base level of the underground voids. In the case of the Victoria and Cantacuzino mines, up to the floor of the 12th level (elevation + 145m), respectively of the 11th level (elevation + 193 m); and in the case of the Carol mine, up to the elevation of + 276 m and of the Mihai mine, up to the elevation of + 270m.

This procedure is applied when there is no access to the underground voids through the network of opening mining workings or when the length of the transport route is too long, so that the cost of drilling the boreholes and their use becomes lower.

In the case of using boreholes, depending on the final purpose of the backfill, the backfill operation was performed through a single borehole or through several boreholes, arranged according to a certain location scheme. After tubing the holes and completing the backfill operation (e.g., one level), the column of tubes is retracted and repositioned on the next floor and so on. If the purpose of the backfill is only to form vertical backfill pillars, the backfill duration decreases accordingly (Figures 6 and 7).

The main advantage of this process is that, in the case of the Slănic Prahova rock salt mine, the level difference between the surface and the mining excavations is large enough to generate, gravitationally, the pressure necessary to pump the backfill into the underground voids. The disadvantage is the cost of drilling and piping the boreholes, which is quite important for the depths of the underground voids from this salt mine.

b) In the second case, the backfill prepared at the surface, near the access mining site, is introduced at the backfill site through a network of underground mining workings, with the shortest total length. The greater the transport distance of the backfill paste, the more it affects the cost of the backfill operation, due to: the long length of the transport pipelines; higher energy consumption, generated by a higher friction at movement; the need of purchase and use, for the horizontal sections of the transport route, of the horizontal displacement pumps.

This system is recommended when there are connections through the network of opening mining workings, between the surface and the underground mining voids, and the cost of the backfilling operation is lower than in the case of using backfilling through boreholes drilled from the surface.

The introduction of the backfill into a certain underground area, such as the eastern portion under the roof of the Cantacuzino mine deposit (shown in Figures 6 and 8), strongly affected by fractures, requires the construction of a temporary retaining wall. This can be done by initially filling some plastic formwork with backfill paste, which will be left for a certain period for hardening, after which the actual backfill operation will start, behind the formed wall. In this case, the end of the backfill pipeline must be located in the backfill area and its position changed according to the gravitational distribution of the backfill paste, behind the retaining wall. The difficulty of the backfilling operation consists in completing the filling behind the wall to the ceiling. In order to facilitate the filling until the final phase of the void, if there are favorable conditions, it is recommended that the void be filled with backfill paste from the upper level, through the ventilation mining workings or through a borehole drilled in the ceiling between the two levels.

c) The third case is a combination of the first two situations. It applies when there is no direct access from underground mining works to the voids that need to be backfilled or when the backfilling operation through boreholes drilled from the surface is too expensive.

In this situation, due to the complication of the transport route and implicitly to the increase of the resistance to movement of the backfill paste through the pipelines, it may be necessary to use the horizontal displacement pumps located underground.

In addition to filling underground mining voids, backfill paste can also be used to fill dissolution voids, such as those around affected shafts, for plugging the fractures that appeared in the covering formations and in the safety crown pillar from the roof. In this case, the injections of backfill paste will be made through boreholes made from the surface or even from inside the shafts. It is preferable to inject the backfill paste simultaneously with the discharge with high flow pumps of the brine accumulated in the dissolution voids.

An economic calculation for the real conditions of application of a backfill filling technology can be performed only when the real design data of a backfill paste mass are established, for a certain underground location.

The cost of one m^3 of backfill mass, with certain physical-mechanical characteristics, depends mainly on the specific cost of the backfill, the total volume of backfill to be prepared and the transport and introduction of the backfill.

The cost of the backfill paste is greatly influenced by the volume and specific costs of the materials in the composition. The composition of the backfill paste is established according to the cheapest available materials located in the vicinity of the Slănic saline, combined in a composition that leads, after the hardening of the paste, to the characteristics of the backfill solid mass imposed by design.

The highest percentage (of about 75-80%) of the composition of the paste is represented by the rocks, which also dictate the total cost of the backfill paste. As the opening mining workings at the Slănic Prahova saline are excavated in the rock salt massif, the source of the waste rocks must be from the surface. There are no waste dumps on the surface, because the waste from the preparation station was deposited in the collapsed holes of the old mines. Therefore, the only sources of waste rock may be crushed stone, resulting from the open pit mines or gravel aggregates. Near the Slănic salt mine there are no stone open pit in operation or the possibility to develop such open pits, and their transport from a great distance would make this backfill material unprofitable.

Following this analysis, it results that the only available material is the gravel aggregates, which can be purchased from a local producer or can be excavated by the Slănic Prahova saline. The extraction by the saline is profitable only if the total volume of the aggregates is very large, so as to make efficient the investment in the extraction equipment used in a gravel pit. In the case of smaller volumes of material, it is recommended to purchase from a manufacturer of aggregates, classified according to a certain particle size distribution, required by the backfill paste composition.

Another backfill paste material, which increases its cost is Portland cement and which participates with a percentage of approx. 1-5% in composition, depending on other additives with much cheaper cementing properties, such as pozzolans (slag, ash, silica, etc. very fine grade minerals) and other cementing materials (gypsum, lime, etc.). The place of origin of the additive materials determines, by means of the transport distance, their cost at destination.

In addition to the backfill paste, the total cost of the backfill mass is also determined by the applied procedure/technology of the backfill, noting the technical diversity of this process.

Depending on the transport route of the backfill, the equipment and materials are different, which results in very different operating costs. The lowest cost is generated by the introduction of backfill paste on pipes placed in vertical (shafts, rises) and horizontal or short inclined mining workings, using gravitational transport. And the most expensive could be determined by a long transport route on a network of inclined and horizontal mining workings, combined with boreholes, and which requires the use of positive displacement pumps. The value of these high-pressure pumps (up to 165 bar), with a price of more than USD 200,000, is only justified if the volume of the backfill installed is very high. The cost of transport and installation of the backfill paste also includes the drilling and tubing of the boreholes and the value of the backfill transport pipes (both with specific costs per linear meter, depending on the diameter, which is correlated with the granulometry of the solid material from the composition of the backfill).

4. CONCLUSIONS

Slănic Prahova salt mine has been operated over a period of over 350 years, using different methods and technologies of mining: the extraction in bell-type mines (Ocna din Deal and Ocna din Vale, etc.); underground mining with large trapezoidal chambers (Sistematica, Carol, Mihai and Unirea mines); underground mining with small rooms and square pillars (Victoria and Cantacuzino mines). The extraction of over 15.5 million m^3 from the deposit led to the occurrence of the phenomena of loss of stability of the underground excavations, surface deformation and implicitly the damage of some constructions located underground or on the surface.

Thus, the situation of the mining excavations at the Slănic salt mine is as follows: all the very old mines (bell shaped chamber) are collapsed to the surface; all the Old mines (except the Unirea mine) are inaccessible, having different degrees of degradation; the Victoria mine is inaccessible due to the collapse of the ceilings and pillars; the Cantacuzino mine has fractured ceilings in the eastern area, except of those from the last two levels. The degradation of the underground structures and of the surface were also accentuated by the appearance of some phenomena of rock salt dissolution, due to the infiltrations of water through cracks and fissures.

Technical measures (such as drainage and water evacuation, filling of the underground voids with concrete or waste rocks, waterproofing of watercourses, etc.) taken over time, against these phenomena of degradation of structures and surface, have had limited efficiency and only in the short term.

In order to improve the stability of the underground mining excavations and of the surface from the Slănic saline, two solutions are proposed to consolidate the underground structures, namely: consolidating the pillars and ceilings with cablebolts and partially or totally filling the mining voids with backfill paste. The proposed consolidation systems are adapted to the local conditions of application, depending on the technical and economic efficiency of each solution.

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ANALYSIS OF THE BEHAVIOR OF THE RESISTANCE STRUCTURES FROM THE CANTACUZINO MINE, BASED ON THE DISPLACEMENT MEASUREMENTS

DACIAN-PAUL MARIAN[1], ILIE ONICA[2]

Abstract: *The Cantacuzino mine was operated for 26 years by the mining method with small rooms and square pillars, on 7 descending levels. As the mining deep developed, there was a less significant degradation of the pillars towards the northern part and the appearance of cracks in the ceilings towards the eastern limit of the deposit, accompanied by their accentuated degradation. This article presents a prognosis of the vertical displacements and the ceilings stability based on topographic measurements performed during the period 2004-2019.*

Keywords: *rock salt, room, pillar, ceiling, displacement, fissure, strain, stress, monitoring, prognosis*

1. GENERALITIES

The rock salt deposit from Slănic Prahova has a lenticular shape, with a length of approx. 2,700 m, on the north-south direction, the width of the lens is between of 800 and 2,300 m, and the maximum thickness is of 499 m - Figure 1 [5].

From a geographical point of view, the region belongs to the hilly area of the Curvature Carpathians, the landform having altitudes ranging between of 359 m (Slănic brook valley) and 662.80 m (Gorganu peak).

The formation of the rock salt deposit from Slănic Prahova indicates the existence of a gulf that appeared, probably, during the regression period of the flysch sea where, in the conditions of a very dry climate, from the supersaturated waters the salts successively precipitated.

At Slănic and respectively in the area crossed by Slănicului Valley, deposits appear belonging to the Paleogene-Quaternary stratigraphic interval.

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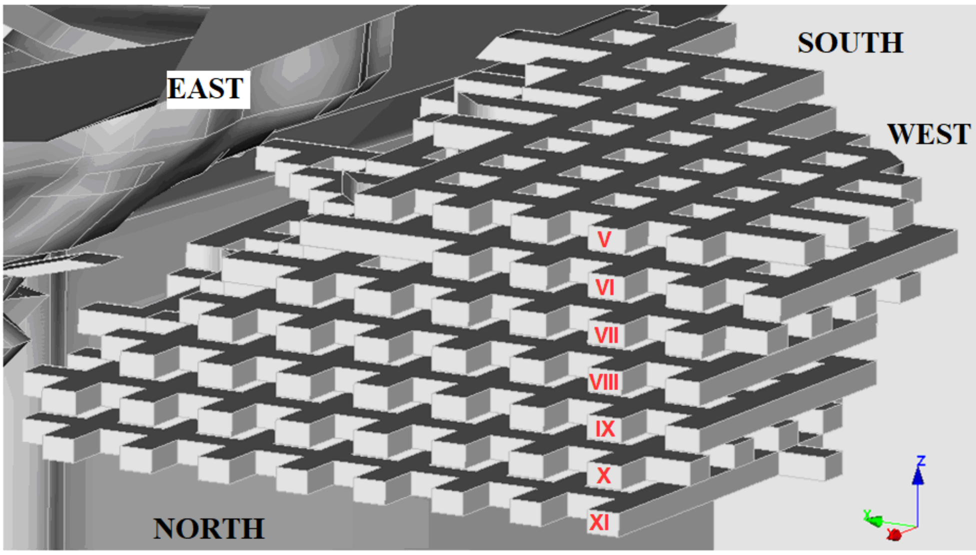

Figure 1. 3D view of the Cantacuzino mine [8]

The main types of rocks in the deposit are: rock salt, volcanic tuffs, clays, marls and sandstones.

The rock salt in the deposit is in the form of white stratiform deposits, alternating with strips of gray salt. The change of color indicates the change of precipitation conditions both due to climatic variations and terrigenous contribution, more or less abundant.

The underground mining of the rock salt deposit from Slănic began between 1 665 -1 865 with the help of bell-type rooms and continued with the extraction in large trapezoidal rooms in the Old Mines (Sistematica 1865-1875; Principatele Unite mine or Carol, between 1831-1935; 23 August mine or Mihai, between 1912-1943; Unirea mine, in the period 1947-1971), from where a volume of over 5.5 million m^3 of rock salt was extracted.

In 1970, the Victoria Mine was opened, where the mining method with small rooms and square pillars, with multi-storey levels was applied [5], with which a volume of 7,379,128 m^3 was extracted from the deposit.

In 1993, the activity continued at the Slănic Prahova salt mine by opening the Cantacuzino mine, where the mining method with small rooms was applied, square pillars and a straight ceiling, between the levels V and VII, and starting from level VIII, the same method was applied, but with rooms with arched ceilings. The dimensions of the pillars increased with the depth, as follows: for levels V - VII, L_p = 16 m; for levels VIII - X, L_p = 17 m; for level XI, L_p = 18 m [5].

By 2019, from the Cantacuzino mine were mined approx. 4,964,880 tons of rock salt resulting a total volume of mining voids of approx. 2,364,229 m^3. The depth on which the underground mining voids have developed is 103 m, under a massif of rock salt and covering rocks, which varies between of 102 m and 160 m (depending on the configuration of the surface). Taking into account these general data, it can be noted that, from the point of view of stability, the geological and mining conditions of the Cantacuzino mine are much more favorable, compared to those specific to the Victoria mine and the Old mines.

As the exploitable reserves at the Cantacuzino mine, located above the +200 m level, have run out, currently the activity continues below the +200 m horizon, starting with level XIV, located under an equalizing pillar, with an average thickness of 40 m.

2. DEFORMATION OF THE PILLARS FROM THE CANTACUZINO MINE

The underground mining activity of the deposits of useful mineral substances causes a redistribution of the stresses in the massif and an increase of the pillar loadings, schematized principled in Figure 2. For the state of stress developed in the pillars, compared to the in-situ resistance of the rock mass, in general the pillars must remain intact and respond elastically to the increase in the state of stress. Normally, the main interest is focused on the maximum working capacity of the pillars and then on the final behavior/load-displacement limit of the pillar [2].

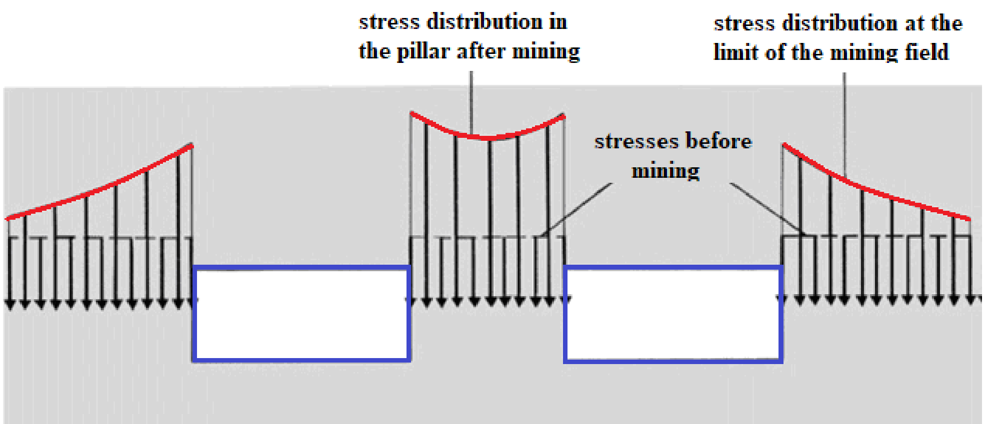

Figure 2. The redistribution of the normal stresses on the pillars in the same time with mining development [2]

The response of the structure of a pillar to the mining pressure is determined by the properties of the rocks, the geological structure, the absolute and relative sizes of the pillar and the type of constraints applied to the pillar by the surrounding rocks. Three modes of behavior of a pillar subjected to stresses are known (Figure 3), which can be reproduced qualitatively following laboratory tests on machines with displacement control [2].

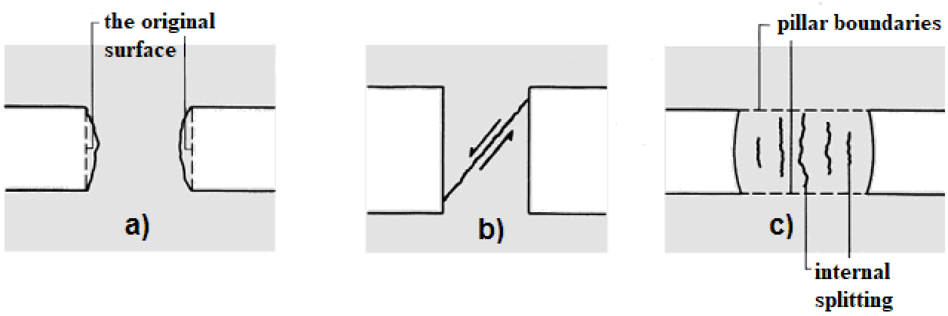

Figure 3. Main behavior patterns of pillar deformation [2]

Relative to the mass of rocks, the most obvious symptom of the stress of the pillars is given by the detachment of rocks at their surface, as illustrated in Figure 3.a. Over time, this will cause a "shrinking" of the pillar. In a detailed study, Lunder and Pakalnis [7] described the progressive stages of pillar degradation, respectively the pillar deformation modes, represented in Figure 4. Regarding the breaking behavior of rock salt pillars at Slănic Prahova saline, depending on the geoeological-mining conditions of each pillar, any of the modes shown in Figures 3 and 4 may occur.

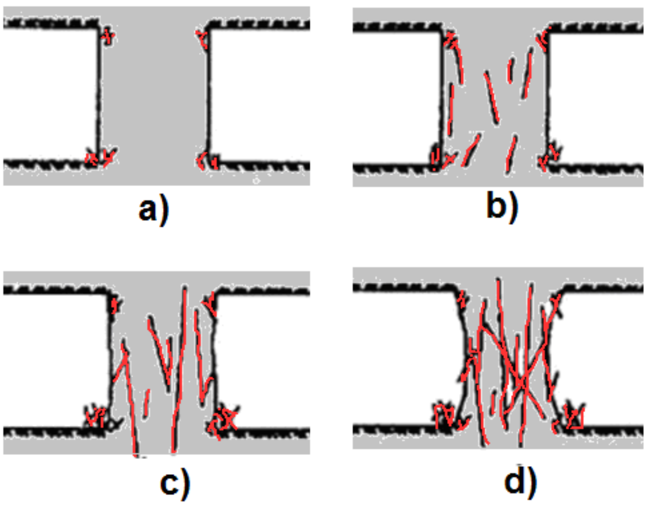

Figure 4. Schematic illustration of the evolution of the fracturing and breaking in a pillar's mass [7]:
a) Shear breaking the corner of the excavation; b) Partial breaking by the surface and the appearance of isolated internal fractures; c) Breaking by pillar's shrinking and the appearance of extensive internal fractures; d) Shear breaking of the internal fractures

The in-situ research of the behavior of the pillars from the Slănic saline was started by ICEMIN Bucharest, in 1971-1972, and was continued by ICPMS Cluj-Napoca, between 1974-1990, then by the University of Petroșani, in collaboration with the specialists from the Slănic Prahova saline. The measuring system was made using Schmidt devices and spacer plates. Horizontal devices were used to measure the elongation of the pillars and vertical devices to measure the shortening of the pillars [10].

Depending on the surface configuration, was found a variation of the pillar stresses find out at the same level. The variation of the state of stresses and deformations, on levels and depending on the depth measured from the surface is highlighted in Tables no. 1 and 2, specific to the Old mines, Victoria and Cantacuzino mines. In this respect, it was found that the northern parts of the measured pillars are affected by higher stresses than the southern parts of the same pillars.

More specifically, the total deformation of some pillars is 0.499%, in the northern part and 0.414%, in the southern part. Hence it is obvious that the degree of stress of the monitored pillars depends on the depth *H* from the surface [10].

Table no. 1. Deformation and deformation speed of the pillars [10]

Pillar	**Stress degree**	**Total deformation,** ε_t **%**	**Medium deformation speed, mm/h**
A	0,349	0,18900	0,0339
B	0,209	0,00465	0,00080
C	0,228	0,37700	0,0675
D	0,228	0,49900	0,0865
F	0,278	0,13000	0,0210

Table no. 2. The stress degree of the pillars, depending on the depth *H* [10]

Depth, *H*, in m	**Stress degree,** Δ_i	**Depth, *H*, in m**	**Stress degree,** Δ_i	**Depth, *H*, in m**	**Stress degree,** Δ_i
139	0,254	171	0,287	203	0,319
155	0,270	187	0,303	219	0,333

Following the comparative analysis of the deformations, it was found that, for the pillars located in the center of the mined level, the horizontal deformation speed is higher than the vertical deformation speed.

From the point of view of the degree of stress, all the pillars from the Slănic Prahova salt mine are located in the stability zone of creep, respectively of the behavior of deformation in time.

Pillar deformation measurements confirmed that, depending on the position of the pillars at the level and their geometric shape, the stress distribution is uneven and the load transmission differs from pillar to pillar.

Analyzing the measured values, it was concluded that all existing pillars at Slănic Prahova saline are, at the time of research, in the field of stability in terms of creep behavior, field that is within limits $(0{,}3 \div 0{,}45) \cdot \sigma_{rc}$ [10].

3. EVALUATION OF THE STABILITY OVER TIME OF THE CEILINGS BETWEEN THE LEVELS

The evaluation of the stability over time of the mining workings, based on the subsidence determination (vertical displacements) of the ceilings between the levels is very difficult, due to the complexity of the geomechanical phenomena, respectively the behavior in time of these ceilings.

In the mappings made on the level's situation maps, it can be seen that these cracks follow somewhat parallel the boundary of the deposit with the sterile rocks, having the directions N-S, E-V, NV-SE, NE-SW and N-S. The monitoring of the evolution of cracks/fractures, from the level of levels V-IX, was performed by topographic measurements and measurements performed on some landmarks, by periodically recording the value of horizontal and vertical displacements. Thus, four crack systems were registered, oriented N-S, NV-SE, E-V, NE-SV, with angles between them of approx. 45^o and with variable lengths, from level to level, between 20 m and 150 m – Figure 5 [9].

Following the analysis of the distribution of cracks in the ceilings, it can be seen that the total area affected by cracks/fractures in 2009, increased by approx. 4 times, compared to 2001 [9]. This can be explained both by the continuous action of stress concentrators around the mining excavations, and by the presence of factors that have contributed over time to the degradation of the rock salt massif, such as the action of moisture and mine atmosphere and the systematic effect of seismic waves, generated by the detonation of explosives.

The analysis of the fractures/cracks appeared in the resistance structures (especially in the ceilings between the levels) from the Cantacuzino mine, at the levels VIII, IX and X, was also performed with the help of electrometric measurements [1, 11, 12].

Following the macroscopic finding of cracks in the ceiling and floor of the levels, the specialists from Slănic Prahova saline decided to monitor the stability of the ceilings between levels, by measuring the vertical displacements of several landmarks mounted in the floor of all levels.

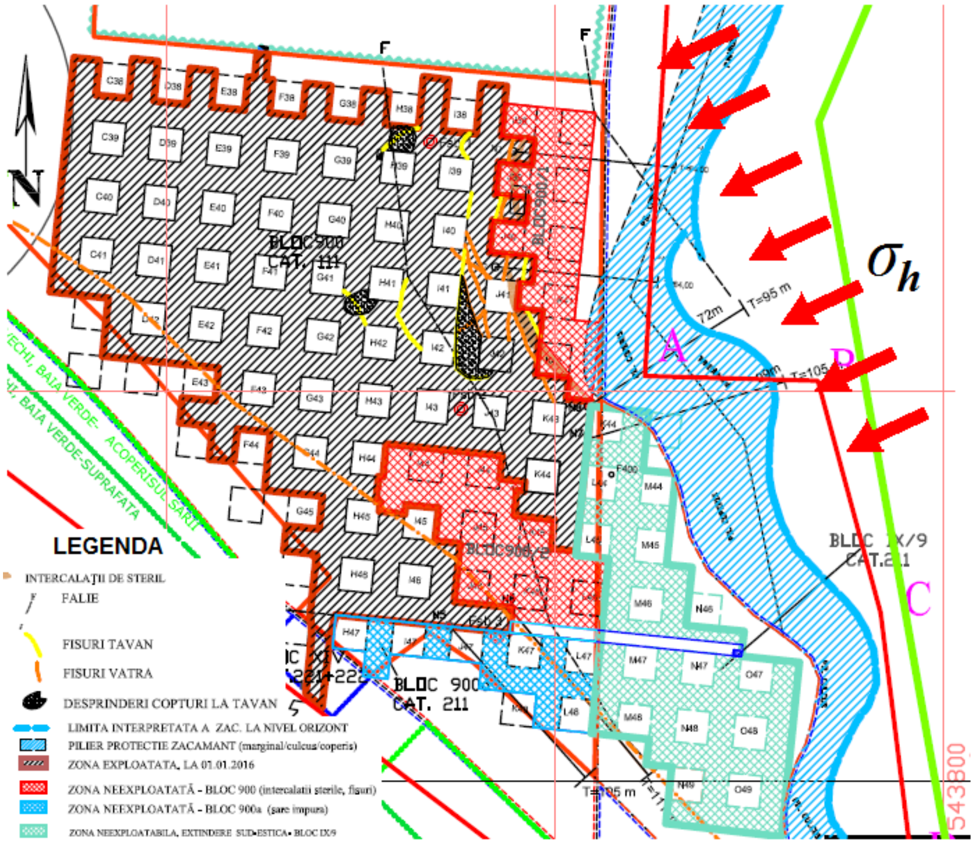

Figure 5. Situation map of the level IX (+225m), with the representation of the crack systems (yellow – roof; orange – floor) [9]

The high-precision topographic level measurements were supported on some reference points, located on the surface and correlated with the underground ones by landmarks mounted along the main inclined trucks access plane. The monitoring campaign was started on 26.01.2004, for levels V-IX and on 25.01.2008, for level X, after which the measurement interval was annual. The last measurement was made on 24.04.2019. The landmarks were mounted on alignments in the areas of interest, where the most accentuated vertical displacements or failure deformations of the ceilings were found, as follows: on the 5th floor, 13 landmarks were mounted, on 1 alignment; on the sixth floor, 26 landmarks on 3 alignments; on the 7th floor, 34 landmarks on 6 alignments; on the 8th floor, 39 landmarks on 5 alignments; on the ninth floor, 32 landmarks on 5 alignments; on the X floor, 25 landmarks on 5 alignments.

Although, assessing the stability of the safety ceilings over time, from a scientific point of view, cannot have an acceptable degree of certainty due to the complexity of the geomechanical phenomena to which the ceilings between the levels are subjected [3], however, the following we will try such an evaluation, starting from a critical subsidence estimated to be 800 mm. It is a value based on the experience presented in the literature from which, we consider, local phenomena of destabilization of the ceilings and local phenomena of collapse can occur [13]. Thus, it was considered that a ceiling will lose its stability, reaching collapse, when a single landmark reaches the value of critical subsidence. It is well known that the phenomena of deformation of rock salt go through three phases of creep behavior (transient, constant and tertiary) [6]. In this context, the loss of stability, i.e. the collapse of a ceiling occurs in the last phase, the tertiary, in which the deformation speed is the highest.

This analysis was based on the time deformation curve of rock salt, presented in the paper [6], approximating the law of deformation of the ceilings based on the subsidence measurements performed over time. For this purpose, at the level of each level, of all the measured landmarks, the highest values of the maximum cumulative subsidence, from each alignment, after the last measurement campaign were taken into account. For the selected landmarks, presented in Table no. 3, a series of behavioral laws were established to approximate the measured values as well as possible. In various specialized works, different authors have recommended for the study of the deformation of the rock salt massif a law of behavior of power type [4, 14, 15].

Following the analysis of the database, it was found that for the case of the study of the deformation in time of the ceilings, the most appropriate law of behavior is the power type, providing a degree of accuracy of almost 100% ($R^2 \cong 0{,}99$), for most selected landmarks. Exceptions to this legality are some of the landmarks on the ninth level and all the selected landmarks on the tenth level, for which the most appropriate approximation law is a linear one. Being the last ceilings built, it is assumed that they go through the first phase of creep behavior, completely different from the other ceilings. Interestingly, two of the landmarks selected on the ninth level follow a power law, which makes this ceiling can be placed as one with intermediate behavior, between the ceilings on the V-VII levels, the oldest and the tenth level, latest. As an additional argument of these conclusions, if we look at the distribution of the surfaces affected by cracking of the ceilings between levels, it is clear that the most affected levels are those in the center of Cantacuzino mine, respectively the levels VI, VII and VIII, which highlights an area of induced vertical stresses concentration, accentuated by the time factor [9].

Based on the formulas for approximating the evolution in time of the subsidence, from the graphs (for example Figures 6 - 9) it was possible to obtain the time after which the points on the ceiling, related to the selected landmarks, reach the critical subsidence. We mention once again that these predictions are very much altered by the characteristics of fractures in the ceilings and by the ratio between the initial vertical and horizontal stresses [3].

Table 3. The approximation of subsidence/vertical displacement of the ceilings between the levels and the stability time until critical subsidence is reached [8]

Landmark	Approxim-ation law	Approximation formula of subsidence, $S_{(t)}$ mm	Determination coefficient, R^2	Stability time T_s	
				months	years
Level V					
12F	*power*	$S^{V}_{12F(t)} = 8{,}138 \cdot t^{0{,}7644}$	0,9989	224,8	18,7
11	*power*	$S^{V}_{11(t)} = 2{,}2515 \cdot t^{0{,}9403}$	0,9945	336,3	28,0
12	*power*	$S^{V}_{12(t)} = 3{,}6736 \cdot t^{0{,}8537}$	0,9911	368,3	30,7
Level VI					
19B	*power*	$S^{VI}_{19B(t)} = 2{,}0874 \cdot t^{0{,}9651}$	0,9945	294,6	24,6
17V	*power*	$S^{VI}_{17V(t)} = 0{,}9177 \cdot t^{1{,}0794}$	0,9970	349,2	29,1
14	*power*	$S^{VI}_{14(t)} = 2{,}0691 \cdot t^{0{,}9114}$	0,9987	509,3	42,4
24	*power*	$S^{VI}_{24(t)} = 2{,}8147 \cdot t^{0{,}8393}$	0,9988	657,8	54,8
Level VII					
19B	*power*	$S^{VII}_{19B(t)} = 1{,}0754 \cdot t^{1{,}1246}$	0,9855	177,2	14,8
16A	*power*	$S^{VII}_{16A(t)} = 0{,}4821 \cdot t^{1{,}248}$	0,9906	199,6	16,6
24	*power*	$S^{VII}_{24(t)} = 1{,}4844 \cdot t^{0{,}9796}$	0,9983	433,7	36,1
R2	*power*	$S^{VII}_{R2(t)} = 0{,}5163 \cdot t^{1{,}1469}$	0,9933	424,1	35,3
30	*power*	$S^{VII}_{30(t)} = 2{,}2446 \cdot t^{0{,}8988}$	0,9913	510,1	42,5
14	*power*	$S^{VII}_{14(t)} = 2{,}2687 \cdot t^{0{,}8346}$	0,9954	946,9	78,9
11	*power*	$S^{VII}_{11(t)} = 118{,}18 \cdot t^{0{,}1953}$	0,9543	17711,7	1476
Level VIII					
42	*power*	$S^{VIII}_{42(t)} = 0{,}00008 \cdot t^{2{,}738966}$	0,9147	177,3	14,8
27	*power*	$S^{VIII}_{27(t)} = 0{,}0585 \cdot t^{1{,}5688}$	0,9804	252,3	21,0
32	*power*	$S^{VIII}_{32(t)} = 1{,}3814 \cdot t^{0{,}9818}$	0,9973	471,0	39,2
29	*power*	$S^{VIII}_{29(t)} = 1{,}6545 \cdot t^{0{,}9453}$	0,9978	510,8	42,6
10C	*power*	$S^{VIII}_{10C(t)} = 0{,}3346 \cdot t^{1{,}1504}$	0,9949	684,1	57,0
9	*power*	$S^{VIII}_{9(t)} = 0{,}087 \cdot t^{1{,}1897}$	0,9884	1965,1	163,8

Level IX					
31A	*linear*	$S^{IX}_{31A(t)} = 2{,}0955 \cdot t - 133{,}56$	0,9957	264,9	22,1
23	*power*	$S^{IX}_{23(t)} = 0{,}0006 \cdot t^{2{,}2483}$	0,9661	349,3	29,1
19	*power*	$S^{IX}_{19(t)} = 0{,}1007 \cdot t^{1{,}4282}$	0,9940	357,3	29,8
33	*linear*	$S^{IX}_{33(t)} = 1{,}2604 \cdot t - 80{,}685$	0,9692	518,1	43,2
16	*linear*	$S^{IX}_{16(t)} = 0{,}8267 \cdot t - 66{,}4054$	0,9595	867,4	72,3
Level X					
31B	*linear*	$S^{X}_{31B(t)} = 0{,}3144 \cdot t - 14{,}98$	0,9393	2455,1	204,6
16	*linear*	$S^{X}_{16(t)} = 0{,}2773 \cdot t - 12{,}508$	0,8252	2793,0	232,7
25	*linear*	$S^{X}_{25(t)} = 0{,}1764 \cdot t - 11{,}626$	0,7630	4464,0	372,0
23	*linear*	$S^{X}_{23(t)} = 0{,}1399 \cdot t - 7{,}2058$	0,7470	5632,8	469,4
19	*linear*	$S^{X}_{19(t)} = 0{,}0984 \cdot t - 4{,}889$	0,9135	8042,7	670,2

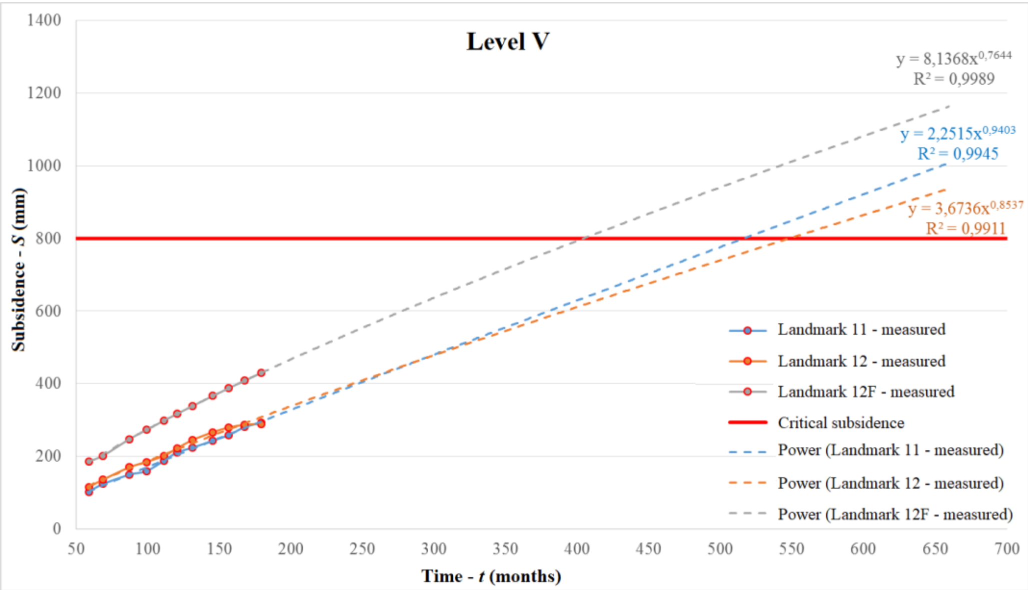

Figure 6. The evolution over time of the measured and predicted subsidence for level V, for the landmarks with the highest value of subsidence [8]

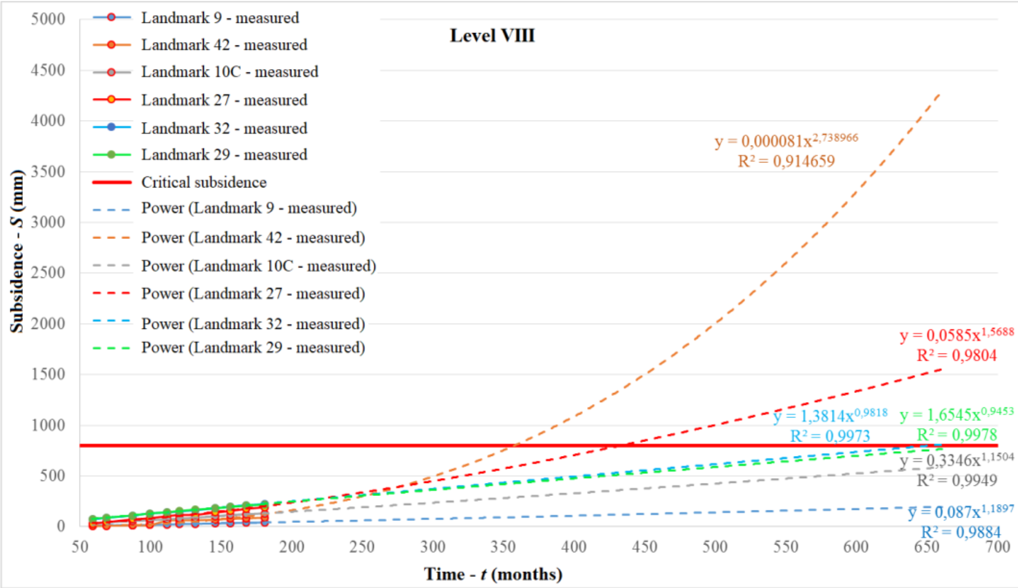

Figure 7. The evolution over time of the measured and predicted subsidence for level VIII, for the landmarks with the highest value of subsidence [8]

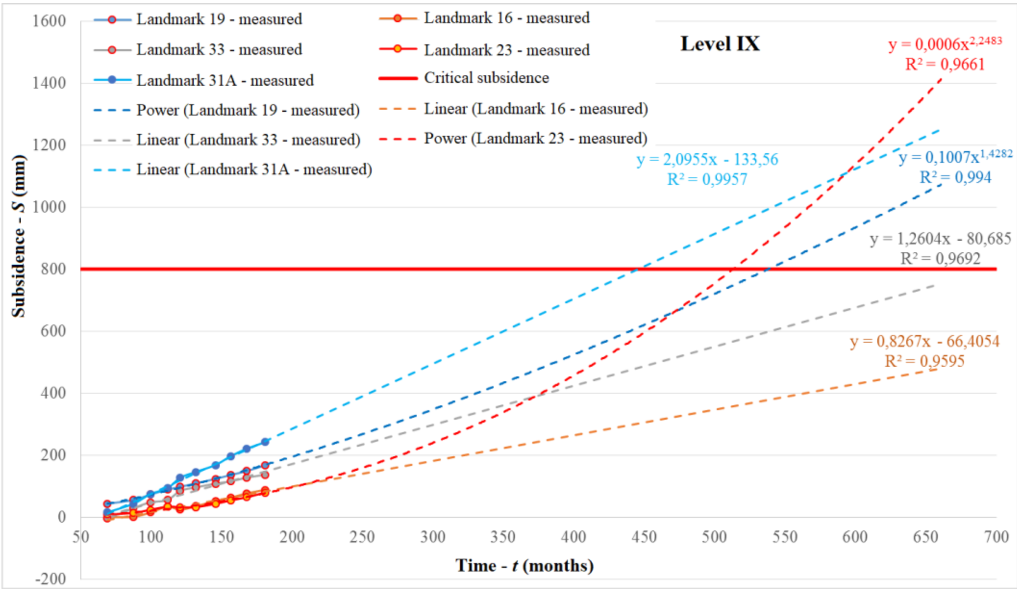

Figure 8. The evolution over time of the measured and predicted subsidence for level IX, for the landmarks with the highest value of subsidence [8]

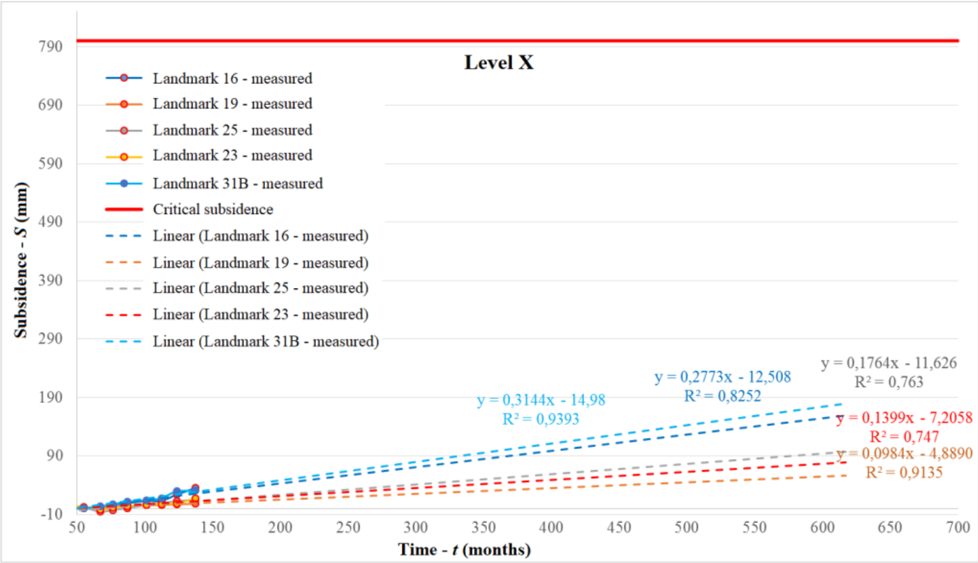

Figure 9. The evolution over time of the measured and predicted subsidence for level X, for the landmarks with the highest value of subsidence [8]

From the data presented in Table no. 3, it can be seen that the predicted stability period for the ceilings between the levels, taking into account the landmarks with the highest accumulated subsidence at each level, is variable, between the minimum and maximum value there are differences several times greater. This dispersion of the values of the stability periods is explained by the prism of the very diverse geomechanical phenomena of deformation, suffered by the ceilings near the selected landmarks. Continuing the logic for which the analyzed landmarks were selected, we can say that the area where the destabilization process of a ceiling begins is represented by the landmark for which the predicted stability period is the shortest, this duration can be attributed to the stability of the entire ceiling, 18.7 years, for level V; 24.6 years, for level VI; 14.8 years, for level VII; 14.8 years, for level VIII; 22.1 years, for level IX; 204.6 years, for the X floor [8].

Given the current functionality of the X level, its predicted stability period of over 204 years is well beyond the technical period of operation of the level [8].

4. CONCLUSIONS

The complexity of the geomechanical behavior of the ceilings makes it very difficult to assess their stability over time and implicitly of the rooms located in their vicinity, for the following reasons:

-Theoretically, the distribution of subsidence on the surface of a ceiling is a function of the position of the landmark in relation to the mining edge, towards the center of the mining field having even the maximum values, due to more accentuated settlement of the pillars arranged towards the center and a progressive reduction of their settlement to the mining limits;

-Although the subsidence of the ceilings towards the mining limits of the levels would, in theory, be lower, the distribution of tensile and shear stresses in the ceilings is more important towards the limits than towards the center, which leads to the idea that not only maximum subsidence it is the one that generates the distribution of breaking forces in the ceilings and implicitly the loss of their stability, but rather the intensity of the bending of the ceiling;

-Even if the displacement measurements were performed simultaneously, they captured different phases of behavior of each ceiling, taking into account the fact that the operation of the level was carried out in stages in time (starting with 1992, the 5th level and 2003, level X), and the stresses of each floor being a function of depth, and the creep phase (transient, stationary, tertiary), in which the stressed rock salt is found in each floor, is also different;

-The presence in the ceilings between the levels, especially towards the east of the deposit, of sets of natural fissure, with an orientation approximately parallel to the boundary between the deposit and the rocks and with a random amplitude, induces a high degree of uncertainty in evaluating the stability of the ceilings;

-The failure of the ceilings after the cracking surfaces occurs at much lower values of the mass stresses, compared to the continuous rock salt mass, due to the very low values of the resistance parameters of these low-strength planes, which would be a factor of amplification of the subsidence phenomenon;

-The horizontal stresses calculated theoretically, depending on the average Poisson's ratio of the massif, in the conditions of the Slănic Prahova salt mine, represent approx. 39% of the vertical geostatic stresses. However, following the analysis of the available geological and geomechanical information, it can be assumed that the horizontal stresses are close in value to the vertical ones, with the mention that the maximum direction of the horizontal stress vector is NE-SW;

-Due to the shrinkage stresses generated by excessive horizontal stresses on the ceilings between levels, the dislocation of the ceilings after natural fractures is unlikely, even if the measurements show an increase in subsidence phenomena. More precisely, these friction stresses hold together the floor segments, between two parallel fractures, in a single plate;

- The phenomena of expansion of the floors found locally as a result of the leveling measurements are precisely the effect of the excessive lateral pushes, which determined the ascending, tangential sliding of the ceiling segment along the dislocation surface. This phenomenon is another argument in favor of the existence of excessive horizontal natural stresses in the Slănic Prahova deposit;

-The appearance, in time, of some phenomena of collapse in the structure of some ceilings and even their collapse in the voids, will occur only by the formation of some cavities (collapse vaults) in the ceiling of the lower rooms, which will propagate to the floor of the upper level, forming in the ceiling real sinkholes. If we can assume that such phenomena have already occurred in the Victoria mine, regarding the

Cantacuzino mine, we estimate that these phenomena will occur starting with the eastern rooms, only after a period of several decades.

The analysis of the time behavior of the ceilings between the levels, from the Cantacuzino mine and the main inclined access truck plan based on the subsidence measurements carried out over 15 years (2004-2019) allowed the calculation of displacement speeds and the evaluation of the stability times of the ceilings, starting from a critical subsidence estimated to be 800 mm. It was finally established that the stability periods for the ceilings at the level of the first 5 levels, taking into account the landmarks with the highest accumulated subsidence at the level of each level are between 14.8 and 22.1 years. Taking into account the current functionality of level X, its expected duration of stability of over 204 years is well beyond the technical period of operation of the level.

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scopul asigurării stabilității de ansamblu a zonei, Etapa II/Partea 2 – Redimensionarea elementelor structurilor de rezistență (pilieri, planșee) a zonelor aflate în exploatare (mina Cantacuzino) în scopul asigurării stabilității de ansamblu a zonei, SC MINESA-ICPM SA Cluj-Napoca, Contract nr.10 848/2011/26.10.2007; Simbol proiect 49-724-01.

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SIZING OF THE DIKES LOCATED IN THE RAMP OF THE SHAFTS IN VIEW OF THEIR CLOSURE THROUGH FULL PACKING

ALECSANDRU VALENTIN TOMUȘ [1], MIRCEA GEORGESCU [2]

Abstract: *The article presents a proposal for sizing the thickness of the embankment retaining dikes located in the ramps of the shaft according to their depth of location and the execution of these dikes.*

Keywords: *retaining dike, embankment*

1. INTRODUCTION

In the process of closing the mines after the completion of the operation, the last operation provided for the prohibition of underground access and the protection of the deposit is the backfilling of the transport and aeration shafts used during the productive activity. In order to avoid the dispersion of the backfill material in the horizontal works network of the mine, in all the ramps of the shaft, concrete dikes must be made in advance, embedded in the wall of the mining works. The thickness of the retaining dikes varies depending on their depth and the profile of the mining works in which they are executed.

2. CALCULATION METHOD

For the analysis, it will be considered that the embankment retaining dikes are located at depths H with respect to the elevation of the land surface in concrete ramp-type mining works (R.B.-4.0, R.B.-5.0 or R.B.-6.0), located at the intersection with a P.B.-4.0, P.B.-5.0 or P.B.-6.0 shaft (fig. 1).

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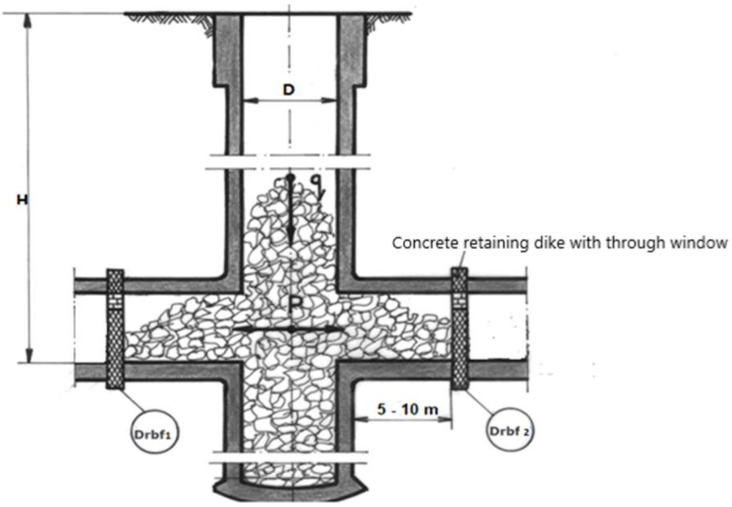

Figure 1. Scheme of location of retaining dikes in shaft ramps

The vertical pressure q exerted on the retaining dike by the backfill material, according to Janssen /1/ is:

$$q = \frac{\gamma \cdot R_h}{\mu' \cdot k}\left[1 - e^{\left(-\mu' \cdot k \frac{H}{R_h}\right)}\right] \quad (\mathrm{kN/m^2}) \qquad (1)$$

where:

γ - specific weight of the material used; γ = 25 kN / m^3;

R_h - hydraulic radius, depending on the diameter of the shaft D: $R_h = D/4$;

μ' - the coefficient of friction of the material of the shaft walls: $\mu' = \mathrm{tg}\varphi$;

φ - internal friction angle:

- for dry material: 25-30^0
- for saturated material: 5-10^0

μ' = tg26° - for dry material = 0.488

μ' = tg5^0 - for saturated material = 0.0966

k - lateral thrust coefficient (Rankine ratio):

$$k = \frac{1 - \sin\varphi}{1 + \sin\varphi} = tg^2(45^0 - \frac{\varphi}{2})$$

- for dry material φ = 26°; k = 0.39
- for saturated material φ = 5°; k = 0.84

H - depth of the shaft (from the surface to the level of the ramp): H = 100-500 m

The horizontal / lateral pressure p acting directly on the retaining dike is:

$$p = k \cdot q \qquad (kN/m^2) \qquad (2)$$

Equations (1) and (2) can be used to determine both vertical and horizontal pressure at different depths H, depending on the type of shaft (PB) and ramp (RB) and the type of material used (wet or dry), resulting in the diagrams represented in fig.2.

Thus, for the backfill material in its natural state (dry), 90% of the value of the maximum vertical pressure qa is reached at a depth of 20 m, and the percentage of 96% of the maximum pressure qa at a depth of 28 m.

In the case of wet backfill material (saturated with water) the vertical pressures will have higher values (their size will almost double compared to dry rocks) so that 90% of the value of the maximum pressure qb will be reached at a depth of approx. 38 m, and the percentage of 96% of the maximum value qb at a depth of approx. 54 m.

From these diagrams it results that, starting from a certain depth, the vertical and horizontal/lateral pressures (pa - dry material; pb - wet-saturated material) vary insignificantly with the increase of the depth of the embankment retention dam.

Please note that the vertical pressures calculated above are for static conditions related to the volume of backfill introduced into the shaft and which will function as a storage silo. The metal elements through which the shaft was compartmentalized and which may take over some of the static loads exerted by the backfill material, including the dynamic shocks created by their fall, which will lead to the settlement and placement of the tailings introduced into the shaft, were not taken into account.

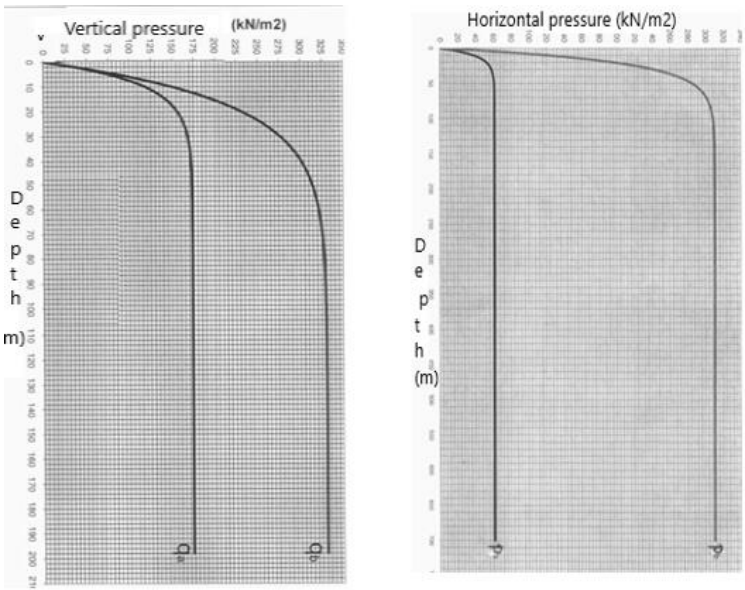

Figure 2. Variation of vertical and horizontal pressures of dry and wet material when filling the shaft

3. DETERMINATION OF THE THICKNESS OF THE RETAINING DIKE

The retaining dike will be assimilated with a circular plate embedded in the contour, on which acts a uniformly distributed load *p*.

The sizing of the dike thickness, *d*, will be done according to two hypotheses /2/:

- maximum load:

$$d = \frac{R}{2} \cdot \sqrt{\frac{3p \cdot c}{R_b}} \quad \text{(cm)} \tag{3}$$

- maximum permitted arrow:

$$d = \sqrt[3]{\frac{3\left(1-\mu^2\right) \cdot p \cdot R^4 \cdot f}{16E}} \quad \text{(cm)} \tag{4}$$

where:

p– the horizontal/lateral pressure acting on the dike, (daN/cm^2);
R - radius of the mining work (shaft ramp), (cm);
R_b- breaking strength of concrete, daN/cm^2;
c- safety factor;
μ - Poisson's ratio, for concrete: 0.1-0.15
E - modulus of elasticity, for concrete: (0.15-0.4) $\cdot$ 10^6 daN/cm^2
f - allowed arrow for the concrete slab: 1/10 - 1/12

The calculation of the thickness of the retaining dikes according to the most disadvantageous hypothesis, which is the one at maximum load, is centralized in table no. 1 for a *maximum load* depth of 500 m.

Table 1. Calculation of the thickness of the embankment dikes, depending on the type of mining work in which it is performed

Ramp type / Shaft type	Shaft deep H [m]	Hydraulic radius, Rh=D/4 [m]	Coefficient of friction of the embankment of the shaft walls, μ'		Specific weight of the backfill γ [kN/m^2]	Ratio Rankine, k		Internal friction angle, φ [°]		Vertical pressure on the dikes, q [kN/m^2] (eq.1)		Lateral/horizontal pressure on the dikes, p [kN/m^2] (eq.2)		Thickness of the retaining dike of the embankment [m]			
														Concrete monolith C12/15		Reinforced concrete with rails c.f.i	
			Dry material	Saturated material		Dry material	Saturated material	Dry material	Saturated material	Dry material	Saturated material	Dry material	Saturated material	Dry material	Saturated material	Dry material	Saturated material
R.B.4,0 P.B.4,0		1.0								131	267	52	225	0,30	0,50	0,20	0,35
R.B.5,0 P.B.5,0	500	1,25	0,488	0,0966	25	0,39	0,84	26	5	161	310	63	261	0,40	0,70	0,25	0,50
R.B.6,0 P.B.6,0		1,5								189	343	74	289	0,50	0,90	0,30	0,60

In order to increase the safety of the construction and to reduce the thickness of the dike (to reduce the amount of concrete) the retaining dikes can be made of reinforced concrete usually using a mixed reinforcement (rigid - railway rails and flexible - concrete steel). In this case, a check of the reinforcement scheme is required according to the following procedure:

1. Choosing the reinforcement scheme

In fig. 3 proposes a reinforcement scheme, which is currently used for the execution of reinforced concrete retaining dikes using railway rails type 17.65 kg/m, recovered during the closure works.

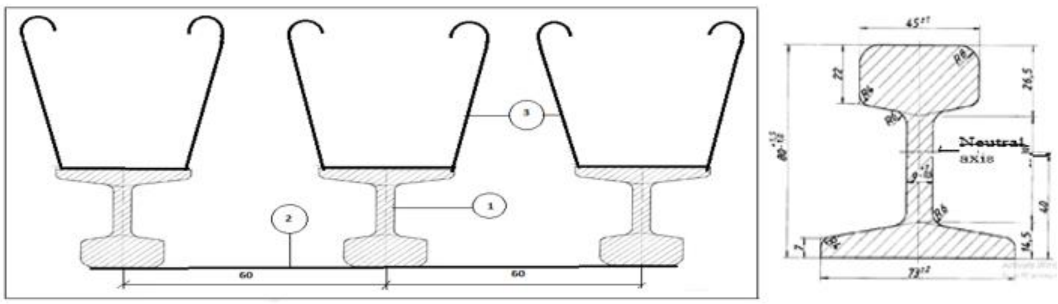

Figure 3. Reinforcement dike reinforcement scheme

1- rail c.f.i type 17.65 kg / m, vertical resistance reinforcement; 2 - 5 ϕ 14, horizontal distribution reinforcement; 3 - welded anchors on c.f.i., from OB-37, 3 ϕ 12 / ml; welding $\rightarrow$ 7x100

2. Determination of the uniformly distributed load acting on the unit length of a strip:

$$p_1 = p \cdot b \qquad \text{(daN/m)} \tag{5}$$

where: p - horizontal / lateral pressure acting on the dike, daN/m^2

b - the width of the strip of the dike surface, corresponding to a metal pillar that will be able to take over the efforts created by the backfill material introduced in the shaft, m.

3. The maximum moment created by the uniformly distributed load:

$$M = \frac{p_1 \cdot b_1^2}{12} \qquad \text{(daN·m)} \tag{6}$$

where: b_1 - the maximum height of the strip, determined between the hearth and the vault of the mining work, m.

4. Percentage of retaining dike reinforcement:

$$p\% = \frac{A_a \cdot 100}{b \cdot h_0} \Rightarrow \xi \tag{7}$$

where: A_a - reinforcement area of a metal profile, cm^2;

h_0 - the thickness of the concrete calculated between the metal reinforcements and the surface of the non-reinforced dike

5. Position of the neutral axis of the concrete area to be compressed:

$$x = \xi \cdot h_0 \quad \text{(cm)} \tag{8}$$

6. The thickness of the retaining dike wall that will act on tensile forces (distance between the neutral fiber of the metal profile c.f.i. and half the distance from the neutral axis to the area to be worked on compression):

$$l_1 = h_0 - e_{x\,metalic} - \frac{x}{2} \quad \text{(cm)} \tag{9}$$

where: $e_{x\,metallic}$ - eccentricity, cm.

7. Determination of the magnitude of the force that can be taken by the thickness of the dike:

$$N = \frac{M}{l_1} \quad \text{(daN)} \tag{10}$$

8. Checking the section of metal fittings

$$A_{a\,nec} = \frac{N}{R_a} < A_{selected\ profile} \quad \text{(cm}^2\text{)} \tag{11}$$

where: R_a - the allowable tensile strength of the chosen profile material, daN/cm^2

9. Checking the section of the chosen concrete

$$A_{b\,nec} = \frac{N}{R_c} < A_{b\,chosen} \quad \text{(cm}^2\text{)} \tag{12}$$

where: R_c - permissible compressive strength of the chosen concrete, daN/cm^2

Calculation example

Considering the calculation scheme from fig.3 and relations (5) - (12), an example of calculation will be given to check the chosen reinforcement scheme taking the following input data: R.B-6,0, P.B-6,0, H = 500 m, saturated material.

According to table no. 1 the maximum horizontal pressure that will act on the surface of the dike will be:

$$p = 289 \text{ kN/m}^2 = 2.89 \text{ daN/cm}^2$$

According to the same scheme: $b = 0.60$ m and $b_1 = 3.8$ m;

The uniformly distributed load that will act on the unit of strip length will be:

$p_1 = 17{,}340$ daN/m, and the maximum moment created by the uniformly distributed load will be: $M = 20{,}866$ daN·m

The reinforcement area of a metal profile of railway type 17.65 kg/m is $A_a = 23$ cm^2, and the thickness of the concrete calculated between the metal reinforcements and the surface of the dike that is not reinforced $h_0 = 60$ cm.

The percentage of reinforcement of the retaining dike will be:

$$p\% = 0{,}64\,\% \Rightarrow \xi = 0{,}15\,\% \,.$$

Neutral axis of the concrete area to be compressed $x = 9$ cm.

The thickness of the retaining dike wall that will act on stretching efforts is: $l_1 = 53.75$ cm.

The size of the force that can be taken over by the thickness of the dike: $N = 38{,}820$ daN.

It follows that the required section of the rail reinforcements c.f.i. with $R_a = 2100$ daN/cm^2 (OL-37) is:

$$A_{a\,nec} = 18{,}48 \text{ cm}^2 < A_{rail\ cfi} = 23 \text{ cm}^2$$

The required section of C12 / 15 brand concrete ($R_c = 95$ daN/cm^2) is:

$$A_{b\,nec} = 409 \text{ cm}^2 < A_{b\ chosen} = 8 \cdot 60 = 480 \text{ cm}^2$$

From the verification calculations it results that in the retaining dike, both the section of the metal reinforcements and of the concrete will resist the efforts that will be created by the backfill material.

4. PROPOSAL FOR THE CONSTRUCTION OF A RETAINING DAM (FIG.4)

The dikes will be embedded in stable rock, at a depth of 0.5 m. In order to increase the safety coefficient of the constructions and to reduce the amount of concrete used, railway rails type 17.65kg/m, recovered during the closure works.

The metal parts of the retaining dike construction will be placed near the surface of the area to be closed, they will take over the stretching efforts, and the concrete part, located outside them will work on the compression loads.

The retaining dikes in the well ramps shafts be provided with a through window to ensure adequate ventilation of the work fronts during their execution. The closing of these windows will be done simultaneously, with rescue teams, by building with vaults, based on a program prepared by the executor and approved by the mine management.

C12/15 concrete will be used in the construction of these dikes.

Given that immediately after the completion of the dikes, the operation of filling the well will begin, it is not considered necessary to equip the construction with pipes for gas control and water evacuation.

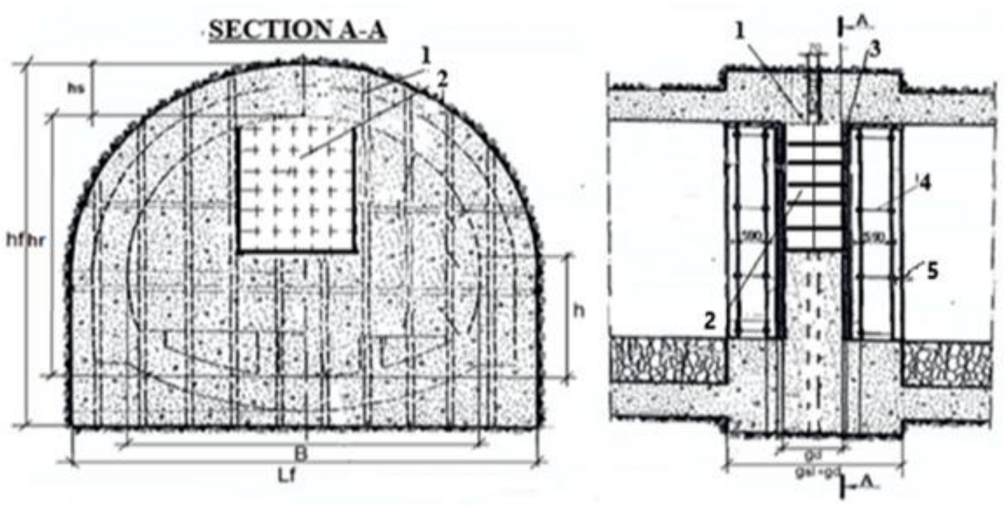

Figure 3. Construction of a retaining dike for backfilling shafts /3/

B-width ramp; Lf-width final dike; h-ramp height, up to radius of curvature; hr- ramp height; hf-height dike; hs-depth recessed cleft; gd-thickness dike.

1-rail c.f.i. recovered; 2-passage window (will be built with prefabricated blocks); 3-formwork from spruce spiles;4-metal spacer;5- concrete center

5. CONCLUSIONS

The construction of retaining dikes in the ramps of the shafts, to be backfilled, is a matter of great importance in the process of closing a mine. The subsequent stability of such embankments will depend on the correct sizing of such constructions, which will then ensure a safety of the entire area to be closed.

The paper presented a method for sizing these retaining dikes, which applied to the mines in the Jiu Valley proved viable, allowing the authors of this paper to draw up a table (table no. 1) in which any designer can find the values of retention for the given conditions. At the end of the work, an example is given of the construction of a retaining dike can be achieved at all mines in closing process of the connections with surface.

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DEFORMATION SPEED CALCULUS FOR HORIZONTAL MINING WORKS WHICH ARE EXECUTED IN DEEP SEDIMENTARY ROCKS

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Abstract: *In this paper we will analyze the deformation way for horizontal mining works executed in deep sedimentary rocks, at Petrila Mining Exploitation. These studies were possible through the deployment of monitoring stations for rock pressure and rock movement on work contour, which led to determining of deformation speed and mining work convergence in deep sedimentary rocks. The deformations were detected by these stations deployed at horizon 100 and 150.*

Keywords: *mining work, rock pressure, rock deformation on the contour of mining work*

1. INTRODUCTION

From the studied perimeter, at horizon 100 level, we studied the main transversal gallery, because this intercepts all the existing rock types. Horizon 150 was opened through a main transversal gallery digged on a length of 470 m to the layer roof 4. At the moment of measurements, in the layer 4 bedrock a directional gallery was executed, which serves as exploitation of layers 4 and 5.

2. THE MAIN TRANSVERSAL GALLERY, AT HORIZON 100

The main transversal gallery at horizon 100 is situated at a depth of 780 m. The mining work profile is GDM -11, the framework type is TH5, special with SG-23. The reinforcement step is 0,5 m, figure 1, the length of the mining work being 450 m.

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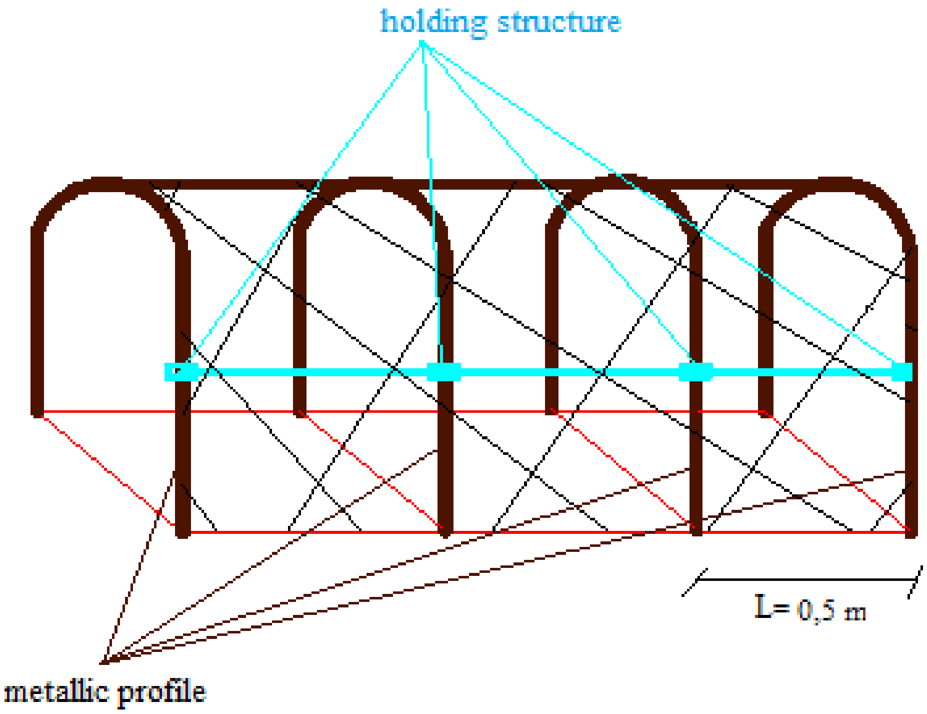

Figure 1. The representation of the reinforcement step noted with L

3. THE MAIN TRANSVERSAL GALLERY, AT HORIZON 150

The main transversal gallery is situated at the depth of 850 m, under sea level. This intesects rocks as sandstones, sandy clays, coaly clays, clays and coals, without water inflitrations. The proportion of rocks in the studied perimeter is as follows: clay 32,48 %, sandy clay 26,77%, sandstone 27,08 %, marl 0,84 %. According to geological data, we see that as depth is rising, the proportion of clay rocks is also rising. The measuring stations are presented in figure 2. The values recorded at station 1 of the main gallery of horizon 150, are presented in figures 3 and 4.

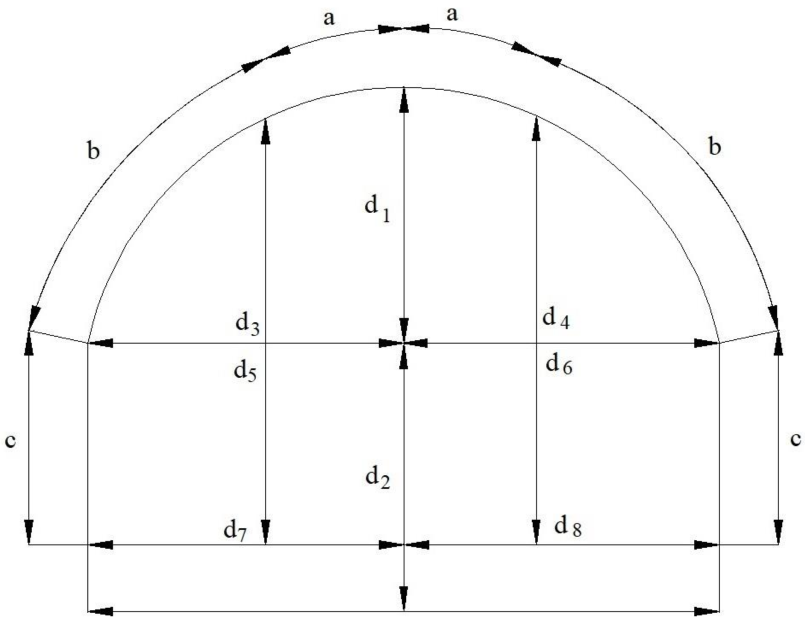

Figure 2. The representation of the measurement stations

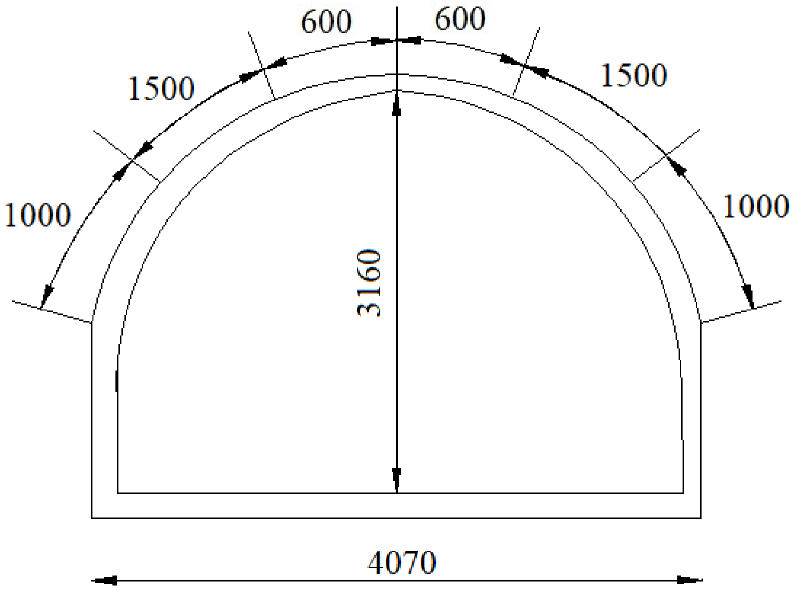

Figure 3. The representation of the deformation values in mm

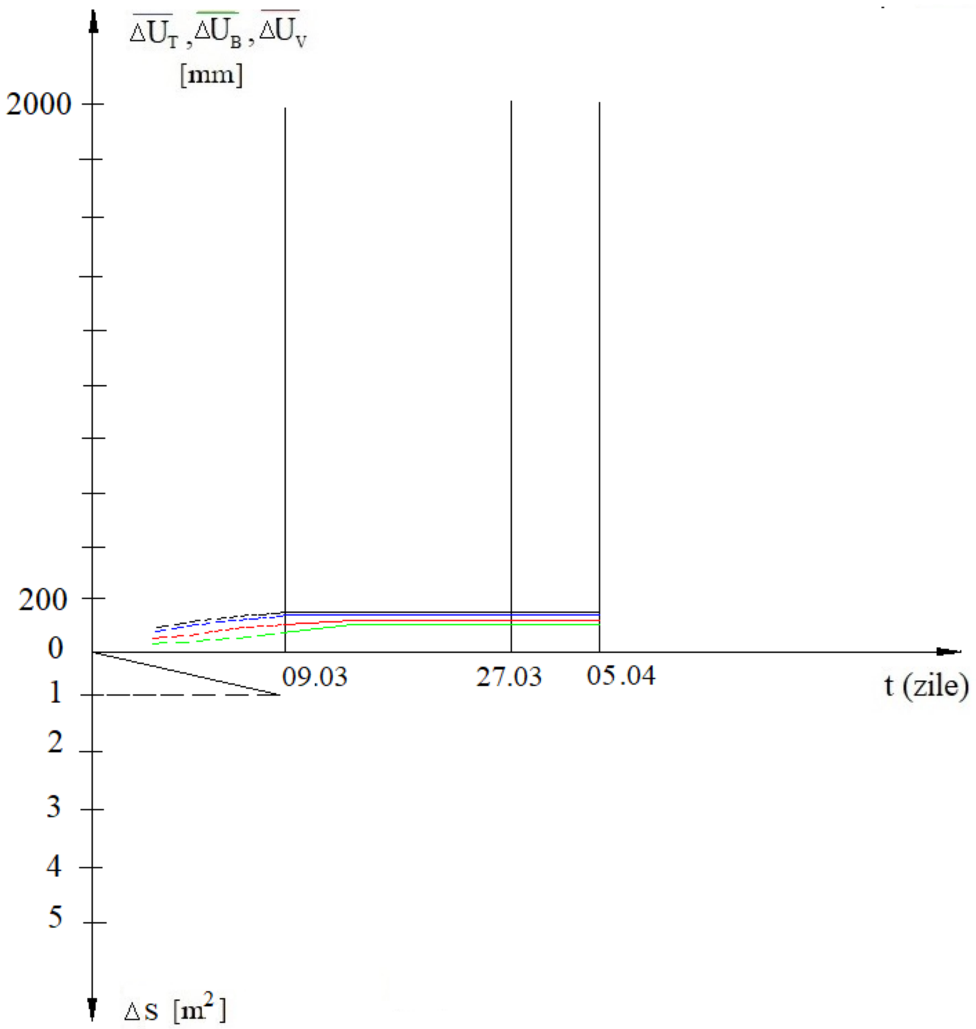

Figure 4. The deformation speed and convergence representation

4. THE DEFORMATION SPEED CALCULUS

For deformation speed calculus, the calculus relations are presented.

We note with U_T the ceiling-bedrock deformation, which is calculated with the following relation:

$$U_T = (d_1 + d_2)_{STAS} - (d_1 + d_2)_{MAS} \quad (mm) \tag{1}$$

where $(d_1 + d_2)_{STAS}$ is the height of the armed gallery profile, (mm);
$(d_1 + d_2)_{MAS}$ is the height of the subteranean measured gallery, (mm);

The deformation of the width of the gallery is noted with U_B and is calculated with the following relation:

$$U_B = (d_7 + d_8)_{STAS} - (d_7 + d_8)_{MAS} \quad (mm) \tag{2}$$

where $(d_7 + d_8)_{STAS}$ is the width of the armed gallery profile, (mm);
$(d_7 + d_8)_{MAS}$ is the width of the subteranean measured gallery, (mm).

The deformation of the gallery bedrock is noted with U_V and calculated with the following relation:

$$U_v = Xv_{STAS} - Xv_{REAL} \quad (mm) \tag{3}$$

where Xv_{STAS} is the distance from the bottom wire to the gallery bedrock according to the arming monograph;
Xv_{REAL} is the measured subteranean distance and is aproximated with the following relation:

$$Xv_{REAL} = (d_1 + d_2)_{MAS} - \left(\frac{d_5 + d_6}{2}\right)_{MAS} \qquad (mm)$$

The deformation speed which is noted with V_D will be calculated with the following relation:

$$V_D = \frac{U}{t} \qquad (mm / zi) \tag{4}$$

where U is the variation of deformation in the time interval between two consecutive measurements, (mm);

t is the time interval between two consecutive measurements, (days).

The ceiling, wall and bedrock deformation speed was noted with V_T, V_B, V_V.

For the studied mining work the convergence calculus and deformation speeds were made on the basis of data from measurments forms and relations (1.1), (1.2), (1.3) și (1.4), which were previously shown.

5. MEASUREMENTS AND RESULTS OBTAINED FOR THE MAIN TRANSVERSAL GALLERY, HORIZON 100

For the main transversal gallery situated at horizon 100, the station placement is at 20 m from the closing embankment for the 6th and 7th exploited layers.

The height of the armed profile gallery (d1 + d2) STAS = 2580 mm.

The width of the gallery bedrock (d7 + d8) STAS = 4100 mm.

The distance Xv_{STAS}=1130 mm.

Table 1

Measurement date	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8
10.03	1000	1760	1889	2042	1680	1720	1935	1990
27.03	997	1760	1885	2040	1680	1780	1930	1980
06.04	995	1760	1885	2040	1680	1780	1930	1975

Table 2

Deformation registered in date	U_T	U_B	U_V
10.03	220	175	70
27.03	223	150	73
06.04	225	195	75

Table 3

Deformation speed registered in interval	V_T	V_B	V_V
1	0,17	0,87	0,17
2	0,8	0,5	0,2

6. RESULTS AND MEASUREMENTS OBTAINED FOR THE MAIN TRASNVERSAL GALLERY, HORIZON 150

The main transversal gallery situated at horizon 150 of the Petrila Mining Exploitation, is sustained with special TH5 metallic frames, the profile of the mining work being GDM -11. The used bandage type is grid metallic net. The arming step, noted with L is 0,7.

The height of the armed profile (d1 + d2)STAS = 3200 mm.
The width of gallery bedrock (d7 + d8)STAS = 4100 mm.
The distance Xv1 STAS=1280 mm și Xv2 STAS=2380 mm
In the following section the measurement of station 1 will be shown in tables, with deformations and deformation speeds for the main transversal gallery situated at horizon 150.

Table 1

Date of the measurement for Station 1	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8
09.03	1060	2100	1760	1730	1917	1915	2030	2040
27.03	1020	2063	1781	1726	1910	1890	2020	2038
05.04	1020	2060	1990	1738	1920	1890	2025	2025

Table 2

Deformation registered in date	U_T	U_B	U_V
09.03	40	30	36
27.03	117	42	97
05.04	117	50	98

Table 3

Deformation speed registered in interval	V_T	V_B	V_V
1	1,00	0,22	1,00
2	1,88	2,22	1,88

Table 4

Date of the measurement for Station 2	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8
09.03	1020	1995	1600	1790	1995	1595	1830	2100
27.03	1014	1983	1597	1780	1620	1600	1826	2105
05.04	1035	1945	1600	1772	1644	1626	1800	2016

Table 5

Deformation registered in date	U_T	U_B	U_V
09.03	165	170	0
27.03	203	174	18
05.04	220	194	35

Table 6

Deformation speed registered in interval	V_T	V_B	V_V
1	1,00	0,22	1,00
2	1,86	2,22	1,88

7. CONCLUSIONS

Following the deformations recordings of the main transversal gallery of horizon 100, it is shown that these have the biggest values on the lateral wall, the most meaningful deformation recorded being 2042 mm. The deformation speed for the first time interval does not exceed 0,87 mm/day, this speed becoming smaller in the second time interval at 0,2-0,5 mm/day, on the side walls, ceiling and bedrock. The biggest deformation speeds were recorded on the first time interval.

Following the deformations recorded at horizon 150 stations, it was shown that these have the biggest bedrock values, the most significant deformation recorded being 2063 mm. The deformation speed for the first time interval does not exceed the maximum of 1,00 mm/day, this speed increasing on the second time interval at 2,22 mm/day, on the side walls. Also, both on the ceiling and the bedrock, bigger deformation speeds were recorded on the second time interval.

It is remarkable that the bedrock suffers deformations by rock movement on the work contour, UT și UV, with values between 0 to 98 mm, while on the ceiling values until 220 mm were recorded. These deformations provoked by rock movement on the work contour, also by mining pressure, lead to values of deformation speeds and their convergence.

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THE ANALYSIS OF DEFORMATION METHODS OF THE HORIZONTAL MINING WORKS EXECUTED IN DEEP LAYER SEDIMENTARY ROCKS

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Abstract: *Rock pressure around the contour of horizontal mining works, has different values which are variable in time. Periodic rising of deformations on the supporting structure is corelated with gradual rising of rock pressure, which we will call primary pressure. As soon as the opening deformation stops, the primary pressure turns into secondary pressure. Both primary pressure and secondary pressure, show certain particularities which we will analyze in depth in this study.*

Keywords: *deformation, mining work, rock pressure, mining supporting structure*

1. INTRODUCTION

The experimental characteristics which will be shown, include mining works at horizon 50, which means 730 meters deep from the surface, (+0,00), which are executed at Mining Exploitations of Petrila. In this context, experimental measurements allowed the study of the influence of rising the mining extractions levels on the intensity of the deformation of mining works. The experimental observations and measurements were realized în block II. At the moment of measurement of the mining works network the total distance measured 3555 meters. This network of mining works spanned 33 % sandstone, 21 % clay, 29 % sandy clay, 7% marl and 10 % coal and carbonaceous clay.

2. DATA REGARDING THE STUDIED LOCATIONS

The proportion of rocks in block II, as shown in figure 1, is structured as following: clay 32,48 %, sandy clay 26,77%, sandstone 27,08 %, marl 0,84 %. According to geological data, we see that as depth is rising, the proportion of clay rocks is also rising. Laboratory analysis have shown the intermediate values of compression resistance, as shown in table 1.

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Table 1

Name	Average compression resistance values daN/cm^2
sandstone	200 – 400
marl sandstone	300 – 650
marl	400 – 500
clay	120 – 200
bituminous schists	100 – 180

As we can see from table 1, because of the low mechanical resistance of rocks, they present pronounced deformation characteristics which negatively influence status of structural supports. The majority of mining works analyzed in this study were executed by perforation and explosive cartridge usage, with the following profiles:

- GDM - sustained by metallic arches SG - 23 which corresponds to a TH5 special profile;
- GDM - 8 sustained by metallic arches SG -18 or SG -23 and correspond to normal TH5 profiles, used in directional galleries inside the 3 and 5 layer.

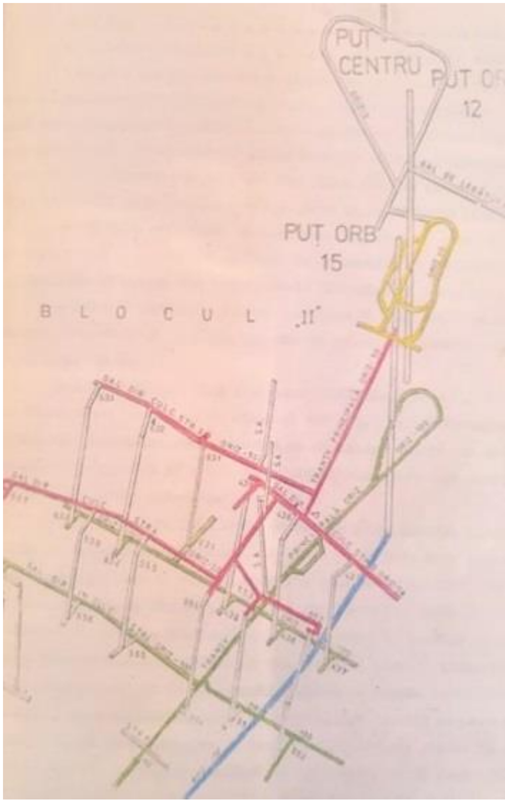


Figure 1. Map of block II, E.M.Petrila

3. DEFORMATION MEASUREMENT METHOD

Inside block II, at horizon 50, we studied the main transversal galleries, the directional gallery inside the 3rd layer west, and the head gallery inside 4th layer. Generally, at the level of horizon 50, we observed the most intense support structure deformations. When we analyze deformation particularities, inside each mining work we set up observation stations marked by measurement milestones of rock movement on the ceilling, bedstone and walls, according to the model presented in figure 2. In total, we built 12 observation stations for mining works inside block II. Knowing the initial profile of galleries, according to arming monographs, we could graphically illustrate the evolution of the process of deformation, and calculate three base parameters: the deformation of ceiling-bedstone, noted as Ut; the deformation of the width of the galleries at the level of bedstone, noted as Ub; the inflation of the bedstone, noted as Uv.

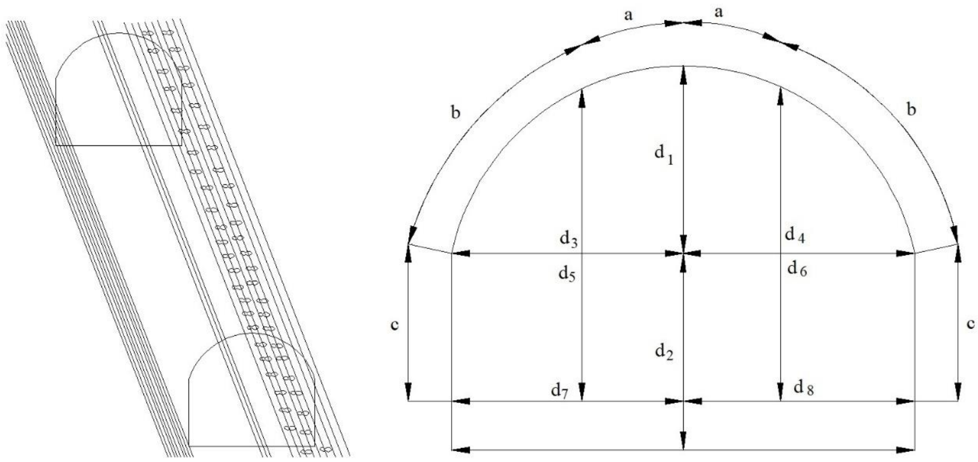


Figure 2. Guide lines of measurements of rock displacement

4. OBTAINED EXPERIMENTAL RESULTS

Knowing the fact that for a rock deformation speed on the contour of mining works, higher than 3mm/day, the process of support structure deformation occurs, we intended that in the elaboration of this study to determine the deformation speed and also to establish the main direction from which the pressure acts with maximum intensity. On the level of horizon 50, we observed the most intense support structure deformations. This phenomena is determined by the influence of cracks situated under horizon 50, at 33 meters in layer 3 and 30 meters in layer 5.

4.1. The main transversal gallery

During the elaboration of the study, this gallery showed a uniform deformation across the length, the main phenomena of the bedstone inflation reached 0,785 meters from the initial profile. The deformation speeds varied between 0,11-2,22 mm/day, which indicates that this mining work maintained its stability, without being influenced by the actions of cracks, figure 3.

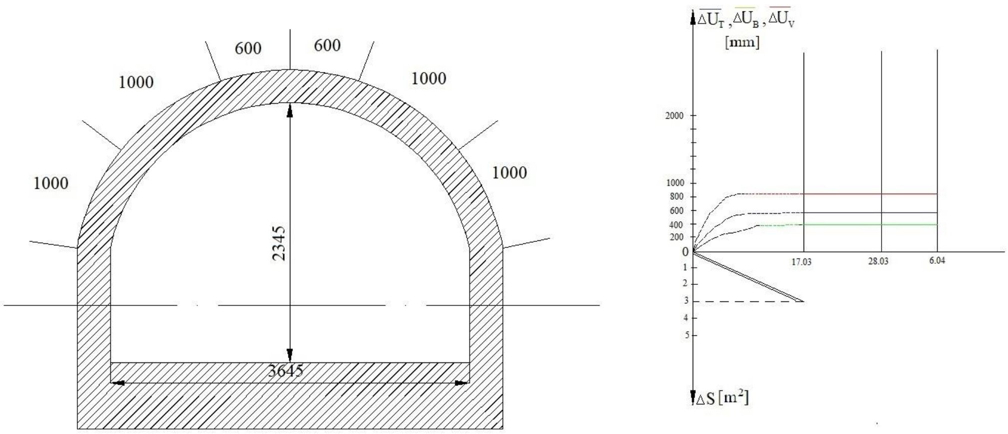


Figure 3. Diagrams for main transversal gallery deformations, horizon 50 (H=730 m)

4.2. The directional gallery on the 3rd layer (east-west)

This gallery is found at 730 meters from the surface, and is situated at 39 meters inside layer 3, allowing access from the main transversal gallery in the IVth sector. Both the western side and the eastern side are characterized by a pronounced deformation of both the bedstone and walls, the access being difficult in some areas, as shown in figure 4.

During the elaboration of the study we recorded the highest deformation speeds on the western side, with speeds varying from 7,45-16,11 mm/day. Alongside the gallery we observed different deformation stages, with portions needing reprofilings.

The deformations on the walls reached 0,9 - 1,1 meters and those in the bedstone at 0,355 - 0,636 meters.

4.3. The directional gallery in the 3rd layer (west)

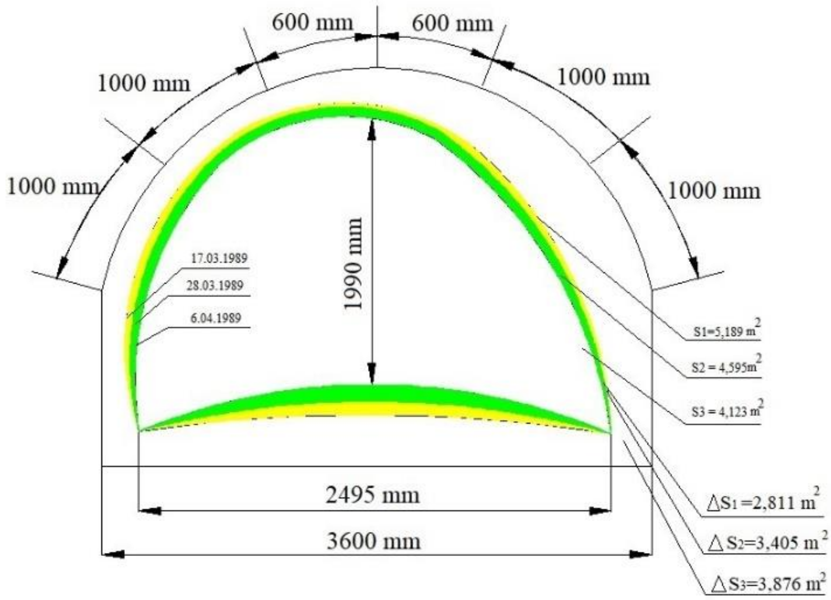
The deformation method of the contour of this gallery is not uniform. In the interaction zone with the main transversal gallery, the deformations are small, according to the distancing from the transversal, and the closeness from the exploitation zone, the deformation reach 0,315 - 0,61 meters, the most prominent being those in the walls and bedstone, figure 5. On the route of the work, the bedstone is fractured, the pillars of the armature are pushed inside the interior of the profile, and those from the 3rd layer are deformed. At the date of the measurements reprofilation works were underway, and on a 12 meters distance experimental support structures were mounted, with 2 rows of pillars. Even though the distance was higher inside layer 3, the deformation speeds was between 2,7 -5,6 mm/day.

4.4. The directional head gallery on layer 4

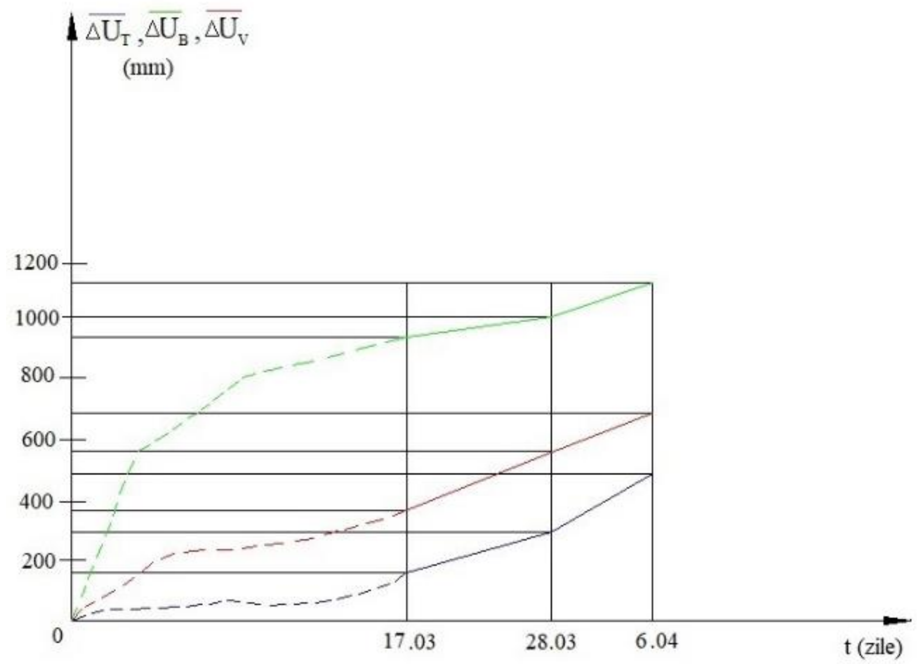
This gallery is sustained by metallic TH profiles and serves the sector V air shafts, which are situated at H=730. Inside this gallery too, the method of rock deformation is different along the length, and 3 measurement stations were mounted which showed the following results:

- at 6 meters from the air shaft raiser wall deformations are predominant which record 0,74 m.
- at 56 meters from the air shaft raiser, we see a rising in wall deformations until 0,975 meters, and bedstone inflation at 0,48 meters;
- at 106 meters from the air shaft raiser were 3 measurements stations were mounted on 3 reinforcements until 1,855 meters, as shown in figure 5.

The deformation speeds were rising as we approached the extraction zone from 0,25 to 3,13 mm/day.

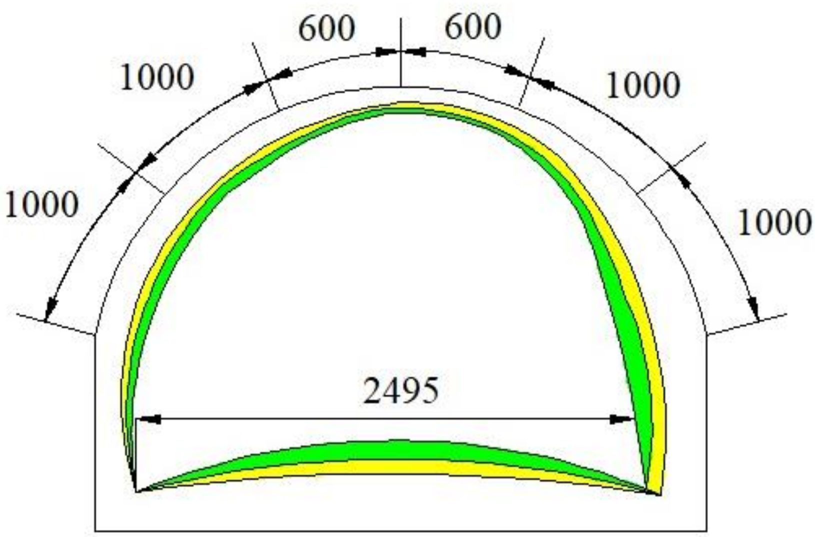


a)



b)

Figure 4. Directional gallery in bottom of layer 3, west part, horizon 50 (H=730 m).
a – deformation values in mm; b – deformation in time.



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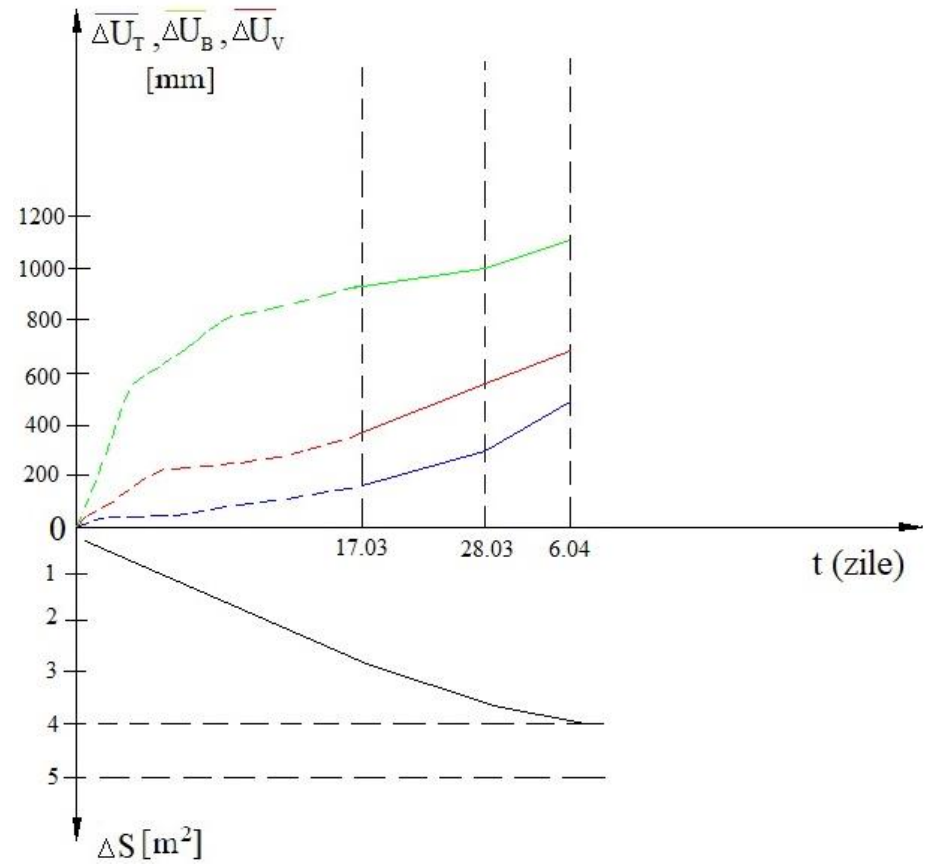

b)

Figure 5. Directional gallery in bottom of layer 3, est-west part, horizon 50 (H=730 m).
a – deformation values in mm; b – deformation in time.

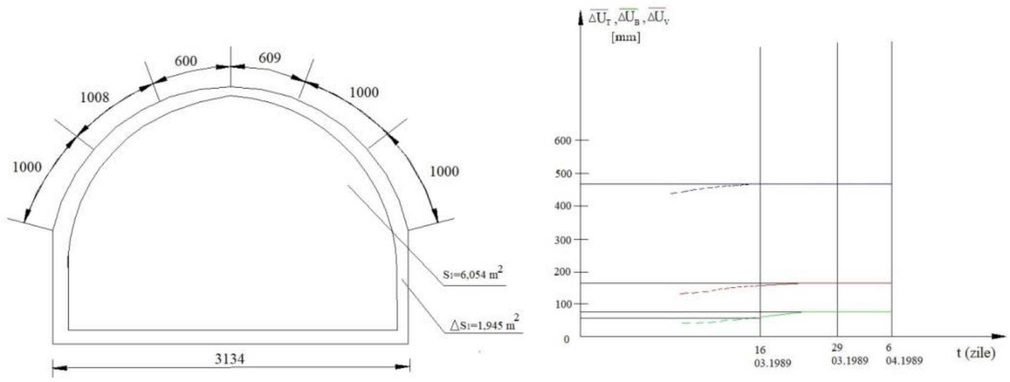

Figure 6. Directional gallery in layer 4, horizon 50 (H=730 m)

5. CONCLUSIONS

From our study we observe that the method of deformation is not uniform. In the intersection area between the main transversal gallery, the deformations are small, as we go further from the transversal and closer to the exploitation zone, the deformations reach 0,315 - 0,61 m, being more predominant in the walls and bedstone. On the route of the mining work, the bedstone is fractured, the reinforcement pillars are pushed to the inside of the profile, and those in the wall near the layer 3 were already deformed at the date of the measurements.

Inside the main transversal gallery we observe a uniform distribution of rock pressure on the contour of the mining work. The deformations do not exceed 0,225 m and the speeds of deformation are smaller, between 0,37 - 0,67 mm/day.

Regarding the measurements conducted in the main gallery on layer 4, we observe that the eastern side, sustained by metallic profiles TH7, and the western side, sustained by metallic profiles TH5, uniform deformations appear that do not exceed 0,11 m.

Different from the deformation speeds specific to the galleries on layer 3, for the 4th layer, the deformation speeds have values between 0,5 -1,1 mm/day.

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METHODOLOGICAL STEPS FOR COLLECTING GAS SAMPLES

DANIELA IONELA CIOLEA[1]

Abstract: *Air pollutants have a number of negative effects on both materials and vegetation, animals and humans, causing damage. The harmfulness of industrial gaseous effluents that can be considered potential aggressors of the environment (humans, animals, vegetation, materials) depends, first of all, on the concentration of these substances in the air in the vicinity of the soil. It is therefore important to specify the conditions for the dispersion of pollutants into the atmosphere and the effectiveness of the technical means available to control this dispersion. There are a number of methods of collecting gas samples: collecting gas samples in closed bottles and collecting by suction.*

Keywords: *environmental protection, legislation, sustainable development, industrial gaseous effluents.*

1. INTRODUCTION

Between the diffusion of solid and gaseous particles emitted continuously by the chimneys of large combustion plants, there are differences as follows: the maximum concentration downwind, starting from the chimney is practically independent of atmospheric turbulence, and in the case of an aerosol - the maximum concentration at ground level increases strong when turbulence decreases; the maximum concentration at ground level, starting from the chimney, is practically inversely proportional to the square of the height of the source, and in the case of aerosols this maximum is inversely proportional only to the height of the source [2, 7]. The following considerations must be taken into account when collecting air or gas samples:

1. The place of collection must be determined in such a way that the sample is representative.
2. During the harvest, the meteorological conditions (temperature, pressure, air movement, presence or absence of clouds) will be noted.
3. The recommended harvest time is 30 minutes for the current concentration and 24 hours for the average daily concentration.
4. The volume of air collected varies depending on the assumed concentration and sensitivity of the analysis method.

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5. After harvesting, the devices must be transported to the laboratory in conditions that do not change during transport.

6. For the determination of dust, the harvesting device must be packed during transport to avoid contamination (dusting). [6]

2. COLLECTION OF GAS SAMPLES IN CLOSED BOTTLES

Collection in closed bottles is recommended for high concentration gases, as this method does not allow a concentration of the pollutant. Harvesting vessels are made of glass or plastic with a capacity of 1 - 5 liters hermetically sealed with rubber taps or plugs. Harvesting can be done by three methods [1]:

1. Collection by emptying (the bottles after being washed are filled with distilled water and transported to the collection site. Here by draining the water the air will enter the bottle, after which it will be hermetically closed.

2. Air replacement (the washed and dried vial is adapted to a suction system and a volume 10 times the volume of the vial is collected to ensure that the entire amount of air in the vial has been replaced with the gas to be be aspirated).

3. Vacuum collection (with the help of a vacuum pump equipped with a manometer, the air is removed from the bottle (volume V_0) until a maximum vacuum P_0 is reached, and at the place of collection the bottle is opened and due to the vacuum, the air will enter inside the bottle (fig. 1). Note the air pressure at the P_R collection site. To calculate the volume of air collected (V) use the formula (1):

a) b)

Figure 1. a) Vacuum bottle for instantaneous sampling. [5]
b) Container with liquid displacement, used for collecting instant samples

$$V = \frac{V_o \cdot (P_R - P_o)}{P_R} \tag{1}$$

3. SUCTION COLLECTION

It is used when the gas in the air to be analyzed has a low concentration. It has the advantage of long-term harvesting. For suction, an air volume measuring device and a device for retaining the substances or suspensions to be analyzed are used. The most important suction devices are the water pipe and the mechanical vacuum cleaners. Rheometers, rotameters and gasometers are used to measure the air volume. By their construction the restraint devices must ensure the complete absorption of the analyzed substance from the collected air. If solid absorbents are used, the device must be constructed in such a way that air travels as long as possible through the absorbent layer for the complete retention of the intended substance. If liquid absorbents are used, the absorption vessel must ensure a slow bubbling, small bubbles to ensure maximum interphase contact and to prevent its entrainment.

3.1. Methodological steps for collection of air samples by suction (for the determination of SO_2 by the spectrophotometric method)

Methodological steps:

1. check the installation (fig. 2) for collecting samples (suction device, air volume measuring device, retaining device);
2. prepare the absorbent solution: 11.7 g of NaCl is dissolved in 500 ml of double-distilled water, in a 1000 ml volumetric flask. Add 27.2 g of $HgCl_2$, stir until dissolved and make up to the mark with double-distilled water;
3. 10 ml of absorbent solution are introduced into the suction device;
4. the type of determination is established (momentary concentration, average daily concentration);
5. the sampling point is established;
6. the trip is made to the chosen collection point;
7. specify in the collection sheet the weather conditions at the time of sampling: temperature, humidity, pressure, clouds, precipitation, etc.;
8. the value of the collected air flow is established at a value of approx. 1 l/min for the momentary concentrations or 0.5 - 0.7 l/min for the daily average concentrations;
9. avoid light absorber during sample collection;
10. turn on the suction device;
11. aspirate air for a maximum of 30 minutes, then turn off the suction device;
12. the suction device is transported to the laboratory.

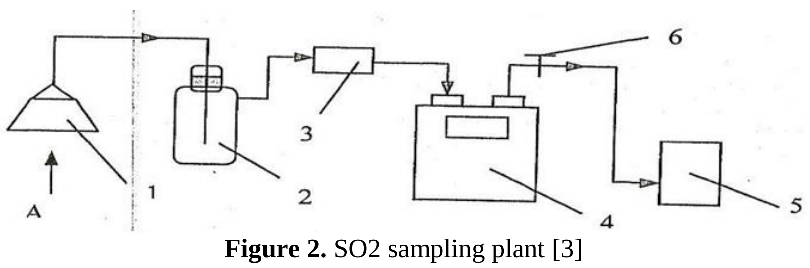


Figure 2. SO2 sampling plant [3]
1 - glass or plastic funnel, pointing downwards; 2 - harvesting vessel; 3 - glass device, for retaining acid aerosols, with a length of about 15 cm and a diameter of about 1 cm, filled with glass wool; 4 - device for measuring the air volume (gas meter); 5 - air suction device; 6 - air flow regulating device.

3.2. Methodological steps for collection of air samples by suction (for the determination of SO_2 by nephelometric method)

Methodological steps:

1. the installation for sampling is checked (suction device, air volume measuring device, retention device);
2. prepare the absorbent solution: potassium chlorate 2.5 %;
3. 10 ml of absorbent solution is introduced into the suction device;
4. the type of determination is established (momentary / daily average concentration);
5. the sampling point is established;
6. the trip is made to the chosen collection point;
7. specify in the collection sheet the weather conditions at the time of sampling: temperature, humidity, pressure, clouds, precipitation, etc.;
8. the value of the collected air flow is established at a value of approx. 1 l/min for the momentary concentrations or 0.2 - 0.3 l/min for the daily average concentrations;
9. turn on the suction device;
10. aspirate air for a maximum of 30 minutes, then turn off the suction device;
11. the suction device is transported to the laboratory.

3.3. Methodological steps for Collection of air samples by suction (for NO_2 determination - method I)

Methodological steps:

1. check the installation (fig. 3) for collecting samples (suction device, air volume measuring device, retaining device);
2. prepare the absorbent solution: KI 0.3 N or 15 %;
3. the sampling point is established;
4. travel to the chosen harvesting point;
5. specify in the collection sheet the weather conditions at the time of sampling: temperature, humidity, pressure, clouds, precipitation, etc.;
6. prepare two microabsorbents connected in series;
7. place in each microabsorbent 10 ml of absorbent solution;
8. set the value of the collected air flow at a value of approx. 0.3 l/min;
9. turn on the suction device;
10. aspirate air for a maximum of 30 minutes, then turn off the suction device;
11. the suction device is transported to the laboratory.

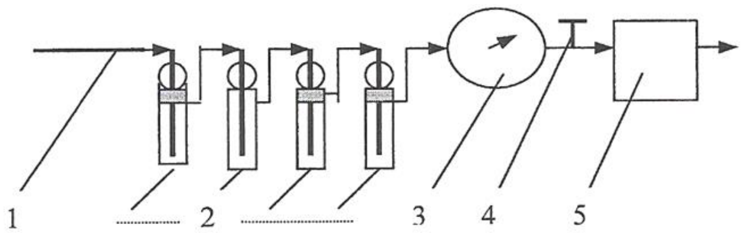


Figure 3. NO2 sampling plant [3]

1 - glass or plastic pipe ∅ 8 m; 2 - absorption vessel with frit, useful capacity of 50 cm^3;
3 - device for measuring the air volume; 4 - air flow control device; 5 - suction device.

3.4. Methodological steps for collection of air samples by suction (for NO_2 determination - method II)

Methodological steps:

1. the installation for sampling is checked (suction device, air volume measuring device, retaining device);
2. prepare the absorbent solution: in a 1000 ml volumetric flask dissolve 5 g of anhydrous sulphanilic acid in about 600 ml of double-distilled water. To accelerate the dissolution, the flask is heated to 50-60ºC; 50 ml of glacial acetic acid, 10 ml of acetone and 0.05 N-1-naphthylethylenediamine hydrochloride are added; complete with double-distilled water;
3. the sampling point is established;
4. travel to the chosen harvesting point;
5. specify in the collection sheet the weather conditions at the time of sampling;
6. prepare two microabsorbents connected in series;
7. place in each microabsorbent 10 ml of absorbent solution;
8. set the value of the collected air flow at a value of approx. 0.3 l / min;
9. turn on the suction device;
10. protect the vessels from direct sunlight absorption;
11. aspirate air for a maximum of 30 minutes, then turn off the suction device;
12. the suction device is transported to the laboratory.

3.5. Methodological steps for collection of air samples by suction (for NO_2 determination - method III)

Methodological steps:

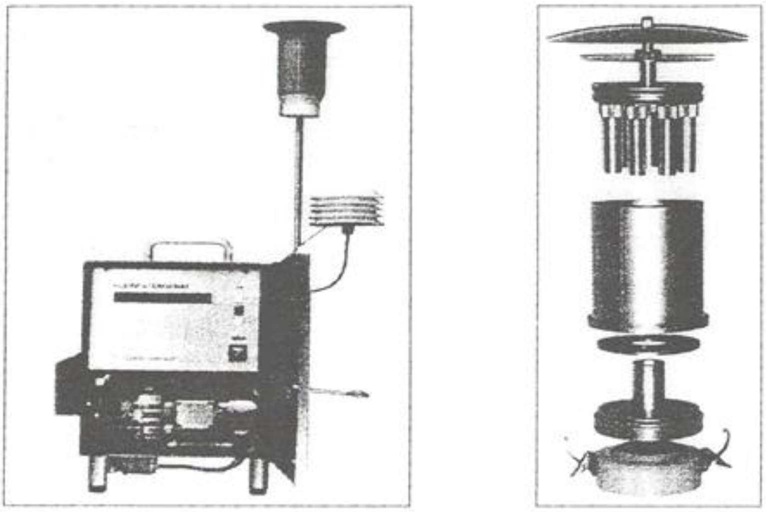
1. the installation for sampling is checked (suction device, air volume measuring device, retention device);
2. prepare the absorbent solution: NaOH 0.1 N;
3. the sampling point is established;
4. travel to the chosen harvesting point;
5. specify in the collection sheet the weather conditions at the time of sampling: temperature, humidity, pressure, clouds, precipitation, etc.;

6. prepare two microabsorbents connected in series;
7. place in each microabsorbent 5 ml of absorbent solution;
8. set the value of the collected air flow at a value of approx. 0.3 l/min;
9. turn on the suction device;
10. aspirate air for a maximum of 30 minutes, then turn off the suction device;
11. the suction device is transported to the laboratory.

3.6. Methodological steps for collection of air samples by suction to determine suspended dust

Methodological steps:

1. check the installation (fig. 4) for collecting samples (suction device, air volume measuring device, retaining device);
2. dry the filters for 24 hours in the desiccator;
3. weigh the filters at the analytical balance;
4. mount the filters in the dust retention devices;
5. the sampling point is established;
6. the trip is made to the chosen collection point;
7. the sample retention device is fixed;
8. the value of the collected air flow is established at a value between 0.3- 3 l/min.;
9. turn on the suction device;
10. aspirate air for a maximum of 30 minutes, then turn off the suction device;
11. disassemble the sample retention device;
12. pack the filters;
13. the filters are transported to the laboratory.



a) b)

Figure 4. a) Dust sampling system LVS; b) Dust sampling head

3.7. Methodological steps for collection of air samples for the determination of sedimentable dusts

Methodological steps:

1. the harvesting vessels are chosen (cylindrical vessels with a diameter of 20 cm and a height of 40 - 50 cm, made of glass or plastic, fig. 5);
2. wash the harvesting vessels with sulfochromic mixture, detergent, rinse with tap water and double-distilled water;
3. dry the dishes in a dust-free place;
4. cover the containers with paper to avoid dusting during transport;
5. the vessels are transported to the place of collection;
6. put in each vessel 150 - 200 ml of distilled water (in winter, 25 - 30 % alcoholic solution);
7. the vessels are placed in protection boxes;
8. note the place, date and time of the location of the vessels;
9. after 30 days, cover the vessels and transport them to the laboratory.

The collection vessels / containers used (green plastic buckets, fig. 1.5) were not placed in protection boxes, being very easily swayed by the wind and not being protected from the birds. The two sampling points were not well chosen, being very close to trees, vegetation and buildings.

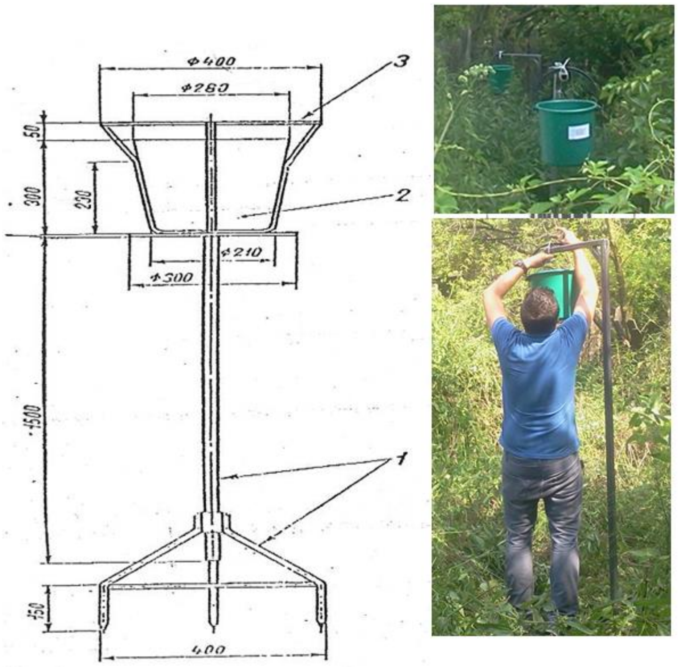


Figure 5. Sedimentary powder sampling device [2, 4, 6]
1- support with a height of 1.5 to 2 m; 2- the collection vessel with an inner diameter of 250… 300 mm and a height of 1… 3 times the diameter; 3- metal ring

CONCLUSION

Sampling and sampling is a particularly important step in the analysis process, because the samples must be representative, must not introduce errors in the composition and qualities of the environmental factor under study due to poor technique or incorrect preparation conditions. material, it is known that errors due to improper harvesting can no longer be corrected. Pollution control includes the assessment of the physical, chemical and biological properties of environmental factors, which in one way or another, exert a considerable influence not only on human health, but also on their living conditions. Environmental pollutants are multiple with a cumulative action due to the natural cycles that take place in each ecosystem - air, water, soil - and become harmful when they exceed certain concentrations.

When a solid or liquid substance is emitted into the air in the form of particles, its properties and effects may change. When a substance is broken down into smaller and smaller particles, a larger area of its area is exposed air. In these circumstances, the substance, regardless of its chemical composition, tends to combine physically and chemically with other particles and gases in the atmosphere. The resulting combinations are often difficult to predict.

Many substances, which oxidize slowly in their massive state, will oxidize extremely fast or possibly even explosive, when dispersed as fine particles in the atmosphere. Dust explosions, for example, are often caused by burns unstable or oxidation of fuel particles. Absorption and catalytic phenomenon they can also be extremely important in analysis and understanding pollutant particle problems. Conversion of sulfur dioxide to corrosive sulfuric acid, under the catalytic action of Iron oxide particles, for example, demonstrate the catalytic nature of certain types of particles in the atmosphere.

The degree of volatility of an air contaminant may affect the method of depollution, because it determines the physical state of the compound in the air.

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EVALUATION OF SOIL HEALTH ACCORDING TO CHEMICAL INDICES OF SOIL AIR

CIOLEA DANIELA IONELA[1], DUNCA EMILIA CORNELIA[2]

Abstract: *Sampling is the most important step for an analytical process. Sampling can involve very complicated procedures often requiring several subdivision steps before the final analytical result is obtained. In order to develop an efficient sampling procedure, the following aspects must be taken into account: the sample taken must be representative of the volume of the entire material; the amount of sample to be taken must be determined; the subsequent handling and storage of the sample must be correct. A sampling procedure may involve several steps before the material is made. The soil samples collected are not analyzed in the laboratory directly but are operated in soil sub-samples. The collection of soil samples for analysis is influenced by certain factors (microrelief, variety of crops), which can lead to harvesting errors. All soil studies, regardless of their destination, are performed in the field, but especially in the laboratory on samples or samples, collected from the surface under analysis so that they mirror as accurately as possible the reality, so they are representative. This is all the more necessary as the results obtained by analyzes are usually extrapolated to large areas with the same soil.*

Keywords: *environmental protection, soil pollution, legislation*

1. INTRODUCTION

Law no. 246/2020 on land use, conservation and protection regulates the activities regarding the use, conservation, improvement, bioproductive capacity assessment, economic recovery, soil protection and monitoring integrated soil quality, in the context of sectoral policies to ensure use sustainable development of this non-renewable natural resource. [3]

The objective of this law is to establish the unitary framework of measures and actions for:

a) prevention of soil degradation and possible changes detrimental to its quality, in the purpose of avoiding disturbances / modification of its ecological functions and heritage conservation pedological and cultural heritage objectives;

b) conservation of the cultural, energetic, socioeconomic functions of the soil for the purpose of use durable salt;

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c) restoration and restoration of lands affected by degradation as a result of rain erosion and wind, deficit or excess moisture, declining organic matter content and nutrients, biodiversity reduction, compaction, acidification, sodification, alkalinization, desertification, landslides and lands affected by microorganisms such as viruses, bacteria and dangerous fungi;

d) reduction of the surface of the lands removed from the agricultural circuit or from other categories of non - agricultural use by optimizing the maximum use of the areas approved by urban plans;

e) elaboration of plans for use, conservation, improvement, quality increase and soil protection, using the data and information obtained to achieve the national system soil-land monitoring for agriculture, especially those related to development conservative agriculture.

2. PRINCIPLES UNDERLYING LAND USE, CONSERVATION AND PROTECTION

The principles underlying land use, conservation and protection take into account [3]:

a) the role of soil, as a component part of the geological environment, a vital factor of terrestrial ecosystems, fundamental natural resource;

b) the importance of soil, as a living environment for humans, plants and animals, for conservation biodiversity and the genetic reserve present in the soil;

c) ensuring food safety and security of food, food raw materials and / or fodder;

d) ensuring in the long term an optimal and significant contribution of agriculture, forestry and al other socio-economic branches that use the soil for gross domestic product;

e) maintaining, improving soil quality, preventing soil degradation, stopping desertification and removal of pollutants that endanger soil quality, while respecting the specific legislation in force;

f) protection of soil multifunctionality, ecological - economic - social, maintenance, improving and conserving soil and ecosystem biodiversity;

g) development of rural space in order to use sustainably and efficiently manage soils;

h) direct assurance of participation and support from the state, civil society, a economic operators and each citizen in the elaboration and application of measures and actions on the use, conservation and protection of the soil;

i) stimulating the direct participation, with own contribution, of the owners and users of lands when implementing measures and actions regarding the use, conservation and protection of soil;

j) elaboration of programs, plans and actions of national, regional and local interest regarding land use, conservation and protection, in which the state has the role of initiator or co-financier;

k) elaboration of programs, plans and measures for protection, prevention and reduction of negative effects on soil at national, regional and local level;

l) identification of anthropogenic activities with negative effects on the soil in all ecosystems and natural risk areas;

m) elaboration of land use and planning policies, taking into account the need protection of soil properties and functions;

n) the creation of the institutional system necessary for the use, conservation and protection of the soil and providing specialized personnel;

o) educating and raising awareness of civil society on issues of use, conservation and soil protection to protect human health and ensure sustainable development;

p) development of international collaboration to ensure the implementation of national programs use, conservation and protection of the soil at technical-economic and ecological standards;

q) harmonization of the legislation on land use, conservation and protection with regulations European Union;

r) the archaeological heritage of the soil is public property, regardless of the legal regime of ownership of the land where those goods would be located.

3. SOIL FUNCTIONS

The soil functions are [3]:

a) cultural / archive functions:

1 - natural history and cultural history of human society;

2 - cultural environment for population and human activities;

b) ecological functions:

1 - physical environment for the development and conservation of soil biodiversity;

2 - physical environment for the population;

3 - vital component of natural or anthropogenic ecosystems;

4 - environment for decomposition, regulation and restoration of ecological balance as a result of properties of storage, filtration, buffering and transformation of substances, nutrients and, in particular, groundwater protection;

5 - genetic reserve;

6 - regulating the composition of the atmosphere and hydrosphere by participating in the circuit of substances chemical and water;

7 - geothermal, relief protectors;

8 - buffer for sudden variations of climate, acidity, etc.;

c) energy functions:

1 - accumulation of chemical energy and transfer of substances and energy between geospheres;

2 - absorption and heat (solar radiation) and its propagation in the atmosphere;

d) socio-economic functions:

1 - source of raw materials;

2 - source of coal / organic matter;

3 - physical environment for human settlements, development of human socio-economic activities and necessary human society infrastructures - means of agricultural production and forestry / biomass production;

4 - GIS - Geographic information system.

4. DEPTH AND TIME OF SAMPLE COLLECTION

The arable layer is researched on samples collected every 10 cm, and from 30 cm samples are collected every 25 cm, up to 1 m or on the entire thickness of the soil profile, depending on the purpose of the research. Sampling will be done before sunrise or after crop harvesting, and when necessary during vegetation. The main condition is that the soil should not be too wet, but not too dry.

Collection of soil samples for analysis

Soil harvesting for analysis is a very important operation on which the accuracy of the results depends to a large extent. Soil samples rise from each horizon and sub-horizon separately; from the thick ones 2-3 samples are taken, and from the short horizons a central sample is taken. Soil samples are collected in artificial structure up to a depth of 1m, or more, depending on the nature of the soil and the characteristics of the pollutant pursued. The soil surface to be researched is established by delimiting a plot between 25-50 m2 on which the harvesting points are fixed.

Tools - used in soil harvesting:

- shallow: wells, spades or shovels with which a ditch is dug to the desired depth from where the soil sample is then collected;
- surface: metal spatulas are used to scrape the surface of the soil.

The soil is harvested in glass or polyethylene containers with a wide neck and airtight closure, previously washed with sulfochromic mixture or detergents. Rinse well with tap water, distilled and double-distilled water and then dry.

Soil harvesting from the surface is done after a preliminary removal of dust, roots, leaves, or other residues that are on the soil surface.

The recommended depths for soil harvesting are [1]:

- for chemical analyzes they are taken on a thickness of 5 - 10 cm;
- for islets in contact with wastewater - 5 cm;
- for vegetable arable land treated with wastewater - 20 cm;
- for soils with contaminated points when there is a suspicion of contamination - 1m.

Soil samples are collected in order to control soil pollution and evaluate its quality. For chemical, bacteriological and helminthological analysis, soil samples are taken at least once a year. For the control of heavy metal pollution, soil samples are taken at least once every three years. For the control of soil pollution in kindergartens with children, curative-prophylactic institutions and recreation areas, samples are collected at least twice a year - spring and autumn.

For the control of soil pollution in the agricultural area, depending on the character of the pollution source, the cultivated plant and relief, every 0.5-20.0 ha a land with an area of 10 × 10 m is separated. For the control on the sanitary condition of the territory on which is the kindergarten, the playground, the septic tanks, the garbage cans, etc. a plot of land measuring 5 × 5 m is separated.

From these lands the samples are taken from one or several layers or horizons by the envelope method, diagonally or by another method.

Samples are harvested with a knife, spatula or special screed. The average sample is made by mixing the samples taken from the five points of the "envelope"; the mass of the combined sample must have not less than 1 kg of soil. Samples intended for the determination of volatile chemicals are immediately poured into glass vials or jars, which are filled and closed with glass stoppers. For bacteriological analysis on a lot-lot, 10 unit (average) samples are taken. Each joint sample is obtained from 3 combined samples with a mass of 200-250 g each, taken in layers at 0-5 cm and 5-20 cm. For bacteriological purposes, the samples are taken in aseptic conditions with sterile instruments, placed in sterile vessels.

For the purpose of the helmentological investigations on each lot-land, an average sample of 200 g is taken, consisting of 10 unit samples with a mass of 20 g each, taken from the layers with a depth of 0-5 and 5-10 cm. (fig. 1)

The soil samples for chemical analysis are well dried and stored in cloth bags, cardboard boxes or glass jars.

Figure 1. The soil samples for chemical analysis

Soil samples for the determination of volatile and unstable chemicals are transported to the laboratory and immediately analyzed.

Samples for bacteriological analysis are transported to the laboratory in cold bags and immediately analyzed. Their storage is allowed at a temperature of 4-5 ºC, duration - up to 24 hours.

In the case of coliforms and enterocytes, the soil samples shall be stored in refrigerators for not more than three days.

Soil samples intended for helminthological determinations are transported to the laboratory immediately after harvesting. If it is not possible to perform the analysis immediately, the samples can be stored in the refrigerator.

For investigations of biohelminth eggs, soil samples without a certain processing can be kept for up to seven days, for investigations of geohelminth eggs - up to one month. In order to prevent drying and larval development, the soil is moistened and aerated once a week: the samples are left for three hours at room temperature, moistened to the required extent and placed in the refrigerator again.

If it is necessary to keep the soil samples for more than one month, preservatives are used: the soil is passed to the crystallizer, covered with a 3% solution of formalin prepared on isotonic sodium chloride solution or with a 3% hydrochloric acid solution, then put in the fridge.

Preparation for analysis. To determine the chemicals in the laboratory, the soil sample is poured onto a sheet of paper or chalk. Crush the lumps, remove the roots of the plants, insects, pebbles, pieces of glass, charcoal, bones, etc. Then the soil is crushed in a mortar (pestle) with the help of a pistil, sifted through a sieve with a diameter of 1 mm. The removed neoformations are analyzed separately, being prepared for analysis as well as soil samples.

To determine the content of mineral components in the sieved sample, take up to 20 g and grind in a mortar to powder.

In order to determine the volatile substances, the soil is taken without any prior preparation.

For the purpose of bacteriological analysis, soil samples are prepared analogously to those for the determination of chemicals, but with careful observance of aseptic conditions: the soil is poured on a sterile surface, all operations are done using sterile instruments, sieved through sterile sieves 3 mm and covered with sterile paper. The soil is crushed in sterile mortar.

For helminthological analysis, the soil is prepared analogously to that for the determination of chemicals.

5. BIOLOGICAL ANALYZES OF THE SOIL

5.1. Determination of the total number of germs

Take 10 g of soil in a mortar and grind as homogeneously as possible, place in a flask with pearls, then add 90 ml of distilled water, obtaining a dilution of 1:10; the suspension is shaken thoroughly, left for 2-3 minutes. for submission. Take with sterile pipette 1 ml of the suspension obtained and place in a test tube, add 9 ml of sterile water, obtaining a dilution of 1:100. Thus higher dilutions can also be obtained.

One ml of each dilution is placed in a Petri dish, then melted agar is poured over the suspension at 45 °C, the contents are homogenized and placed in a thermostat at 37 °C for 24 hours. Count the colonies grown on the whole surface with the naked eye, dividing the plate into quarters, or with the help of the colony counting network.

Only plates on which less than 300 colonies have grown are considered. The calculation is made to express the final result in the number of germs per 1 g of dry soil. (fig. 2)

Figure 2. The calculation is made to express the final result in the number of germs per 1 g of dry soil

5.2. Determination of the titer of coliform bacteria

It can be done in two ways:

1. seeding the soil suspension in test tubes with liquid lactose broth medium or in Kessler - Svenerton medium;
2. membrane filter method.

When the soil is not too polluted, use the accelerated method of membrane filters, which consists of the following: through sterile membrane filters no. 3, filter 5-10 ml of soil suspension in 1:10 dilution centrifuged beforehand 5 minutes for sedimentation of macroparticles. The filters with the absorbed bacteria are taken with a flamed forceps and placed on the surface of the Endo nutrient medium previously poured into the Petri dish. 4 filters can be placed in a box. On the box under each filter, write the sample number and the volume of the filtered suspension. The seeds are left in a thermostat at 37 °C for 24 hours. After incubation, the colonies are counted and the coli titer is calculated (number of coliforms per 1 g of dry soil), 2-3 typical colonies are stained by the Gram method and identified by the titrometric method. [2]

5.3. Determination of helminth eggs in soil

The principle of the method consists in the flotation of helminth eggs in saturated sodium nitrate solution, 5-10 g of homogenized soil are placed in a flask with pearls then 10-20 ml of 5 % sodium hydrate or potassium solution are added which has the role of to separate eggs from parasites from soil particles.

Stir the mixture well for 30 minutes. Centrifuge at 200-300 turation/minute for 1-2 minutes, then remove the supernatant by decantation. To the obtained sediment add a double amount (relative to the sediment) of saturated sodium nitrate solution with a density of 1.19, mix with a glass rod and centrifuge 5-6 times for two minutes at low speeds.

From the surface layer, with an L-shaped glass rod or rod, films are harvested, which are added to a 10 cm3 centrifuge tube, in which 1 cm3 of saline or distilled water were prepared. Centrifuge for 15 minutes at 200-300 turation/minute. At the end, the supernatant is siphoned with a pipette fitted with a rubber pair and examined entirely in fresh preparation under a microscope, noting the number and species of helminths. [1, 2]

6. CONCLUSIONS

The hygienic conclusion regarding the harmlessness of the soil for the health of the population is based on laboratory analyzes. Based on the data on the mechanical composition of the soil, conclusions are drawn about the natural content of organic substances, about the filtration capacity of the soil, the permeability for air and water, the self-purification capacity.

Mechanical (particle size) analysis allows the determination and naming of soil particles and soil type. Important is the name of the percentage composition of clay, sand, mud, etc.

Soil pollution from a chemical point of view is assessed depending on the content of pollutants, as well as the content of organic nitrogen, carbon, ammonia, nitrites, nitrates, chlorides compared to their content in the soil of the control sector. The degree of soil pollution with pesticides and other toxic substances is assessed by comparison with maximum allowable concentration (M.A.C.). theirs. The magnitudes of biological pollution, including bacteriological, are assessed by comparison with established regulations, which are also used to assess chemical pollution of soil. For this purpose, data on the chemical composition of the soil air are also recommended (Table 1).

Table 1. Assessment of soil health according to chemical indices of soil air

Characteristic	Soil air content (T^0C, Hg column pressure 760 mm) at a depth of 1 m in % volume			
	CO_2	O_2	NH_3	H_2
Non-polluted	0.38-0.08	20.3-19.8	-	-
Slightly polluted	1.2-2.8	19.9-17.7	-	-
Polluted	4.1-6.5	16.5-14.2	-	-
Very polluted	14.5-18.0	5.5-1.7	0.8-2.7	0.3-3.4

Obtaining the data on the degree of soil pollution, the conclusion about the age of the pollution is formulated, the measures to prevent the internal pollution and the ways of its remediation are sketched.

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SOLUTIONS FOR ECONOMIC RECOVERY OF CÂMPULUNG MUSCEL AREA, IN THE CONDITIONS OF DEINDUSTRIALIZATION AFTER 1990

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Abstract: *The paper aims to identify the main issues of the Câmpulung Muscel area and to offer the proper solutions for economic recovery. In the paper, were studied the physical-geographical, demographic, economic and technical, social and ecological indicators at different periods of time, by comparison, which establish the level of development. The regeneration of the area, focused on stimulating economic, agricultural and tourism activities, as well as the development of basic infrastructure to increase living standards and improve individual health, must be set as objectives of a sustainable development strategy, which must be implemented as soon as possible.*

Keywords: *economic recovery, sustainability, deindustrialization, Câmpulung Muscel*

1. INTRODUCTION

The Câmpulung Muscel area, like most of the localities in Romania, was put, after 1990, in front of solving a general paradigm, with institutional character, but with economic point of view and which diversifies into:

- incompatible legislation with a market economy, much less the functional one;
- high taxes in relation to the level of real development of all economic sectors;
- lack of concrete measures to reduce the acute social and economic crisis, mass poverty;
- eliminate of huge corruption at the level of all political dimensions;
- lack of objective information in encouraging and supporting community initiatives;
- lack of local policies, especially economic, of planning, systematization, organization and efficient spatial planning;
- intuitive and non-qualitative management in the evolution process.

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These phenomena have generated a negative impact on the inhabitants of the analyzed area, among which are:

- poor information of the population;
- indifference, established as a result, towards the surrounding events;
- apathy towards the Romanian society, as a result of the non-fulfillment of the unrealistic electoral “promises” and of the “expectations” attributed to the central entities [1];
- the increase of the wave of mass emigration, from villages to cities, and abroad, etc.

2. EVALUATION OF STRATEGIC ENVIRONMENTS

There is a serious impediment in the evolution of the whole country, and, even more, of the rural localities being represented by (table 1):

- exorbitant fiscal policy;
- lack of legal framework to facilitate investors (and disadvantage of local investments through fiscal instruments);
- the insignificant remuneration of civil servants, which causes corruption at all public levels;
- the wave of emigration abroad;
- lack of modern and sincere visions to approach problems etc.

Table 1. Main features of the town

Area - ha		31.820
Number of localities		7
Total population		62.283
Emigrants		1.914
Câmpulung Muşcel and township	Câmpulung Muşcel	39.111
	Aninoasa	3.450
	Berevoieşti	3.429
	Godeni	3.377
	Boteni	4.218
	Poienarii de Muşcel	3.624
	Schitul Goleşti	5.074
Population density /km² (total area)		240,57

In the paper, were studied the physical-geographical, demographic, economic, housing and technical, social and ecological indicators at different periods of time, by comparison, which establish the level of development and the current particularities:

- economic settlement;
- natural and human resources;
- economic sectors (primary, secondary and tertiary);
- positioning towards economic centers;

- positioning in relation to sales markets, roads, transport etc.

There is a large potential for infrastructural and technical assets, which can be integrated into the production and processing of Community goods. The infrastructure of the former animal farm complex and of the preserved space of the Poienarii de Muşcel thermal power plant serve as foundations for the construction of an (pre) industrial (agro) platform [4]. These complexes have sufficient capacities, as well as optimal necessary conditions, to integrate in a cohesive value system the priority recommended strategies in the sustainable evolution of the sectors of the analyzed area (table 2).

Table 2 Economic and social indicators

Indicators	**Câmpulung Muşcel area**		**Total area**
Territory equipment	Town	Township	
Total area (ha)	3.559	28.261	31.820
Establishments (no.)	13.483	7.208	20.691
Length of drinking water distribution (km)	115	21	136
Sewer length	-	-	59 km
Landline phones	650	1.200	1850
Mobile phones	15.870	8.150	24.020
Population	39.111	23.442	62.283
Stable population	38.741	21.898	60.639
Female population	-	-	31.653
Employees	-	-	23.042
Education, health and social assistance	-	-	1.700
Educational units			
Students	12.449	2.864	15.313
Teaching staff	902	208	1.110
Culture and art			
Library	-	-	50
Health			
Doctors	118	20	138
Average medical staff	403	28	431
Agriculture			
Agricultural area (ha)	-	-	14.666
Arable (ha)	-	-	1.713
Pastures (ha)	-	-	6.086
Hayfields (ha)	-	-	3.625
Orchards	-	-	3.215
Cattles	-	-	7.143
Sheeps	-	-	15.832
Pigs	-	-	5.045
Horses	-	-	2.500

Chikens	-	-	82.849
Milk production (hl)	-	-	18.838.681/an
Egg production (pcs)	-	-	51.000/zi
Meat production (t)	-	-	64.300/an
Fruit (t)	-	-	5.947
Vegetables (t)	-	-	1.456
Potatoes (t)	-	-	5.257
Corn (t)	-	-	1.148
Rye wheat (t)	-	-	75
Wool production (kg)			5.152
Tourism			
Hotels	1	-	1
Tourist chalets	-	-	2
Campsites and cottage units	-	-	2
Other objectives	-	-	5

The research demonstrates the Community performance achieved in obtaining raw materials, both in agriculture and in animal breeding, products which, if used and managed wisely, by succession of primary activities and including processing interventions, their diversification within the categories semi-finished and finished, can, with obvious certainty, give great chances to establish a functional climate in the conditions of a real market economy.

In conclusion, the analyzed area has a considerable potential in terms of obtaining fruits (over 20 t / ha), fodder plants (over 1000 t on an area of 450 ha), it is also provided with forestry and hydrographic elements and sufficient animal production capacity [3].

A strictly necessary condition in the elaboration of strategies is the analysis of market offers. In line with this, the main sales markets in the commercial are: Câmpulung Muşcel Central Market, Small Market and Round Market.

3. RECOMMENDED PRIORITY OF SUSTAINABLE ECONOMIC STRATEGIES

In the process of elaborating the economic strategies on the area, the following essential aspects were taken into account [2]:

1. external opportunities it offers to the community, the regional, national and international resource markets;

2. the existing community potential and the possibility of its integration in the system of external opportunities;

3. modern visions of efficiency, of increasing the quality and competitiveness of the diversified community activities, which would ensure the prevention of the departure of the community capital in the form of raw materials, at ridiculous prices and its reintegration in the sustainable economic evolution;

4. the level of the poor population in the communes, reducing its number through their direct involvement in the strategic system, which should provide a sufficient number of jobs for the reintegration of the poor population;

5. strengthening the joint actions of the community initiatives, by involving all the economic, institutional and social entities in the area.

3.1. Fields of strategic intervention

The Local Center for Sustainable Development, a non-governmental organization, set up under the Câmpulung Muşcel City Hall, has the mission:

- to implement the Strategic Plan;
- to continue the research of the external and internal advantages of the community;
- to identify the optimal ways to implement the elaborated strategies, the necessary accessories and the financial capital, especially for the medium and long term strategies;
- to found the Câmpulung Muscel Holding - an organization that includes all the economic, administrative, social and cultural entities of the area, with the aim of promoting and defending against external competition the products of the area. The local center, at the initial stage, has internal functions (spatial research and methodological improvement) and external (identification of financing and investment opportunities, market research), and later, its functions are limited only to internal analysis, and namely with the establishment of the Holding, which has exclusively external attributions.

3. 2 Preconditions of the recommended priority strategies

Based on the performed analyzes, we identified, first of all, three priority areas in relation to the market advantages that are offered to the area, namely the insufficiency and poor insurance with dairy products, finished meat products and the inefficiency of tourism by not involving of decision-makers. The same phenomenon was reversed, with the maximum potential that the area can offer, namely in terms of raw materials and technological lines (need in construction). Among them, the dairy field stands out: the dairy line (over 2200 t of cow's milk per year, the existing health services in this field); meat processing branch (over 2500 t annual meat production, necessary infrastructure and utilities), tourism. Obviously, other options have been identified, but within them, the most viable at the moment, able in the immediate future to give real chances to achieve the forecasts taken as priorities in developing strategies, as well as to facilitate the implementation of other strategic options. Their analysis also took into account the cost of options to implement all identified strategies, as well as their market advantages.

4. CONCLUSIONS

The evaluation of the socio-economic system of the Câmpulung Muscel area highlighted the vulnerabilities that are manifested at the level of the economic-social capital. The components of the socio-economic system are on a downward trend, characterized by:

- lack of jobs through massive layoffs;
- the fall of some branches of industry that held a large share in the economy of the area;
- uneven and inefficient economic development;
- very large number of unemployed;
- deepening the gap between rich and poor.

The problems that need to be solved urgently, in order to prevent a much more acute state than the current one, must be reflected on:

- the economic environment that is hostile to future development;
- lack of fiscal incentives;
- qualification and requalification of the labor force;
- agricultural development;
- the development of a diversified industry that also provides for export and the domestic industry, given the fact that the work refers to a rural area;
- the development of tourism which is conducive to the area.

The conclusion that emerges from this analysis is that the regeneration of the area, focused on stimulating economic, agricultural and tourism activities, as well as the development of basic infrastructure to increase living standards and improve individual health, must be set as objectives of a sustainable development strategy, which must be implemented as soon as possible.

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ANALYSIS OF CLIMATE INDICATORS WITH A SPECIFIC ROLE IN TOURIST ACTIVITIES FROM THE PETROȘANI DEPRESSION. CASE STUDY: THERMAL REGIME

CIPRIAN NIMARĂ[1]

Abstract: *This paper presents the evolution of the thermal regime of the Petroșani Depression, Hunedoara county, Romania, in the context of developing the tourist potential of the region, given that in the future the main economic sector of the region will be tourism, becouse the mining activity will be closed. Climatic factors are one of the attraction keys for tourists arriving in mountain destinations. Thus, the air temperature, the precipitation regime as well as the thickness and duration of the snow layer represent the strong point of a mountain resort aimed for winter sports. In general, all forms of outdoor activity are influenced in one way or another by the effects of climate change.*

Keywords: *climate, thermal regime, climate change, tourism, Petroșani*

1. INTRODUCTION

The impact of climate change depends on the vulnerability of different economic, social and environmental sectors. The sectors and areas affected by the increase temperature and the change in the precipitation regime, as well as by the manifestation of extreme meteorological phenomena are: agriculture, energy sector, tourism, transport, residential environments, etc. Economic sectors such as: food industry, wood processing, textile industry, biomass and renewable energy production are also indirectly affected. [1]

For many local communities, tourism is one of the most important economic sectors, and poor climatic conditions can severely affect the level of economic and social development of that community. The most vulnerable tourist areas to the effects of climate change are coastal areas and mountainous regions. [3]

Romania is part of the international tourist circuit with unique touristic resources both natural and anthropogenic, whose smart recovery could substantially strengthen the role of the tourism industry in the national economy, with positive

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effects on the entire society. Currently, in Romania, tourism has an indirect contribution of 6.3% of GDP and 3.1% of employment and the direct contribution of 5.2% and 1.9%.

Petrosani Depression also called “Jiu Valley” is a small region consisting of three municipalities: Petrosani, Lupeni, Vulcan and three cities: Petrila, Uricani, Aninoasa, with a total population of 120,734 inhabitants, according to the 2011 census. The geographical position, as the entire tourism potential that it possesses a highly recommended as a tourist destination waiting to be fully discovered. [2]

In the mountains, the most affected by the effects of climate change are the resorts for winter sports. The increase of temperatures will determine the reduction of the tourist season, and the opportunities for sports and recreational activities will decrease. As a result, more pressure will be created on areas at higher altitudes. At the same time, the summer season will register a higher demand, with negative effects on the environment and exceeding the support tourist capacity of certain areas. [4]

In the Petroșani Depression there are two meteorological stations that monitor the evolution of meteorological parameters: one is located in the Parâng Mountains and the other in the town of Petroșani. [5]

2. THE EVOLUTION OF THE THERMAL REGIME AT PETROȘANI METEOROLOGICAL STATION

Air temperature is the parameter that characterizes the state of heating or cooling of the atmosphere, in the immediate vicinity of the Earth's surface. Air temperature is one of the most important parameters of air condition, the result of the interaction of circulation and radiation processes with the earth's surface.

The temperatures measured at the Meteorological Station, are quite different. Being in a depression area, the temperatures are much higher than at the Parâng Meteorological Station. The variability of the average monthly temperatures differed from one month to another depending on the seasons during the year.

From figure 1 we can observe the deviation of annual temperature averages, from the multiannual average, from year to year, having a gradual increase, the lowest annual average being registered in 1985 (6.9° C), and the highest being in 2014, 2015 and 2018 (9.3° C).

At the values of the annual averages for the period 1980-2019 it is observed that there are deviations from one year to another, the annual thermal regime generally evolving towards an obvious heating. For this study, it has been chosen the decadal analysis of this interval, aiming to deviate the average of each decade from the others.

For the decade 1980-1989, we can see that the average of the decade is 7.6° C, 0.6° C lower than the multiannual average which is 8.2° C. We can also see that in 1982, 1983, 1987, 1988 and 1989 the average annual values are higher than the average of the decade, in 1980 1984 and 1985 (where it was the lowest average of the decade, 6.9° C), the annual average values are below the decade average, and the years 1982 and 1986 have the same average as the decade average (7.6° C).

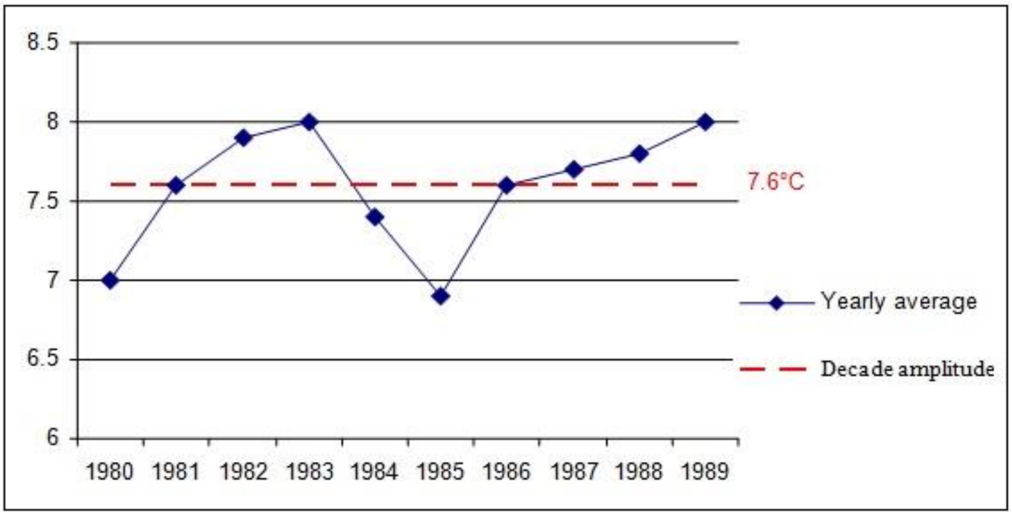

Figure 1. Evolution of average annual temperatures for the 1980-1989 period

For the period 1980-1989 we can see from Figure 1 that the average of the decade is 8.0° C, 0.2° C lower than the multiannual average. We can also see that the first 5 years vary from the decade average, and the last 5 years tend to grow slowly.

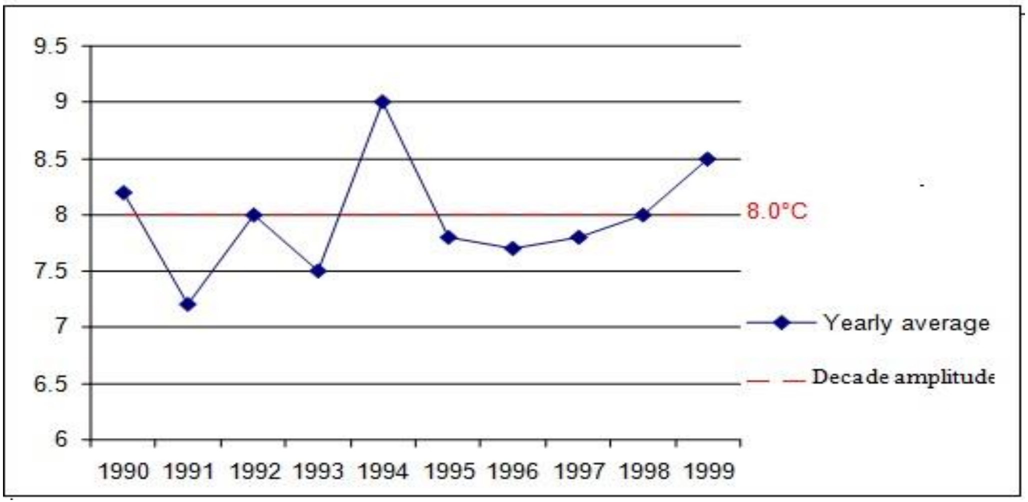

Figure 2. Evolution of average annual temperatures for the 1990-1999 decade

For the period 1990-1999 we can see, from figure 2 that the average of the analyzed period is 8.5° C, with 0.3° C higher than the multiannual average, which shows a gradual warming of temperatures. We can also see from the graph that the lowest average annual temperature in 2005 was 7.8° C, and the highest in 2007 was 9.2°C.

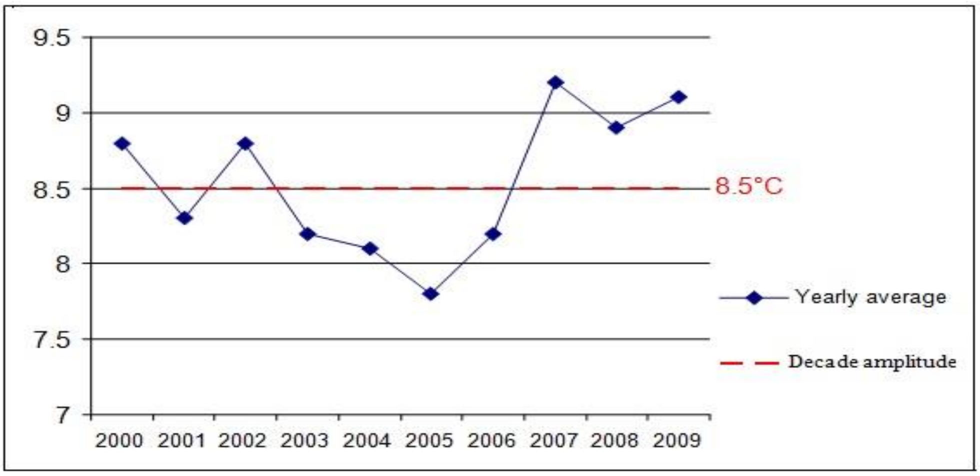

Figure 3. Evolution of average annual temperatures for the 2000-2009 period

For the 2010-2019 period we can see from figure 4 that the average of the period is 8.9 ° C, 0.7 ° C higher than the multiannual average. Here we can see that the lowest annual average (8.1° C in 2011) is 0.1° C higher than the highest annual average (8.0° C in 1983 and 1989) in the 1980s. 1989, which results in a very large increase in average annual temperature.

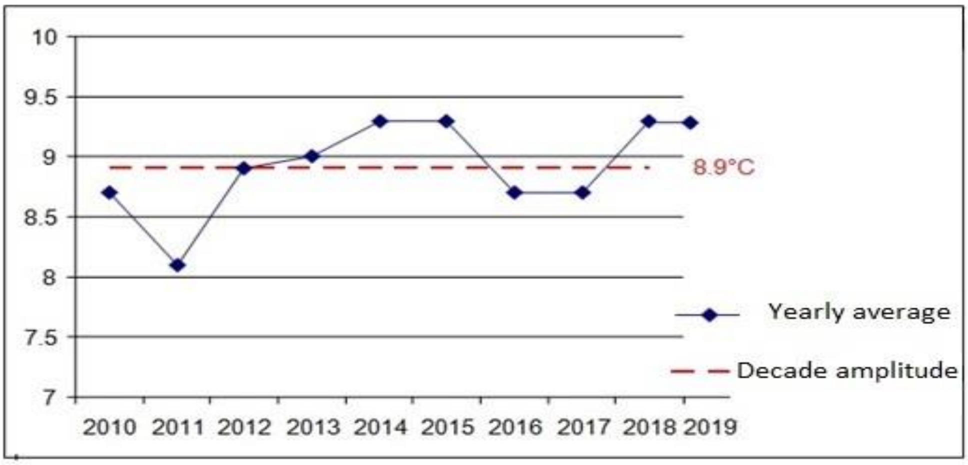

Figure 4. Evolution of average annual temperatures for the 2010-2019 period

3. THE EVOLUTION OF THE THERMAL REGIME AT PARÂNG METEOROLOGICAL STATION

The average monthly and annual temperatures are influenced by the location of the Meteorological Station in a mountainous area at an altitude of 1548 m, with much lower temperatures than the Petroșani Depression. The variability of the average monthly temperatures differed from one month to another depending on the seasons during the year.

The highest average temperatures were recorded in the summer months thus, in July (11.5°C), August (11.1°C) in 1980. In 1990 a significant increase is observed in July (12.7° C). C), in August (13.5° C), and in 2015 in July (15.9° C) and in August (15.4°C), the amplitude is 4.4°C, compared to 1980 (Figure 5).

The lowest average temperatures were recorded in the winter months of December (-4.1° C); January (-7.3° C), February (-6.2° C) since 1980, with cold winters in 1984/1985, December (-4.3° C), January (-7.5° C) , February (-11.0° C) and December 2016/2017 (-5.0° C); January (-8.1° C); February (-1.6° C), but also with milder winters than in 2013/2014, December (-0.2° C); January (-0.3° C); February (0.6° C). Most features of the thermal regime are highlighted by the extreme instantaneous values of air temperature during the year or throughout the multiannual period.

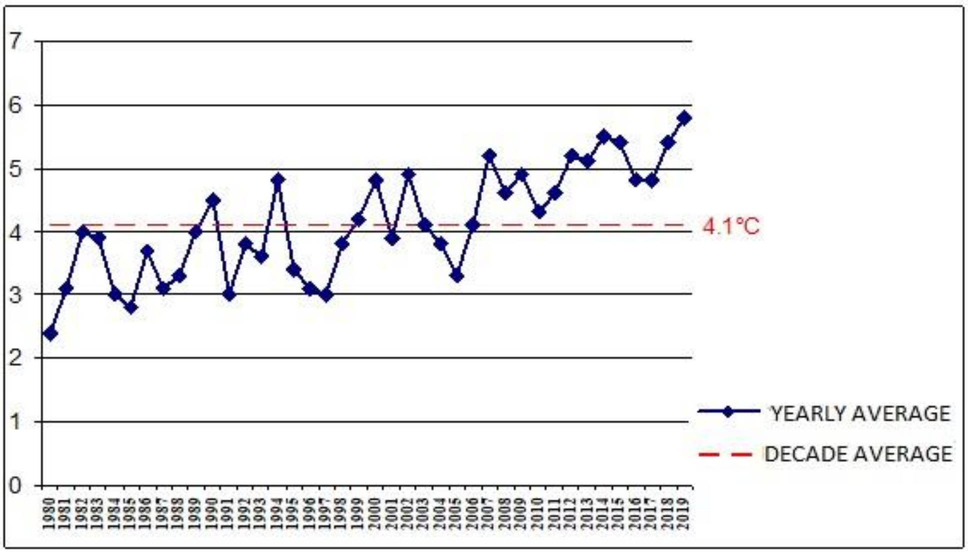

Figure 5. Evolution of average annual temperatures

4. CONCLUSIONS

The Petroșani Depression was for a long time, the main coal basin of Romania (coal), which supported the evolution of the industry during the communist era, being at the same time one of the most important points on the economic map of the country. Following the political, economic and ecological problems, the systematic closure of the mines in this region was resorted to, so that the tourist potential of the depression will remain in the future one of the economic resources that will have to be capitalized.

According to forecasts, the increase in temperatures due to climate change will reduce the tourist season, and opportunities for sports and recreation will decrease. As a result, greater pressure will be created on areas at higher altitudes. At the same time, the summer season will register a higher demand, with negative effects on the environment and exceeding the support tourist capacity of certain areas.

According to the data, it can be observed, that at the Parâng Meteorological Station during 1980-2019 the annual thermal regime, with an average value of 4.1° C, has generally evolved towards to an obvious heating, concretized aspect especially in the last years (2000-2019) and at Petroșani Meteorological Station, the annual thermal regime, having an average value of 8.2° C, being 3.8° C higher than Parâng Meteorological Station, which tends to a heating as well.

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FLOOD ALLEVIATION SCHEME – GEOENVIRONMENTAL CONSIDERATIONS AND QUALITATIVE RISK ASSESSMENT

CAMELIA MADEAR [1]

Abstract: *Areas situated on low-lying land have always been prone to flooding. Flood alleviation schemes involve designing and constructing different floodwalls, banks, storage, and drainage structures to reduce flood risk to homes and commercial properties identified as being at significant risk. Before commencing the work, a proper geoenvironmental evaluation is required, and an adequate risk assessment must be carried out. Qualitative analysis of risk serves three main functions: 1 - prioritise risks according to probability & impact; 2 - identify the main areas of risk exposure; 3 - improve understanding of project risks. The paper highlights the qualitative risk assessment results, emphasising that a risk-based approach is encouraged, considering technical and non-technical aspects when making decisions on land contamination resulting from past, present, or future human activities. Environmental risk assessment relies on identifying a pollutant linkage based on source, pathway, and receptor, known as Conceptual Site Model.*

Keywords: *geoenvironmental, qualitative risk assessment, flood alleviation, pollutant linkage, source, pathway, receptor, Conceptual Site Model*

1. PROJECT DESCRIPTION

The Flood Alleviation Scheme in Kenilworth comprises approximately 650 m of new 1500 mm diameter concrete foul sewer along Warwick Road and Waverley Road, 230 m of new 450 mm diameter concrete foul sewer along Station Road, 385 m of new 900 mm diameter concrete foul sewer along Offa Drive, Whateley's Drive, Spring Lane, and Henry Street and to upsize an existing surface water sewer to 1050 mm along Lockhart Close and Builders Yard.

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2. SITE DESCRIPTION

2.1. Site Location

Kenilworth's town is situated in Warwickshire, UK, lying approximately halfway between Warwick and Coventry (about five miles north of Warwick and five miles south of Coventry). The centre of the site is located approximately 500 m north of Kenilworth Town Centre.

The site is subdivided into two. The first part of the site is situated along Warwick Road and turns right on Waverley Road to the junction with Station Road. Lockhart Close and Builders Yard are situated east of Waverley Road. The second part of the site starts at Offa Drive, crossing Whateley's Drive and runs up Spring Lane to Henry Street, the site's final point.

A railway parallels the entire site area, between 50 m to 200 m to the east of the site. The site is located about 1.5 km northwest of the A46 (T), and the A452 crosses the site area.

The site area is predominantly residential but also includes a petrol station. Ground elevations vary from approximately 90 m in the north to approximately 70 m OD in the south.

Site location and the area of interest is presented in Figure 1.

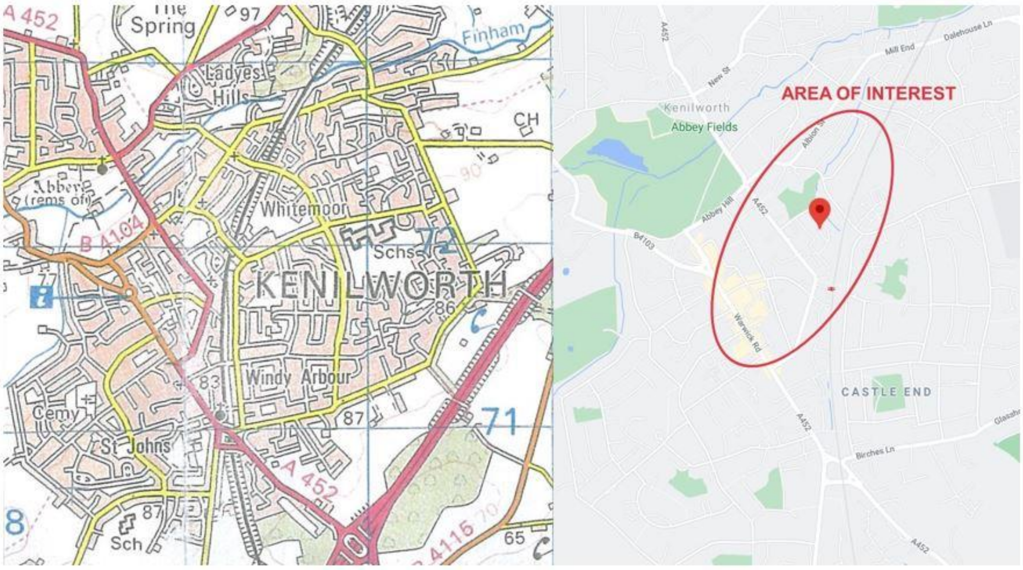

Figure 1. Site location and area on interest

2.2. Hydrology

The River Avon is located approximately 2 km southeast of the site meandering in a southwest-northeast direction. Inchford Brook and the unnamed tributary merge and flow into the Finham Brook. Finham Brook is a major tributary of River Avon. Finham Brook is located about 250 m north of the site. About 500 m west of the centre of the site is an unnamed tributary of Inchford Brook.

The closest surface water abstraction is 589 m north of the centre of the site. There are several abstractions points in the area, all of them at the north of the site.

2.3. Site Walkover

During the site walkover, the following general observations were made:

- On Warwick Road (A452): The pipe route commences at Leamington Road's junction and heads in a north-westerly direction towards the town centre before turning east into Waverly Road. The A452 is a single carriageway road with footpaths on both sides and no verges. It is very heavily trafficked. Waverly Road is a wide tree-lined street which slopes in a north-easterly direction. Numerous services can be expected along the route, both underground and overhead. The pipe route terminates at the junction Station Road and Lockhart Close;
- On Station Road: The pipe route commences at the junction of Bertie Road and heads in a south-easterly direction along Station Road, before crossing Waverley Road into Lockhart Close and finally turning north into the grounds of a builder's merchants where the proposed route terminates. Station Road is narrow in places with trees on both sides. The ground slopes easterly along the pipe route. Evidence of numerous underground and overhead services was noted. The builder's merchants' yard is currently in use and is crowded with building materials;
- Offa Drive: The pipe route commences at the southern end of Offa Drive, a cul-de-sac. It heads north along Offa Drive until it crosses Whateley's Drive and enters school playing fields. It skirts the southern boundary of the grounds to exit on to Spring Lane where it turns east and terminates approximately 50 metres along Henrys Street. Numerous services can be expected along the route, both underground and overhead. The ground slopes in a northerly direction towards Spring Lane before rising to the junction of Henrys Street;
- Offa Drive, Spring Lane and Henrys Street are residential roads.

3. GEOLOGY AND HYDROGEOLOGY

Based on the available background information, the following superficial deposits and strata are expected at the site and its environs. They are described in Table 1 from the youngest to the oldest:

Table 1. Summary of Geology

Age	Formation	Description
Recent	Topsoil/ Made Ground	Composition and thickness is likely to be of a variable nature
Quaternary	Baginton Sand and Gravel	Well-rounded pebbles and fine to medium sand
Enville Group - Permian	Ashow Formation including Sandstone	Red-brown mudstone and sandstone

Topsoil is expected to be encountered in areas of undisturbed ground and over Made Ground. Topsoil has been proven in some historical boreholes with thickness up to 0.40 m.

The BGS geological map does not show any areas of Made Ground within 1 km of the site. However, Made Ground is expected to be encountered at the site due to historical activities, such as road construction and site preparation for nearby structures and buildings. The Made Ground's composition and thickness are likely to be varied, and contaminated materials may be present. Made Ground was found in nearby historical boreholes and trial pits ranging in thickness from 0.1 m to 2.20 m and consisting of brown slightly sandy clay with brick fragments, concrete, charcoal, and gravel; soft to firm and firm brown mottled silty sandy gravely clay; black ashy silty sand with some fine gravel and brick fragments; firm, brown, slightly sandy, silty clay with occasional fine to medium rounded to subrounded gravel and occasional black carbonaceous fragments.

The geological map indicates that Baginton Sand and Gravel is present along the Finham Brook at approximately 500 m north from the centre of the site and may be found at the site itself.

Alluvium was found in four boreholes located 500 m north of the site near Finham Brook, consisting of soft brown mottled silty clay, sandy, clayey silt, and firm red-brown silty clay with some gravel. The thickness of the Alluvium ranged between 1.2 m and 4.0 m at the borehole locations.

Ashow Formation, including Sandstone, comprises all the Enville Group above the Kenilworth Sandstone. It is predominantly argillaceous red mudstones but contains several thick sandstones. The total thickness of the formation is about 170 m. The upper part of the formation is poorly exposed and occurs in fault-bounded inliers. As a result, a detailed succession and thickness remain somewhat uncertain.

According to the BGS Memoir, the Ashow Formation Deposits base is marked by the incoming sequence of mudstones 50 m to 65 m thick, divided in places by sandstone up to 15 m thick. These are the Whitemoor Marls and Whitemoor Sandstone. The mudstones are red-brown, blocky, with abundant green reduction spots, and interbedded with siltstones. A few lenses of sandstones occur. They are usually red-brown, but some are pale grey-green. Some sandstone beds may be relatively thick beds or lenses. On Warwick Road, the sandstone becomes flaggy with many green partings, and abundant load casts picked out in green sandstone. Mudstones overlie the sandstone.

The nearby exploratory holes, located about 150 m west and on-site, recorded clay, and siltstone as weathered Ashow Formation. At depths, borehole records indicate weak red-brown mudstones and weak red-brown sandstones as part of Kenilworth Sandstone. The thickness of these deposits has not been proved at borehole locations.

The River Avon is located 2 km southeast of the site meandering in an east-west direction. The River Avon's tributary – Finham Brook is located about 250 m north of the site flowing in an approximately southwest-northeast direction.

The Made Ground and any Sand and Gravel deposits are likely to contain perched water tables. Any Baginton Sand and Gravel deposits should be expected to be in continuity with the Finham Brook.

The Ashow Formation is classified as a Minor Aquifer with high permeability. Although not producing large quantities of water for abstraction, it is essential for local supplies and supplying base flow to rivers. The Kenilworth Sandstone nearby is a Major Aquifer providing public water supply.

According to the Environment Agency website, the site is not within a Groundwater Source Protection Zone. However, north of the site, there are several source protection zones, the nearest being at approximately 300 m north of the site.

Regarding the soil classification in the area, soils of high leaching potential are likely to be encountered.

4. SITE HISTORY

A review of the former uses of the site, with notable features and potential contamination sources, is summarised below:

- **Warwickshire 1888, 1889, 1890**

Notable features: Land use on and immediately surrounding the site is dominantly rural residential with three Public Houses along the main street, two Churches, three Schools, an Institute, a Fire Engine House, a Hotel, a Tannery and three Smithys, and also it is Rural Farmland with well-defined field boundaries. The London and North West Railway – Coventry & Leamington Branch pass site southwest to northeast, approximately parallel to the future pipeline at an average of 100 m distance to the east on its northeast to a southwest route. Major and minor roads exist connecting Kenilworth to Coventry and Royal Leamington Spa. The River Avon meanders northeast-southwest approximately 2.5 km east, and the Finham Brook passes north of the end of the site. A Smithy and a Tannery are present on site. Priory Mill and St. Mary's Priory are located west of the site at approximately 600 m. Gravel Pits are indicated about 800 m northeast of the end of the site, just north of the Finham Brook, and Cayfields and Brickworks are located 200 m east from the Railway Line. A Gas Works is located about 700 m northeast of the site, next to the Railway Line, in Mill End area. Kenilworth Mill is present on Finham Brook.

Potential Contamination Sources: On-site - Agricultural pollutants, Constructions, Road and associated Made Ground, Smithy, Tannery, Railway. Off-site - Agricultural pollutants, Gravel Pit, Clayfield, Smithy, Gas Works, Brickworks, Road and associated Made Ground.

- **Warwickshire 1905, 1906**

Notable features: Developments of the residential building have continued in Kenilworth. Expansion of Gravel Pits northeast of the site, next to the Finham Brook. Expansion of Cherry Orchard and Whitemoor Brickworks, on the opposite side of the Railway line. A Saw Mill is indicated near the gas works, where the railway crosses the Finham Brook. A new Pumping Station has been constructed north of the Finham Brook, approximately 600 m northeast from the site. Fellmongery (animal skin cleaning and preparation) Works are indicated east of the Pumping Station, approximately 100 m. Swimming bath appears along Finham Brook 650 m west of the proposed works. Tanks are present on-site near to the railway line. A Gravel Pit is 200 m north of Cherry Orchard Brickworks, on the Railway line. A Quarry is indicated at approximately 800 m northwest from the northern end of the site. A Pheasantry is located 900 m southeast from the southern end of the site, next to the Leamington Road. An Old Sand Pit and Tanks are indicated on site in The Nurseries area. Carriage Works appears next to the Tannery.

Potential Contamination Sources: On-site - Agricultural pollutants, Constructions, Road and associated Made Ground, Old Sand Pit, Tanks, Carriage Works, Smithy, Tannery, Railway. Off-site - Agricultural pollutants, Gravel Pits, Clayfield, Quarry, Smithy, Fellmongery, Gas Works, Brickworks, Road and associated Made Ground and Saw Mill.

- **Warwickshire 1925, 1926**

Notable features: Developments of the residential building have continued in Kenilworth. Expansion of Cherry Orchard and Whitemoor Brickworks, on the opposite side of the Railway line. A new Quarry is mapped in The Spring area, approximately 900 m northwest from the site. A new Sand Pit is indicated near to the junction between Coventry Road and Manor Road, approximately 500 m northwest from the site. Fish Pond is mapped 800 m west of the proposed works. One Gravel Pit and one Sand Pit are indicated on-site, next to the railway line, northeast of Spring Lane. On-site Smithy is no longer indicated on maps. A New Smithy is constructed next to Finham Brook, in The Hall area. A Cemetery is marked 500 m west of the site. New Farms and Allotment Gardens are mapped off-site. Old Sand Pit is no longer indicated on site. Saw Mill is no longer present on historical maps.

Potential Contamination Sources: On-site - Agricultural pollutants, Constructions, Road and associated Made Ground, Gravel and Sand Pits, Tanks, Carriage Works, Railway, Tannery. Off-site - Agricultural pollutants, Gravel Pits, Clayfield, Quarry, Smithy, Fellmongery, Gas Works, Brickworks, Road and associated Made Ground, Cemetery.

- **Warwickshire 1938**

Notable features: Developments of the residential building have continued on-site and off-site. Tanks and Gravel and Sand Pits are no longer indicated on site. Woodland is developed on the southeastern part of the site.

Potential Contamination Sources: On-site - Constructions, Road and associated Made Ground, Carriage Works, Tannery, Railway. Off-site - Agricultural pollutants, Gravel Pits, Clayfield, Quarry, Smithy, Fellmongery, Gas Works, Brickworks, Road and associated Made Ground, Cemetery.

- **Ordnance Survey Plan 1955**

Notable features: Developments of the residential building have continued on-site and off-site. Expansion of Cherry Orchard and Whitemoor Brickworks, on the opposite side of the Railway line.

Potential Contamination Sources: On-site - Construction, Road and associated Made Ground, Carriage Works, Tannery, Railway. Off-site - Agricultural pollutants, Gravel Pits, Clayfield, Quarry, Smithy, Fellmongery, Gas Works, Brickworks, Road and associated Made Ground, Cemetery.

- **Ordnance Survey Plan 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1978, 1981**

Notable features: Developments of the residential building have continued in Kenilworth. Kenilworth town is also developed in the western, southwestern and eastern part of the site. Cherry Orchard Brickworks is mapped as Claypit and Works are located between Claypit and Railway line. Whitemoor Claypit is filled with refuse or slag heap. Engineering Works is located on-site. Electrical Substations are marked on-site next to the Railway line. Tanks are present on-site next top the Railway line. Brickworks, Engineering Works and Tanks are located on the opposite side of the Railway line. Builder’s yards are present on site. Works are located approximately 300 m west of the site. Railway Station is marked now as disused. Coal Yard is located between Waverley Road and the Railway line. Garages and Car Parks are present on Warwick Road. Former Gravel Pits and Quarries are no longer present on maps. Smithy, Gas Works, Fellmongery and Tannery are not mapped on these maps.

Potential Contamination Sources: On-site - Constructions, Road and associated Made Ground, Engineering Works, Electrical Substation, Tanks, Railway and Garages. Off-site - Agricultural pollutants, Gravel Pits, Clayfield, Landfills, Brickworks, Road and associated Made Ground, Cemetery.

Ordnance Survey Plan 1982, 1983, 1985, 1986, 1988, 1989, 1990, 1992, 1993, 1994, 1999

Notable features: Developments of the residential building have continued in Kenilworth. A46 is located in the southeastern part of the site. Cherry Orchard workings are marked as disused. Former Gravel Pits north of Finham Brook in Mill End area, are rehabilitated as Parkland. Priory Mill, remains of St. Mary’s Abbey and Abbey Pool are still present west of the site.

Potential Contamination Sources: On-site - Constructions, Road and associated Made Ground, Engineering works, Electrical Substation, Railway, Tanks and Garages. Off-site - Landfills, Road and associated Made Ground, Cemetery.

5. PRELIMINARY CONCEPTUAL MODEL

5.1. Source Characterisation

Potential on-site source of contamination identified are the following:

- Roads and associated Made Ground - The site is located on major roads, a potential source of contamination of fuel and oil spillage as is the Made Ground associated with the construction of the roads. Any contamination would be likely to be localised around the roads. Made Ground is expected to be encountered on site;
- Housing/ Building Developments and Construction Materials - Residential construction has occurred over time on and all around the site. There is considerable potential for construction materials to have been incorporated into any Made Ground on the site. The site walkover, however, revealed that most of the buildings had been constructed with natural materials. Older building materials should not pose a significant hazard;
- Made Ground associated with constructing the buildings on and off-site is a potential source for contamination. However, any contamination would be localised around the buildings. Therefore, housing and other non-specific buildings at a distance are unlikely to be a significant source of contamination;
- Sand and Gravel Pits - There have been major historical open pit mining of Sand and Gravel on-site and off-site. On-site, Pits were rehabilitated after 1938, as they no longer are indicated on subsequent historical maps. Off-site Sand and Gravel Pits were rehabilitated, too. Although these Pits are disused, there is still potential contamination from former on-site Pits, as the filling content is unknown. Off-site Sand and Gravel Pits will not be considered further due to the distance and surrounding geology;
- Agricultural/ Domestic Pollutants - On-site land and the land immediately surrounding the site has been used for agricultural purposes such as farming. Contamination build-up through continued use of pesticides/ fertilisers may occur as either localised concentrations or diffused slightly raised values. Continued contamination may occur through any land and might be spread through airborne movement across the site. Therefore, agricultural pollutants pose a potential pollution source to site;
- Railway and Associated Made Ground - The Railway line is located approximately 100 m east of the pipeline's proposed route. Due to the presence on-site, there is a high risk of direct contamination. There is a risk of the Railway line as being a potential source of hydrocarbon-type contamination to the groundwater. Therefore, the Railway line and Sidings will be considered further as a possible source of contamination;

- Smithy - The closest Smithy was located on-site, on Station Road, but has not been operational since 1925. The off-site Smithys were disused since the 1960s. Smithy is a potential source of contamination comprising metals, semi-metals, non-metals, inorganic chemicals, asbestos, phenols, oil & fuel, hydrocarbons, and aromatic hydrocarbons, PAHs and PCBs. However, due to the distance of off-site Smithys, the geology of the site and the time it has been disused (both on and off site), it is unlikely that either Smithy is a potential source that can directly affect the site and will therefore not be considered further;
- Tannery - A Tannery was developed on Station Road and was indicated on 1889 edition of the historical maps. Potential contaminants, including chloride, sulphate, ammonium, phenols, hydrocarbons and land gases, are determined by intrusive investigations. These contaminants could be originated from historic escapes of Tannery effluent, historic landfilling practices and hydrocarbon storage on site. Although the Tannery is no longer indicated on current maps, there is still potential contamination from this source;
- Tanks - Storage Tanks for fuels and chemicals are present on-site since 1905, and they are a possible source of contamination;
- Garages and Fuel Distributors - The new pipeline route runs along major roads where there are located Garages and Fuel Distributors. There is a reasonable probability that associated contaminants will be present as hot spots;
- Electrical Substation - Electrical Substations are present on-site since 1970. Associated contaminants will likely be present as hot spots;
- Carriage/ Engineering Works - The Carriage Works were located on-site. The Engineering Works is located on-site. Due to the presence on-site, there is a high risk of direct contamination. There is a risk of these activities being a potential source of contamination to the groundwater. The Contemporary Trade Directory Entries listed in the Landmark Envirocheck Report are in the Engineering Works area. They, therefore, are not considered further in this contaminant risk assessment for the site;
- Quarrying - There have been minor historical small-scale Quarrying in the area. Although these have not been on-site, there is still potential for run-off from Old Tips. However, given the distance and surrounding geology, there is a negligible risk of Quarrying being a potential source of contamination. While there is the potential for unrecorded Quarrying to have taken place at the site as there is no evidence of this is having occurred, this potential source of contamination will not be considered further;
- Gas Works - The Gas Works were located about 700 m to the northeast of the site and ceased operations around 1960. By-products of the manufactured gas process and plant structures often remain on site when the plants were closed. This site can contain coal tar, gas purifier wastes and coal ash. Due to the distance, the geology of the site and the time it has been disused it is considered unlikely that the Gas Works is a potential source that can directly affect the site and therefore will not be considered further;

- Landfills and Clayfields - There are two Registered Landfill Sites located 189 m northeast (down gradient) and 278 m northeast (down gradient) of the site respectively, and one BGS Recorded Landfill Site (Cherry Orchard Landfill) located 228 m northeast of the site. These Landfills are former Claypits filled in with non-hazardous/ inert wastes. Although these Landfills are nearby the site, due to the railway cut between the site and the Landfills and the underlying geology, these Landfills can be discounted as a potential source of direct contamination and will not be considered further;
- Brickworks - The brickworks were associated with the above presented Claypits. Therefore, due to the railway cut between the site and the landfills and the underlying geology, these landfills can be discounted as a potential source of direct contamination and will not be considered further;
- Fellmongery - A Fellmongery (animal skin cleaning and preparation) was located on 1905 historical map at 700m northeast. Due to the distance, the geology of the site and the time it has been disused it is considered unlikely that the Fellmongery is a potential source that can directly affect the site and therefore not be considered further;
- Saw Mill - A Saw Mill was located next to the Finham Brook on 1905 historical map at 700m northeast. Timber preservatives used in this country was creosote derived from coal tar. Due to the distance, the geology of the site, and the time it has been disused (probably 1925), it is unlikely that the Saw Mill is a potential source that can directly affect the site and therefore not be considered further;
- Cemetery - A Cemetery and a Crematorium are mapped since 1925 at approximately 500 m west of the site. Due to the site's distance and geology, it is considered unlikely that the Cemetery is a potential source that can directly affect the site and will therefore not be considered further;
- Groundwater - Several potentially contaminating sources have been identified in the vicinity of the sites that do not pose a risk of directly polluting the site. However, these sources do have the potential of contaminating the underlying groundwater. As such, the groundwater itself should be considered to be a potential source of contamination.

5.2. Contaminants of Concern

As a result of characterising the identified potential sources that could reasonably be linked to the site, the following are considered to be the potential source of contamination that can affect the site: Sand and Gravel Pits; Agricultural Pollutants; Roads, buildings and associated Made Ground; Railway; Tannery; Storage Tanks, Garages and Fuel Distributors; Electrical substation; Groundwater.

The Contaminants of Concern associated with the construction of the proposed works are given in Table 2.

Table 2. Contaminants of Concern associated with the historical use of the site

Source	Metals	Semi-metals	SO_4, SO_3	pH	Fuels & Oils	Aromatic Hydrocarbons PAHs	Asbestos	Ground Gas	Other
Roads, Buildings and associated Made Ground	Y	Y	Y	Y	Y	Y	Y	Y	SVOC
Agriculture	Y		Y	Y	Y	Y	Y	Y	Organo-metals, Inorganics, Pesticides, Herbicides, Sewage Sludge
Sand and Gravel Pits (waste disposal)	Y	Y		Y	Y	Y	Y	Y	Inorganic Chemicals, VOC, PCB, Dioxins and Furans
Railway (Railway land)	Y		Y		Y	Y	Y		VOC, PCB
Tannery (Chemical works: paints)	Y	Y			Y		Y		Inorganic Chemicals, Phenols, VOC, SVOC, Organotin Compounds
Storage Tanks, Garages and Fuel Distributors	Y	Y	Y		Y	Y	Y	Y	Organolead Compounds, VOC, SVOC
Electrical Substation	Y	Y		Y		Y	Y		Inorganic Chemicals, VOC, PCB
Groundwater	Y	Y	Y	Y	Y	Y	Y	Y	VOC, SVOC, PCBs

Note: VOC Volatile Organic Compounds
SVOC Semi-Volatile Organic Compound
PCB Polychlorinated Biphenyls
PAH Polycyclic Aromatic Hydrocarbon

5.3. Pathway Characterisation

The potential pathways by which receptors might be exposed to contaminants (sources) at the site can vary depending on the proposed or current land use as follows:

Humans - For humans, the three possible routes of exposure to contaminants are as follows: Inhalation of dust, gas or pathogens; Ingestion of dust, soil or pathogens either by hand-to-mouth activity, by eating plants grown in contaminated soils; Dermal (skin) contact with contaminated soils and waters and transfer of contaminants through the skin into the body;

Plants and Animals - For plants and animals, the main pathway for exposure involves direct contact with contaminated soils, ground gas or groundwater;

Property in the form of Buildings and Services - The main pathways by which buildings can be affected are soil gas pooling within the structures, contact with aggressive or acidic soils or groundwater or service trenches acting as preferential migration pathways;

Controlled Waters - The primary routes by which controlled waters can be affected are: Run-off from the site surface entering surface watercourses near the site; Poor construction of boreholes during a ground investigation; Leaching of contaminants from the soil migrating vertically or laterally to groundwater beneath the site; Movement of dissolved contaminants in soil pore water; Movement of contaminants via groundwater to surface water bodies.

5.4. Receptor Characterisation

Potential receptors at this site, related to the development proposals, the current use of the site, its location relative to sensitive environmental receptors and the ground and groundwater conditions are as follows: Humans; Property in the form of Buildings and Services; Property in the form of Crops and Livestock; Controlled Waters; Ecology.

Human Receptors - The human receptors associated with the proposed development are: Public; Construction workers; Maintenance workers;

Property in the form of Buildings and Services - The property receptors are Buildings; On-site services in the form of buildings and services; On-site services; Proposed pipeline;

Property in the form of Crops and Livestock - The property receptors, in the form of crops and livestock, are: Council trees and vegetation along roads and recreational grounds; Council/ Private grass, trees and shrubs; Pets;

Ecology - The ecological receptors associated with the proposed development are: Countryside Stewardship Scheme Target Area is mapped at the site; Countryside Stewardship Agreements and Registered Parks and Gardens (Kenilworth Castle) are located about 900 m northwest of the site;

Controlled Waters - The controlled waters receptors associated with the proposed development are: Surface waters adjacent to the site; Groundwater.

5.5. Pollutant Linkages

This section discusses and defines the potential pollutant linkages that could reasonably exist, linking the sources and receptors identified by the study.

Following the construction of the works, the site will remain a public domain.

Humans - The following potential human health pollutant linkages have been identified from this study: Inhalation of dust or pathogens in the soil; Inhalation of ground gas and volatile hydrocarbons within the Made Ground or spills; Ingestion of dust, pathogens or soil by hand to mouth activity as a result of construction activities and use of the site by the end uses; Dermal (skin) contact with contaminated soils and waters or spills and transfer of contaminants through the skin into the body;

Property in the form of Buildings and Services - Both the proposed and existing structures and services on this site could be at risk from: Aggressive soil and groundwater conditions; Ground gas generated by the sewage, fill materials and Alluvium; The selection of design and construction materials will need to take this into account;

Property in the form of Crops and Livestock - Plants and animals could be at risk from direct contact with contaminated soils, ground gas and groundwater. Plants could also be at risk from the uptake of contaminants through the roots. Appropriate restoration of the site post-construction will minimise the risk of harm;

Controlled Waters - The surface water north of the site may be exposed to additional contaminants from disturbance resulting from the proposed work. Disturbance of contaminants may affect the Minor Aquifer in Ashow Formation or Major Aquifer in Kenilworth Sandstone. However, there do not appear to be groundwater abstractions close to the site; therefore, the risk to groundwater is minimal (the nearest water abstraction well is approximately 600 m from the site);

Ecology - The following potential ecology pollutant linkages have been identified: Inhalation of dust/ pathogens and ground gas generated from Made Ground or spills; Ingestion of dust, pathogens or soil by feeding activity as a result of construction activities and use of the site by the end-users or spills; Dermal (skin) contact with contaminated soils and waters or spills and transfer of contaminants through the skin into the body.

6. QUALITATIVE RISK ASSESSMENT

The preliminary Conceptual Site Model outlined above has been used to undertake an initial qualitative risk assessment for this site, to identify any significant risks that may exist to the proposed new pipeline due to contamination on or within the ground.

The risk assessment is set out in Figure 2 to Figure 9. This shows that potential risks to controlled waters, construction workers, end-users and buildings exist from the following potential contamination sources: Source 1: Road, Made Ground and Construction Materials; Source 2: Sand and Gravel pits; Source 3: Agricultural Pollutants; Source 4: Railway; Source 5: Tannery; Source 6: Tanks, Garages and Fuel distributors; Source 7: Electrical substation; Source 8: Groundwater.

Source	Contaminant of concern	Receptors		Pathway	Assessment	Likelihood of Occurrence	Risk Rating	Further investigation required
Road Made Ground Construction Materials	- Metals - Semi-Metals - Sulphates - pH - Fuels & Oils - PAH - Ground Gas - Asbestos - SVOC	Humans		Inhalation Ingestion Dermal Contact	Made Ground is capped and stable Low risk of pathway unless disturbed	Moderate	Moderate	Yes
		Controlled Waters		Run-off	Proximity and gradient to surface waters increases risk	Moderate	Moderate	Yes
					Surface run-off into soils	Moderate	High	Yes
				Leaching from soil Via soil pore water Via groundwater to surface water	Pore water and groundwater movement through contaminated Made Ground	Moderate	High	Yes
		Ecology		Inhalation Ingestion Dermal Contact	Significant Ecological issues identified at site Pollutant linkage significant	Moderate	Moderate	Yes
		Property	Buildings & Services	Airflow	Possibility of build-up of explosive gases	Moderate	Moderate	Yes
				Contact with aggressive soil	Foundations and services in aggressive ground conditions	Moderate	Moderate	Yes
			Plants	Direct Contact Uptake	Trees and shrubs present on site	Low	Low	No
					Grass usually resistive to contamination	Low	Low	No
			Animals	Inhalation Ingestion Dermal Contact	Pets on site Risk as for humans	Moderate	Moderate	Yes

Figure 2. Risk Assessment for Source 1

Source	Contaminant of concern	Receptors		Pathway	Assessment	Likelihood of Occurrence	Risk Rating	Further investigation required
Sand and Gravel Pits	- Metals - Semi-Metals - pH - Fuels & Oils - PAHs - Asbestos - Ground Gas - Inorganic chemicals - VOC - PCB - Dioxins and Furans	Humans		Inhalation Ingestion Dermal Contact of contaminants migrating to site	Former sand and gravel pits on site	High	High	Yes
		Controlled Water		Run-off	Proximity and gradient to surface waters increases risk	Moderate	High	Yes
					Surface run-off into soils	Moderate	High	Yes
				Leaching from soil Via soil pore water Via groundwater to surface water	Pore water and groundwater movement through soil contaminated Made Ground	Moderate	High	Yes
		Ecology		Inhalation Ingestion Dermal Contact	Significant ecological issues identified at site Pollutant linkage significant	Moderate	Moderate	Yes
		Property	Buildings & Services	Airflow	Possibility of build-up of explosive gases	High	High	Yes
				Contact with aggressive soil	Foundations and services in aggressive groundwater conditions	Moderate	Moderate	Yes
			Plants	Direct Contact Uptake	Trees and shrubs present on site	Moderate	Moderate	No
					Grass usually resistant to contamination	Moderate	Moderate	No
			Animals	Inhalation Ingestion Dermal Contact	Pets on site Risk as for humans	Moderate	Moderate	Yes

Figure 3. Risk Assessment for Source 2

Source	Contaminant of concern	Receptors		Pathway	Assessment	Likelihood of Occurrence	Risk Rating	Further investigation required
Agricultural Pollutants	- Metals - sulphates - pH - Fuels & Oils - PAH - Asbestos - Ground Gas - Organo- metals - Inorganics - Pesticides - Herbicides - Sewage sludge	Humans	Inhalation Ingestion Dermal Contact of contaminants migrating to site		Proximity to site increases risk	Moderate	Moderate	Yes
		Controlled Water	Run-off		Proximity to site increases risk	Moderate	Moderate	Yes
			Leaching from soil Via soil pore movement Via groundwater to surface water		Pore water and groundwater movement through contaminated Made Ground	Moderate	Moderate	Yes
		Ecology	Inhalation Ingestion Dermal Contact		Proximity to site increases risk	Moderate	Moderate	Yes
		Property	Buildings & Services	Airflow	Possibility of build-up of explosive gases	Low	Low	No
				Contact with aggressive soil	Foundations and services in aggressive ground conditions	Low	Moderate	Yes
			Plants	Direct Contact Uptake	Trees and shrubs present on site	Moderate	Moderate	Yes
					Grass usually resistant to contamination	Moderate	Moderate	No
			Animals	Inhalation Ingestion Dermal Contact of contaminants migrating to site.	Pets on site Risk as for humans	Moderate	Moderate	Yes

Figure 4. Risk Assessment for Source 3

Source	Contaminant of concern	Receptors		Pathway	Assessment	Likelihood of Occurrence	Risk Rating	Further investigation required
Railway	- Metals - Sulphates - Fuels & Oils - PAH - Asbestos - VOC - PCB	Humans		Inhalation Ingestion Dermal Contact of contaminants migrating to site	Risk of asphyxiating affecting construction workers	High	High	Yes
		Controlled Waters		Run-off	Proximity and gradient to surface waters increases risk	Moderate	High	Yes
					Surface run-off into soils	Moderate	High	Yes
				Leaching from soil Via soil pore water Via groundwater to surface water	Pore water and groundwater movement through soil contaminated Made Ground	Moderate	High	Yes
		Ecology		Inhalation Plant Roots	Significant ecological issues identified at site Pollutant linkage significant	Low	Low	No
		Property	Buildings & Services	Airflow	Possibility of build-up of explosive gases	Low	Low	No
				Contact with aggressive soil	Foundations and services in aggressive ground conditions	Low	Moderate	Yes
			Plants	Direct Contact Uptake	Trees and shrubs present on site	Moderate	Moderate	No
					Grass usually resistant to contamination	Low	Low	No
			Animals	Inhalation	Pets distant from site Risk as for humans	Low	Low	No

Figure 5. Risk Assessment for Source 4

Source	Contaminant of concern	Receptors		Pathway	Assessment	Likelihood of Occurrence	Risk Rating	Further investigation required
Groundwater	- Metals - semi metals - sulphates - pH - Fuels & Oils - PAH - Asbestos - Ground Gas - VOC - SVOC - PCB	Humans		Inhalation Ingestion Dermal Contact of contaminants migrating to site	Low probability due to distance	Low	Moderate	Yes
		Controlled Water (Surface Water)		Via soil pore movement Via groundwater to surface water	Pore water and groundwater movement through contaminated Made Ground	Low	Low	Yes
		Ecology		Inhalation Ingestion Dermal Contact	Significant ecological issues identified at site Pollutant linkage significant	Low	Moderate	Yes
		Property	Buildings & Services	Airflow	Possibility of build-up of explosive gases	Low	Low	No
				Contact with aggressive soil	Foundations and services in aggressive groundwater conditions	High	High	Yes
			Plants	Direct Contact Uptake	Grass usually resistant to contamination	Low	Low	No
			Animals	Inhalation Ingestion Dermal Contact of contaminants migrating to site	Pets on site Risk as for humans	Low	Low	No

Figure 6. Risk Assessment for Source 5

Source	Contaminant of concern	Receptors		Pathway	Assessment	Likelihood of Occurrence	Risk Rating	Further investigation required
Tannery	- Metals - Semi-Metals - Fuels & Oils - Asbestos - Inorganic chemicals - Phenols - VOC - SVOC - Organotin compounds	Humans		Inhalation Ingestion Dermal Contact	Made Ground is capped and stable Low risk of pathway unless disturbed	Moderate	Moderate	Yes
		Controlled Waters		Run-off	Proximity and gradient to surface waters increases risk	Moderate	High	Yes
					Surface run-off into soils	Moderate	High	Yes
				Leaching from soil Via soil pore water Via groundwater to surface water	Pore water and groundwater movement through contaminated Made Ground	Moderate	High	Yes
		Ecology		Inhalation Ingestion Dermal Contact	Significant ecological issues identified at site Pollutant linkage significant	Low	Low	No
		Property	Buildings & Services	Airflow	Possibility of build-up of explosive gases	Low	Low	No
				Contact with aggressive soil	Foundations and services in aggressive ground conditions	Moderate	Moderate	Yes
			Plants	Direct Contact Uptake	Trees and shrubs present on site	Moderate	Moderate	Yes
					Grass usually resistive to contamination	Low	Low	No

Figure 7. Risk Assessment for Source 6

Source	Contaminant of concern	Receptors		Pathway	Assessment	Likelihood of Occurrence	Risk Rating	Further investigation required
Storage tanks, Garages and Fuel Distributors	- Metals - Semi-Metals - Sulphates - Fuels & Oils - PAH - Ground Gas - Asbestos - Organolead compounds - VOC - SVOC	Humans		Inhalation Ingestion Dermal Contact	Made Ground is capped and stable Low risk of pathway unless disturbed Surface spillage probable	High	High	Yes
		Controlled Waters		Run-off	Proximity and gradient to surface waters increases risk	Moderate	High	Yes
					Surface run-off into soils	High	High	Yes
				Leaching from soil Via soil pore water Via groundwater to surface water	Pore water and groundwater movement through contaminated Made Ground.	Moderate	High	Yes
		Ecology		Inhalation Ingestion Dermal Contact	Significant ecological issues identified at site Pollutant linkage significant	Moderate	Moderate	Yes
		Property	Buildings & Services	Airflow	Possibility of build-up of explosive gases.	High	High	Yes
				Contact with aggressive soil	Foundations and services in aggressive ground conditions	Moderate	Moderate	Yes
			Plants	Direct Contact Uptake	Trees and shrubs present on site	Moderate	Moderate	Yes
					Grass usually resistive to contamination	Low	Low	No

Figure 8. Risk Assessment for Source 7

Source	Contaminant of concern	Receptors		Pathway	Assessment	Likelihood of Occurrence	Risk Rating	Further investigation required
Electrical substation	- Metals - Semi-Metals - pH - Fuels & Oils - PAH - Asbestos - Inorganic chemicals - VOC - PCB	Humans		Inhalation Ingestion Dermal Contact	Made Ground is capped and stable Low risk of pathway unless disturbed	Low	Moderate	Yes
		Controlled Waters		Run-off	Proximity and gradient to surface waters increases risk	Moderate	High	Yes
					Surface run-off into soils	Moderate	High	Yes
				Leaching from soil Via soil pore water Via groundwater to surface water	Pore water and groundwater movement through contaminated Made Ground	Moderate	High	Yes
		Ecology		Inhalation Ingestion Dermal Contact	Significant ecological issues identified at site Pollutant linkage significant	Low	Low	No
		Property	Buildings & Services	Airflow	Possibility of build-up of explosive gases	Low	Low	No
				Contact with aggressive soil	Foundations and services in aggressive ground conditions	Low	Low	No
			Plants	Direct Contact Uptake	Trees and shrubs present on site	Low	Low	No
					Grass usually resistive to contamination	Low	Low	No

Figure 9. Risk Assessment for Source 8

8. CONCLUSIONS

The Qualitative Risk Assessment undertaken for Kenilworth Flood Alleviation Scheme, based on the preliminary Conceptual Site Model, has identified the low possibility of harm to human health, property, and the potential for pollution of controlled waters. Further investigation of the potential contamination sources and associated pollutant linkages was recommended.

These sources and their associated potential pollutant linkages required an intrusive investigation before the construction activities being effectively undertaken.

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THE INFLUENCE OF PRECIPITATION ON TOURISM DEVELOPMENT IN PETROSANI DEPRESSION

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Abstract: *Sustainable tourism in the Petroșani Depression, as an alternative to the closure of mining activities, should aim to achieve a balance between development and conservation, to find the best tourism activity taking into account both ecological and socio-economic elements. of it. But, the forms of tourism practiced in the open air, are intensely conditioned by the climatic conditions such as: air temperature, amount of precipitation, thickness of the snow layer, wind speed, etc. This paper aims to present an evolution of the amount of precipitation over a period of 40 years and to highlight the problems that may occur in the hot or cold season, depending on which, tour operators should take into account in tourism planning.*

Keywords: *climate, amount of precipitation, tourism, Petroșani Depression*

1. INTRODUCTION

After the systematic closure of the mining activity in the Petroșani Depression, tourism will be an alternative in terms of sustainable development of the analyzed area. The sustainable development of tourism depends directly or indirectly on the sustainable development of other areas. General improvement of infrastructure, decrease of corruption, economic growth, increase of living standard etc. will lead to the creation of the necessary conditions for the sustainable development of tourism in the Petroșani Depression.

The Petroșani Depression is a region descended within the Southern Carpathians, being limited to the North by the mountain massifs: Retezat and Şureanu, to the South and South-East by the Vâlcanului and Parâng Mountains. It has approximately NNE-SSV orientation, stretches over a length of about 45 km and a width ranging from East to West between 9-12 km. [2]

It consists of six localities with related administrative units: Petrila (Lonea, Jieț, Cimpa), Petroșani (Dâlja, Livezeni), Aninoasa (Iscroni), Vulcan (Dealul Babii, Paroșeni), Lupeni, Uricani (Valea de Brazi, Câmpu lui Neag) with a population of

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120,734 inhabitants, the city with the largest population being Petroșani (37,160 inhabitants).

Mountain tourism, specific to the Petroșani Depression, includes a wide range of recreational, spiritual and economic activities that take place in various mountain regions. It is an important economic source of many mountain communities, generating jobs, incomes that, in the end, allow the locals to organize and continue their life in accordance with their own cultural traditions and roots.

2. THE EVOLUTION OF THE PLUVIOMETRIC REGIME IN PETROȘANI DEPRESSION

Precipitations are a direct consequence of the general circulation of air masses in the country. Cyclonal air masses usually cause most of the precipitation as it causes atmospheric instability and causes significant cloud formations. In the temperate continental climate, precipitation falls in different forms.[4] Most of the year there is liquid precipitation, especially in the hot season. In the cold season, especially in winter, the precipitations are in solid state, but there are also mixed precipitations (sleet, drizzle etc.).

The annual minimum of precipitation is registered in the winter months, in January and February, when at the level of the country an high-pressure area dominates. Compared to this distribution there are in the temperate climate and frequent deviations from the rule. Thus, sometimes, the maximum precipitation occurs in another month (July or August), while the annual minimum can be recorded in another month.

Atmospheric precipitation is also one of the most important characteristics of the climate, it is of particular interest in knowing the regime of atmospheric precipitation.[1, 3] The characteristic of all the months is the great variability of the pluviometric regime.

The variability of precipitation differs from year to year depending on the season. The highest amounts of precipitation were generally recorded in the summer months of 202.3 mm in June, 235.8 mm in July (1991), 225.2 mm in July (2005), 253.0 mm in June (2016), with a maximum rainfall of 295.8 mm in July (2014), with the lowest rainfall in the winter and autumn months of 5.0 mm in November (1986), 5.4 mm in January (1989), 1.8 mm in November (2011) and the month with the lowest rainfall being 1.5 mm in October (2000) [5].

At the values of the annual amounts, in the pluviometric regime, for the period 1980-2019 we notice that there are increasing deviations from year to year, except for the first years of the study which were drier than the next period. For this study I chose a decadal analysis of this period, following the deviation of each decade from the other (Figure 1).

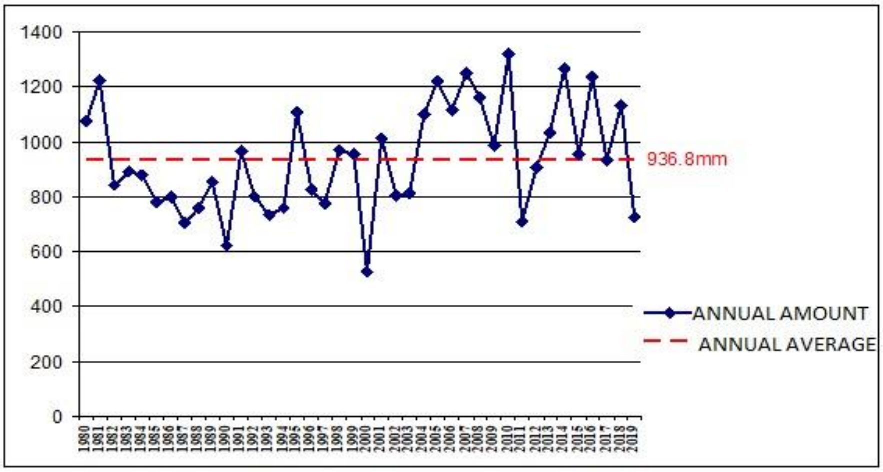

Figure 1. Evolution of average annual precipitation for the 1980-2019 period at Parâng Meteorological Station

For the decade 1980-1989, we can see, from figure 2, that the average of the decade is lower than the multiannual average, which shows that this decade is drier than the others (except the next decade), the driest year being 1985 (563.5mm) . We can observe that in the years 1980, 1981 and 1984, compared to the other years of the decade, the annual amounts (712.6 mm, 888.8 mm and 743.8 mm respectively) register higher values than the following years, which results that in this decade is a deviation very large in the first part, followed by a slower decrease in precipitation.

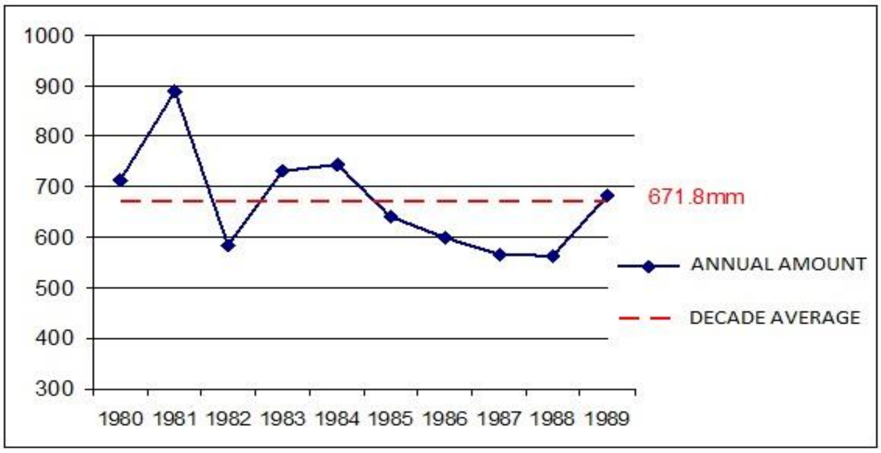

Figure 2. The evolution of the pluviometric regime for the 1980-1989 decade

For the 1990-1999 period, we can see from Figure 3, that the average decade (628.7mm) is lower than the average of the previous decade and compared to the multiannual average, resulting in the driest decade in this study. Here it is shown that the annual amounts of the rainfall regime vary from the average of the decade, the driest year being 1990, and the wettest 1999.

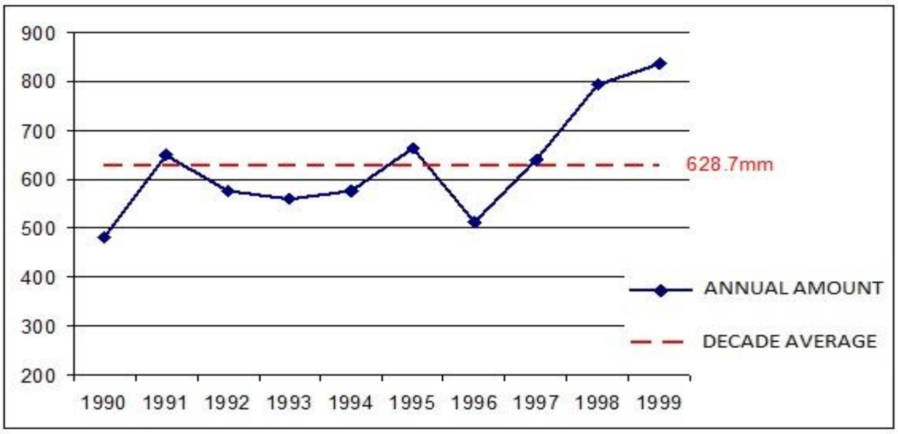

Figure 3. The evolution of the pluviometric regime for the 1990-1999 decade

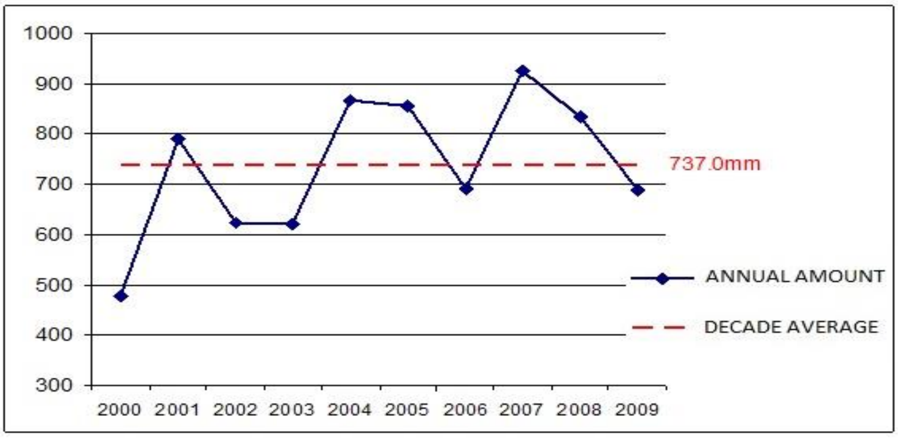

Figure 4. The evolution of the pluviometric regime for the 2000-2009 decade

For the 2000-2009 time period, we can see from figure 4 that its average (737.0mm) is higher than the multiannual average and than the other two decades, which results in an increase in the amount of precipitation. We can also see that the annual amounts vary from year to year, except for the year 2000 and where the amount of precipitation is well below the average of the decade.

For the 2010-2019 time period, we can see from figure 5 that the average decade (806.4 mm) is higher, compared to the other decades studied and compared to the multiannual average, resulting in a significant increase in precipitation. We can also observe a variation of the annual amounts compared to the average of the decade, thus, the years 2010, 2013, 2016, and 2018 register values above the average of the decade, and the years 2011, 2012, 2014, 2015, 2017, have the registered values are below the average of the decade.

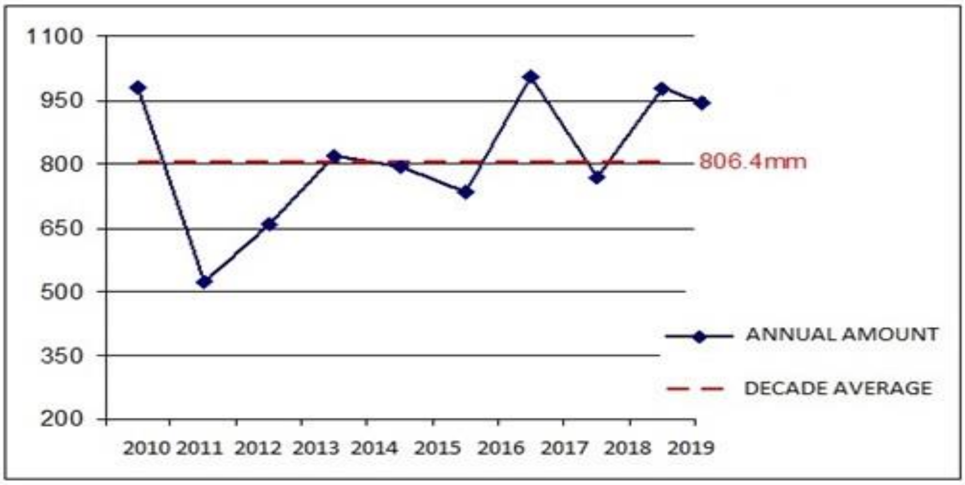

Figure 5. The evolution of the pluviometric regime for the 2010-2019 decade

From the analyzed data, we can observe an increase by 177.7 mm of the decadal averages from the studied period, but also a deviation of the annual amounts from year to year, where, in 1990, the annual amount being the smallest (481.2 mm), from the whole period studied, and in 2016 the annual amount being the highest (1006.7 mm).

The solid precipitations have a rather long duration (at over 1500 m altitude the snow carpet lasts even over 3 months), the favorable conditions for the formation and maintenance of the snow layer can sometimes be found in the high areas from the beginning of October until the first part of May.

At an altitude of over 1500 m, the average thickness of the snow layer exceeds one meter, the largest accumulations occurring in the last decade of February and the first part of March.

3. CONCLUSIONS

In the Petroșani Depression there are deviations from the multiannual averages, both in the thermal and in the pluviometric regime, where we can distinguish that in the cold season of 2000 at the Parâng Meteorological Station, was registered the lowest amount of precipitation (524.3 mm) and in October (1.5 mm) and November (8.4 mm) there was a period of drought. Also in the same year, according to the values recorded at the Petroșani Meteorological Station, there was a period of drought, in October (0.0 mm), when no amount of precipitation was recorded and in November, only 9.9 mm , as well as in 1990 with an annual average of 481.2 mm, in January only 9.4 mm of rainfall was recorded resulting in a dry period as well.

For the warm season, at Parâng Meteorological Station in 2014, in April (123.6 mm), May (173.2 mm), June (151.6 mm), July (295.8 mm), and August (118, 0 mm), the highest amount of precipitation was recorded.

At the Meteorological Station in Petroșani in 2003, there was a deviation from one month to another so in July, the amount of precipitation recorded was 121.6 mm, followed by a month of drought in August (0 mm), then returning in September with a considerable amount of precipitation (112.7 mm). In 2017 and 2018 in June (189.0 mm and 269.1 mm respectively) and July (152.9 mm and 184.8 mm respectively), large amounts of precipitation were recorded, being a period with a risk of floods.

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ASSESSMENT OF THE ENVIRONMENTAL RISK AND IMPACT OF TĂUȚII DE SUS POND - CLOSED AND NON-CONFORMING REHABILITATION

ADINA BUD[1]

Abstract: *The paper analyzes an extreme situation of a tailings pond located upstream of the city of Baia Mare and flanked by two localities: Satu Nou de Sus and Tăuții de Sus. The two localities have agricultural and animal husbandry activities, including in the contamination area of the pond, with an increased risk to the health and safety of the population due to its chemical and physical instability. A personal analysis carried out recently has revealed worrying effects on some people and animals in the area. The cause of these effects could be the state of unfinished closure and greening works. Residents directly affected are not warned by the authorities about the risks, and those who requested information before the construction of the houses at the base of the pond began, were assured that the pond is rehabilitated and does not present risks.*

Keywords: *closed non-compliant pond; environmental and public health risks; toxic waste in the community; acid drainage; constructions at the base of the pond.*

1. INTRODUCTION

The closure of the mining activity has generated a significant environmental impact with short, medium and long-term risks. Sources of pollution are underground mining works, tailings ponds, mining concentrate depots and tailings dumps. The tailings ponds are mostly close to human communities, as in the case of Baia Mare [1] metropolitan area.

Particular attention should have been paid to the closure of mining to these sites, which are sources of pollution for all environmental factors: air, water and soil. Tăuții de Sus tailings pond has a special feature due to the fact that it is located in a crowded area, in continuous expansion and it is considered by the inhabitants to be properly ecological. In reality, the situation is serious due to: a strong acid drainage along the entire contour of the pond; the geometric shape of the sink in the upper part with water accumulations; the slope of the embakment at risk of physical instability; constructions on the alignment of the base of the pond at distances of only a few tens and hundreds of meters; animals grazing and consuming water from and in the vicinity

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of the pond; crops and greenhouses in contaminated areas; rides and driftings with off-road vehicles and ATVs on the slope of the pond; clogged drains; geocomposites and geomembranes exposed to the weather; abandoned drainage pipes on the surface of the pond, etc.

2. CONSTRUCTIVE DATA REGARDING THE POND

It is a lowland pond, located near the Central pond, in the middle of densely populated areas. It was put into operation from 1962, until its closure in 2006, serving the Baia Sprie preparation plant. The surface at the level of the canopy is 30 ha and has a total tailings amount of approximately 14 million tons, a height of 37 m and an average slope of 18 degrees. The area at the base of the pond (footprint) is estimated at 54 ha. The calculation of the surfaces was made based on the measurements on the orthophotoplan from atlast.anpm.ro and imported into google earth. The permeable surface (in which rainwater easily infiltrates) is estimated at 32 ha and includes the outer slope of the pond, the canopy and the inner slope with permeable characteristics. These areas were measured in order to achieve the scenario on the water balance in the perimeter of the pond for risk assessment in the cases analyzed below.

Figure 1. The location of Tăuții de Sus pond and its condition on 23.08.2020 (google earth)

Figure 1 shows the condition of the pond on 23.08.2020 with the shape of a sink in the central - southwestern area with accumulation of water contaminated by yellow - reddish color (specific to ocher). The respective area presents erosion phenomena of the material entrained towards the central area, aspects presented in photos 1 and 2 taken on December 6, 2020. In August 2020, the amount of precipitation in Baia Mare was 143.6 l / sqm, and in November (period before the photos) was 10.9 l / sqm (ANM data from www.vitalmm.ro/ro/precipitatii-anm). Thus, it is noted that in periods of low evaporation and low rainfall in the water accumulation area, its volume is significant, a worrying fact in a scenario with large amounts of precipitation in short periods of time. Breaking the dam on the south side would endanger the population and the houses at the base of the pond. The lack of intervention in the next period will reduce the volume of water stored in the central area by entraining material from the inner slope, helping to increase the risk of reaching a critical beach (distance between canopy and water luster) which will eventually lead to instability dam.

On the western side (common side) of the Tăuții de Sus pond is the Central pond with a capacity of 10 million tons, for which a project of exploitation and relocation of 8.5 million tons was foreseen (the difference of 1.5 million would be left to support the Tăuții de Sus pond). By relocating the 8.5 million tons, an area of 48 ha would have been released and returned to the economic circuit. The project was blocked by the local authorities in 2012 (the expected duration of the works was 5 years). Currently, the Central Pond presents a major risk, amplifying the situation in the area.

For the Tăuții de Sus pond, there is a closure and rehabilitation project through which the execution of some works has started, but for various reasons they have been abandoned in a deplorable state.

3. DESCRIPTION OF ENVIRONMENTAL IMPACT AND RISK

Currently, this pond poses a major risk of physical and chemical stability. The southern side is close (on the order of tens of meters) to an intensely inhabited area with old and new constructions, some even in the construction stage. From my personal analysis, I found that most of the population is not aware of the risk, being informed that the pond is rehabilitated. The sad aspect is given by the paradox of the society with easy access to information, with countless competent authorities, NGOs, media, etc., but the population in the area still grows vegetables and raises animals on contaminated land. From the analysis, it was noted the increased incidence of autoimmune diseases among the population in the area. Of all the cases, one stands out by the fact that an educated, athletic young man, following a possible contamination with heavy metals as a result of daily consumption of vegetables and goat's milk raised at the base of the pond and even on the pond, his body became vulnerable to any type of infection, not responding to conventional treatments. His health deteriorated about 8 years after his move to the area, he built his house less than 100 m from the base of the pond. One of the infections is caused by Borrelia Burgdorferi, and the specific treatment did not give any positive results, to the astonishment of the doctors. Studying the existing information [2], it was identified that an organism contaminated with heavy metals does not respond to the treatments known so far, effective in situations of uncontaminated ones. The farmer of goats fed in the area of the pond perimeter reported that he had kids with malformations that he could not explain, thus proving the lack of information of the population about the risks to which they are exposed.

In a civilized society, the authorities do not allow the population to be exposed to such risks. There is also the risk of breaking the dam by the fact that the physical stability of the pond is not ensured by: accumulation of water in the sink (lake area) during periods of excessive rainfall, producing the phenomenon of overflow and rupture of the dam; clogging of the drainage system at its base, highlighted by the obstructed systems (due to the precipitation phenomenon) entirely on the entire southern side; the development of vegetation of shrubs and trees directly on the slope, which raises the hydrostatic level and additionally loads the forces acting on the slope (the action of weight and water). Stabilization and rehabilitation should have complied with the Technical Regulations in force, including the geometry that involves the formation of a dome instead of a sink (current situation), as well as waterproofing to stop the reactivity of the material in the pond. Breaking the dam poses a risk to the lives of the inhabitants and the destruction of property.

The following pictures show a part of the reality on the ground regarding the way in which the stabilization and rehabilitation works of the Tăuții de Sus pond, located in the immediate vicinity of the residential areas, were designed and executed.

Photo 1. Degradation status of rehabilitation works

Photo 2. Water puddles in the center of the pond in the shape of a sink and traces of animals consuming water from the pond

Photo 3. Acid drainage at the base of the pond where the perimeter gutter was arranged (concrete degradation and clogging of the drainage system)

Photo 4. Residential and construction areas at the base and in the vicinity of the pond stabilized and improperly rehabilitated

4. SCENARIOS REGARDING THE WATER BALANCE IN THE PERIMETER OF THE POND

The entire amount of water falling into the perimeter of the pond (except evaporation) will be transformed into acid drainage (water with a pH between 2 and 3) and loaded with heavy metals. On most of the surface of the pond (estimated at 32 ha), the material being permeable (dusty sand, sand) precipitation water will enter the structure of the pond without intense evaporation during dry periods, as in the case of the central area . In the situation of January 2020 when the amount of precipitation was 119.3 l / sqm or December 2018 of 118.2 l / sqm (months when the evaporation on normal ground is about 12 l / sqm), according to The calculations show that approximately 100 l / sq m infiltrates into the body of the pond, leading to the accumulation of 1 000 m3 / month / ha of rainwater, respectively 32000 m3 for the entire pond. This amount of water is converted as a result of oxidation reactions of sulfur in the pond into acid drainage, which is then released into the environment. In 2018 the amount of precipitation was 761.1 l / sqm and in 2019 737 l / sqm, years considered dry for the Baia Mare region. In 2018, the total amount of fallen water was 76,110 m3 / ha, which represents over 2 million m3 of water infiltrated into the body of the pond in the permeable area, transformed into toxic water. In the situation of repeating a meteorological phenomenon with the probability of occurring once every 100 years, such as the one in 1970, when they fell 121.4 l / sqm in 24 hours, it would inevitably lead to exceeding the storage capacity of water in the pond sink and breaking dam with catastrophic consequences. At an area of 30 ha inside the canopy, 36,420 cubic meters of water would accumulate, exceeding the safety capacity of the water volume in the pond. Another exceptional precipitation situation presented in the National Geographic Romania magazine (natgeo.ro) is that of Seini locality, Maramureș county, when between 12 and 15 May 1970, at an altitude of 145 m, 200.5 mm of precipitations were registered [3].

In the current context of climate change and intense rainfall, any vulnerable structure is at a major risk, as is the case of Tăuții de Sus pond. In 2020, upstream of Șurdești locality, on a small area, there was heavy rain, with the entrainment of material (crushed stone and raw stone resulting from detonations) from the Dâmbul Lupului quarry leading to the road blockage of Baia Sprie – Cavnic route and clogging of the bridge. The area, where the phenomenon occurred, is located between Vrănicioara Pond and Plopiş-Răchiţele Pond, which are tailings ponds improperly rehabilitated. If the meteorological phenomenon had occurred in the perimeters of these ponds, the consequences would have been dramatic. Thus, it is easy to conclude the danger represented by these incorrectly stabilized and rehabilitated ponds or of those without any stabilization or rehabilitation works (Bozânta, Săsar, Central, Leurda pond, etc.).

In the current state of the pond, the rainwater that falls on its surface has an environmental impact both physically and chemically with adverse consequences.

Closure and rehabilitation works should have ensured physical and chemical stability for an indefinite period, by complying with the technical requirements imposed by the Technical Regulation on landfilling [4].

5. CONCLUSIONS

The current state of Tăuții de Sus pond presents a very high risk both physically and chemically.

From a physical point of view, breaking the dam would lead to loss of life and destruction of the property at its base. A special meteorological phenomenon such as heavy rainfall, would allow the accumulation of a large amount of water in the upper part of the pond in the form of a sink, which would lead to overflow and rupture of the dam with the entrainment of very large amounts of material. Recently, in the area there have been events on small areas with heavy rainfall, known as "breaking clouds".

The chemical instability of the pond is intense due to the sulfide content, which generates acid drainage as a result of oxidation reactions. The reactivity is given by the fact that no waterproofing works were performed. The entire amount of precipitation on the surface of the pond participates in the oxidation of sulfides that are released on the contour through the perimeter ditches or percolating the foundation of the pond directly into the groundwater.

Adjacent to the Tăuții de Sus pond with the mentioned risks, there is the Central pond with other particularities regarding the environmental risks (slopes and plateau exposed directly to environmental factors, traces of a deposit of 110,000 tons of arsenious pyrite gold concentrate treated by bacterial leaching) and Flotation central. Central Flotation is a site contaminated with abandoned and unprotected ore deposits and concentrates.

The purpose of the article is to sound the alarm about the risks to the population living in the vicinity of areas contaminated with heavy metals due to physical and chemical instability of the tailings ponds.

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MANAGEMENT OF HAZARDOUS WASTE IN HUNEDOARA COUNTY, ROMANIA, IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Abstract: *Waste is one of the most acute environmental problems. Waste management policies aim to reduce the impact on the environment and health and to improve resource efficiency. The long-term goal is to transform into a recycling society, avoiding waste and using the inevitable as a resource, whenever possible. The aim is to achieve much higher levels of recycling and minimize the extraction of additional natural resources. This paper wants to highlight a few options of waste management in Hunedoara county, as a conclusion that proper waste management could be a key element in the context of sustainable development.*

Keywords: *municipal waste, waste management, sustainable development, Hunedoara county*

1. INTRODUCTION

The quantities of waste generated are growing rapidly from year to year, and the impact it has on the environment and implicitly on the community is growing. The issue of waste, especially hazardous and toxic waste, is attracting increasing interest in both industrialized and developing countries. Addressing it has become a priority goal of environmental policies.

The volume of waste disposed can be seen as an indicator of resource efficiency in a society, because excess waste generation is linked to the inefficiency of production processes, low sustainability of products placed on the market and inappropriate consumption patterns. [2]

Sustainable development recommendations include the flow of materials needed at various stages of production, consumption and use that should be managed so as to facilitate and encourage their optimal reuse and recycling. This avoids wastage and prevents depletion of the stock of natural resources. [4]

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Municipal waste management is a major responsibility primarily for public administration authorities, but also for the population. In Hunedoara county, municipal waste management is performed through four main stages: collection, transport, treatment and storage.

2. MAIN FEATURES OF HUNEDOARA COUNTY

Hunedoara County is located in Romania, Transylvania region, is part of the West Development Region and its residence is Deva. At European level, the county is part of the DKMT Euroregion. Hunedoara County is located on the middle course of the Mureș River, near the Apuseni Mountains (N), Orăștie and Șureanu (S-E), Retezat-Godeanu, Vâlcan and Parâng (S) and Poiana Ruscă Mountains (S-V). The most important rivers that cross the county are: Mureș, Strei, Râul Mare, Crișul Alb and Jiu. The extensive depressions of Hațeg and Zarand are located on the territory of the county.

The county is composed of seven municipalities (Brad, Deva, Hunedoara, Lupeni, Orăștie, Petroșani, Vulcan), seven cities (Aninoasa, Călan, Geoagiu, Hațeg, Petrila, Simeria, Uricani) and 55 communes. It borders the counties: Arad, Alba, Vâlcea, Gorj, Caraş-Severin and Timiş.

Figure 1. Geographic position of Hunedoara County

3. HOUSEHOLD WASTE MANAGEMENT IN THE COUNTY

In Romania, the responsibility for municipal waste management belongs to the local public administrations, which, by their own means or by concession of the sanitation service to an authorized operator must ensure the collection (including separate collection), transport, treatment, recovery and final disposal of this waste.

Municipal waste is disposed of exclusively by landfill. So far, no installations for incineration of municipal waste have been put into operation in the county.

Municipal waste management involves collection, transport, recovery and disposal, including monitoring of landfills after closure.

In 2019, the situation of non-compliant deposits in the county was according to the table below:

Table 1. The situation of non-compliant deposits in the county, in 2019

Location of the landfill	**Year of closure**	**Disposal situation**	**Alternative location for storage**	**Nr. closure notice / environmental permit / reception**
Brad	2004	stopped	Deva	Notice of closure no.27/27.02.2007
Hunedoara	2006	stopped	Orăştie	Notice of closure no.6/31.03.2008 Reception at the end of the works 12.10.2015
Petrila	2008	stopped	Vulcan	Environmental permit at the cessation of activity no. 21/18.12.2008 Reception at the end of the works 25.08.2015
Haţeg	2008	stopped	Vulcan	Environmental permit at the cessation of activity no 1/14.01.2009 Reception at the end of the works 26.11.2015
Geoagiu	2009	stopped	Orăştie	Closing notice no.25/09.02.2007
Călan	2009	stopped	Deva	Closing notice no.35/22.03.2007 Reception at the end of the works 13.08.2015
Uricani	2009	stopped	Vulcan	Regulatory act for establishing the obligations regarding the restoration of the environment quality no.8470/01.02.2010

Lupeni	2009	stopped	Vulcan	Reception at the end of the works 21.11.2015
Simeria (Rapolt)	2010	stopped	Orăştie, Deva	Reception at the end of the works 26.11.2015
Orăştie	2015	stopped	inconsistent	Reception at the end of the closing works 19.04.2017
Deva	2015	stopped	inconsistent	Reception at the end of the closing works 29.05.2017
Aninoasa	2016	stopped	inconsistent	Reception at the end of the closing works 13.10.2015
Vulcan	2016	stopped	inconsistent	Environmental obligations

Currently, the county is divided into four waste management areas as follows:
- Area 1. Brad - covers the northern part of the county.
- Area 2. Haţeg - covers the central-southern part of the county;
- Area 3. Deva Center - covers the central part of the county;
- Area 4. Jiu Valley - covers the southern part of the county.

The analysis of the data on the degree of coverage with sanitation services (expressed as the population served by sanitation services) highlights the fact that annually there was an increase in the percentage of coverage with sanitation services. The percentage of coverage with sanitation services in the county is over 92% for 2019 (figure 2). At the same time, there is a continuous increase in the degree of coverage in rural areas.

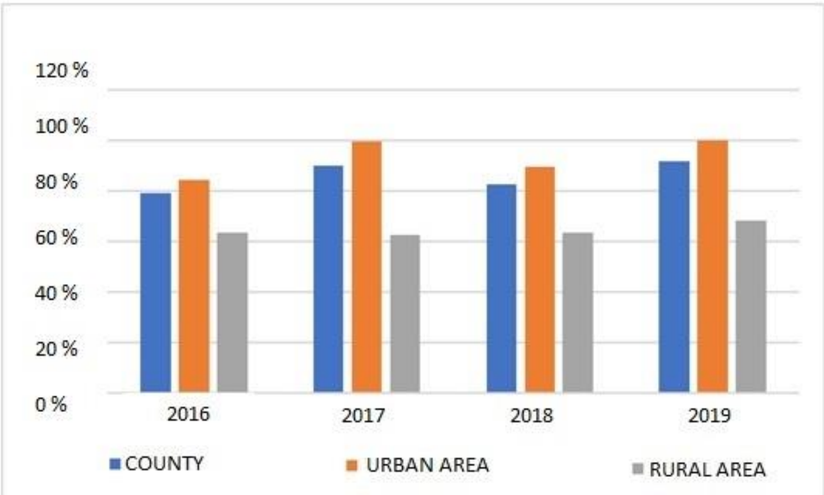

Figure 2. Land coverage with sanitation services in the county

In order to streamline the collection and transport activity, at the level of Hunedoara county there are currently the following transfer stations:

• Brad transfer station;

• Brad transfer station receives the waste from the sorting station, composting station and transporting them to the landfill at Bârcea Mare. The station has been operating since 2010;

• Hateg transfer station, operating since 2010;

• Petroșani transfer station, has been operating since 2018. The waste is transported to the landfill in Bârcea Mare.

The household waste generation indicator, at the level of Hunedoara county, has a fluctuating evolution during the analysis period, both in urban and rural areas. The values of the generation indices are lower than those calculated at national level in the National Waste Management Plan.

Compared to the average data in Romania, the lower value of the identified waste generation index is explained by the fact that Hunedoara County is less developed, which leads to a lower degree of waste generation.

Table 2. Forecast of municipal waste production in Hunedoara county

WASTE TYPE	**TONS WASTE / YEAR**		
	2020	**2021**	**2022**
Household waste collected in a mixture and separately	76744	75646	73572
Similar waste from trade, industry, institutions, mixed and separate collected	33360	32883	31925
Waste collected from gardens and parks	5761	5761	5761
Waste collected from markets	688	688	688
Collected street waste	4887	4887	4887
Total municipal waste generated	121440	119865	116833

4. MUNICIPAL HAZARDOUS WASTE MANAGEMENT

The separate collection of hazardous waste from municipal waste is not extended at national level, the quantities collected being extremely small. After collection, they are temporarily stored and transported for disposal to existing hazardous waste disposal facilities.

According to the European Waste List, the following categories are part of municipal hazardous waste (Table 3):

Table 3. European list of municipal hazardous waste (source: GD no. 856/2002)

WASTE CODE	WASTE TYPE
20 01 13*	Solvents
20 01 14*	Acids
20 01 15*	Alkalis
20 01 17*	Photochemistry
20 01 19*	Pesticides

20 01 21*	Fluorescent tubes and other mercury-containing wastes
20 01 23*	Decommissioned equipment containing chlorofluorocarbons
20 01 26*	Oils and fats, other than those mentioned in 20 01 25
20 01 27*	Paints, inks, adhesives and resins containing dangerous substances
20 01 29*	Detergents containing dangerous substances
20 01 31*	Cytotoxic and cytostatic drugs
20 01 33*	Batteries and accumulators included in 16 06 01,16 06 02 or 16 06 03
20 01 35*	Decommissioned electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing dangerous components
20 01 37*	Wood containing dangerous substances

According to EUROSTAT data, the average generation of municipal hazardous waste in Romania was 2 kg / inhabitant / year in 2018.

In the case of the European Union, the average generation was 5 kg / inhabitant / year in 2014, increasing to 7 kg / inhabitant / year in 2016. During the analysis period, according to statistical data, the quantities of municipal hazardous waste from individuals, managed at the level of Hunedoara county in the period 2013-2017 are presented in the following table:

Table 4. Evolution of the quantities of hazardous waste from municipal waste collected, recovered and disposed of Hunedoara county

QUANTITIES OF HAZARDOUS WASTE COLLECTED (TONS / YEAR)					
OPERATION	**2013**	**2014**	**2015**	**2016**	**2017**
Collection	54,46	43,36	35,64	27,58	65,48
Redeemed	82,93	18,83	52,59	59,73	58,71
Removed	0	0	0	0	0

According to the provisions of Law 211/2011 on the waste regime, with subsequent amendments and completions, the local public administration authorities have the obligation to "ensure and be responsible for the separate collection, transport, neutralization, recovery and final disposal of waste, including hazardous household waste". It must also ensure "the spaces necessary for the separate collection of waste, its endowment with containers specific to each type of waste, as well as its functionality".

The collection options provided in the Regulation of the Sanitation Service for Hunedoara County are the periodic collection campaigns, through temporary fixed collection points, according to an annual program established at the beginning of the year.

There is also the possibility that certain categories of municipal hazardous waste can be collected through stores that ensure the disposal of those products before they become waste (used oil, used batteries and accumulators, expired drugs), but could not identify a record of quantities of hazardous waste collected in this way.

According to statistical data up to the level of 2017, there is no information on the quantities of municipal hazardous waste collected separately by sanitation operators. The quantities of waste mentioned in the previous table come from the activity carried out by economic operators authorized for waste collection, other than sanitation operators.

5. PROPOSED OPTIONS FOR MUNICIPAL HAZARDOUS WASTE COLLECTION

We must mention that it is not only sufficient to collect hazardous waste from houses, it is also important to ensure the proper disposal of this type of waste. The following municipal hazardous waste management options have been identified:

a) Direct collection from homes, has the advantage of minimum handling requirements from generators, but the costs are much higher;

b) Collection campaigns have the advantage that the locations where the collection machines are parked can be alternated, to allow a larger number of people during a year. The quantities collected are significant in relation to costs. Disadvantages: discomfort for the generator due to the distance to the location of the collecting machine. Generators have to wait for campaigns, temporarily storing waste in the household, which increases the risk of accidents;

c) Public collection centers, fixed or mobile. They are functional all year round, citizens can bring waste from the moment they are produced, but require fairly high investment costs in collection infrastructure (collection point arrangement, specialized containers), high operating costs (qualified personnel, administration);

d) Unguarded containers for certain types of hazardous waste. It encourages the responsibility of the citizens, being without costs from them, sometimes even with bonuses. They can be arranged in the collection centers to increase their degree of safety, having the lowest degree of safety. The disadvantage is that there is no adequate control over the quality of the waste collected;

e) Reception at distributors or specialized companies. It has the advantage of being free of cost for citizens, low collection cost. Disadvantages would be: the organization of the system depends on those responsible and only certain categories of hazardous waste are covered. [3]

6. CONCLUSIONS

Generally speaking, the priority objectives of municipal waste and hazardous waste management, in the context of sustainable development, are the prevention and reduction of waste production by:

- development of clean technologies, with low consumption of natural resources;
- development of technology and the marketing of products which, by way of manufacture, use or disposal, do not have an impact or have the least possible impact on increasing the volume or danger of waste, or on the risk of pollution;
- development of appropriate technologies for the final disposal of hazardous substances from waste destined for recovery;
- material and energy recovery of waste, with its transformation into secondary raw materials, or the use of waste as an energy source. [1]

In the context of sustainable development, in Hunedoara County there are a few options for hazardous waste management. One of these can be highlighted by the possibility of waste collection through stores that ensure the disposal of those products before they become waste (used oil, used batteries and accumulators, expired drugs), but unfortunately we could not identify a record of quantities of hazardous waste collected in this way. Another option which can be very easy to implement are the unguarded containers for certain types of hazardous waste. In this way it is encouraged the responsibility of the citizens, being without costs for them, sometimes even with bonuses.

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THE LIFE CYCLE OF COAL FROM PETROSANI DEPRESSION IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT OF ROMANIAN ENERGY SECTOR

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Abstract: *Coal from the Petrosani Depression has long been the main energy resource in the region, being an important factor in the development of industry in Romania since the communist period. Given the national economic and political conditions, but also geopolitical ones, they led to the life cycle of this energy resource approaching the end quickly, even if in terms of quantity, it could have been exploited for decades.*

Keywords: *coal, sustainable development, energy sector, energy policy, Petroșani Depression, Romania*

1. INTRODUCTION

In general terms, worldwide, fossil fuels are the main source of primary energy used to meet the demand for electricity and / or heat and probably will remain the main source in the first half of this century. Fossil fuels cover over 85% of primary energy needs, the rest being covered by nuclear, hydro and renewable. [2] On the other hand, the use of fossil fuels for energy production leads to increased concentrations of greenhouse gases in the atmosphere.

In fact, the energy sector is next to the industrial one the main polluter, at least from the point of view of climate change. Thermal power plants emit more than a third of global CO_2 emissions into the atmosphere. For example, a coal-fired power plant generates between 6 and 8 million tons of CO_2 / year. For the same amount of energy produced, the amount of CO_2 generated in the process of burning fossil fuels is 1 for coal, 0.75 for fuel oil and 0.6 for natural gas.

In Romania, since 1990 and until now, one by one, several capacities for the exploitation of primary energy resources, as well as for the production of electricity and heat have been closed. The main reasons for these closures are related to the

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general reduction of economic activity, the low degree of profitability or the non-adaptation to the new environmental norms.

Mining in the Petroșani Depression has a history of over 200 years and the industrialization of Romania could not be achieved without the deposit from here. During the economic boom, there were 48 active mines, four surface quarries and five preparation plants. 1997 was the year when mining began to be restructured on economic grounds, with the promise that alternatives to mining (jobs for the population) would be created as soon as possible. Five years ago, there were seven mines and a preparation plant at Vulcan. Currently, only four mines are considered to be viable: Lonea, Livezeni, Vulcan and Lupeni. Although the Romanian state is no longer interested in domestic coal, the field is far from over.

The narrowing of the perimeters and the closure of the non-performing mines led to the situation in which only about 30% of the total geological reserves of coal are still found in the perimeters under the Hunedoara Energy Complex concession. According to the directives, the European Union allowed the continuation of the subsidy for coal mining until 2018 and conditions this fact by the strict application of a mine closure program that generates losses. It can be estimated that the evolution of production costs, the additional costs of CO_2 emissions and the elimination of production subsidies (required by the E.U.) will lead to a further reduction in the competitiveness of domestic coal and thus to a significant reduction in production.

2. THE COAL ISSUE IN REGIONAL ENERGY POLICY

Climate and environmental policies, which focus on reducing GHG emissions and changing social attitudes in favor of "clean energy", are a second determinant, shaping investment behavior and consumption patterns in the energy sector.

The 2015 Paris Agreement and European policies to prevent climate change contribute to a sustainable energy system. According to the IEA, by 2040, most RES will be competitive without dedicated support schemes; photovoltaic technology will have an average cost decrease of 40-70% by 2040 and offshore wind technology will have average costs at least 10-25% lower. [1]

The IEA's November 2016 Energy, Climate Change and Environment Report (IEA 2016a) presents a list of measures to reduce GHG emissions in the energy sector, with the aim of limiting global warming to no more than 2° C above pre-industrial levels, including:

- increasing energy efficiency;
- introduction of a global price of pollution (for CO_2);
- creating a global set of decarbonisation indicators;
- increase the capacity of governments to implement the energy transition process.

The European Union has set itself the objectives of completing and functioning of the internal market in electricity and cross-border trade, as well as ensuring optimal management, coordinated operation and sound technical developments in the European electricity transmission network.

The European association of transmission system operators (ENTSO-E) shall draw up a ten-year electricity network development plan and include an assessment of the adequacy of the pan-European electricity system every two years. This plan envisages the integrated model of the European electricity network, the development of scenarios and the assessment of the resilience of the system.

Within ENTSO-E, six regional groups have been created in which the European network development plan is analyzed and finalized (figure 1).

Figure 1. ENTSO-E Regions

Romania is part of the priority corridor no. 3 on electricity: "North-South interconnections on electricity in Central and South-Eastern Europe" ("NSI East Electricity"): interconnections and internal lines in North-South and East-West directions to complete the internal market, and for the integration of production from renewable sources. Member States involved: Bulgaria, Czech Republic, Germany, Greece, Croatia, Italy, Cyprus, Hungary, Austria, Poland, Romania, Slovenia, Slovakia.

Coal is the basic primary energy resource in the energy mix, being a strategic fuel in support of national and regional energy security. In extreme weather periods, coal is the basis for the resilience of energy supply and the proper functioning of the National Energy System (SEN), covering one third of electricity needs.

The known coal resources in Romania are 232 million tons [85 million toe] of which 83 million tons [30 million toe] are exploited in leased perimeters. At an average consumption of reserves of 0.3 million toe / year, the degree of insurance with coal resources is 104 years for hard coal, but the exploitation of this primary energy resource is conditioned by the economic feasibility of the exploitations. The average calorific value of the coal exploited in Romania is 3.650 kcal / kg and the average calorific value of hard coal from Peroșani Depression is 5400 kcal / kg. The estimated annual production for each primary energy resource in Romania and their life exploitation expectancy are shown in the tables below (table no. 1 and table no. 2):

Table 1. Estimated annual production for each primary energy resource in Romania

PRIMARY ENERGY RESOURCE	RESOURCES		RESERVES	ESTIMATED ANNUAL PRODUCTION		
	Mil. t.	Mil. toe	Mil. t.	Mil. toe	Mil. t.	Mil. toe
LIGNITE	690	124	290	52	25	4.5
HARD COAL	232	85	83	30	0.8	0.3
OIL	229. 2	-	52.6	-	3.4	-
NATURAL GAS	726.8	-	153	-	10.5	-

Table 2. Life exploitation expectancy for each resource

PRIMARY ENERGY RESOURCE	INSURANCE PERIOD (YEARS)	
	RESOURCES	RESERVES
LIGNITE	28	12
HARD COAL	290	104
OIL	67.4	15.5
NATURAL GAS	69.2	14.6

Even if they were closed on economic or political criteria, the mining perimeters from Petroșani Depression have important geological reserves that could have been exploited (table no. 3, table no. 4)

Table 3. Situation of geological reserves in closed mining perimeters (thousand tons)

CATEGORY	MINING PERIMETER					
	Câmpu lui Neag	**Valea de Brazi**	**Aninoasa**	**Dâlja**	**Petrila South**	**Lonea Pilier**
Probable geological reserves	978	18.355	99.678	24.254	27.209	41.693
Total geological reserves in the mining perimeter	1.748	88.352	99.849	84.367	87.063	94.353
Energetic value (kcal/kg)	4.776	5.343	5.539	5.434	5.566	5.788

Table 4. Situation of geological reserves in closed mining perimeters, considered unreliable (thousand tons)

CATEGORY	MINING PERIMETER		
	Uricani	**Paroșeni**	**Petrila**
Probable geological reserves	62.924	19.039	69.720
Total geological reserves in the mining perimeter	110.769	41.473	88.457

The coal supply at the level of Romanian producers is about 33 million tons, about 5 million tons less than the estimated demand for the period 2010-2020, and the degree of production insurance is 38.6 years for coal and 14 years for lignite. The coal industrial reserve for the Petroșani Depression is 56 million tons, and the average production capacity is about 1.5 million tons / year.

The Romanian Government has come to the conclusion that losing companies cannot be kept indefinitely alive. Currently, Hunedoara Energy Complex is in insolvency with a debt to the state budget of 165 981 506 lei, and to the local budgets of 2 180 403 lei and short-term internal bank loans of 48,632,182 lei, respectively long-term bank loans of 117 240 591 lei.

The price of coal is currently set freely, through direct negotiations between the producer and the beneficiary. For coal, the price is lower than the cost of production, the difference being covered by State aid under the conditions of EC Directive 1402/2002.

In order to develop coal production in the current conditions, it is necessary to promote long-term contracts between suppliers and thermal power plants, based on pricing formulas based on stock quotes of other similar primary energy carriers, to substantiate the results of feasibility studies (plans business) on a real basis.

According to forecast studies, conducted worldwide (CME) by 2030, on all markets in the world is estimated a slight upward trend in the price of coal, compared to substantial increases in other energy resources (crude oil and natural gas). Forecasts confirm that this energy resource, in addition to the long duration of insurance, presents a guarantee of sustaining the energy needs in the future, at competitive prices with the price of other primary energy resources.

The need of coal for electricity and heat production will be provided by the production of Vulcan and Livezeni mines supplemented with the need for imports, until the reconfiguration of unprofitable thermal energy capacities from coal to another more efficient primary energy resource.

In the context of current policies and measures, the forecast shows a decrease in energy production, mainly caused by a reduction in the production of solid fuels and natural gas (figure 2). On the other hand, an increase in the production of nuclear energy is expected, including after 2030, following the commissioning of nuclear power units 3 and 4 in Cernavoda Power Plant, as well as an increase in the production of energy from renewable sources.

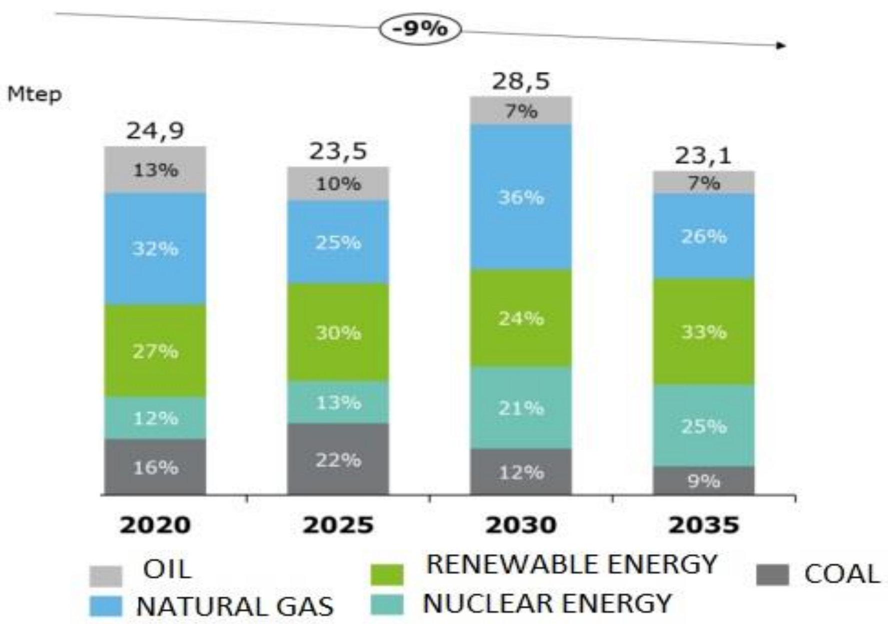

Figure 2. Expected evolution of energy production on energy sources, in the context of current policies and measures

Regarding the net import, Romania is expected to remain a net exporter of electricity, although at a much lower level than before. Imports of crude oil and petroleum products are also expected to remain high in order to meet demand (figure 3). Overall, dependence on imports is expected to increase in the context of the forecast increase in primary consumption and a decrease in production.

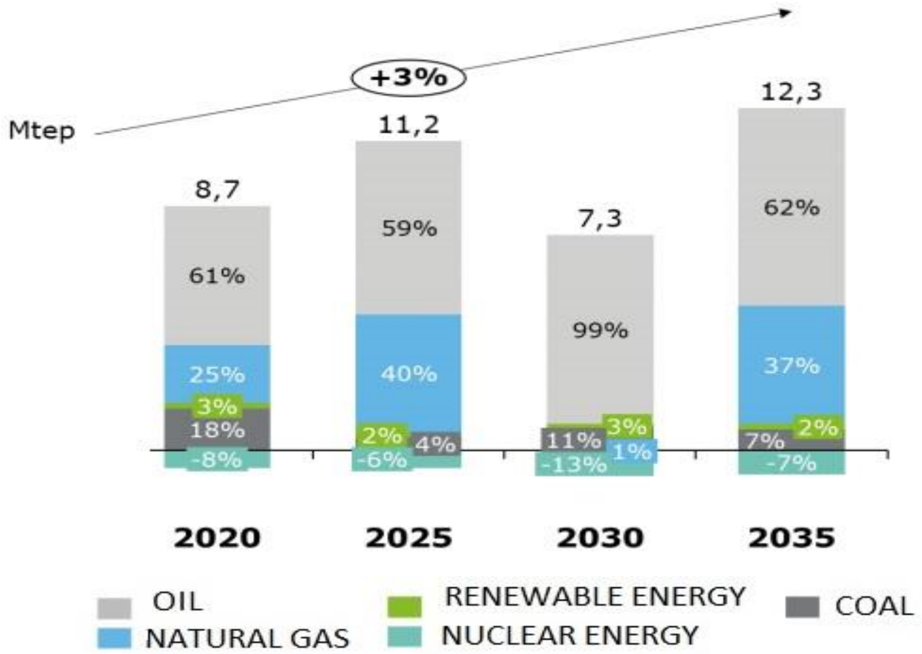

Figure 3. Expected evolution of net energy imports, by energy sources, in the context of current policies and measures

3. CONCLUSIONS

According to the Romania's energy development strategy, was established as a strategic objective, the improving energy efficiency in the whole system: natural resources, production, transport, distribution and final use, through optimal use of mechanisms of market economy, with an estimated reduction of 3% per annum in energy intensity of the national economy by 2020.

Until 2030, it is expected, in Romania, the withdrawal from operation of the capacities based on natural gas and coal that are at the end of the life cycle and where modernization is not justified, in order to meet the emission standards. As old capacities are withdrawn from reserve or decommissioned, new capacities are needed in their place.

In the context of current policies and measures, the forecast shows a decrease in energy production, mainly caused by a reduction in the production of solid fuels and natural gas. Romanian coal is a medium quality coal, with high extraction costs, requiring subsidies of about 40-50%.

Low domestic coal production (intentionally) requires appreciable imports of superior coal. Instead, lignite is a lower coal with low calorific value, high humidity and ballast, obtained from surface mining, without the necessary subsidies. Lignite remains economically viable if used "at the edge of the coal pit", the cost of transport being prohibitive.

As a conclusion, to answer the question: In terms of sustainable development of Romanian energy system, is the coal's life cycle from the Petroșani Depression close to the end? The answer is yes, there is no opportunity in the near future for the life cycle of coal from this part of the country to resume, in order to be useful in the Romanian energy system. At least, not in the conditions and terms imposed by the European Union, having as context sustainable development and climate change.

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REALIZATION OF A SITUATION PLAN USING THE DRONE (UAV) AS PHOTOGRAMMETRIC EQUIPMENT

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Abstract: *Photogrammetric measurements performed with drones, from which geospatial data can be extracted for the elaboration of site plans are an alternative technology to topographic measurements made with total stations or GPS stations, which are performed in a shorter time and at lower costs. This technology is too little used in our country, but our more developed neighbors in the European Union have been using it for some time. The purpose of this article is to show the stages and procedure by which a site plan of an area can be created starting from the measurements made with the drone and reaching the site plan.For this process we used a DJI Phantom 4 Pro Plus drone, third party software as follows: for image processing (AgisoftMetashape), for extracting 3D points (PointCab), and for preparing the site plan (Autocad). The use of third-party software has helped to process data faster. The measurements made with the drone were performed from an altitude of 30 meters, and the accuracy of the images obtained is 7.49 mm / pixel, and the site plan drawing scale is 1: 500.*

Keywords: *drone measurements, spatial data, point cloud, orthophoto, site plan, 3D points, photogrammetry*

1. INTRODUCTION

Site plans are graphical representations of objects in the field. Photogrammetric measurements are also representations of objects in the field, the only difference is the approach of the use of different topographic tools, collecting data from the field, post-processing them, but their results must overlap with high accuracy.

Drones are remotely controlled flying objects using special controllers that help maneuver them. First of all, these flying vehicles were created and used by the army, the first being created in the 2000s in Indonesia, but they soon realized that these vehicles could be created by several companies, and their use can also have non-military purposes and can be handled by civilians in order to check various construction works in the field, infrastructures even for making maps or terrestrial measurements.

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These data taken by drones are important because they reduce the time of map making and terrestrial measurements, are more accurate than satellite images (and cheaper) at the same time, it must be considered that we are bound by certain factors involved in this operation, namely: it cannot be flown in an unfavorable weather with low visibility, strong gusts of wind, snow or precipitation or other weather, cannot fly on routes delimited for air traffic, obstacles that may deteriorate or damage the drone must be avoided, here I mean high voltage cables, tall trees, towers etc. we must have visibility to the drone throughout the flight from take-off to landing.

To perform the flight route, different applications can be installed in the drone controller and according to the settings implemented for the route to be followed, the drone will perform the aerial photographs at the desired altitude in order to have high precision results. We mustn't forget that this technology is too little used in our country, because the regulations are not very precise and clear, without a „user manual", but we know all too well the benefit of this "machine", namely, that in a very short time we can have a good insight of the work we want to achieve.

For this article we used drone measurements made in Mun. Baia Mare, Maramureș County.

2. WORKING METHOD WITH DRONE

As I mentioned, I used the DJI Phantom 4 Pro Plus drone, with a photo application on a predefined route to have the highest possible accuracy.

On the day of the flight the sky was clear, with very smooth wind, and the visibility on the drone was good. The drone flew at a constant height of 30 meters, and the photo of the delimited area lasted 8:30 minutes, including take-off and landing.

On the ground I mounted two landmarks (crosses) which were measured with GPS Trimble R6, using the RTK method (real-time kinematic measurements) with internet connection, receiving corrections from the Baia permanent station, the two points having the coordinates in the Stere70 national system, these targets being visible in the photos taken by the drone, and which were required in the post-processing phase of the images.

The drone was used with a pre-check and cleaning, for all sensors to be functional, and due to the intensity of the sunlight, it was chosen to thread an ND8 filter (neutral density) to benefit from better images and a greater depth of field in the images, this helps to create overlapping points in images (fewer gaps appear, spaces burned due to sunlight, which would reduce the details in the photos).

3. THE METHOD OF DATA PROCESSING COLLECTED FROM THE MEASUREMENTS MADE WITH THE DRONE

We start Agisoft software, an on the *Workspace*, in the *chunk* we add our images by right click on the *chunk*and selecting *add* → *add photos*. (*Fig. 1.*)

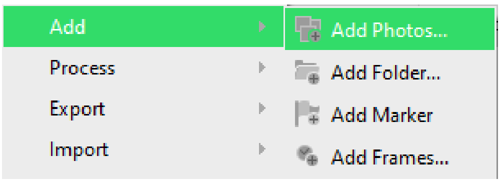


Figure 1. Adding images to project

After this step, we are looking forward to convert the reference system in a desired one, by selecting the*Convert*buttonfrom the*Reference*pannel. *(Fig.2.).* By default images are taken in the **WGS84(EPSG::4326)**coordinate system.In*Convert reference* pannel, we select**Pulkowo 1942(58) / Stereo70(EPSG::3844)** coordinate system(*Fig.3.*), because this is the reference system used in Romania, and for the processing in the next steps this will make a big difference regarding the precision and accuracy of the processing.

Figure 2. Convert command from the Referencepannel

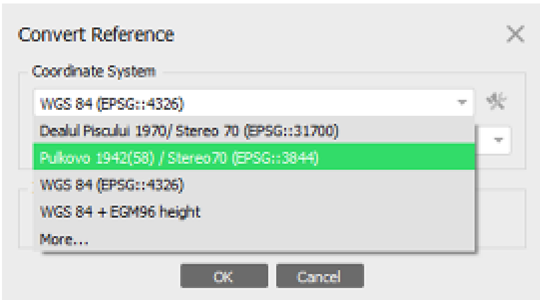


Figure 3. Coordinate system's

Given that this reference system has an accuracy of 3.00 meters, we need to select the images and change the accuracy of the images using the following steps: *select images→ right click→select Modify → select Modify reference*. We select the*Accuracy (m)*column, and we modify the*Value* from 10 mto 3 m.(*Fig.4. și Fig.5.)*

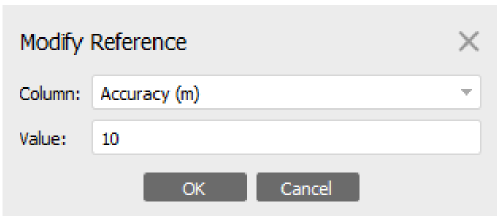


Figure 4. Modify accuracy

Cameras	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)
DJI_01...	394297.305551	684713.478263	185.953605	**3.000000**
DJI_01...	394297.649188	684709.712746	185.753598	**3.000000**
DJI_01...	394298.470807	684703.155437	185.653591	**3.000000**
DJI_01...	394299.252061	684697.256815	185.653586	**3.000000**
DJI_01...	394299.767182	684691.415481	185.653574	**3.000000**
DJI_01...	394300.153919	684685.514669	185.653560	**3.000000**
DJI_01...	394300.769381	684679.449125	185.653550	**3.000000**

Figure 5. Modify accuracy

The image alignment step is practically the first step towards creating the orthophoto. To proceed we follow the next steps: right click on the *chunk* → select *Process*→ select *Align photos. (Fig.6.)* The image alignment definition window opens, where we have a few options that we need to set for the most accurate quality, clarity, and alignment of these images, in order to reduce the errors that occurred from their overlap.

We use the following settings *Fig. 6.*, because the accuracy with which the program works and processes is important.

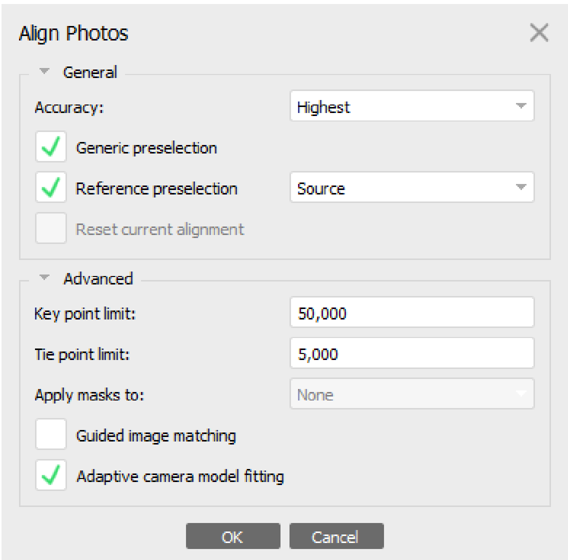


Figure 6. Image alignment

Key point limit and *Tie point limit,* there are two essential settings, here we define the upper limit of the key points and tie points; the *key point* limit indicates the upper limit of the feature points on each image to be considered in the current processing phase, the use of zero value allows Metashape to find as many key points as possible, but this will lead to a large number of less reliable points. which must be found in the adjacent images for their most subtle alignment; the *tie point* limit indicates the upper limit of the matching points for each image, the use of the value zero does not apply any filtering of the equality points. The higher these limits, the more accurate the alignment of the images, but it will increase the processing time for this operation.

Adaptive camera model fitting it is necessary to select it to let the program search from the image exif the camera model used in this procedure, in order to determine and eliminate the optical distortions. For datasets with strong geometry, such as images of a building taken from all around, including different levels, it helps to adjust several parameters while aligning the camera in the first phase. For data sets with poor camera geometry, such as a typical aerial data set, it helps prevent parameter divergence. For example, estimating radial distortion parameters for data sets with only small central parts covered by the object is very uncertain. When the option is unchecked, Metashape will improve only fixed parameter sets: focal length, main point position, three radial distortion coefficients (K1, K2, K3) and two tangential distortion coefficients (P1, P2).

The next step is very important to bring to the real coordinates with a high accuracy of measurements, namely the indication of control points. Mostly contains information such that these points should be delineated in each image manually, but this leads to an error of the control points as it happened in countless cases during the tests performed. The best way to do this is to use the *Detect markers* function, which looks for points in each image that are found in the overlapping images and that have the same coordinates. To proceed we follow the next steps: select *Tools →select Markers →select Detect markers.* Here the settings are made according to the user's needs, depending entirely on the type of marker used, it can be circular or cross. (*Fig. 7.*) I used cross-type markers, so I need to select the cross-marker type for the program to perform this search procedure correctly. (*Fig. 8.*)

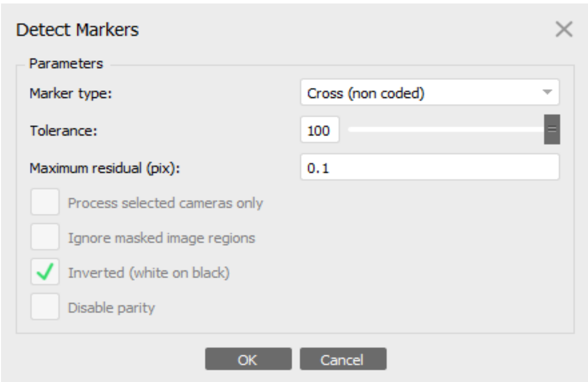


Figure 7. Marker detection

Figure 8. Cross type marker

Using these settings, the program generated over 100 markings, points that completely overlap and are found in at least two images. To do this, we must select the first marking point in the list and check in the images what exactly is its status, whether it is point A or B between the control points of interest or not. To proceed we follow the next steps: right click on the 1st marker from the markers list→ *Filter photos by markers*, from the list of images we check where exactly he put this marker. As shown, it is positioned in the middle of the *B control point* (*Fig. 9.*), we check this on all images checked by the program by zooming in on each image, to ensure that the same marker appears in the specified images and does not overlap with another control point. (*Fig. 10.*)

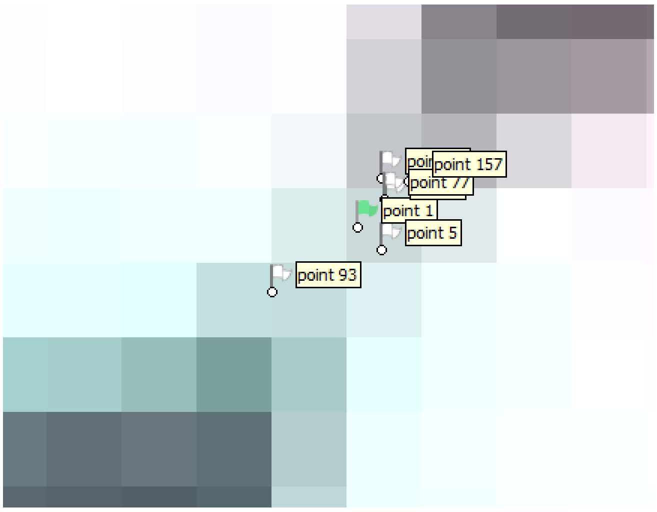


Figure 9. 1st marker point

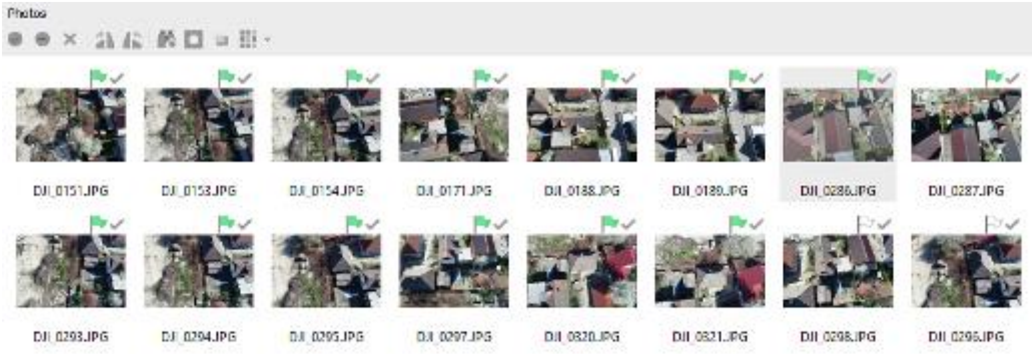


Figure 10. Selected images for 1st point

Given that we have control points A and B, we checked the first two markers, which are associated with our control points. We rename 1stmarker and the 2ndmarker following the next steps: right click on 1st marker → *Rename*: *B;* we do the same to the 2ndmarker which we rename A. We select the rest of the markers and delete them from the markers list using the function *Delete markers.*

Knowing the *A* and *B* markers, we import the information from the measurements made with the Trimble R6 GPS, i.e., the coordinates and the altitude of the *Ground control points*. We do this by following the next steps: in the *Reference* panel we select *Import reference* → we select the file that contains the measured points, *A* and *B* → in the import window we define the coordinate system, the type of delimitation (*tab/semicolon/comma/space/other*) and columns specific to the name, coordinates and altitude (*Label/Easting/Northing/Altitude*), according to *Fig. 11*.

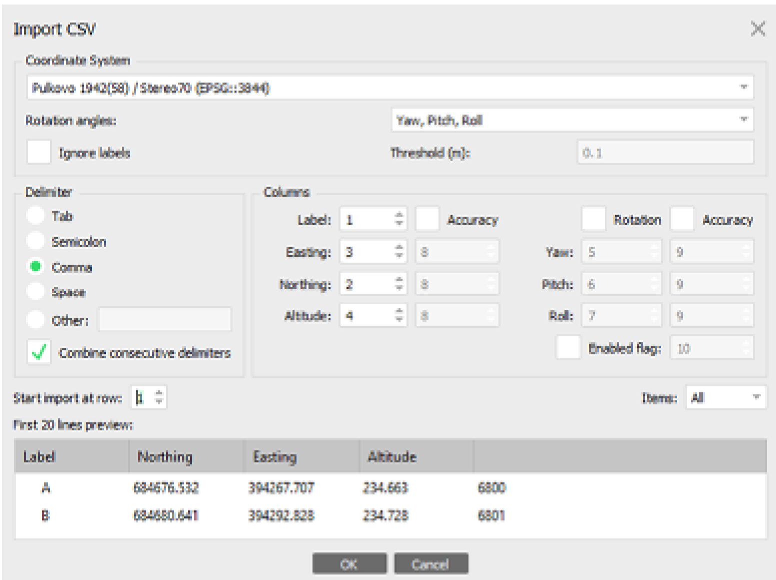
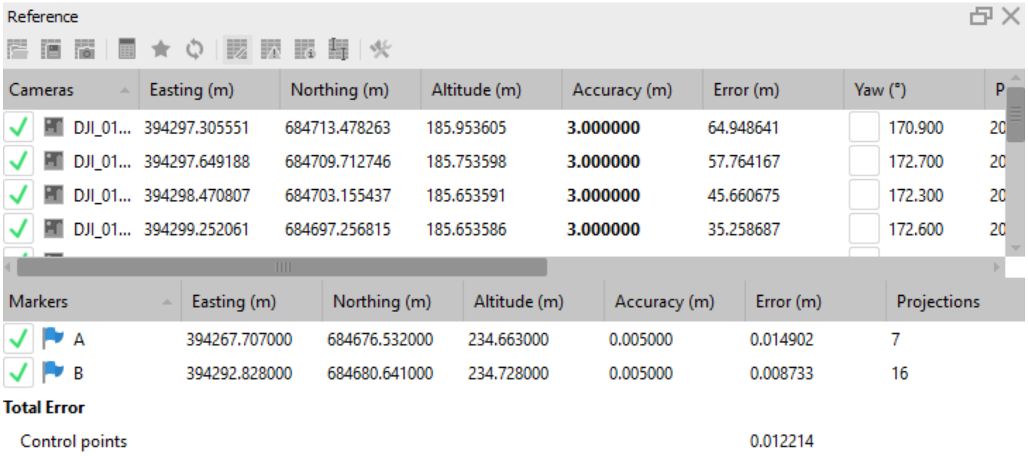


Figure 11. Ground control points import panel

Note: if we leave the rest of the markers delimited by the program, the error of the ground control points and markers will becomes much higher, leading to a higher cumulative error per pixel, which would lead to a distortion of the orthophoto.

As can be seen in Fig. 12. *Ground control points* were overlaid with the 1st and 2nd markers, which now appear under the name of *A* and *B*, with well-defined coordinates, against which the next data processing steps will be performed. It can be seen that the altitude of the control points and images differ, due to the fact that the GPS in the drone works with other parameters and is not in symbiosis with a permanent station such as the permanent GNSS station Baia, which belongs to Rompos - the Romanian position determination system which ensures the precise positioning in the European ETRS89 reference and coordinate system.



Reference

Cameras	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Yaw (°)	P
DJI_01...	394297.305551	684713.478263	185.953605	**3.000000**	64.948641	170.900	20
DJI_01...	394297.649188	684709.712746	185.753598	**3.000000**	57.764167	172.700	20
DJI_01...	394298.470807	684703.155437	185.653591	**3.000000**	45.660675	172.300	20
DJI_01...	394299.252061	684697.256815	185.653586	**3.000000**	35.258687	172.600	20

Markers	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Projections
A	394267.707000	684676.532000	234.663000	0.005000	0.014902	7
B	394292.828000	684680.641000	234.728000	0.005000	0.008733	16
Total Error						
Control points					0.012214	

Figure 12. Altitude differences between GCP and images

This difference will be adjusted by the following method: a script is downloaded from the internet and introduce to the software using python language to change the altitude of the images, as they are much too different from GCP. Select *Tools* menu→ select *Run script*, after which a new menu titled *Custom menu* will be displayed→ select *Add reference* (*Fig. 13.*)

Figure 13. Custom menu for changing the reference altitude

Before starting this procedure, we need to select GCP A and view the images attached to it. We do the arithmetic mean of the altitude on the set of images, and we subtract the obtained value from the altitude value GCP A, we do the same in the case of GCP B - we obtain the obtained values because the dimensions of points A and B are higher than the dimensions of the images taken from their exif data. From the two new values obtained we apply the arithmetic mean again, this value will be added - because the image altitude value is lower than that of the two GCPs - to all images to adjust and correlate at the same time the image altitude with that of GCP A and GCP B. To do this we follow the next steps: we select all the images in the left column under the name *Cameras*, after that in the *custom menu* → select *Add reference altitude*. In the window that appears write the value that resulted from the arithmetic mean calculated in the previous step (*Fig.14.*), after the completion of these function the elevations of the images are much closer in value to the value of altitude at *GCP A* and *GCP B* points. (*Fig. 15.*)

Figure 14. Altitude adjustment window

Cameras	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)
DJI_0167.JPG	394292.059866	684646.775113	234.746218	10.000000	29.196582
DJI_0168.JPG	394291.810271	684652.176130	234.846234	10.000000	28.989895
DJI_0169.JPG	394291.024366	684658.513478	234.746241	10.000000	28.793346
DJI_0170.JPG	394290.251663	684664.655980	234.746247	10.000000	28.589466

Markers	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)
A	394267.707000	684676.532000	234.663000	0.005000	0.002037
B	394292.828000	684680.641000	234.728000	0.005000	0.001561
Total Error					
Control points					0.001814

Figure 15. Altitude of images and GCP after adjusting the reference altitude

After performing this process, the images must be optimized, so that the alignment takes over the exact markers of GCP A and B, this is easily done by following the steps: from the *Reference* panel we select *Optimize cameras* command– the *star icon*→ in the window that appears, check *Fit additional corrections* and *Adaptive camera model fitting* (*Fig. 16.*), they help reduce errors and distortions caused by image realignment compared to GCP.

Note: If a reverse image of the model is created, the following steps must be added before optimizing the images: select all the images in the *Cameras*→ uncheck all cameras – in this case the optimization will be based on the data of the two GCPs, and the rest of the procedure is done step by step with the above description.

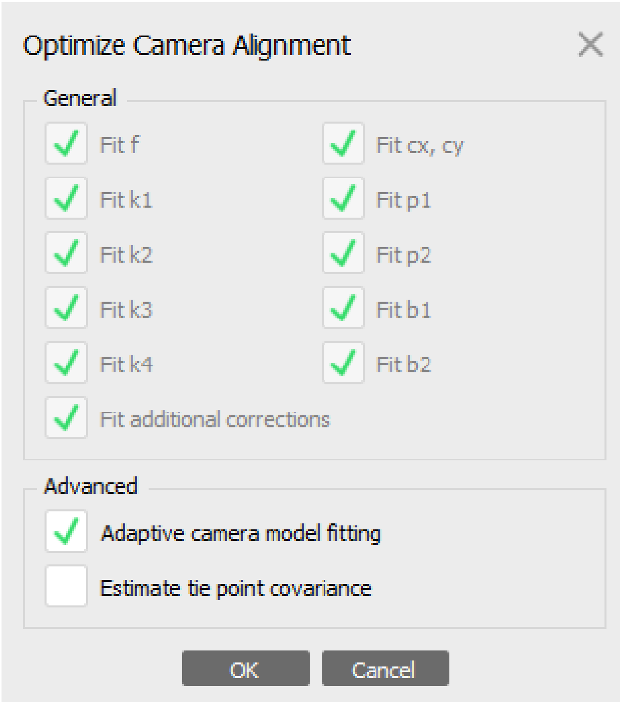


Figure 16. Optimizing alignment cameras

After optimizing the images, we check if any errors have occurred, i.e., if they are overlapped with the field markers on the set of images in which the control points appear. If all of this are in order, we can move on to the next step, *Build dens cloud. The point cloud is a set of 3D data, which is generated based on aligned images that are recognized by the software according to the RGB color palette. (red/green/).*

Steps to follow for *Build dens cloud*: right click on the *chunk* → select *Process* → select *Build dens cloud*. The window of this process allows us to achieve the following two important parameters settings: *Quality* and *Depth filtering*. For greater accuracy, we set*Quality*: *Ultra high* -specifies the desired reconstruction quality, the higher quality settings can be used to obtain a more detailed and accurate geometry, but it takes longer to process – and *Depth filtering*: *Aggressive*– due to the fact that some images have image noise, have not been well focused, or may be a little "blurry", the setting will filter these problems by image filtering algorithms. -, and checkthe*Calculate point colors*and the*Calculate point confidence* – this last setting filters those points on which the user cannot rely or which have an error greater than the tolerances allowed by the previous steps -, according to certain filtering algorithms.

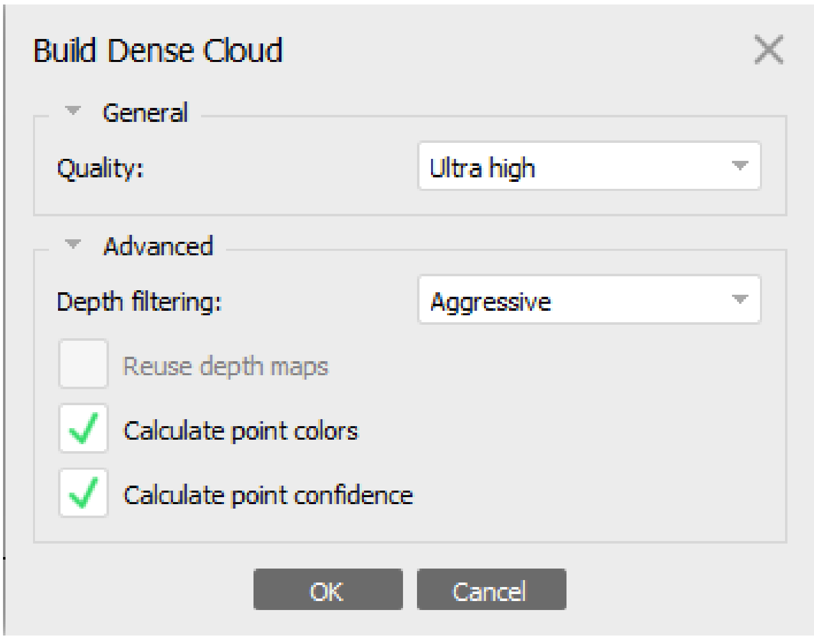


Figure 17. Build dense cloud settings

At the end of this step the results are amazing, because we created a *point cloud* of enormous dimensions, with over 400 million points on this area of about 50 acres, which means one point every 7.5mm^2, which falls within the tolerances allowed in the legislation of the cadaster in our country.

The creation of *DEM* (*Digital elevation model*) is the last step before we can create our *orthophoto*. The digital elevation model is defined as such as a three-dimensional model of the terrain on which the terrestrial measurements are made. This model can be made by several methods based on measurements made with total stations, GPS, laser scanning, etc., but in our case, it is made based on images made with the drone, from which the *point cloud* was obtained. The *DEM* made in this software defines as source the point cloud we created, and using this high precision source using several predefined algorithms it has the ability to process millions of points and create the model. The steps to follow for this process are: right click on the *chunk* → select *Process* → select *Build DEM*. In the panel that opens we leave the presets given by the program, but if we know exactly the area we are interested in, we can make a cut from the entire point cloud in the section *Region / SetupBoundaries*, in this case the orthophoto will be made exactly on the delimitation made by the operator in this section. (Fig. 18.)

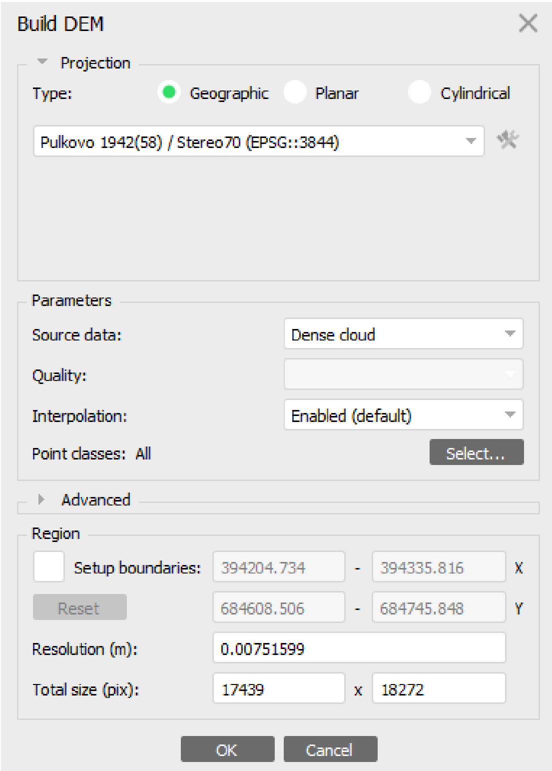


Figure 18. Build DEM settings

Due to the fact that the program uses the projection defined and set at the beginning of the project, it remains valid at this stage, but if we are interested in changing this, having the options in *Fig. 18*, but if it does not satisfy our needs, the is a possibility to create new projections. Interpolation is important for the generated model to fully respect the surface contour of the land, but also to "fill in the gaps" where there is not enough information.

As can be seen, the *DEM* fully reproduced the details in the field, defining by color differentiation the elevation in the field. In the created marginal areas, the image is distorted due to the fact that we do not have enough information (Fig. 19.), this is due to the lack of images that the drone made on the marginal areas. These areas were created from image fragments, but they are not part of the project and the default drone measurement route, this can be deleted by delimitation when defining the boundaries in the process of creating the *DEM*. The accuracy of this model is 7.52mm / pixel, which makes it satisfy even the most demanding demand on the market.

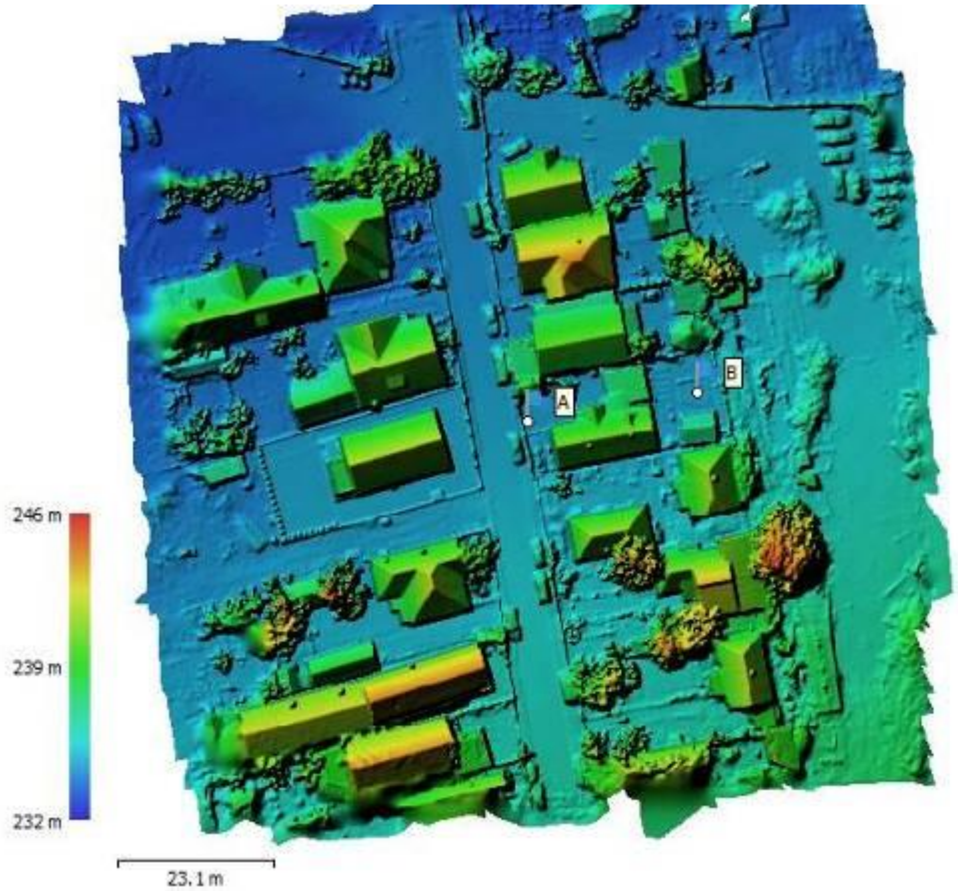


Figure 19. DEM (Digital elevation)

We have reached the culmination of this program, namely the generation of the orthophoto. It is much more accurate than those made by satellite photography, better covers the work area, of interest and gives us greater accuracy. The steps to follow for this process are: right click on the *chunk* → select *Process* → select *Build Orthomosaic*. The panel that opens offers us some configuration possibilities, but you can also use the preset ones. (*Fig. 20*) However, it is good to be careful as an option labeled *Enable hole filling* to be checked, that on the created orthophoto no white gaps to appear, but the program to “cover” them with colors from nearby regions, in case that they do not have information to cover the gaps. Usually, this phenomenon is useful for areas with a lot of vegetation or in the adjacent areas of the *DEM* that are not of interest for the project. The limits of the orthophoto can be set following the same steps as for the classification within well-defined limits mentioned when creating the *DEM*.

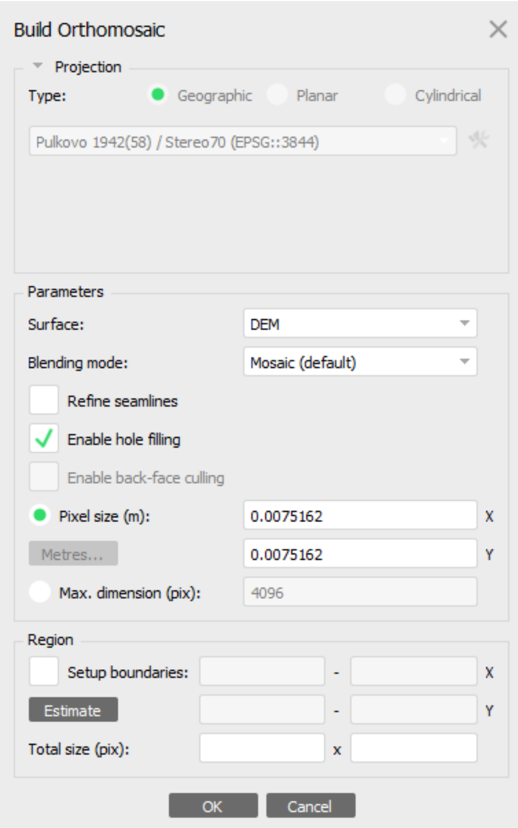


Figure 20. Build Orthomosaic settings

Export of the *orthophoto* and the *point cloud*. For these procedures the steps are similar:

a) for the *point cloud:* right click on the *Dense cloud* → select *Export Dense cloud;*

b) for the *orthophoto:* right click on the *Orthomosaic* → select *Export Orthomosaic* → select *Export JPEG /TIFF/PNG.*

Note: If we do not need all the data in the point cloud, before exporting this data we must filter the point cloud, defining the density of points per cm^2, following the steps: right click on the *Dense cloud* → select *Duplicate* – this is necessary so that the original *point cloud* remains intact if we need data sets at different densities -, right click on the *Dense cloud* → select *Filter dense cloud*, here we enter the value at which we want the data to be filtered, depending on the needs of each situation.

If we know exactly the boundary of the surface we are working on, it is good to use the boundaries of the *orthophoto* to reduce the file size and upload time in other programs. The *orthophoto* contains information such as its creation data, scale, accuracy, but most importantly it contains geographic data in the system I worked in, which was set at the beginning of the project.

Figure 21. The orthophoto without boundaries

Figure 22. The orthophoto with boundaries

4. POINT CLOUD DATA PROCESSING METHOD

For point cloud processing we use the PointCab program, due to the fact that it can load and process a huge data set and has the ability to allow the user to select 3D points, both for viewing and exporting in various formats known by other processing programs.

Note: For this stage we chose to export a *point cloud* of about 2.5 million points, because we are not working on a high-performance network that would process such a large amount of data in a short time, in other words the primary *point cloud* file contained over 417 million points, which would take far too long and it would not be beneficial to process it.

After opening the program select the icon *New*and in the panel that appears we choose our *point cloud*, we set the project *scan type* and save the project. Scan types can be: *Terrestrial scanning project*, *Mobil mapping project* and *Airborne scanning.* After completing these steps the program starts importing the *point cloud*. (*Fig. 23.*)

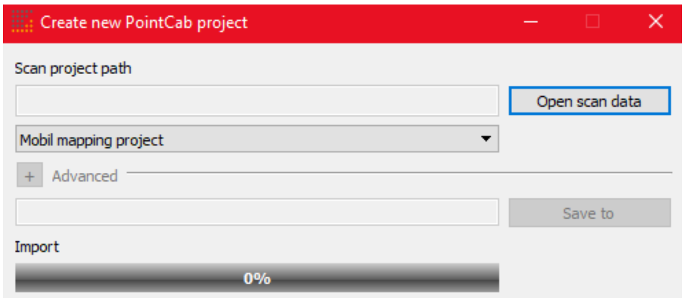


Figure 23. New project panel

Note: After testing each project creation option, it turned out that in order to achieve the purpose of the work, the best project method in our case is *Mobil mapping project*, because in the other two situations in the point cloud a rather blurred and pixelated contour is created, which does not help us to achieve the correct and precise extraction of the 3D points from the *point cloud*. (*Fig. 24*)

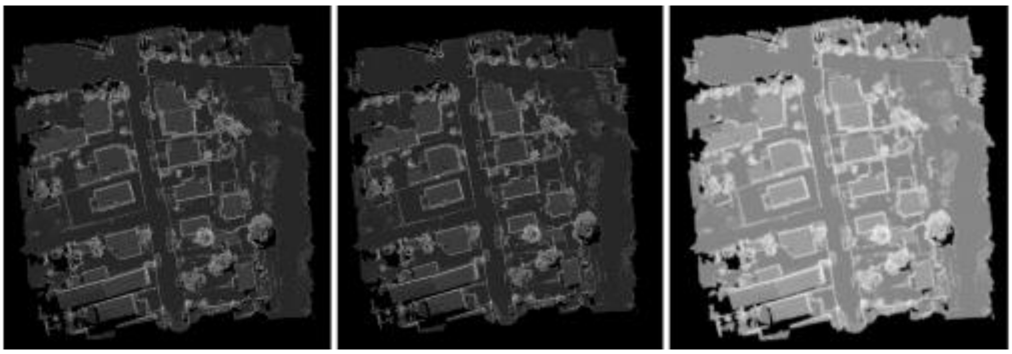


Figure 24. Terrestrial scanning project, Mobil mapping project, Airborne scanning project

After generating and saving the project in the location specified by the user, we check the details in the field. (It can be tested depending on the situation and the version of the program used, the other two options for creating the project, but in this case we use the *Mobil mapping project*).

To select the points of interest of the elements in the field, select from the right panel of the program the button*3D-points*. We hover the mouse over the first element we want to define and click on it. It can be seen that it determines a 3D point, which has well-defined characteristics, by name coordinates and elevation. In the right panel the *Job Editor* allows us to rename this point and renumber it if necessary. (*Fig. 25.*)

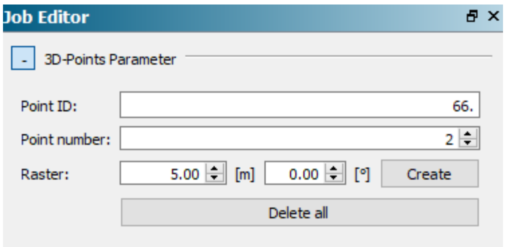


Figure 25. 3D-Points Parameter panel

It is good to complete each type of detail separately so that we do not have to change the name of the points frequently, but if necessary, it is easily done, because the last point added has the same *Point ID* as before, and in the *Job Editor* panel, in the *3D-Points Parameter* menu this can be changed. If we have missed renaming a point or points, this can be remedied later by selecting them and following the previous steps to rename these points.

Defining / naming the points is important, so that in the drawing phase of the site plan we can easily identify each point chosen from the point cloud, for a more precise drawing of the site, without misinterpretations. (*Fig. 26*)

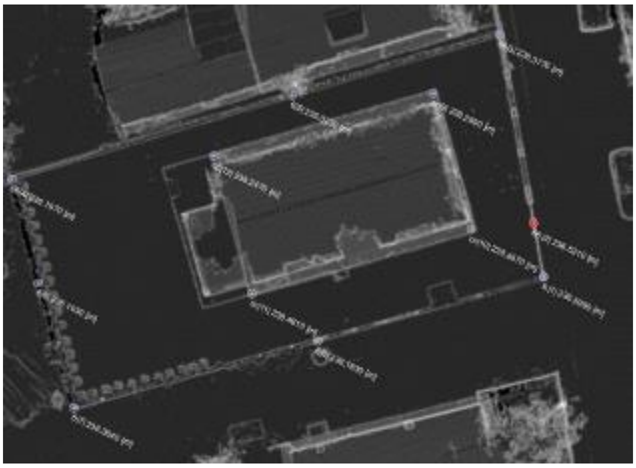


Figure 26. Select 3D points based on the point cloud

Note: Each point taken from this point cloud will have the maximum elevation and not the one from the earth's surface. For example, if we want to select the corners of the house, they will have dimensions related to the height of the roof. If we want to select the fence, the elevation will have the same value taken from the top of it and not from the ground, due to the fact that we work with a point cloud that was created by aerial photography. If we want to have the elevation from the ground for any detail in the field, we must consider the duplication of points of interest, i.e., to add a point at a distance of about 10 cm next to the one we want to use to create the site plan. (*Fig. 27*)

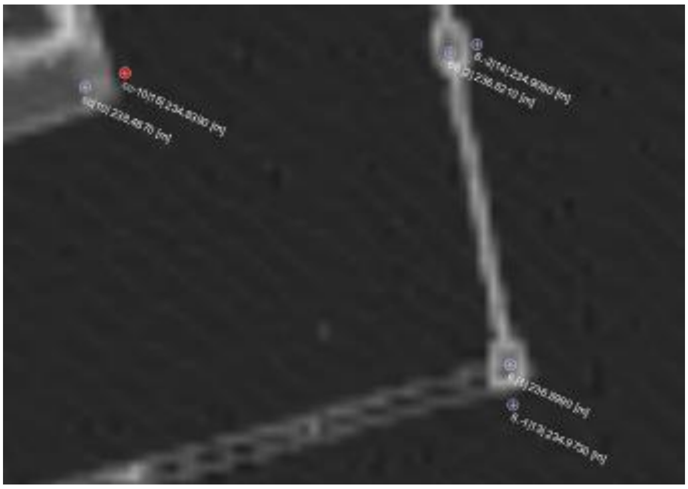


Figure 27. Duplication of 3D points

After marking all the desired elements in the field, we open the *File* menu from the *Job Editor* menu where we select the Export type *.dwg* and *.dxf*, and in the save panel we can choose according to the preference of the user to save this data in .xyz format as well in the location specified by the user. (*Fig. 28*)

By exporting this data it will generate these files that we open in Autocad to perform the last step towards the completion of the site plan.

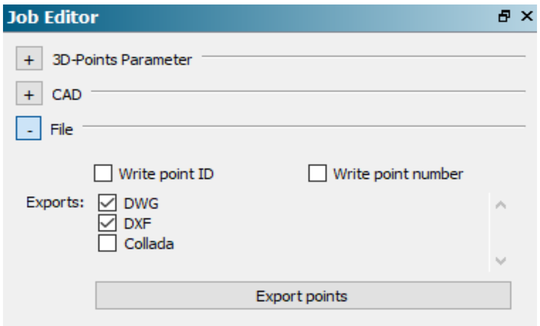


Figure 28. Duplication of 3D points

5. SITE PLAN DRAWING METHOD

We open the Autocad program, where we import the file with the points selected in the previous step. Define the *Layers* for each object, example: fence, road, access gate, pillar, constructions, etc. for these we define in the *Layer proprieties* panel: color, linetype, line thickness, etc. these things help to diversify and visualize as well as possible the site plan we want to draw up. (*Fig. 29*)

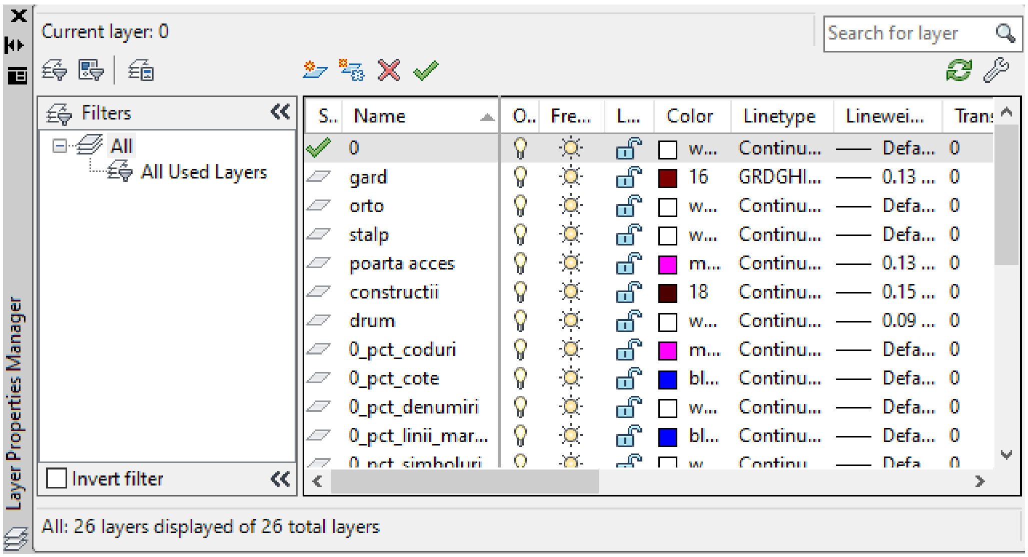


Figure 29. Layer Properties panel

Note: In the background we load the orthophoto we created, to check if the points of the detail elements extracted from the point cloud correspond to what is found in the field.

We select every *Layer* in which we have points, and in these we draw the lines through the points that we have chosen to outline the *site plan.*

After completing the drawing of each proposed detail, the site plan can be framed in a standardized format depending on its needs and use. (*Fig. 30*)

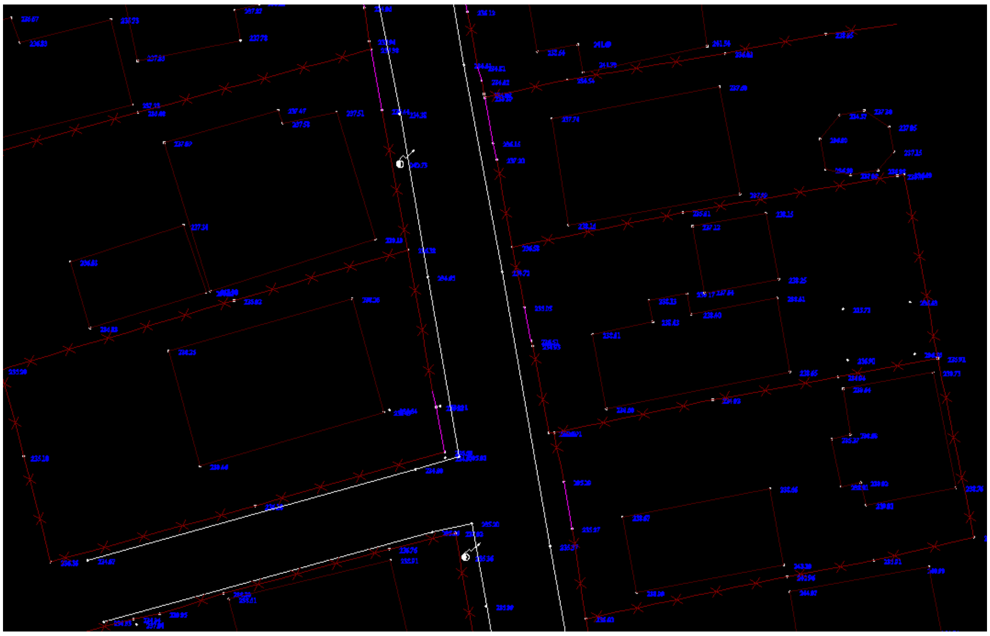


Figure 30. Site plan of the area of interest

6. CONCLUSIONS

At first glance this work can be done much faster using the total station and / or GPS, but if we think about a larger scale, for example measurements to design a road network, or tabulation of all the roads in a city and so on this method would be more beneficial, as data processing is the only one that requires more attention, and field work would be reduced by 80-90% compared to measurements with conventional equipment.

Another aspect is the fact that at the end of the work stages, we have both a database, the *point cloud*, and a map, the *orthophoto*, which has a millimeter accuracy, compared to those made from the plane which as we know may have errors even 1 meter, depending on the scale on which they were created.

If the working and processing steps are used as described, in theory we should not encounter any problems during the data processing procedure, the only condition being the computer on which the post-processing of the data is performed to have the minimum characteristics required by the programs through which the post-processing is performed.

Given these issues, I can certainly say that this alternative method of ground measurements should be exploited to give a higher yield of field work, and not only, to help those who need a completion of the topographic work, photogrammetric work with high accuracy in a relatively short time.

The above method can be used to monitor slopes, quarries and land stability. The basic idea is to have control points (GCP) located in such a way as to include in the plan the highest and lowest points to create a digital model as accurate as possible of the work we want to monitor.

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VISUAL IMPACT ANALYSIS OF THE URBAN LANDSCAPE OF DEVA MUNICIPALITY

CIPRIAN NIMARĂ[1]

Abstract: *The dynamics of cities and the urban system has developed as a research direction based on systemic theory, through which the city is introduced into the equation of geographical analysis more and more as an optimally open thermodynamic and informational system, with dissipative structures and a high capacity organization. The new transition conditions of the Romanian city and Romanian urban system as a whole put their mark on their evolution. From a centralized phase of urban development we move to a relatively chaotic one, in which the structuring processes are very confusing and the lack of adequate tools to control urban development through the intervention of civil society, communities involved and specialists accentuates the disorder. the level of the regional urban systems of the cities themselves.*

Keywords: *urban landscape, visual impact, sustainable development, Deva*

1. INTRODUCTION

The urban landscape is an instrument of territorial design and development, and changes in the national economy accelerate the transformation of the landscape. The defining elements that condition the landscape are the form and the history, and the analysis and reading of the landscape requires the knowledge of the structure and the materials that compose it.

The city of Deva is located in the central part of Hunedoara county, at 45° 52' north latitude and 22°54' east longitude, at an altitude of 187 m above sea level, on the left bank of the middle course of the Mureș. The town is bordered by Poiana Ruscă Mountains and Zarandului Mountains in the west, with the Apuseni Mountains in the north, with Măgura Uroiului in the east. To the south, when the atmospheric conditions are favorable, the Parâng Mountains and the Retezat Mountains can be seen in the distance [2]. The hills near the city are the last northern branches of the Poiana Ruscă Mountains (their maximum height is 697 m) and comprise the city as in a semicircle protecting it from climatic excesses. Piatra Cozia peak (from Cozia village) has an altitude of 686 m.

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Deva includes, outside the city of Deva, the component locality Sântuhalm and the villages belonging to Cristur, Bârcea-Mica and Archia. The component locality Sântuhalm is part of the main body of Deva and is located in the eastern part of the municipality, on DN 7, two km away from it.

The population of Deva is 59.457 inhabitants, of which 597 inhabitants of the component locality Sântuhalm, according to the Census since 2011, and the surface of green spaces per inhabitant is 26.12 m^2.

In accordance with the criteria defined by Law no. 351/2001, regarding the approval of the National Territory Development Plan - Section IV "Network of localities", Deva municipality belongs to the category of second rank localities.

2. VISUAL IMPACT ANALYSIS

The objective bases for the analysis of the urban landscape of Deva municipality are represented by (table 1 and table 2):

- relief, represented by the geomorphological contact between the Mureş meadow and the Metaliferi Mountains and transposed by the hilly aspect, in the neighboring landscape being visible the hills: Paiul Urzicilor, Paiului, Archiei, Bejan, Măgura, Nucet, Decebal, Motor, Piatra Coziei, Colţu, Cetăţii, Finches and Vineyards. The Piedmont porch continues below with Lunca Mureşului, whose width varies between 5 km in Deva and 1 km in Şoimuş. The Central Part is located on the low terrace at 190-220 m altitude. To the west and south the altitudes increase up to 300-350 m, here the city develops in a hilly terraced area. To the north of the Mureş River rise the Metaliferi Mountains, whose panorama can be widely contemplated from the city area. Among the relief units that develop in the perimeter of Deva, the most representative is the Citadel Hill, which has become the symbol of the city;
- natural elements, more or less contribute to visual harmony through diversity [5, 6];
- the buildings, represent testimonies of the human presence and reveal an emotional value not negligible to an observer and constitute an important element of the landscape [7].

Among the built elements, of great importance are: Deva Fortress (Castrum Deva), Citadel Park, Bethlen Castle or Magna Curia (Latin, big yard), Deva Art Theater, Dr. Petru Groza Memorial House, "Drăgan Muntean" Cultural Center, Reformed Church, Franciscan Monastery, Synagogue, "St. Nicholas" Orthodox Cathedral, "St. Mary" Church, Gymnasts Alley.

Following the inventory for the establishment of the Local Register of Green Spaces, the lands defined as green spaces according to Law 24/2007 were identified. The total area of green spaces within the urban limits of Deva is 1,553,179.88 m^2 and 155.31 ha, respectively.

Decision no. 509/2016 on the approval of the Local Register of green spaces located in the built-up area of Deva municipality, includes the annexes with areas and the inventory of trees on the territory of Deva municipality.

Another typology is represented by the lands for sports and leisure, which are not found in the total green spaces on the territory of Deva municipality, but have only been identified and inventoried as follows:

- sports bases, sports playgrounds (2.05 ha);
- sports fields within the educational units (3.91 ha);
- sports fields within the residential areas (0.11 ha);
- playgrounds for children (0.94 ha);

Table 1. Points of analysis of the landscape

Systemic territorial classification	**Orographic classification**	**Structural classification**	**Administrative classification**	**Geomorphologic classification**
Territory (1-10 km^2)	Hilly landscape	Terrestrial landscape	Urban area	Geomorphologic contact landscape, piedmont

Table 2. Points of analysis of the urban landscape

Biological and soil classification	**Climate classification**	**Cultural and historical classification**	**Social and economic classification**	**Dynamic operating status**
Hardwood forest (southeastern Carpathian, western Pontic, Pannonian-Balkan), brown soils, forest and clay soils	Climate of low hills	Pre-modern, modern and contemporary architectural values	Commercial activities, residential areas, tourist or recreational areas	Modified structures, degraded structures

Landscape identification criteria are part of the methodology developed under Law 451/2002 for the ratification of the European Landscape Convention [3]. The Convention takes into account existing legal sources at the international level in the field of protection and management of natural and cultural heritage, spatial planning, local autonomy and cross-border cooperation (table 3) [1, 4, 5].

Table 3. Identifying criteria and quantitative assessment of the landscape

INDICATOR	VALUE					TOTAL
	0	**1**	**2**	**3**	**4**	
HYDROLOGICAL AND GEOMORPHOLOGIC						**5**
Water presence				**x**		
The presence of visible rocks, mineral landscape	**x**					
Relief features			**x**			
NATURAL POTENTIAL						**5**
Overlap of protected area types					**x**	
Vulnerability to the following threats: erosion, desertification, landslides and floods		x				
ARCHITECTURE AND BUILT AREAS						7
The presence of traditional architecture			x			
Presence of buildings registered as heritage					x	
The presence of industrial architecture		x				
URBAN DEVELOPMENT AND TERRITORIAL DEVELOPMENT						18
Accessibility axis / transport infrastructure					x	
The relationship between the built environment and the natural one				x		
Presence of valuable (or protected) built areas					x	
Urban dynamics				x		

Typologies: permanent housing areas, scattered dwellings, grouped villages, small and medium-sized towns, large cities and metropolises					x	
INDICATORS REGARDING HUMAN SETTLEMENTS						5
Variety and distribution of ethnic groups			x			
Birth rate				**x**		
INDICATORS OF INTANGIBLE HERITAGE						**6**
The presence of the craft tradition	**x**					
Traditional festive events and community folklore				**x**		
The reputation of the local landscape in amateur communities or in the tourism sector				**x**		
						46

Interpretation of values based on Table no. 3 is as follows:

a) Group 1, values between 0-10, monotonous landscape, without the presence of spectacular landforms with localities structured on inefficient land use models, without craft traditions with uninhabited or declining areas. Natural environment with discrete presence of the built environment or punctual constructions, insignificant presence of the industrial architecture, are not historical monuments, without accessibility or with reduced accessibility;

b) Group 2, values between 11-25, slightly animated landscape, localities with non-cohesive models with signs of decline, abandoned buildings and poor housing, the presence of craft skills in a single distinctive field with unknown events in outside the area for some distinctive folk features, a few abandoned industrial buildings, very few or even missing historical monuments;

c) Group 3, values between 26-40, distinct landscape, localities have pre-established or organically developed plan, with clear structure, the presence of craft skills, recognized outside the local community, average number of images, paintings or postcards of available landscapes, one or more events recognized for traditional features, relatively stable urban dynamics, with very few changes in recent years, a few industrial constructions in operation, a few new constructions, recent start of an urban system, few historical monuments, good accessibility (one one or more national roads or rail transport of medium-good quality);

d) Group 4, values> 40, well-defined landscape, with localities that have a pre-established or organically developed plan, with distinctive structure, with a high degree of development, expansion and increase of urban density, high availability of images, painting or postcards of the landscape on the Internet or in local, national or international shops, significant number of significant new constructions (tall or large constructions), new neighborhoods, the presence of monuments of national importance or the presence of internationally protected monuments or cultural heritage sites, very accessible good with several transportation alternatives.

From a qualitative point of view, an evaluation was carried out that takes into account 15 indicators, as can be seen in the following table (table 4):

Table 4. Indicators of qualitative assessment

INDICATOR		VALUE		
		LOW	**MEDIUM**	**HIGH**
Historic buildings and monuments	Before 19 th century		X	
	20 th century		X	
Buildings and constructions with architectural value made in the medieval time		X		
New buildings and constructions with architectural value, after 1989			X	
Buildings and constructions made between 1950-1989				X
Green spaces, parks and leisure areas				X
Protected natural areas			X	
Pedestrian complexes, public squares			X	
Homogeneity of the architectural style		X		
Visual homogeneity in height		X		
Visual homogeneity in form and structure			X	
Aesthetic contrast between buildings (shape, structure, color)			X	
Derelict, unused or demolished buildings		X		
Contrast on residential areas			X	
Accessibility between functional areas				X
Industrial areas in operation		X		
Derelict industrial areas		X		
The visual and qualitative aspect of the transport infrastructure				X

Following the qualitative and quantitative evaluation of the urban landscape of Deva municipality, the following were found:

- from a quantitative point of view, the analyzed landscape obtained a score of 46 points, being classified in group 4 with values of over 40 points. City with a high degree of development, expansion and increase of urban density, significant number of significant new constructions, new neighborhoods, the presence of monuments of national importance or cultural heritage sites, very good accessibility with several transport alternatives.

- 15 landscape quality indicators were analyzed;
- of these, 6 indicators had a low rating, 8 a medium rating and 4 a high rating.

3. CONCLUSIONS

Through this paper I wanted to make an analysis of the urban landscape of Deva, based on the technique of quantitative and qualitative evaluation of the urban landscape.

Most of the time, the emphasis is on the objective reality of the landscape, ie on what is measurable, palpable, concrete, but this becomes at some point a subjective reality, being a consequence of the human perception process. Hence, the fact that the landscape is a dual reality, objective and subjective alike.

Following the qualitative and quantitative evaluation of the urban landscape of Deva municipality, the following were found:

- from a quantitative point of view, the analyzed landscape obtained a score of 46 points, being classified in group 4 with values of over 40 points. City with a high degree of development, expansion and increase of urban density, significant number of significant new constructions, new neighborhoods, the presence of monuments of national importance or cultural heritage sites, very good accessibility with several transport alternatives;
- 15 landscape quality indicators were analyzed;
- of these, 6 indicators had a low rating, 8 a medium rating and 4 a high rating.

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THE IMPACT OF BIOECONOMY ON THE SUSTAINABLE DEVELOPMENT

GABRIELA SLUSARIUC[1], CIPRIAN NIMARĂ[2]

Abstract: *The magnitude and intensity of change, especially in the area of technology development, were extremely accelerated especially in the second half of the twentieth century. For this reason, approaches to bio-economic science have taken corrective action that will be able to restore a much more harmonious relationship between human society and the environment.*

Keywords: *sustainable development, bioeconomy, circular economy, impact, European Union*

1. INTRODUCTION

At the political level and especially of public policies, at the international level, in a much more pragmatic way, the bioeconomy is seen rather as an opportunity to address current challenges and generate the necessary transformations in socio-technical systems. [2]

The most serious deficit in terms of sustainability and at the same time the biggest challenge we face is the ecological debt, whose maturity we are approaching through the misuse and depletion of natural resources. This threatens our ability to meet the needs of future generations within the limits of our planet's resources. Globally, pressure on basic resources, from freshwater to fertile land, is endangering humanity (figure 1).

As global consumption of material resources has quadrupled between 1900 and 2020 and is projected to more than double between 2020 and 2050, the world is rapidly approaching several critical points. In addition to environmental pressure, this is a serious challenge for the EU economy, which is dependent on materials from international markets. [4]

The level of global greenhouse gas emissions is growing at an alarming rate, with the main vectors being energy consumption, excessive consumption of resources

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and the destruction of ecosystems. Transport is responsible for 27% of EU greenhouse gas emissions, with many urban areas violating EU-agreed air pollution limits.

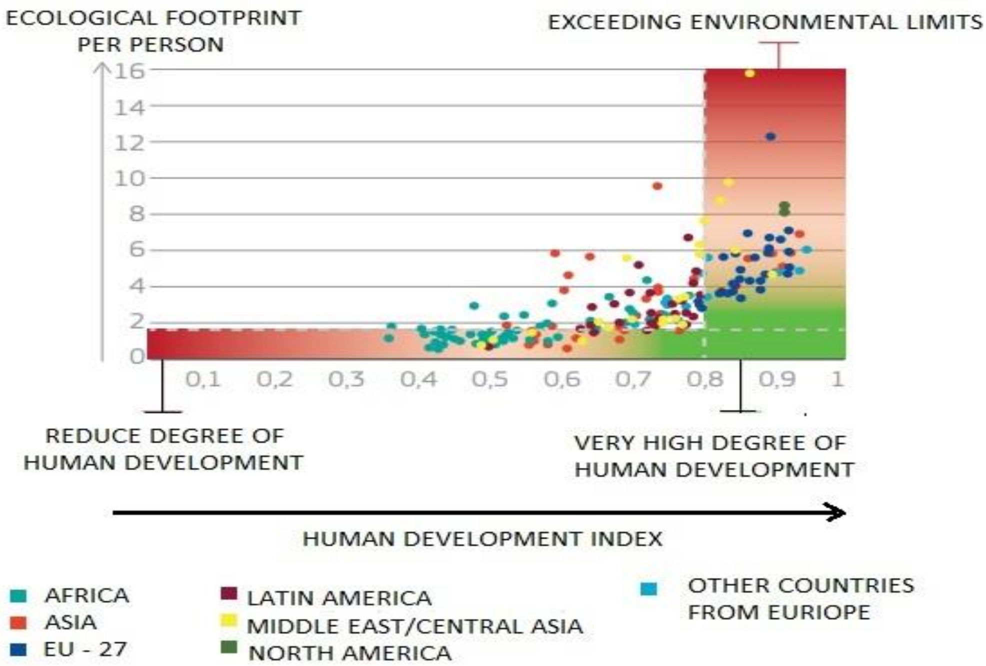

Figure 1. The degree of human development within the limits of Global resources (Source: Global Footprint Network, PNUD 2019)

Food production continues to be a major consumer of water and energy and a producer of pollutants, accounting for around 11.3% of EU greenhouse gas emissions. In the EU, fossil fuels continue to receive public subsidies of around € 55 billion a year, about 20% of the EU import fuel bill, despite ambitious EU decarbonization measures and commitments to phase out subsidies. in the G7 and G20.

It can be assumed that because organic products are wholly or partly from renewable resources, it means that they are automatically sustainable and do not have a negative socio-economic impact or on environment, compared to fossil products. It is logical that it is much more sustainable to use resources that can grow and be maintained according to sustainability practices.

Organic products are part of the Earth's natural cycles, such as the carbon cycle, while fossil products disrupt natural systems.

From the point of view of limited resources and climate change, of course, organic products can still be a very good alternative to fossil-based materials. However, they are not intrinsically sustainable. Type and source of raw material for biomass, energy used in the production process, interdependence with other value chains, recycling and waste scenarios play an important role in terms of sustainability.

2. THE TRANSITION TO CIRCULAR ECONOMY

Increasing the availability and affordability of various raw materials and products has simplified life and helped increase living standards and quality of life in the EU. However, consumption habits have contributed to overexploitation of resources and increased pressures on natural capital and the climate.

The transition to a circular economy, including a circular bioeconomy, is a huge opportunity to create competitive advantages on a sustainable basis. Applying the principles of the circular economy in all Europe's sectors and industries, it will be a social and ecologic benefit. It will also have the potential to generate a net economic benefit of 1.8 trillion EUR by 2030, to create more than 1 million new jobs in the EU by 2030 and make a major contribution to reducing greenhouse gas emissions.

Given that EU products rely heavily on resources from other parts of the world, the EU could, through the transition to a circular economy, reduce global environmental, social and economic pressures while increasing its strategic autonomy. [5]

The Circular Economy Action Plan adopted by the Juncker Commission in 2015 sets out measures to steer the EU economy towards a circular path and help the EU become a world leader in this transition. It includes measures to change consumption and production patterns, giving priority to product design (durability and potential for repair, reuse and recycling), waste management (avoidance of waste, recycling of materials, energy recovery and avoidance of landfilling), as well as improving consumer awareness. Almost all the elements of the action plan have already been provided, but more needs to be done to build a fully circular European economy.

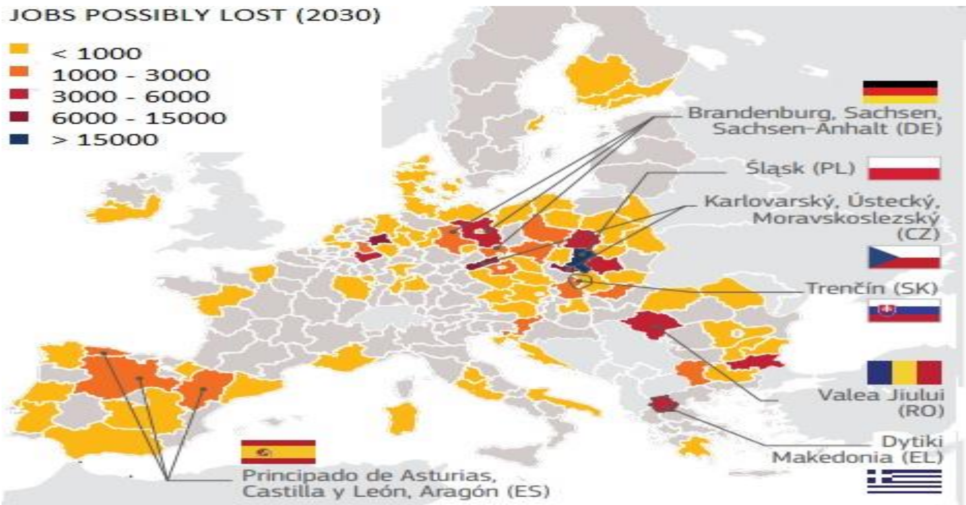

Figure 2. Potential lost jobs in EU by the transition
(Source: European Commission)

This transition has consequences for people employed in the affected sectors of activity and sometimes for entire regions.

In order to be able to frame European society on a sustainable path, it must be ensured that policy enables all Europeans to contribute to this change, including by equipping them with the necessary skills. For example, the Transitional Coal Regions (figure 2) initiative has been launched, which contributes to the development of strategies and projects aimed at ensuring the socially, economically and technologically viable transformation of certain EU regions and which will be extended to high-emission regions of carbon dioxide.

These first initiatives, which anticipate the challenges of transition, should be strengthened and extended to other areas where transformation is needed.

The automotive sector and certain sectors of the food industry could be an example. It is possible and necessary to make more efforts, from the use of recycled materials in vehicles and transport infrastructure to more efficient recycling. For example, increasing the collection and recycling rates of electric car batteries in the EU could reduce dependence on imported materials and help preserve the value of recovered materials in the EU economy.

The bioeconomy is an example of an important contribution to the decarbonisation of the economy and, at the same time, to the creation of jobs in mining areas. Ecotourism and sustainable food systems are also eloquent examples of economic opportunities in mining areas, which involve the protection and enhancement of cultural and natural heritage.

3. THE IMPACT OF BIOECONOMY

The use of renewable organic resources for the production of bioenergy and organic products plays a positive role because it helps to reduce dependence on fossil fuels, which is a limited resource, and they themselves are inexhaustible resources.

In terms of GHG emissions, biomass absorbs CO_2 during its growth, which is again released during use or waste. This means that organic products can be considered climate neutral. Therefore, compared to fossil products, they can be considered to have lower GHG emissions especially in view of the impact of decommissioning. However, biomass production requires the use of fertilizers, which means emissions of nitrogen oxide, a greenhouse gas 298 times stronger than CO_2.

In addition, fossil fuels are needed to produce fertilizers and bio-fuels for agriculture, transport and processing. Therefore, great attention needs to be paid to these issues in determining whether the impact would still be considered positive. A study by the European Commission assessed the environmental impact of organic products compared to their homologous petrochemicals and showed that organic products can provide over 65% savings in GHG emissions.

The big dilemma that calls into question the unsustainability of the environment for bioenergy and organic products is the type of raw material used and its effect on land use change and biodiversity. [3]

Biomass production needs land. Either the land needs to increase biomass needs to compete with the land needed for food, or the new land needs to be prepared for agriculture, causing a change in land use. This is called *indirect land use change*.

The impact of indirect land use change is related to the unintended consequences of release more carbon emissions due to changing land use worldwide, a change induced by the expansion of cropland. Because natural lands, such as rainforests and pastures, store carbon in soil and biomass as plants grow each year, clearing wild areas for new farms in other regions or countries translates into net increase in greenhouse gas emissions and, as a result of this change in soil carbon and biomass stock, the indirect change in land has consequences for the GHG balance in a biofuel.

The impact of indirect land use change and nutrition on fuel / bio-based products is questionable, in particular on first-generation biomass, which uses food resources such as oilseeds (soybean, palm, sunflower, castor and rapeseed), starch-producing crops (maize, wheat, potato) and sugar-producing crops (sugar cane, sugar beet). Second-generation biomass, which uses non-food resources such as lignocelluloses biomass and waste, is less prone to these dilemmas. [1]

In general, it cannot be said that products from bioeconomy are environmentally sustainable or not.

A detailed life cycle assessment must be carried out for each value chain and for each region in order to establish the sustainability of bioenergy and organic products for the environment. All stages of the product life cycle are considered in the assessment, from mining and extraction of raw materials, to transport, directly to the waste dump. Data are taken into account not only for the initial product but also for the entire life cycle of other materials that are used to make the product.

However, the impact on the environment may occur at the regional level. For example, the full use of cyprinid fish catches for food can have a positive impact on regional ecosystems as it helps to reduce water eutrophication. In this case, the use of uncaught fish resources in various forms aligns with the benefits for regional ecosystems.

Another example is the production and use of insulating materials. Sustainable insulating materials have a great potential for environmental protection due to the low energy needs during production, as well as the carbon storage capacity of sheep's wool. Thus, the bioeconomy can contribute to reducing climate change by keeping CO_2 from the atmosphere in organic products. This has a direct impact on the regional CO_2 footprint.

Food safety is one of the most important social impacts to be assessed when analyzing the sustainability of organic products. It is especially important when the raw material used for the production of bioenergy and organic matter is a first generation source. In places where planting and use may affect, for example, the price of the same crops used for food, the product would be considered socially unsustainable according to the impact category.

4. CONCLUSIONS

The bioeconomy is an example of an important contribution to the ”decarbonisation of the economy” and, at the same time, to the creation of jobs in deindustrialized areas.

Analyzing the impact of innovative new organic products on the economy, it can be said that it would have the same impact as any other innovative product. Innovation is an important driver of economic progress that benefits consumers, businesses and the economy as a whole. In the regional context, it can play an important role in waste management and recovery, it can open markets for new products from which locals, among others, could benefit and increase environmental awareness. It can be created added value at regional level, jobs and additional income.

In general, it cannot be said that products from bioeconomy are environmentally sustainable or not because a detailed life cycle assessment must be carried out for each value chain and for each region in order to establish the sustainability of bioenergy and organic products for the environment.

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CALCULATION OF LABOR NORMS IN THE MINING BRANCH

SORIN-IULIU MANGU[1]

Abstract: *The labor standardization system is the basis of the wage system in the mining branch. Given the critical economic efficiency of many mining enterprises, the approach of analyzing the way of calculating the norms appears as fully justified. The organization of the mining production processes is done in extremely varied geological and mining conditions. As a result of these conditions, machines and equipment specialized in complex operations and diversified in type and dimensions are used: (perforators, loaders, conveyors, etc.). Workers are specialized in some jobs but often work with complex teams in which a worker has a multi-qualification, being able to perform two or more complex operations or even all the complex operations of the simple process, being able to be frequently passed from one complex of operations to another. All these particularities can be found in the calculation of the norms in the mining branch.*

Keywords: *mining branch, labor norm, elementary norm, compound norm, complex norm*

1. DEFINING LABOR NORMS

Labor norms, according to the definitions adopted around 1950, are expressed as production norms per unit time (hour, shift) or as time norms (normed time) per production unit. Although the rigor of the definitions and the way of expression are questioned in the literature, these definitions will be presented below, because the necessary reconsiderations have not been made yet in practice.

"The technical norm of production is the quantity of production to be carried out by a worker (or a team of workers) in the unit of time, in determined technical-organizational conditions of the workplace, with a rational organization of work, with the optimal use of all means of production and working time and with respect for quality" [8].

In mining practice, the unit of working time for normal conditions is the shift. The work shift lasted 8 hours; a short period, after the 1977 strike in the Jiu Valley, the work shift lasted 6 hours; it returned to the 8-hour shift by 1990. Nowadays we work in shifts lasting 6 hours and 5 working days, given that all the rules have been established

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for shifts lasting 8 hours. The transition to the 6-hour shifts involved a recalculation of the old norms and norms by dividing them into coefficients established by appreciation. The unit of production through which the production norm is expressed is process specific (tons, meters, cubic meters, square meters, pieces, etc.). In mining, a man working a shift consumes a unit of time known as a job.

"The technical norm of time or the normative time is the time necessary for a worker (or a team) to achieve a production unit in certain technical-organizational conditions of the workplace, with a rational organization of work, with the optimal use of all means of production and working time and with respect to the prescribed quality of the product" [8].

It is observed that the time norm is the inverse of the production norm and is therefore expressed in units of time (minutes, hours or shifts) per a production unit. In mining, the time norms are expressed in positions per ton, per meter, per cubic meter, per square meter, per piece.

The relationships that exist between the two norms take shape

$$N = \frac{1}{t} \qquad \text{or} \qquad t = \frac{1}{N} \tag{1}$$

where: N – production norm, t – time norm.

2. CALCULATION OF LABOR NORMS

Corresponding to the concept of analysis and structuring of the complex process of mining production adopted by the teacher M.Al.C. Luca and those who took over this concept, corresponding to the specifics of the work processes on the underground work fronts, distinct rules must be established at three levels of complexity, namely:

- at operations level: elementary norms;
- at complex operations level: compound norms;
- at simple processes level: complex norms.

In the concept of structuring the simple processes to which we refer there are two more criteria for grouping the process components, which were not referred to, namely:

- the criterion of repeatability of the component considered to achieve a specified volume of the result for the immediately superior component, criterion according to which the process components are categorized as: repeatable (for example, when drilling holes, to make a jump in a working front, the operation of passing from one hole to another is repeated depending on the number of holes), respectively non-repeatable;
- the criterion of contribution to the result of the immediately superior component (operation at the result of the complex of operations, the complex of operations at the result of the simple process, the simple process at the result of the

complex process), criterion according to which the process components are categorized as: main, respectively secondary.

According to the two criteria, an operation complex component can be a repeatable main operation or a repeatable secondary operation, while a secondary operation can be both repeatable and unrepeatable.

For the calculation of the norms, the criterion of “contribution to the result” is non-essential, while the criterion of repeatability is decisive to establish the forms by which the amount of work proposed (granted) is calculated for a given component as a contribution to the result (reference quantity) defined at the level of the next higher component.

The methodology for establishing the three categories of norms (elementary, compound, complex) is amply presented in the works cited in the bibliography. For this reason, this methodology will not be developed, but only some aspects will be highlighted, considered important to ensure the correctness of the size of the rules.

By the correctness of the size of the norm it must be understood that a methodology for establishing a norm and the formulas on which the methodology is based may lead to proposing or granting a quantity of work (standard time) that deviates substantially from the reality of the work system for which the norm is established. Following this option, we will refer, in turn, to the three categories of norms.

2.1. CALCULATION OF ELEMENTARY NORMS

The basic rules are calculated at the level of repeatable operations, be they main or secondary. The calculation is based on the numerical values of labor consumption resulting from the processing of observation data by timing, on process components (handling and / or handling complexes), delimited by measurement benchmarks in the analysis and structuring stage of the operation of which the handles and / or handling complexes are part.

In the text I used, for the brief presentation of the methodology for establishing the basic rules, I found some expressions that raise some questions: “by processing the repeated timings, the average duration of the energy consumption necessary to obtain the works (service benefits) in the same period of time of a cycle is determined” [8].

First, “Average duration of energy consumption” is an expression that could be avoided since it is immediately replaced, when entering the notations of the calculation formula, by the expression “labor consumption necessary for the execution of the operation”. Secondly, "Time period of a cycle" is an expression that hides two hypotheses that are difficult to accept:

- the assumption that there is an identical repeat cycle of the operation;
- the hypothesis that any operation for which the methodology and formulas for establishing the elementary norms are proposed is cyclical.

In addition, for most practitioners familiar with the notion of cycle only at the process level (simple process in the conception of the author of the methodology, for example, a jump when digging a work, one might think that it is such a cycle, which is not appropriate for the general case).

According to the microeconomic theory of production, any figure that expresses a work norm (for example 0.1 hours per shift or jobs per ton) is a value that, under certain conditions, the production function takes. In the case of the example in parentheses, the figure represents the value of labor factor consumption per ton of production, that is, exactly the inverse value of the average unitary product of the labor production factor, average unitary product that has the value of 10 tons / man exchange of a certain duration (or job, in the language of mining practice).

The three quantities proposed by the methodology for calculating the elementary norms are the necessary and sufficient ones to define the labor norms as functions of the unitary average product for the labor production factor.

Calculation formulas for the basic work norm (time) (m_i) and respectively the elementary production norm (N_i), are simple relations resulting from the reasoning on which the definitions of the two types of norms are based. In particular, it is considered that the processing of data obtained by timing results in labor consumption N_i necessary for the execution of the operation, expressed in work units during the period T, and related to the volume of works (services), which was measured during the timings and which would result in the same operation i (Q_i), expressed in natural units over the same period of time T. With these notations, it turns out:

- elementary work norm (time)

$$m_i = \frac{M_i}{Q_i} \qquad \text{[work units / work unit or service]} \qquad (2)$$

- the elementary norm of production, as the inverse of the elementary norm of labor

$$N_i = \frac{1}{m_i} = \frac{Q_i}{M_i} \qquad \text{[work or service units / work unit]} \qquad (3)$$

2.2. CALCULATION OF COMPOUND NORMS

The compound norms are calculated at the level of the complexes of repeatable operations, main and secondary, which compose the simple processes from the underground work fronts (advancement and hewing works). Each repeatable operation complex has a structure composed of repeatable operations i (in relation to the Q_s volume of works or services at the level of the operations complex) and unrepeatable operations j.

The calculation formulas for the compound norms are established based on the following hypotheses:

- a volume of works (services) Q_s will be carried out within the process of the cycle of the complex of operations s, with duration t_s, for which a labor consumption M_s is proposed;
- a number of people n_s work simultaneously to achieve the volume Q_s in the same period t_s;
- the operation complex has q operations, of which p are repeatable operations (depending on the volumes Q_s), primary and secondary, and (q - p) unrepeatable operations (secondary) (i varies between 1 and p, and j between (p+1) and q);
- the proposed labor consumption (granted or regulated) is calculated for each operation and is denoted by M_i and M_j;
- in the execution of each operation j there are n_j workers from those placed at work;
- in each repeat operation j, through labor consumption M_i, a volume of work Q_i will result which will contribute to the realization of the volume Q_s, so the report $Q_i/Q_s = V_i$ designates the specific volume of works (on its unit of measurement Q_s) or the technological consumption of the work and per unit of measurement of the reference quantity of the complex of operations s;
- for all repeatable operations, the work norms are already considered calculated m_i and so, $M_i = m_i Q_i$.

Finally, the following formulas based on labor consumption calculated for q component operations can be obtained:

- the composed norm of work

$$m_s = \sum_{i=1}^{p} V_i \cdot m_i + \frac{1}{Q_s} \sum_{j=p+1}^{q} n_j \cdot t_j \qquad \text{[work units / work unit]} \qquad (4)$$

- the composed norm of production

$$N_s = \frac{1}{\sum_{i=1}^{p} V_i \cdot m_i + \frac{1}{Q_S} \sum_{j=p+1}^{q} n_j \cdot t_j} \qquad \text{[work units / work unit]} \qquad (5)$$

If the additional hypothesis is considered, according to which n_s whole number of workers) are always occupied only with the execution of the operations complex s, during t_s of the operations complex, to achieve the volume Q_s of unknown and calculated works with the relationship:

$$Q_s = \frac{n_s \cdot t_s - \sum_{j=p+1}^{q} n_j \cdot t_j}{\sum_{i=1}^{p} V_i \cdot m_i} \tag{6}$$

In this case, labor consumption M_s is no longer determined as the sum of the proposed labor consumption on the operations of the operations complex, but from the knowledge of the labor fund available for a long cycle t_s in which there are n_s workers occupied simultaneously, meaning $M_s = n_s t_s$.

From defining relations $m_s = \frac{M_s}{Q_s}$ and respectively $N_s = \frac{Q_s}{M_s}$, the second series of calculation relations of the composite norms is obtained, expressed in the same units of measurement:

- the compound work norm

$$m_s = \frac{(n_s \cdot t_s)\sum_{i=1}^{p} V_i \cdot m_i}{n_s \cdot t_s - \sum_{j=p+1}^{q} n_j \cdot t_j} \tag{7}$$

- the compound production norm

$$N_s = \frac{n_s \cdot t_s - \sum_{j=p+1}^{q} n_j \cdot t_j}{(n_s \cdot t_s)\sum_{i=1}^{p} V_i \cdot m_i} \tag{8}$$

2.3. CALCULATION OF COMPLEX NORMS

The complex norms are calculated at the level of the main simple processes (advancement works and demolition) that compose the complex process of a unit of underground exploitation of useful mineral substances (mine). The simple process is performed by a collective executor (team, brigade).

In the last paper dedicated to the study and standardization of work, Professor Luca proposes two schemes for calculating complex norms.

The first calculation scheme assumes that the composite norms can be calculated for the complexes of repeatable operations of the simple process, and for the complexes of unrepeatable operations, at the cycle level of the simple process, time is proposed (granted) for a part of the team workers or, in particular, for all the team workers who have the task of carrying out the simple process cyclically. The cycle is considered to be repeated identically.

Thus, it is shown that a simple cyclic process (PSC) that will be executed based on a complex work norm (NCDM), m_c, is the result of performing a number of repeatable complex operations s = 1÷n and a number r of unrepeatable complex operations, r = (n+1)÷v. It is assumed that for complexes of repeatable operations s, compound work norms have already been calculated (NCM), m_s (s = 1÷n), and for unrepeatable complex operations r (r = n+1 ÷v), under the existing working conditions, times are proposed (granted) t_r to each of the workers involved in the execution of the complex of operations r. The simple process is standardized for complex v operations. When establishing compound work norms m_s for complexes of repeatable operations s (s = 1÷n) the previously presented methodology is applied, namely to the working conditions (CM) specific to each complex of operations are already calculated the elementary norms m_{si} for repeatable operations (OR) and times are normal (TN) which are proposed (granted) for unrepeatable operations (ONR), n_s workers being engaged in unrepeatable operations t_{sj}.

It should be noted that in the methodology summarized in the two calculation schemes it is assumed that whoever the worker performs the unrepeatable operation j (j = p+1÷q) of which n_{sj} involved in the execution of this operation, he is granted the same t_{sj} time like the n_{sj} others; similar is assumed in the case of a complex of non-repeatable operations, i.e. the time t_r is given in the same value to each of the no workers involved in the execution of the complex of non-repeatable operations r (r = n+1÷v).

The complex rules that can be calculated with the formulas that have been deduced on the basis of the two calculation schemes take into account three types of reference quantities:

- repeat quantities at the level of repeatable operation, Q_{si} ($V_{si} = Q_{si}/Q_s$ amount of work in the repeatable operation i which is part of the complex of operations s, which in turn will enter the cycle of the simple process c and is expressed in number of units specific to the operation for a cycle, respectively in number of units per unit of measurement of the works of the complex of operations s;

- the reference quantity at the level of the repeatable complex of operations, Q_s ($V_s = Q_s/Q$), amount of work in the complex of operations repeatable s which is part of the simple process and is expressed in number of units of the complex of operations for a cycle or per unit of measure of the simple process;

- the reference quantity at the level of the simple process, for a cycle Q_c expressed in units of measurement proper to the simple process, in relation to which the complex norm is also expressed.

And in the case of complex norms, the calculation relations are based on two hypotheses: when starting from a workload per cycle (Q_c) technologically imposed and when starting from a cycle duration (t_c) imposed organizationally and the team of n_c people, in which case Q_c results by calculation, depending on the available labor fund.

Following the first calculation scheme, considering predetermined composite norms, the relations are obtained:

- complex work norm

$$m_c = \sum_{s=1}^{n} V_s \cdot m_s + \frac{1}{Q_c} \sum_{r=n+1}^{v} n_r \cdot t_r \quad \text{[work units / work unit]} \tag{9}$$

$$m_c = \frac{n_c \cdot t_c \left(\sum_{s=1}^{n} V_s \cdot m_s \right)}{n_c \cdot t_c - \sum_{r=n+1}^{v} n_r \cdot t_r} \quad \text{[work units / work unit]} \tag{10}$$

- complex production norm

$$N_c = 1/\left(\sum_{s=1}^{n} V_s m_s + \frac{1}{Q_c} \sum_{r=n+1}^{v} n_r t_r \right) \quad \text{[work unit / work units]} \tag{11}$$

$$N_c = \frac{n_c t_c \sum_{s=1}^{n} V_s m_s}{n_c t_c - \sum_{r=n+1}^{v} n_r t_r} \quad \text{[work unit / work units]} \tag{12}$$

Following the second calculation scheme, without considering predetermined compound norms, the relations are obtained:

- complex work norm

$$m_c = \sum_{s=1}^{n} V_s \sum_{i=1}^{p_s} V_{si} m_{si} + \frac{1}{Q_c} \left(\sum_{s=1}^{n} \sum_{j=p_s+1}^{q_s} n_{sj} t_{sj} + \sum_{r=n+1}^{v} n_r t_r \right) \tag{13}$$

$$m_c = \frac{n_c t_c \sum_{s=1}^{n} V_s \sum_{i=1}^{p_s} V_{si} m_{si}}{n_c t_c - \sum_{s=1}^{n} \sum_{j=p_s+1}^{q_s} n_{sj} t_{sj} - \sum_{r=n+1}^{v} n_r t_r} \tag{14}$$

-complex production norm

$$N_c = 1/\sum_{s=1}^{n} V_s \sum_{i=1}^{p_s} V_{si} m_{si} + \frac{1}{Q_c}\left(\sum_{s=1}^{n} \sum_{j=p_s+1}^{q_s} n_{sj} t_{sj} + \sum_{r=n+1}^{v} n_r t_r \right) \quad (15)$$

$$N_c = \frac{n_c t_c - \sum_{s=1}^{n} \sum_{j=p_s+1}^{q_s} n_{sj} t_{sj} - \sum_{r=n+1}^{v} n_r t_r}{n_c t_c \sum_{s=1}^{n} V_s \sum_{i=1}^{p_s} V_{si} m_{si}} \quad (16)$$

3. CONCLUSIONS

From the point of view of the theoretical approach, the aspects related to labor productivity represent a derivative of the economic theory of the use of production factors. Methodologically, the system of factors of production has been outlined in economic theory since the eighth century. Regarding its concretization at the level of the mining branch, it is not possible to go beyond the completely and completely particular way of using the deposit production factor, “product” and, at the same time, “object” of the activities in the mining branch. Basically, this particularity generates the specifics of the activities in the mining branch.

The labor force production factor, to which the concept of labor productivity is organically linked, is characterized both by a quantitative dimension and by a qualitative dimension. The quantitative dimension refers to the volume of work of a certain nature performed in a given production process. This volume can be quantified by the number of units of working time provided under certain, well-specified conditions of production processes. The qualitative dimension implies an approach at individual level and refers to the professional specialization specific to each employer, to his degree of qualification and experience in production, as well as to the level of productivity.

For the activities in the mining industry, characterized by a specific pronouncement of the conditions in which the work is performed, the use of this factor of production raises many particular problems in front of the management. Decisions on these, almost entirely, appeal to labor productivity.

Work standardization, as an instrument of managerial control, is a common field for many researchers and practitioners, with very different professional backgrounds. The peculiarities of the mining industry (technological and organizational), however, led to its own standardization system, which can only be understood by referring to real cases, mining enterprises that extract various useful mineral substances.

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The paper will be edited in a language of international circulation (English, French, German) on A4 format (210 x 297), page setup: top 5,6 cm, bottom 4,6 cm, left 3,7 cm, right 3,7 cm, in WORD or WORDPERFET or WINDOWS and the number of pages must be even between 4 and 16. The size of the symbol is given next and is written in the instructions used to assist in editing the text. It indicates a blank line and does not show in the text of the paper, being obtained by pressing <ENTER>. The size of a <Tab> is 1,27 cm. No blank line is left between the

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[1] *Professor Eng., Ph.D. at the University of Petroşani, adresa email*

paragraphs. Between the last line before the title and the title of the chapter and between the title and the first next line a blank line is left for each.

<Tab> **1.1 Subchapter. Subchapters can be used in the text, numbered with the number of the chapter and a number showing the number of the subtitle within the chapter. The subchapters and the numbers are Times New Roman, 11 points, bold.**

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The text is written in new paragraph and not continuing the subtitle, an 11 point blank line being left between the subtitle and the following text.

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2. PRESENTATION OF THE FIGURES

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Figures should be enclosed in the text in the order of their presentation, as far as possible on the page where reference is made to them. They shall be numbered with Arabic numbers. Black – and – white, high contrast figures are recommended. Photos can be used as well, but they should be of good quality, clarity and sufficient contrast. The figures will have a legend (name of the figure), which, along with the number, will be written underneath with Times New Roman, 10 points, centered as to the figure. The figures will be surrounded by text.

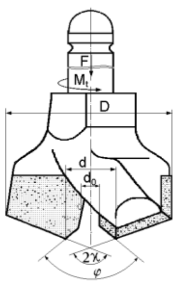

Fig. 1. Detachable bit

· (11 points)

3. PRESENTATION OF THE TABLES

· (11 points)

The tables will be enclosed in the text, a 10 points blank line being left above and under the table, and will be numbered with Arabic numbers. Both the number and the explanations to the table are written with Times New Roman, 10 points, italic, for the number and bold for the explanation to the table, centered in the space of the table and above it. The table entries will be Times New Roman, 10 points, bold, and the data in the table will be Times New Roman, 10 points. The thin lines of the table will be ½ points (0,02 cm), and the thick ones will be ¾ … 1 points (0,03 … 0,04 cm).

· (11 points)

4. PRESENTATION OF THE MATHEMATICAL EQUATIONS

· **(**11 points)

The mathematical equations will be with times New Roman, 11 points, center of the page and numbered on the right with Arabic numbers between round brackets.

· (8 points)<Blank line 8 point high>

$$X^2 + Y^2 = Z^2 \qquad (1)$$

· (8 points) < Blank line 8 point high>

An 8 point high blank line is left between the last line before the relation and the relation and between the latter and the next first line.

The last page will be at least 2/3 full.

The pages of the paper will only be numbered by a pencil outside the printing space.

· (11 points)

REFERENCES (will be written according to the model, Times New Roman 10 points).

· (10 points)

[1]. **Marian I.,** *Mecanizarea în minerit,* Editura Tehnică, Bucureşti, 1969.

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