BABEŞ-BOLYAI UNIVERSITY

FACULTY OF ENVIRONMENTAL SCIENCE

PhD THESIS
(Summary)

BROWN COAL MINING FROM THE VALEA ALMAŞULUI BASIN – ENVIRONMENTAL IMPACT AND REHABILITATION

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CONTENTS

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INTRODUCTION

Due to its abundance, coal was exploited in various parts of the world and continues to be the subject to a significant business activity also today.

The development on a large scale of coal mining took place during the Industrial Revolution and the coal was the main source of energy for industry and transport, from eighteenth century until the 1950 year. Coal remains an important source of energy also in our days, because of low costs, high abundance compared to other fuels, particularly for electricity generation. Coal is widely exploited by underground or surface mining.

The most important effects of coal mining were those related to environmental issues, such as landscape destruction, air pollution, water, and contributing to the process of global warming. Sometimes these negative environmental effects can be very pronounced, and the main recipients of this pollution are the ecosystems and humans. In this study are analyzed three brown coal sites from the north-west of Transylvania Basin: Zăghid, Teştioara and Cristolțel perimeters.

Chapter I. Transylvanian Basin geology with special regards on the north-western sector

The coal mines which we studied are located on the northwestern side of the Transylvania Basin (Romania). This sedimentary basin is a major structure of the eastern sector of the European Alpine chain (HUISMANS ET AL., 1997; CIULAVU ET AL., 2002). It is one of the most important hydrocarbon provinces of southeastern Europe, spread on more than 10 km of sediments (PERRODON, 1980; POPESCU, 1995; CRÂNGANU ET DEMING, 1996).

The formation of Transylvanian Basin has started in Upper Cretaceous after the main deformation phases of the Carpathian chain, once with the end of the orogen stages, which led to the suture of Tisza and Dacia continental blocks (CSONTOS ET AL., 1992).

Evolution of the Transylvanian Basin is related to the subsidence of a crystalline-Mesozoic relief, which began at the end of the Cretaceous and continued intermittently until the Upper Miocene (SĂNDULESCU ET BESSARION, 1976; CIUPAGEA, 1970).

The basin begins its evolution in a regional compression regime with E-W orientation (CIULAVU, 1999), with the possibility of a minor extensional phase during the Lower Badenian (KRÉZSEK & FILIPESCU, 2005), representing a back-arc basin of the Carpathic subduction (HORVATH ET AL., 2006).

The post-tectonic sedimentary fill of the Transylvanian Basin has locally a thickness of more than 5000 m (VANCEA, 1960; CIUPAGEA ET AL., 1970) and it was divided into four major stratigraphic megasequences (KRÉZSEK & BALLY, 2006): Upper Cretaceous (rift, gravitational collapse), Palaeogene (sag), Lower Miocene (flexural), Middle Miocene – Upper Miocene (the backarc sequence).

Currently the Transylvanian Basin is about 400 m above the sea level (SANDERS ET AL., 2002; KRÉZSEK, 2005).

Chapter II. Coal deposits geology from Almaş Valley basin and from adjacent areas, Cristolțel and Solona Valleys

Most of the coal-bearing formations in the northwestern of Transylvania Basin are developed across the Almaş Valley and Agrij Valley, but some coal deposits from the southern part of the basin are developed along the Nadăş Valley, while in the northeast other coal perimeters belong to Someş basin.

The industrial exploitation of brown coal and lignite in Sălaj started around the beginning of 20th century, when important resources had been outlined in several sectors, followed by significant expansion for energy purposes (PETRESCU ET AL., 1986, 1987). Coal was mined in several areas such as Zãghid, Cristolțel, Teştioara, Chieşd, Sărmăşag, Zăuan mines, and others (figure 1; VARGA ET CIURTE, 2007). All these mines closed, some of them being in reconstruction, some already reconstructed, with more or less success.

The most important lignite deposits from the northwestern part of Transilvania Basin are found at Sărmăşag (Sălaj County). The sedimentary sequence contains 27 layers of lignite (most have thin layers, except layer XVI) (CODREA, 1994).

Almaşului Valley coal basin foundation is composed of crystalline schist and Upper Cretaceous sedimentary formations.

The brown coal from the studied areas is Oligocene–Miocene, bore in the Cuzăplac, Cubleşu, Sâncraiu or Dealu Cotului Formations (PETRESCU ET AL., 1987; FÖLDVARY, 1988; FILIPESCU, 2001; FĂRCAŞ ET CODREA, 2004; ŞTEFĂNESCU ET AL., 2006). From this period, in the Almaş Valey Basin have been identified 14 to 23 coal strata, located at different stratigraphic levels (PAPP, 1915; MATEESCU, 1970; PETRESCU ET AL., 1987). From this strata's only eight shows economic importance.

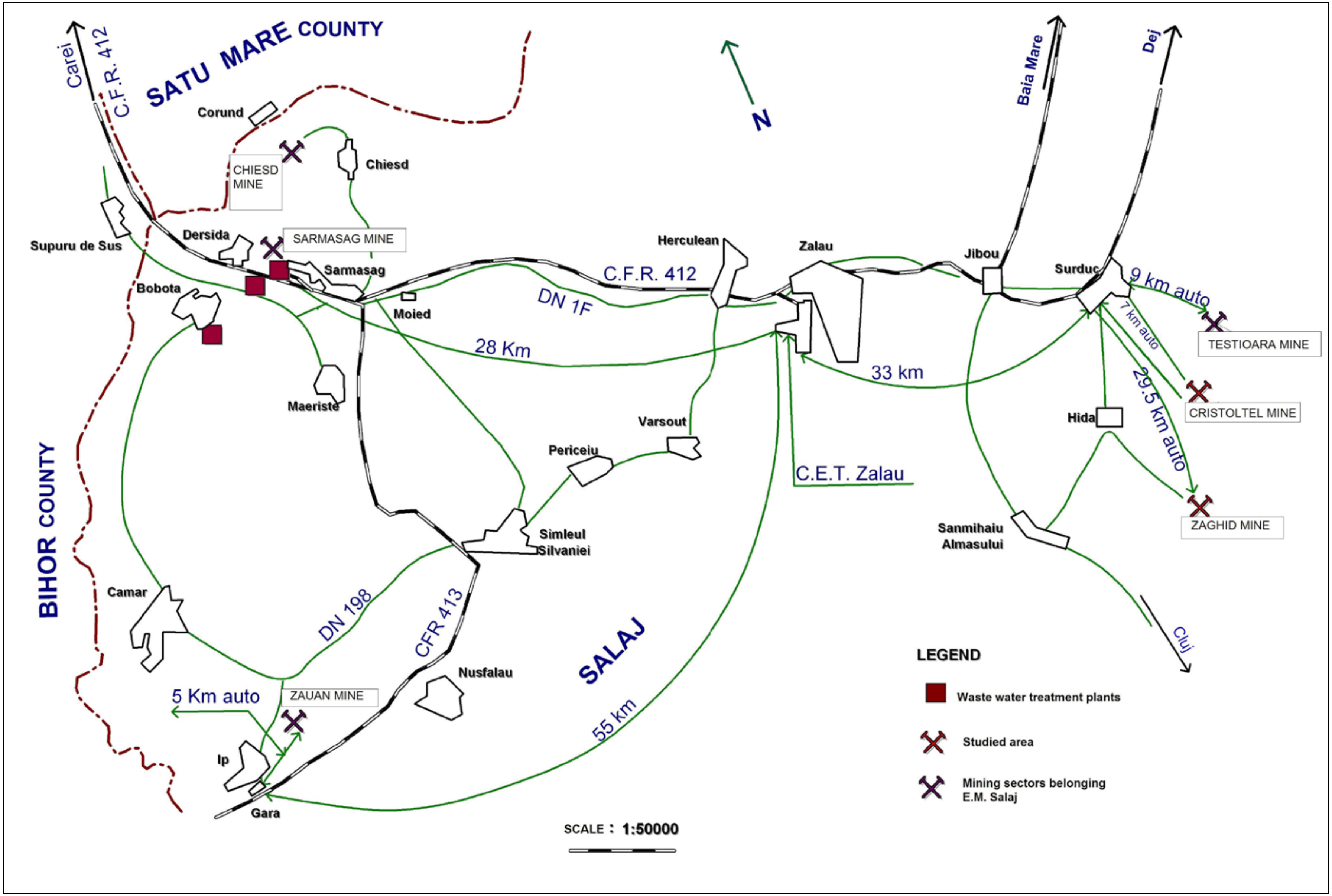

Figure 2.1. *Coal exploitation perimeters belonging to EM Sălaj*

Chapter III. Genesis and physico-chemical characteristics of coals from Almaş Valley basin and adjacent areas, Cristolțel and Solona Valleys

Coal is a natural material composed mainly of carbon and hydrogen and besides these two elements are found oxygen, nitrogen, sulfur and other trace elements (GREB ET AL., 2006).

Coal is called a fossil fuel because it was formed from the remains of vegetation that grew as long as a few million years ago. The most important coal deposits in the northwestern part of Transilvania Basin are beared by *Gresia de Var*, *Cubleşu Formation* and *Dealu Cotului Formation* (PAPP, 1915).

The forestry community with *Taxodium* and *Nyssa* had a decisive role in building the layers of peat, at the level of Var Sandstone (PETRESCU, 1968). In Cubleşu Formation is well represented the high peat bog, with *Sequoia*, *Taxodium*, *Nyssa*, *Alnus* and *Liquidambar* (PETRESCU ET AL., 1986). The coals in Dealu Cotului Formation have been formed from species as *Myrica, Cyrillic, and Alnus* etc.

The physico - chemical properties of coal

Coal is composed from a complex mixture of organic and inorganic compounds (BACIU ET COSTIN, 2008). The organic compounds, inherited from the plants which formed coal, are in big number (millions) (SCHWEINFURTH, 2009), and in addition to these organic compounds can be find more than 100 inorganic compounds in coal.

Based on the analyses conducted by SC ICPET SA in 1997, figures 3.1 and 3.2 summarize the physico-chemical properties of coals from the following areas: Sărmăşag Mine, Bobota Quarry, Cristolțel and Zăghid Mine.

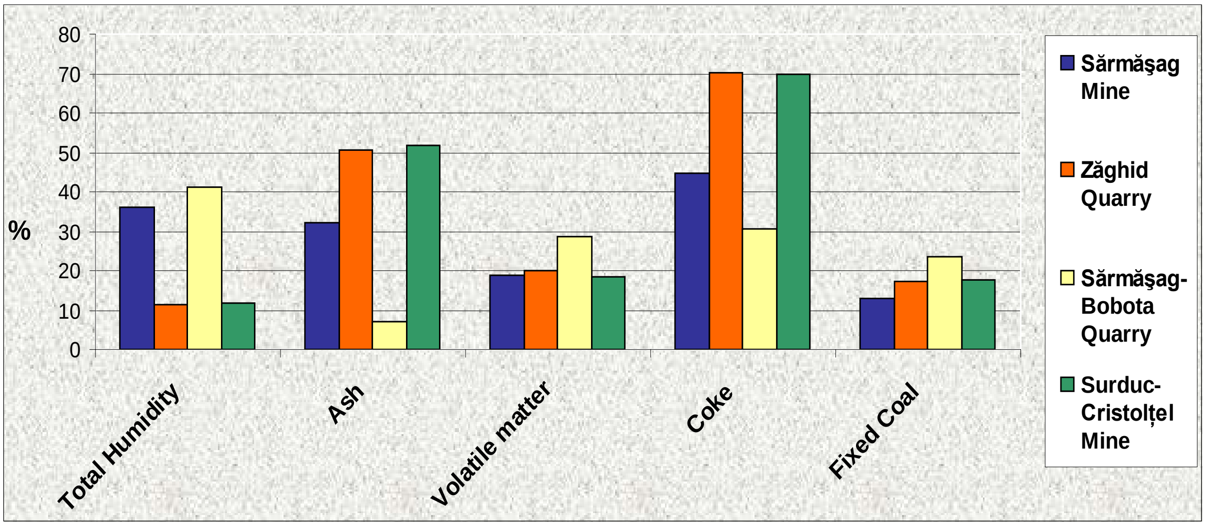

Figure 3. 1. *Physical parameters of the coal from ME Sălaj (source: SC ICPET SA)*

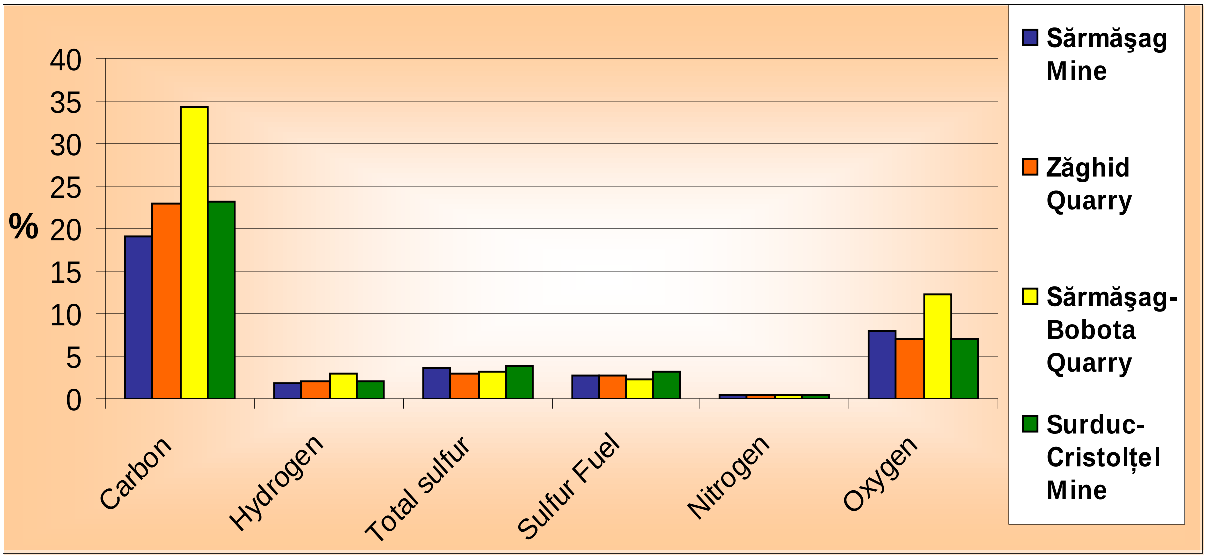

Figure 3. 2. *The chemical composition of coal from ME Sălaj (source: SC ICPET SA)*

From the standpoint of elementary composition and calorific value (lower and upper), the coal from Zăghid Career is very similar to the coal from Surduc - Cristolțel mining area.

Chapter IV. Legislation regarding environmental protection

Mining, as if any other type of industrial activities is regulated by laws, regulations and environmental standards in all is phases of activities.

A. European legislation on environment and mining

The first document that has achieved the sustainable mining problem was the European Commission Communication "*Promoting sustainable development in mining industry of the European Union*" (COM 2000, 265). This document provides a comprehensive review of the mining industry and highlights the need for a balanced approach to economic, environmental and social sustainable development.

The European environmental legislation regulate the industrial activities, which produce wastes by: Council Directive 1975/442/EEC amended by 1991/156/EEC, 1996/350/EC, Directive 1999/31/EC regarding Landfills, Directive 2006/12/EC, Directive 2006/21/EC – regarding waste management resulted from the extractive industries and Directive 2008/98/EC and others.

B. National legislation on environment and mining

The geological environment is defined (according to Law 265/2006 and OUG 195/2006 on environmental protection), as all the earth's geological structure from surface and depth: soil, groundwater and geological formations.

The main regulation governing the mining activities in Romania is the Mining Law no.

85/2003, amended by Law no. 237/2004.

The adequate planning of a mine closure should begin at early stages of feasibility study, and has to be constantly improved over the operating life of the mine. The lack of an appropriate mine closure plan and updated can have severe consequences on the environment and the economy.

C. The application of environmental legislation at the coal mines from Valea Almaşului basin and adjacent areas

Coal was exploited in several different perimeters: Bobota I and II Quarry, Sărmăşag I and II Mine, Zăghid I and II Mine, Zăghid East and West Quarry, Zăuan Mine, Zăuan Quarry, Cristolţel and Teştioara Mine (VARGA ET PETRESCU, 2008). In addition to these mines and quarries, there are two perimeters Marca - Coşniciu Quarry and Lupoaia Quarry where the exploitation was stopped before 1989. These two mines were not closed following the current legal proceedings.

Currently, the activity in the studied coal mines ceased, being past all the quarries in conservation. In the northwestern part of the Transylvanian Basin have been rebuilt ecologically three perimeters: Cristolţel, Teştioara and Chiesd, the closure and reconstruction was received in December 2000 for Teştioara perimeter and June 2001 for Chieşd and Cristolţel areas.

Chapter V. The coal mining from Zăghid, Cristolţel and Teştioara perimeters and the environmental impact

This chapter describes features of three brown coal mines from the northwestern of Transylvania Basin (Zăghid, Cristolţel and Teştioara). It also highlights the environmental effects of mining operations based on physico-chemical analyses and based on field observations.

To characterize the environmental condition of the studied perimeters we have analyzed water, soil, sterile and coal samples as follows:

- mine water samples from Zăghid coal mining region;
- surface water samples from Zăghid river;
- soil and sterile samples from Zăghid mining area, and control soil samples outside de exploitation perimeter;
- coal samples from Zăghid mining area;
- mine water samples, fountain and surface water samples from Cristolţel Valley, upstream and downstream from the pollution source;
- water samples (mine, surface, well) from Teştioara area.

5. 1. ZĂGHID EXPLOITATION AREA (area under rehabilitation)

Geology of the area

In Zăghid mining area is present the *Dealu Cotului Formation*, in which the coal strata which has economic importance is strata XI. Strata XI is composed from (see Figure 5.1):

- at the top from brown coal bed, with thicknesses ranging from 0.38 to 0.70 m.
- at the bottom, from a shale bed coal with thickness between 0.74 to 1.23 m.

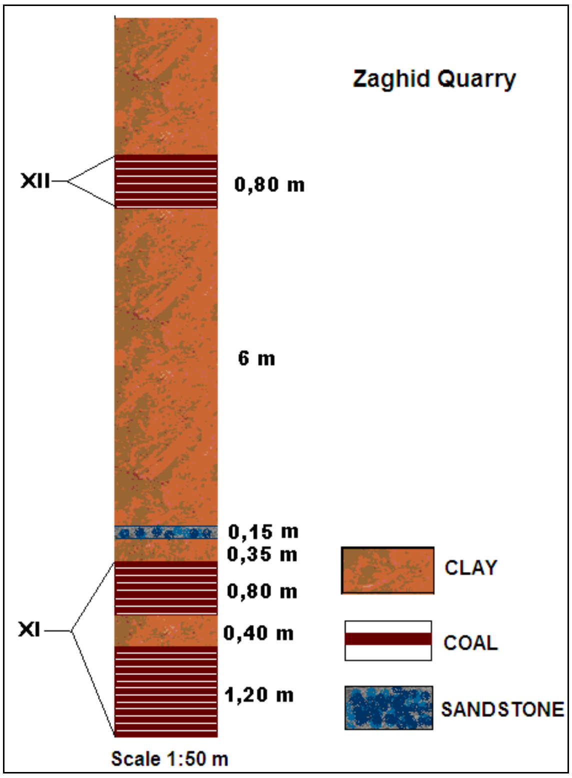

Figure 5. 1. *Stratigraphic sequence at Zăghid Quarry*

Geographical location

Zăghid perimeter belongs to Almaşului Valley basin, located in the northwestern part of the Transylvanian Depression, in Sălaj County and partly in Cluj County.

General description

A. Zăghid Quarry

In the exploitation perimeter Zăghid, were two quarries, Zăghid East Quarry (1978 - 1998) and Zăghid West Quarry (1998-2001).

The total area, which is affected by the mining process at the Zăghid perimeter, is approximately 30 hectares. Here it was extracted coal from strata XI, which has a thickness of up to 3 m and strata XII with has a thickness of 0.5 to 0.8 m.

B. Zăghid Mine

In Zăghid perimeter functioned two neighboring mines (Zăghid I and II Mine). The exploitation in this area has started in the years 1954-1955 in underground at Zăghid Mine I and in 1998 at Zăghid Mine II, these two mines was closed in 1998 and respectively in 2005.

The sterile resulted from the exploitation process it was deposited at the surface in two tailing dumps.

THE IMPACT OF MINING ON WATER QUALITY

This study is based on quantitative analysis of certain pollutants from mine waters in the former coal exploitation perimeter - Zăghid.

The main physico-chemical parameters of water (pH, temperature (T), redox potential (ORP), electrical conductivity (EC), total dissolved solids (TDS) and salinity, were analyzed at the sampling place. It is important to determine these parameters at the sampling place, because until this are transported to the laboratory, the values may decrease or increase, and because of the physical and biological processes which take place into the sample. Analysis were carried out using a Multiparameter WTW 720 Series (InoLab). The pH electrode used in determination present internal temperature compensation. Were also determined the chlorides and chemical oxygen demand by volumetric methods, and the content of heavy metals by Atomic Absorption Spectrometry (AAS).

Determination of the sampling points

Given to the possible polluting influences of the various constituent elements of mining, the set out collection points are presented in figure 5.2.

Sampling

The water samples were collected in three different periods in order to observe the evolution of water parameters in time. Sampling period's: 14. 09. 2007, 22. 11. 2009 and 02. 04. 2010. From Zăghid area have been collected 14 water samples. The water samples were collected in polyethylene bottles and for the analyses of heavy metals the samples were preserved with HNO_3 (65%) to a 2-3 pH.

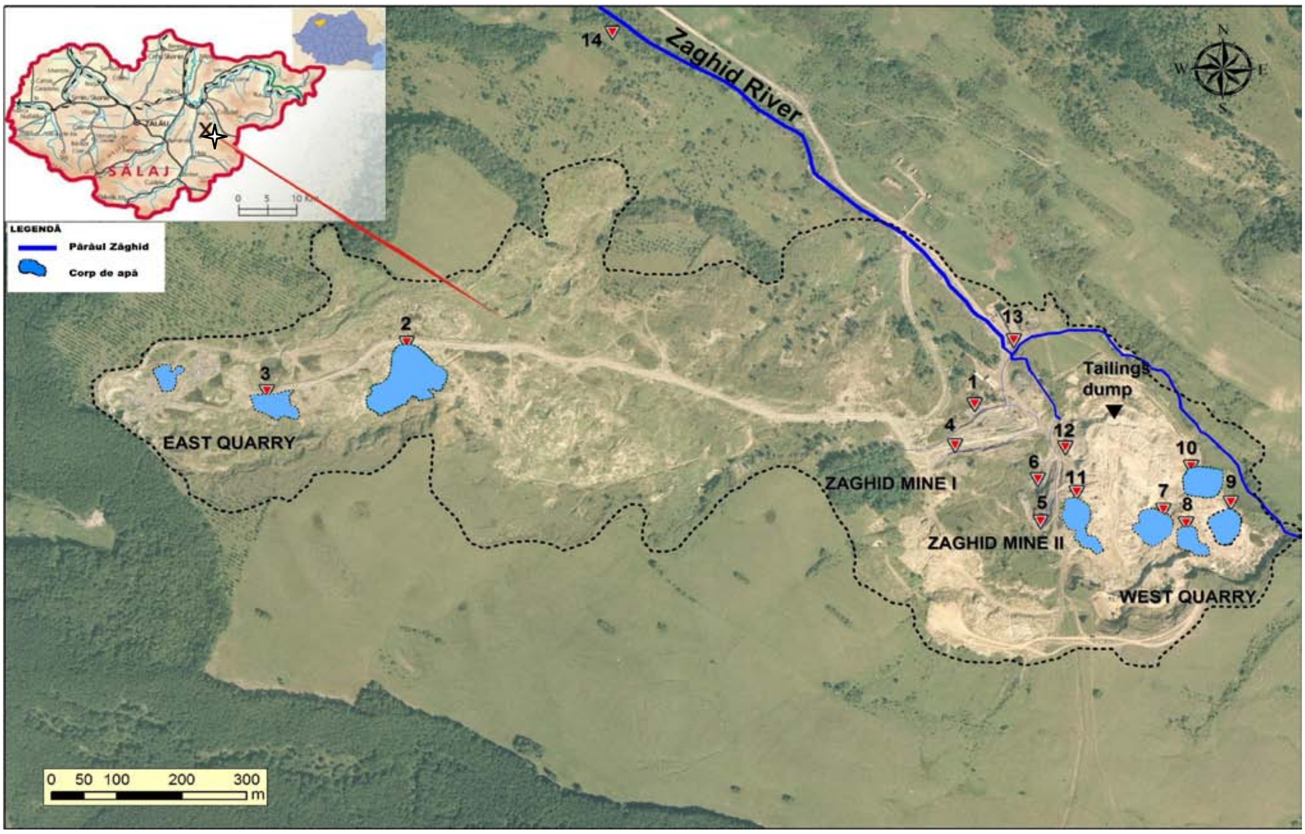

Figure 5. 2. *Representation of water sampling points from Zăghid mining area*

Below are shown some pictures with the most significant sampling points (figure 5.3).

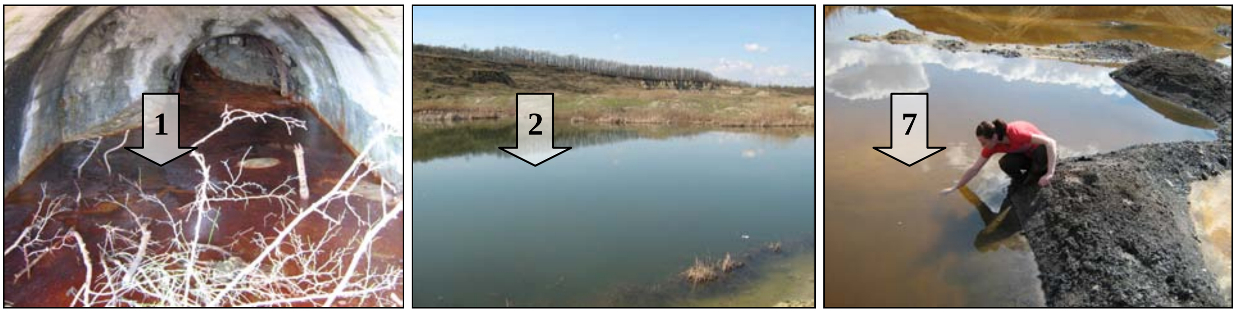

Figure 5. 3. *Water sampling points*

Results and discussions

In the point were the mine water is discharged in Zăghid Valey, the pH range is 5.95 to 7.9, and according to HG 352/2005 (NTPA 001/2005) the wastewaters that are discharged into natural receptors, the limits of pH should be 6.5 - 8.5. Therefore, the value of pH exceeded the MLC (Maximum Legal Concentration) in most of sampling points in especially during periods when rainfall is missing (see figure 5.4).

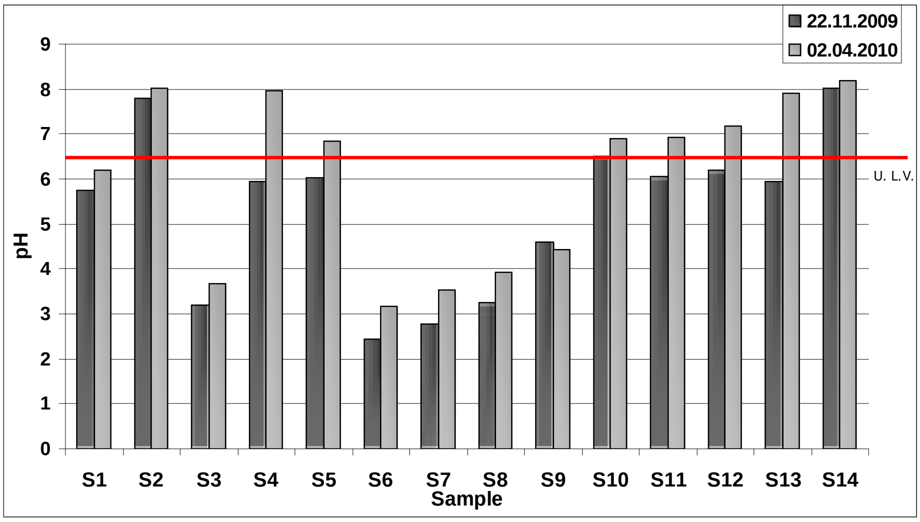

Figure 5.4. *Level of pH in Zaghid area (U.L.V – under legal value)*

Below is presented an isometric map with the variation of pH in waters (figure 5.5) from Zăghid area. Here, the value of pH is related with the composition of rocks, which encounters water.

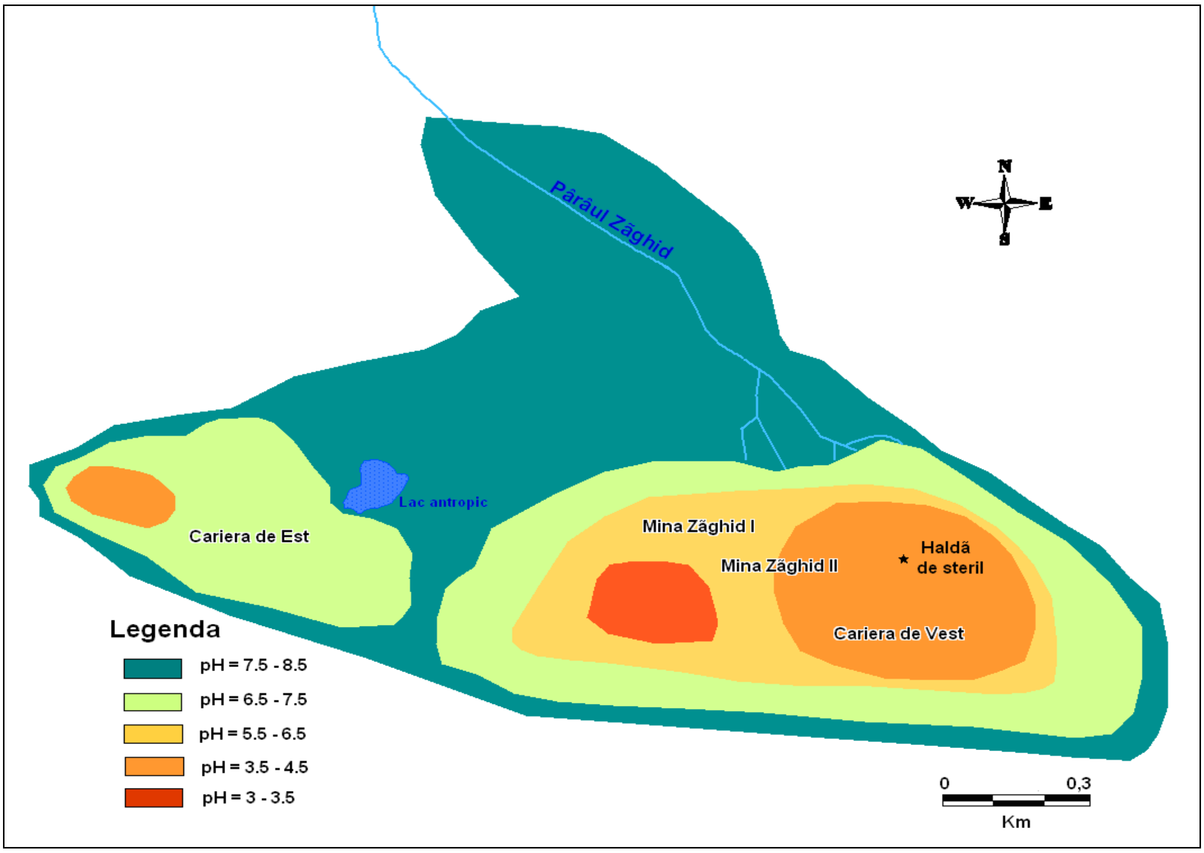

Figure 5. 5. *pH levels in waters from Zăghid mine perimeter*

The evolution of pH, TDS and EC values starting from 2007 through 2010 is important, this parameters significantly lowering their values. For example, pH value was 4.6 in 2007, reaching in 2010 a value of 7.90, which do not exceed the maximum allowed concentration.

Acid mine drainage and oxidation of sulfides is one of the most serious environmental problems created by mining. The acid drainage is a pollutant by its acidity and by the soluble products, which result (COSTIN, 2007).

Over time, landfill materials oxidize forming several zones that migrate over time (see figure 5.6).

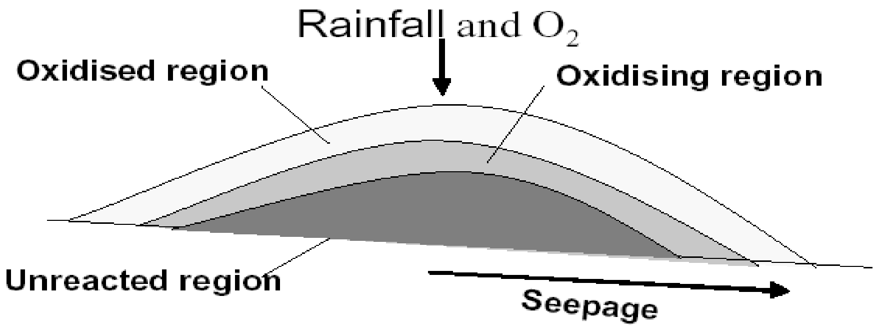

Figure 5.6. *Representing the oxidized / unoxidized zones and oxidation front from tailing dump*

<u>Determination of heavy metal from water samples</u>

The determination of heavy metals Cu, Zn, Cd, Fe, Ni, Cr was done with Atomic Absorption Spectrometer ZeEnit 700 (at Faculty of Environmental Science, UBB, Cluj-Napoca), Pb and Mn were determined by Atomic Absorption Spectrometer Perkin Elmer (at Occupational Medicine Laboratory, Cluj-Napoca). We also determined 41 elements with an – ICP Mass Spectrometer, Perkin Elmer - ELAN DRC II (at ICIA Laboratory, Cluj-Napoca).

The results obtained from the analysis of heavy metals by AAS are given in Table 5.1. Measurement uncertainty (k = 2) of determination is 10%.

Table 5. 1. *The content of heavy metals in waters from Zăghid perimeter*

Sample	Concentration µg/l							
	Cu	Pb	Zn	Cd	Fe	Ni	Cr_T	Mn
Date: 22. 11. 2009								
P.1	34.55	55.60	6.00	135.24	105200	67.60	27.54	36574
P.2	20.21	11.20	80.35	36.27	105.00	105.41	20.35	1180
P.3	120.34	98.00	1800	178.90	80541	6028.32	70.12	65874
P. 4	24.30	35.20	5.60	30.46	2560	30	45.39	3310
P.5	38.40	37.46	102.30	198.76	2205	145.24	12.78	3654
P.6	11840	520	7450	300	213000	14650	1020	142000
P.7	360.12	130.40	950.76	140.39	90624	2815	71.25	80256
P.8	35.72	33.35	300.85	75.60	36741	945	238.50	55489
P. 9	29.82	40.30	10.09	56.98	2750	40	40.00	3750
P.10	3,70	42.12	20.25	67.30	310.26	875.28	32.14	450.69
P.11	15.40	31.33	15.32	45.56	158.79	57.30	107.36	220,54
P. 12	29.16	30.02	29.16	19.87	1070	50	10.56	2630
P. 13	88.21	5.60	4.31	40.84	1050	35.00	12,77	2550
P. 14	31.41	3.67	10.27	29	101.20	5.58	10.62	30

Date: 02. 04. 2010								
P.1	10.86	2.15	21.69	5.58	49500	16.76	6.12	13640
P.2	8.33	1.63	102.60	9.83	67.82	71.79	12.23	860.50
P.3	46.80	2.25	2463	7.62	41740	1194	14.21	25870
P.4	7.17	2.70	21.42	0.71	177.3	109.20	10.05	1342
P.5	11.03	3.00	143.5	7.73	174.80	36.31	2.13	1458
P.6	1038	3.20	6929	41.66	101900	2538	169.90	36780
P.7	75.91	2.56	1163	5.72	47740	563.00	15.71	25540
P.8	32.94	2.54	591.8	3.00	16500	210.5	47.70	18564
P.9	33.52	1.95	746.4	3.38	1392	279.3	46.34	2187.21
P.10	1.85	2.10	50.09	4.46	116.5	175.8	39.91	350.24
P.11	5.60	1.75	210.70	2.77	87.90	19.6	53.75	178.36
P.12	14.08	1.60	187.2	2.31	358.0	40.19	68.69	1210.58
P.13	85.54	1.30	105.53	1.51	325.3	53.00	5.61	1030.50
P.14	30.05	0.50	7.43	1.31	49.32	17.42	4.34	23.56

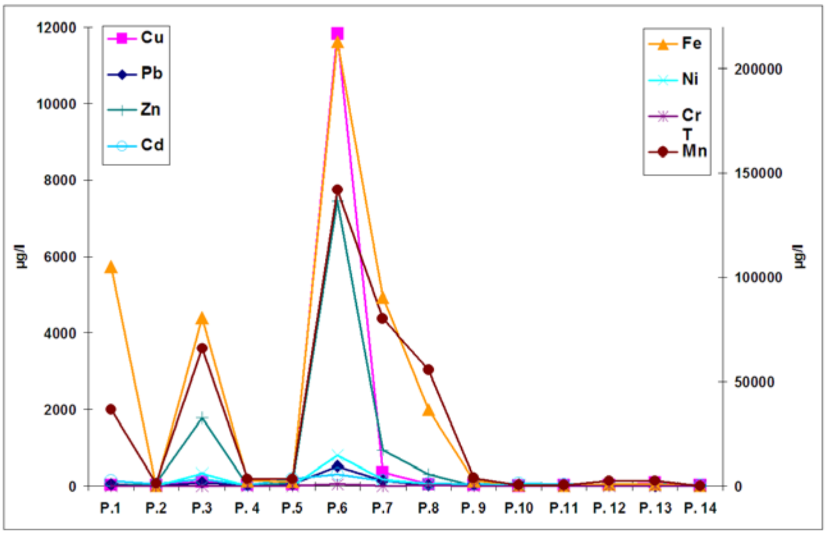

Figure 5. 7. *The content of heavy metals in 11/22/2009*

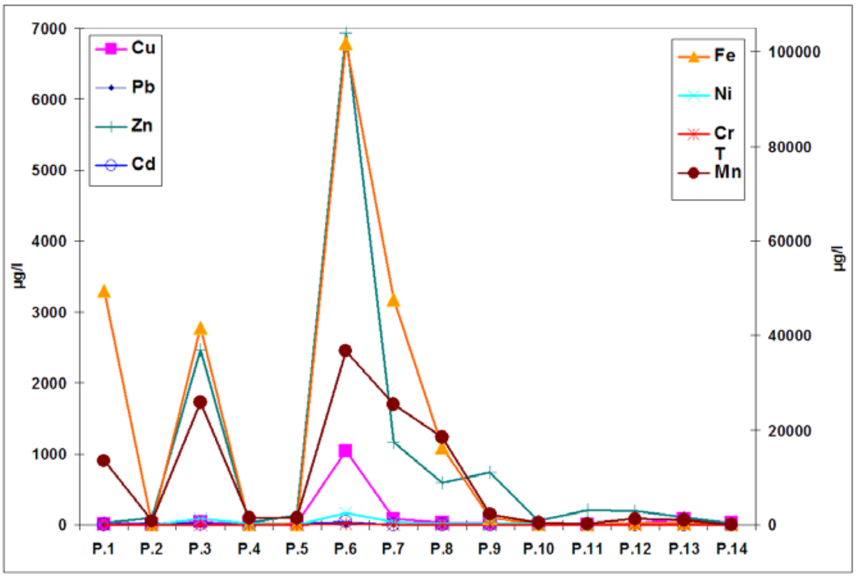

Figure 5. 8. *The content of heavy metals in 02.04.2010*

The most of metals from water samples have the highest concentrations in the point of access in the mine at Zăghid II Mine (P. 6) (see figures 5.7 and 5.8). On its route, the water from the mine and from the waste dumps until to the point of discharge into the Zăghid Valey has significant variation of heavy metals concentrations. The content of metals in mine water decreases significantly with the removal of the pollution source, due to the ability of heavy metals to precipitate at different values of pH.

The content of heavy metals is directly influenced by the geochemical composition of the substrate on which are formed the water accumulations or by the rock composition, which meets water during his flow.

The highest values are recorded for manganese and iron, which is the most abundant metal in the waters from Zăghid area; the smallest concentrations are registered for cadmium and lead. The order of abundance of heavy metals in water samples is the following: Fe> Mn> Zn> Ni> As> Cr> Pb> Cd.

From the data's presented so far, we can say that the brown coal mining activity in the Zăghid exploitation area had a negative influence on the quality of waters.

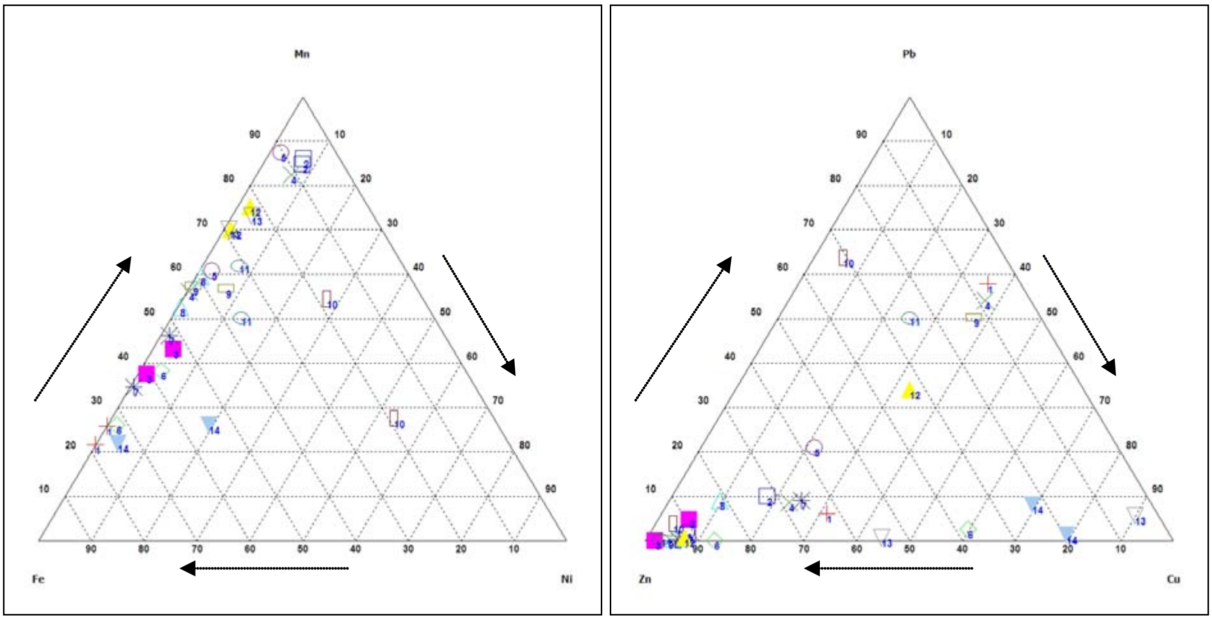

Figure 5. 9. *Ternary diagrams*

In figure, 5.9 are presented ternary diagram, which shows the percentages of the metals Fe, Mn, Ni, Zn, Cu and Pb in waters from Zăghid mining area. These charts show the character of water in the studied area, which contain predominant manganese-iron-zinc, with lead and copper subordinate.

Recording to the 161/2006 Order which approves the Norms on surface water quality classification to determine the ecological status of water bodies, Zăghid river in the collection points P.13 and P.14, in terms of heavy metal content is classified in the classes presented in Table 5. 2.

Table 5. 2. *Zăghid river classification in ecological status classes (in collection points P.13 (Δ) and P.14 (x)*

No.	Metal (mg/l)	I Very good	II good	III moderate	IV poor	V bad
1	Cu		x	Δ		
2	Pb	x Δ				
3	Zn	x	Δ			
4	Cd			Δ	x	
5	Fe	xΔ				
6	Ni	x		Δ		
7	Cr_T	xΔ				
8	Mn	x				Δ

Zăghid Valley quality, in terms of metal content, records an improvement at downstream of mining area, following the natural attenuation phenomenon due to increased intake of uncontaminated water.

In Environmental Analysis Laboratory ICIA, have been determinate 41 elements from two water samples P.6 and P.13, which are considered the most representative samples. It can been observed the evolution of the mine waters quality directly from the pollution source (P.6) to the point were the mine waters are discharged in the natural receiver – Zăghid Valley.

Is observed a significant improvement of water quality in sampling point 13, for all the identified elements in comparison with sample 6 (see figure 5.10).

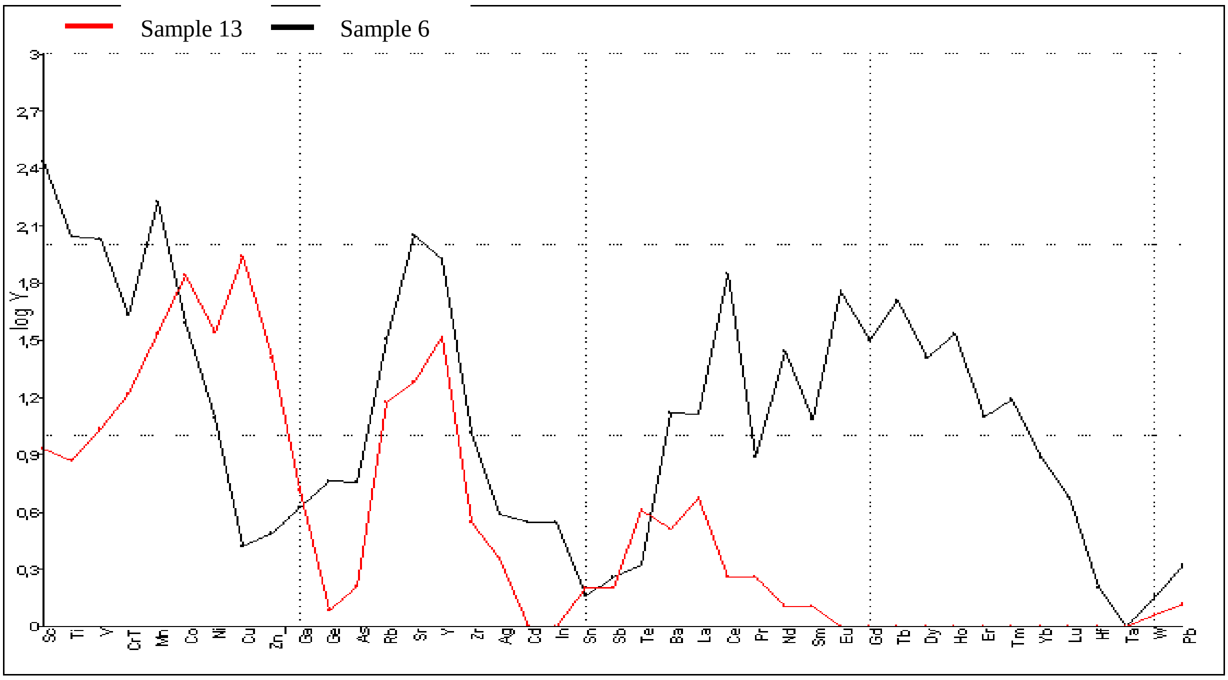

Figure 5. 10. *The content of heavy metals identified by ICP-MS in waters from Zăghid mining perimeter*

Metals which present a high risk to animal and human health, such as arsenic (As) (MCL =

0.1 mg / l), lead (Pb) (MCL = 0.2 mg / l), cadmium (Cd) (MCL = 0.2 mg / l) and mercury (Hg) (MCL = 0.05 mg / l), do not have significant concentrations in waters from Zăghid area.

The result obtained from the comparison between the AAS method and ICP-MS method is very satisfactory. The error coefficient is under 5 % (see figure 5.11).

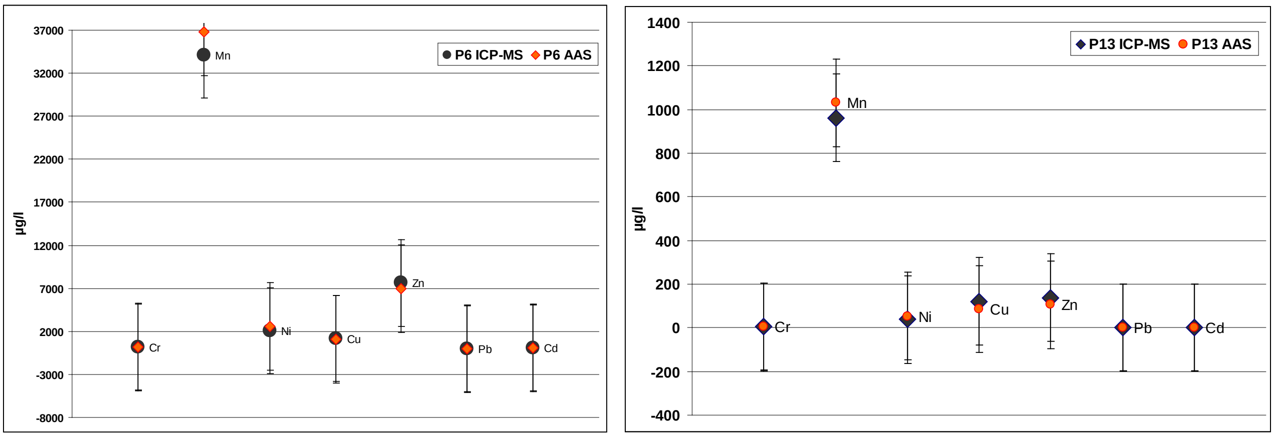

Figure 5. 11. *Comparison between ICP-MS and AAS method*

In the following table are presented the comparisons between the determined value and MCL for the metals from Zăghid mining area.

Table 5. 3. *The concentration of metals in waste water samples*

No	Element	Unit	Concentration/ Sample				MCL NTPA 001/2005
			P. 4 22.11.2009	***P. 4 02.04.2010***	***P. 12 22.11.2009***	***P. 12 02.04.2010***	
1.	Cr_T	mg/l	0.045	0.010	0.010	0.068	1
2.	Mn	mg/l	**3.310***	**1.342**	**2.630**	**1.210**	1
3.	Ni	mg/l	0.030	0.109	0.050	0.040	0.5
4.	Cu	mg/l	0.024	0.007	0.029	0.014	0.1
5.	Zn	mg/l	0.005	0.021	0.029	0.187	0.5
6.	Cd	mg/l	0.030	0.0007	0.019	0.002	0.2
7.	Pb	mg/l	0.035	0.003	0.030	0.001	0.2
8.	Fe	mg/l	2.560	0.177	1.070	0.358	5

* Values, which exceed the MCL, are marked in red

IMPACT OF MINING ON SOIL AND SUBSOIL

The mining activities in Zăghid area led to numerous negative effects:

a) Effects due to tailings disposal (figure 5. 12).

The tailings deposits were formed on a slope with a reduced inclination, which partially blocked the course of Zăghid Valley, creating behind the sterile deposit a small water accumulation.

Figure 5. 12. *Sterile deposits at Zăghid mine*

b) Effects due to excavation.

These are manifested by landslides and collapses on a total 5.5 ha land surfaces (see figure 5. 13 A, B, C).

A **B** **C**

Figure 5. 13. *A - collapse, B - landslide, C - material drop in the West Zăghid career (ravine of detachment of a landslide)*

PHYSICO - CHEMICAL ANALYSES PERFORMED ON SOIL AND STERILE

To analyze the current state of soil quality and the impact of coal mining in the Zăghid area on soil, were taken 9 sterile samples from the tailings deposits and three soil samples, of which two are taken outside the exploitation area (figure 5. 14). These two soil samples (J and K) are considered as control sample.

The soil and sterile samples were taken in plastic bags using a plastic spatula.

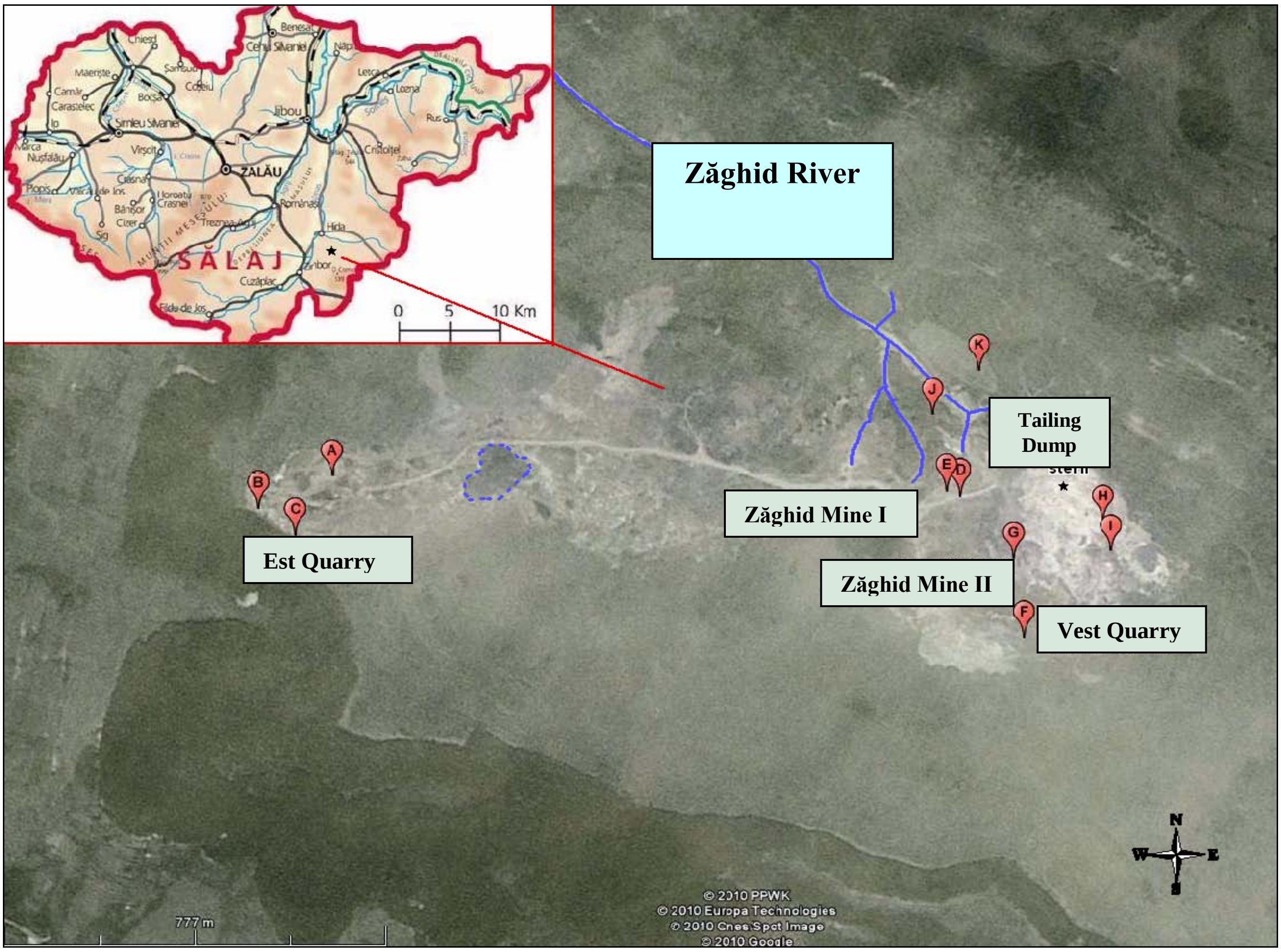

Figure 5. 14. *Soil and sterile sampling points*

To determine the pH of soil and sterile the samples were processed according to SR ISO 10390. In terms of pH, the analyzed samples, except the two control soil samples (J and K) are characterized as very acidic to acidic (figure 5.15).

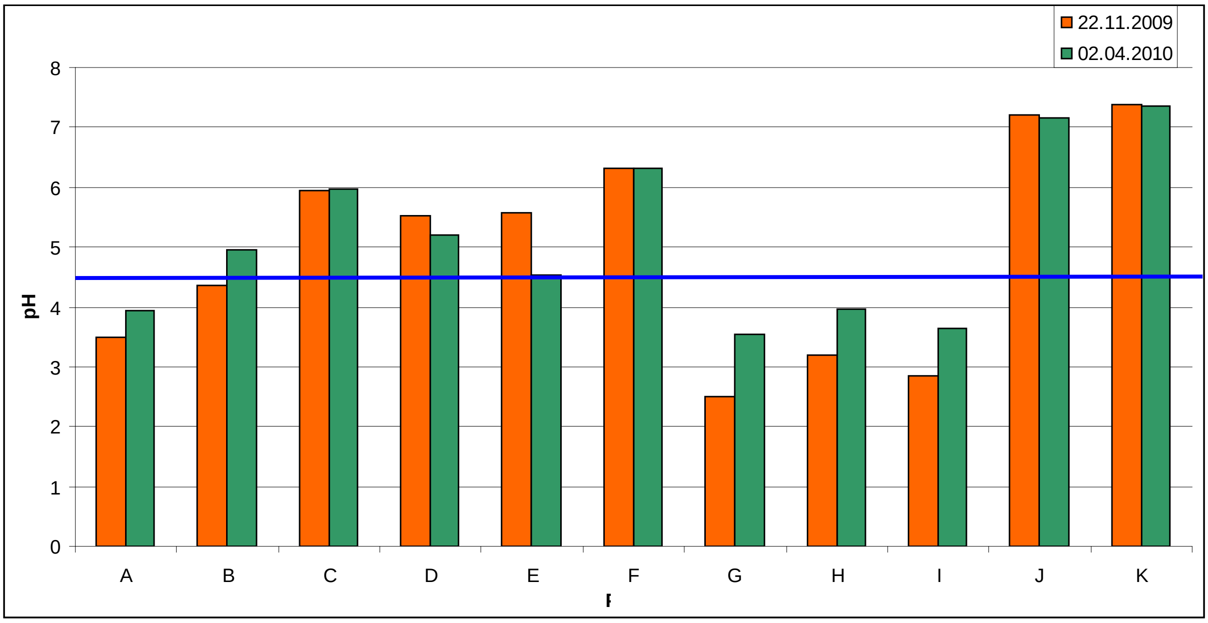

Figure 5. 15. *Soil and sterile pH*

Determination of heavy metals in soil and sterile

To determine the content of heavy metals in soil and sterile by AAS method (using the apparatus ZeEnit) was required their extraction in aqueous solution. Mineralization of the samples was made according to SR ISO 11466 by extraction with aqua regia (3 parts HCl: 1 part HNO3). The investigated soil quality in some sampling point's shows overcomes of normal concentrations at heavy metals. The highest concentrations in soil and sterile presents Ni and Cu (figures 5.16, 5.17).

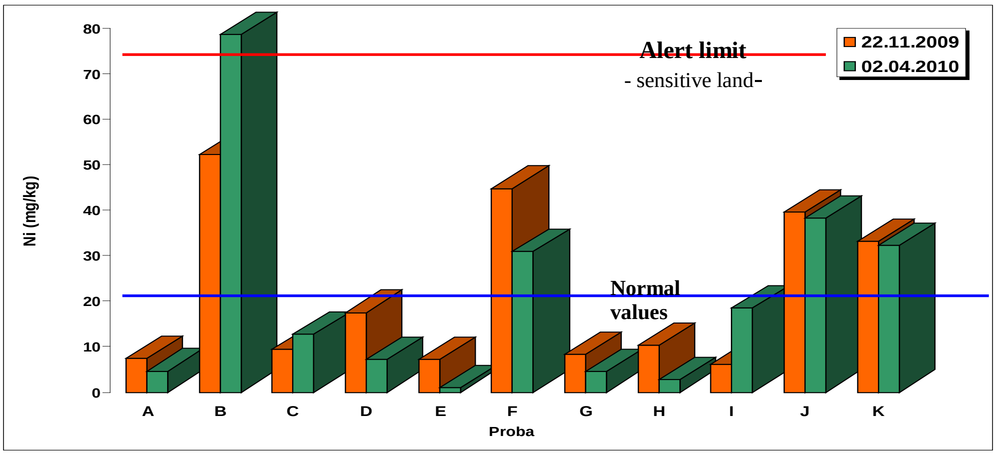

Figure 5. 16. *Ni content in samples of soil and mine tailings from Zăghid perimeter*

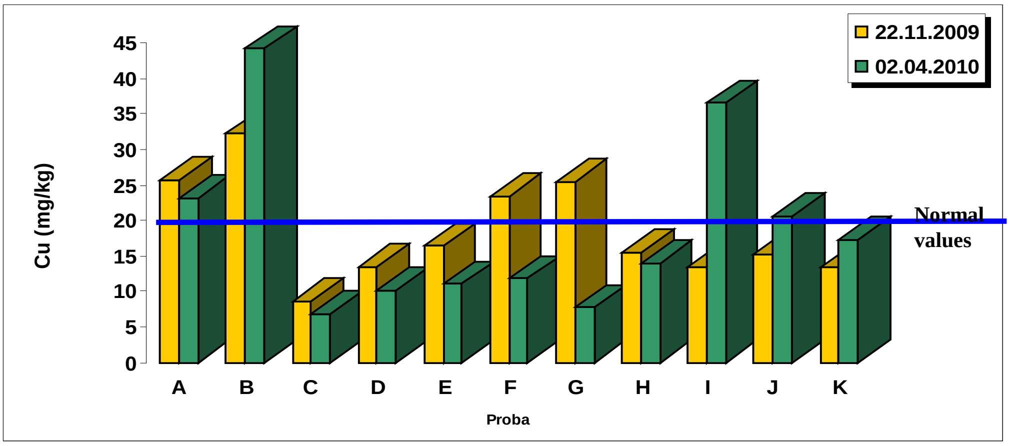

Figure 5. 17. *The content of Cu in soil and mine tailings samples from Zăghid perimeter*

Control soil samples (J and K), taken from a distance of 100 m and 200 m from the mining area, have a very low content of heavy metals in comparison with samples of sterile from the tailing dumps. This suggests that there is no obvious soil contamination with heavy metals approximately of the mine.

Determination of radioactive elements from tailings and coal samples

The coal mining brings to the surface a part of the radioactivity from the earth's crust (COSMA ET. AL., 2007). It is considered that the radioactivity of coal is given in the main by the content of

^{238}U, ^{232}Th and ^{40}K (80%) (MAUN ET MAUN-AREN, 2008). Radioactive elements found in rocks and coal samples from the studied area are ^{238}U, ^{232}Th, ^{40}K, ^{226}Ra şi ^{210}Pb.

Measurements were made using a multichannel spectrometer ORTEC Digidart.

The obtained results are presented in Table 5. 4.

Table 5. 4. *Radionuclide activities identified in soil, sterile and coal samples*

No.	Sample	Description	^{210}Pb	^{226}Ra	^{232}Th	^{40}K	^{238}U
			Bq/kg				
1.	A	coal (with small amounts of clay)	40	128	94	693	42
2.	B	coal (of outcrop)	25	42	60	544	43
3.	C	dusty - sandy clay	41	70	58	670	30
4.	D	sandy clay	23	61	78	512	24
5.	E	sandy clay	44	123	78	700	28
6.	F	sandy clay	18	40	62	507	18
7.	G_1	sandy clay + coal	46	105	71	625	26
8.	G_2	coal (from dump)	54	108	44	382	31
9.	H	sandy clay	30	59	60	563	19
10.	I	sandy clay + coal	55	90	82	483	52

From the data obtained, we note that the samples of coal (A, G2) and sterile samples with a high content of carbon (A, G1, I) have a higher activity compared with samples of soil (sandy clay). In addition, there is an imbalance between ^{238}U and ^{226}Ra due to the geochemical transport; both elements being affected by migration.

Comparing the results obtained by us (in the mining area Zăghid) with those obtained in Oltenia (MAUNA ET MAUNA-AREN, 2008; COSMA ET AL., 2009), we can note that in Zăghid mining area, the coal has a radioactivity around double for ^{232}Th and ^{40}K compared with the Oltenia lignite. Instead, ^{238}U and ^{226}Ra have a lower activity in the area studied by us.

5. 2. MINING EXPLOITATIONS FROM ADJACENT AREAS AND ENVIRONMENTAL IMPACT (rehabilitated areas)

Environmental impact analysis in these rehabilitated areas has the scope to evaluate the effectiveness of the executed operation, highlighting positive and negative effects on the environment. The resulting information can help to improve the environmental quality status at Teştioara and Cristolțel exploitation area and to the development of more effective rehabilitation work in the Zăghid area.

Introduction

Hydro-geographically speaking, the analyzed objectives are located in the Someş river basin, which is situated in the north-vest of Transylvanian basin. This basin formation has started in the upper Cretaceous and continued until the upper Miocene (SĂNDULESCU ET VISARION, 1976;

Săndulescu, 1988; Ciupagea et al., 1970; Csontos et al., 1992; Ciulavu et al., 2000; Demetrescu et al., 2001). The basement is composed of crystalline schist's over which are deposited Paleocene and Miocene deposits. The filling of the basin has a thickness of about 10 km, with significant accumulations of brown coal and lignite (Huismans et al., 1997; Krézsek et al., 2009).

The sedimentary deposits in the Teştioara and Cristolțel perimeter have Eocene, Oligocene, Miocene and Quaternary ages. The coal-bearing formation is being represented by Oligocene with all the terms (Lower, Middle and Upper).

In these two areas, it was exploited brown coal in underground. Cristoltel perimeter was functional during 1940 - 1998 and Teştioara perimeter during 1907 – 1997.

The tailings produced from brown coal extraction process consist of shale rock, clay and coal.

CRISTOLȚEL AREA

The storage of tailings resulting from mining activities was made to surface, in specially designated areas. In this area the storage, it was made in four different areas (see figure 5.18):

- Tailing dump 1, located approximately the mine;
- Tailing dump 2, located across the street at the access to the mine sector;
- Old dump, located in the Cristoltel village at 1 km from the headquarter of the mine;
- Pogor dump, located in the Surduc village.

Figure 5.18. *Tailing dumps from Cristoltel area before reconstruction*

The reconstruction of this dumps have positive and negative aspects. The tailing dumps were remodeled, reshaped and stabilized with retaining walls to prevent their erosion. The watercourses from the base of the dumps were retained in small lakes and treated. The scope of the rehabilitation process had a principal goal, that to reconvert the affected area in an original appropriate status. For this, the dumps were covered with topsoil and vegetation.

The rehabilitation of two dumps has not been done properly, it was observed a temporary stability, and a material flows in the surrounding areas. The quality of waters was also essential affected. At the Pogor dump, can be observed serious erosion phenomena at the base of the dump, which advances to the top, damages of the support wall and pier support gabions, poor and inadequate vegetation even after a few years of the rehabilitation process. The water in this area has a brown-orange color, due to the high content of iron ions. The acid mine drainage (AMD) is present in this area (see figure 5.19).

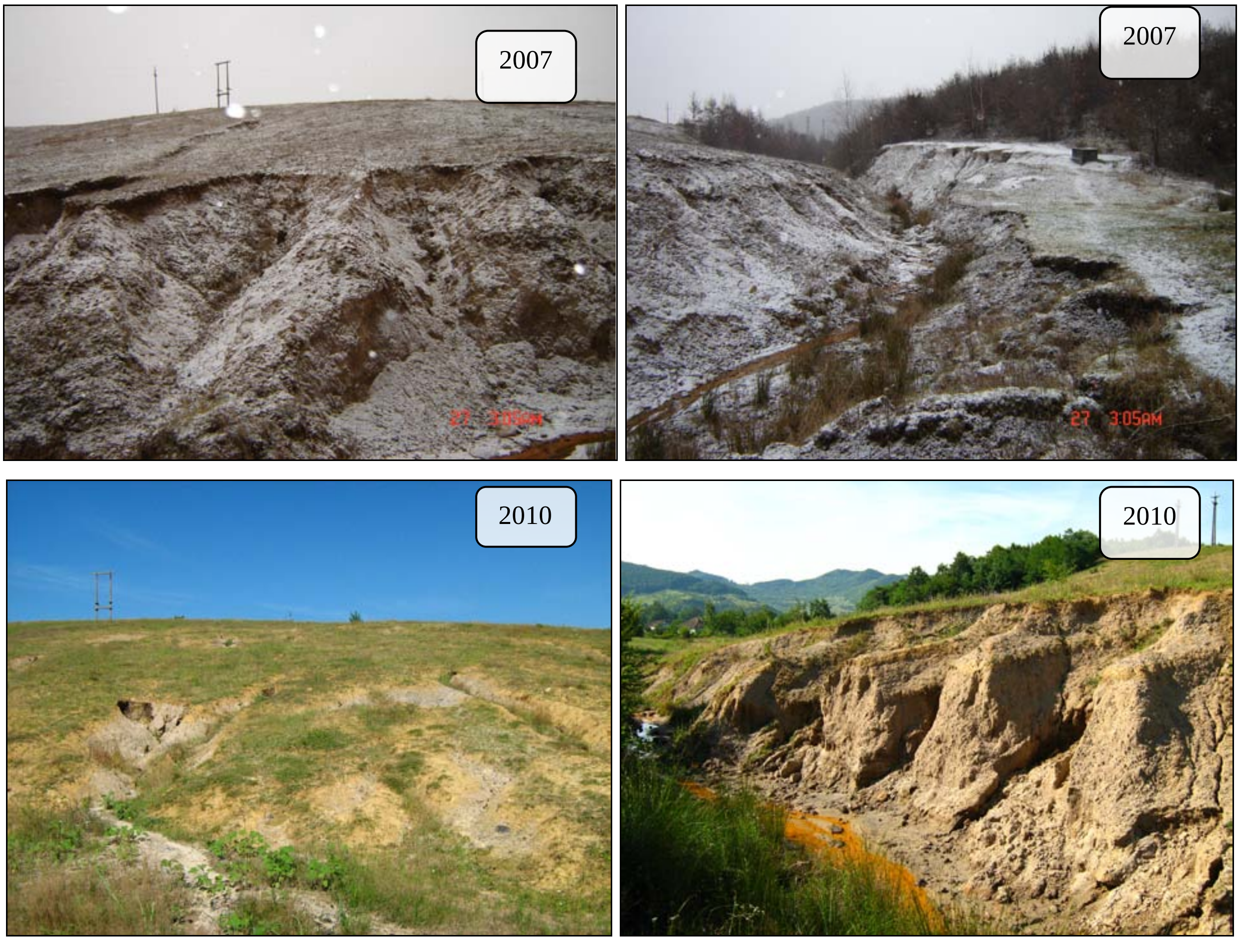

Figure 5.19. *Pogor dump after reconstruction in 2007 and 2010*

However, we can observe a success in the rehabilitation process at two tailing dumps, in Cristoltel area at: Tailing dump 1 and at the Old dump. The vegetation is significant on these tailings and these have been returned successfully to an agricultural use (figure 5.20).

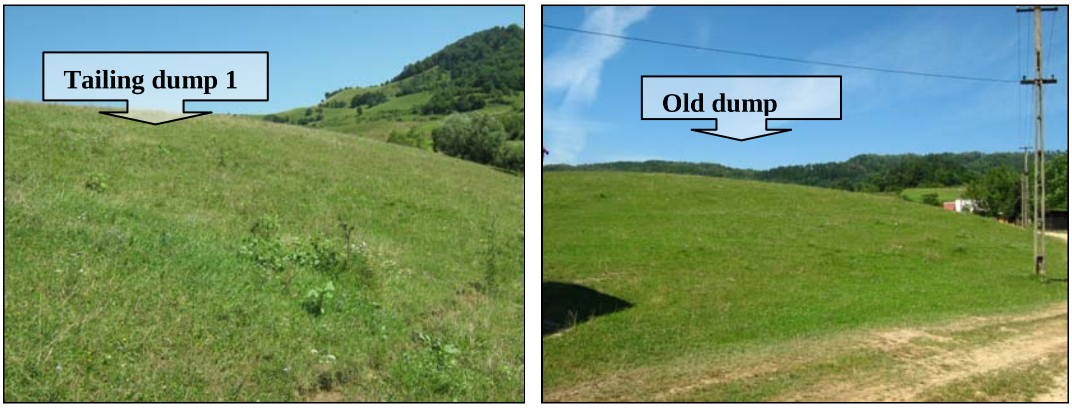

Figure 5.20. *Successful rehabilitation of the dumps*

To study the effect of mining on waters were collected eight water samples on 30.07.2010 and 10.09.2010. Sample 1C, 2C, 3C, 4C and 8C represent mine waters and sample 5C and 6C represent natural water from Cristoltel Valley, at 1000 m, respectively 1500 m, from the point of waste waters discharge. In these points, before the reconstructions, were observed serious problems regarding pH, Fe and Cu. In the second campaign of sampling were taken water samples from Cristolțel Valley upstream exploitation ($3C_1$), downstream (6C1), fountain water upstream exploitation (4C1), and downstream ($5C_1$) (figure 5.21 and 5.22).

The parameters that were analyzed for this study are pH, temperature, oxidation-reduction potential (ORP), electrical conductivity (EC), total dissolved solids (TDS), salinity and heavy metals.

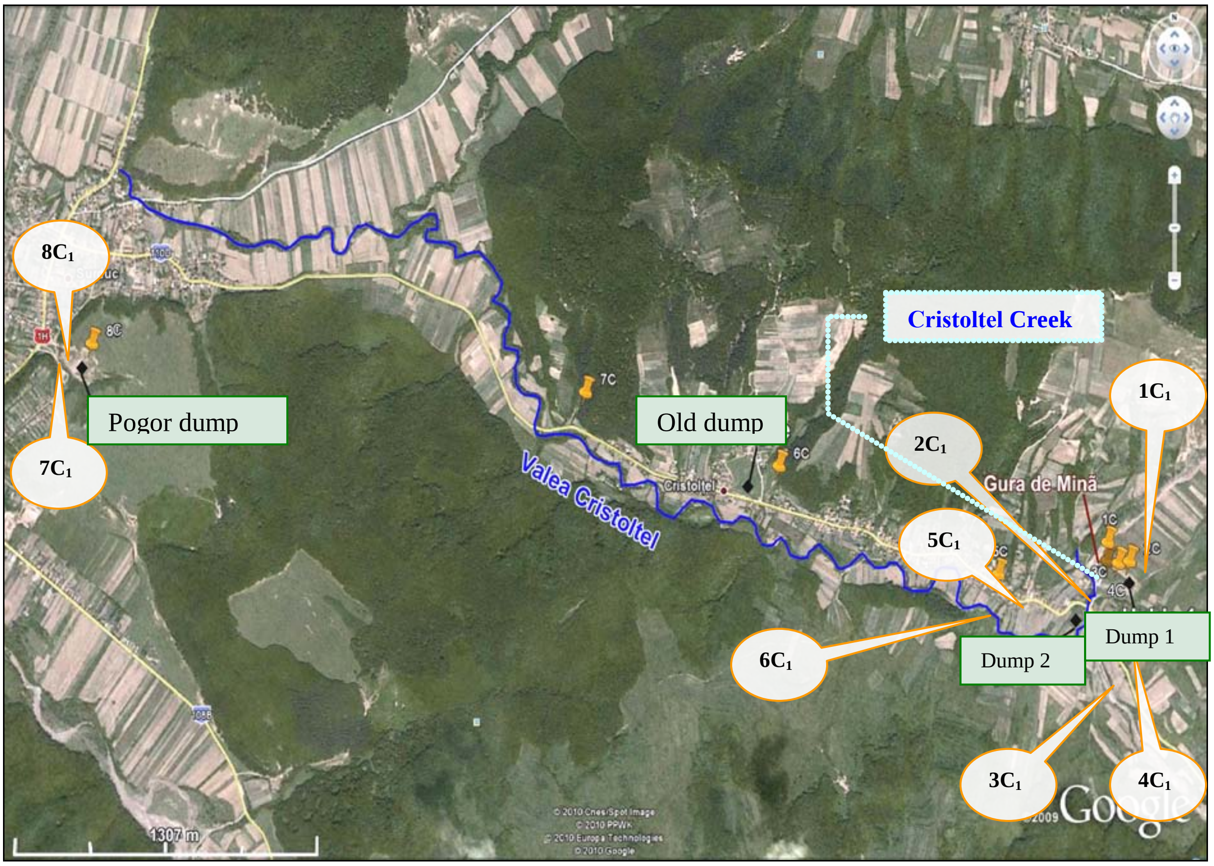

Figure 5. 21. *Cristoltel area – location of the sampling points*

Figure 5. 22. *The main water sampling points*

Methods and results

The principal parameters of waters (pH, ORP, EC, TDS, and Salinity) were analyzed with a Multiparameter WTW 720 Series, at the sampling site.

Water samples in terms of pH, showed a significant improvement after reconstruction and currently this parameters respect the national normative, except the waters from Pogor dump, were the value of pH is significantly low (3,83).

One of the main factors, which favor the dissolution of metals from tailings, is the low pH value.

The following results were obtained for the content of heavy metals.

Table 5. 5. *The level of heavy metals from Cristoltel area (2010)*

Sample	**Concentration mg/l**					
	Cu	**Zn**	**Cd**	**Fe**	**Ni**	**Cr_T**
Date: 30.07.2010						
1C	0.0789	0.2070	0.0028	0.8314	0.3678	0.1620
2C	0.1517*	0.0740	0.0033	1.9300	0.3006	0.1784
3C	0.1579	0.0480	0.0580	1.5310	0.2322	0.1874
4C	0.1579	0.0801	0.0434	8.6430	0.2203	0.1935
5C	0.1669	0.0178	0.0027	0.0508	0.1535	0.2063
6C	0.1710	0.0330	0.0378	4.0690	0.1525	0.2091
7C	0.1718	0.0290	0.0019	0.0468	0.1236	0.2136
8C	0.1686	1.1470	0.0321	75.5200	0.2258	0.2502

Date: 10.09.2010						
$1C_1$	0.0110	0.1380	0.0017	0,0890	0.3390	0.0363
$2C_1$	0.0125	0.2142	0.0041	6.6120	0.4805	0.2526
$3C_1$	0.0155	0.1350	0.0016	0.0199	0.2663	0.1930
$4C_1$	0.0177	0.0091	SLD**	0.0190	0.2353	0.02620
$5C_1$	0.0338	0.1495	SLD	0.0128	0.2400	0.02580
$6C_1$	0.0279	0.1483	SLD	0.0418	0.2037	0.0685
$7C_1$	0.0194	1.8040	0.0137	8.4180	0.4303	0.0588
$8C_1$	0.0278	0,1868	0.0150	5.4730	0.2056	0.2731
MCL waste water NTPA 001/2005	0.1	0,5	0.2	5	0.5	1
MCL drinking water	0.1	0.005	0.005	0.2	0.02	0.05

* The red values represent the values, which exceeds the legal concentration

The obtained data's indicate a high content of Cu in all analyzed samples, with significant concentrations exceeded maximum permitted by law (MCL).

Due to the strong aerobic conditions and the low water flow from the mine, the dissolved iron content is low, although the content of iron exceeds the maximum allowed by law in the following collection points: 4C, 8C, $2C_1$, 7C1 and $8C_1$. The maximum level of iron in this area is 75, 52 mg/l, at the Pogor dump (figure 5.23).

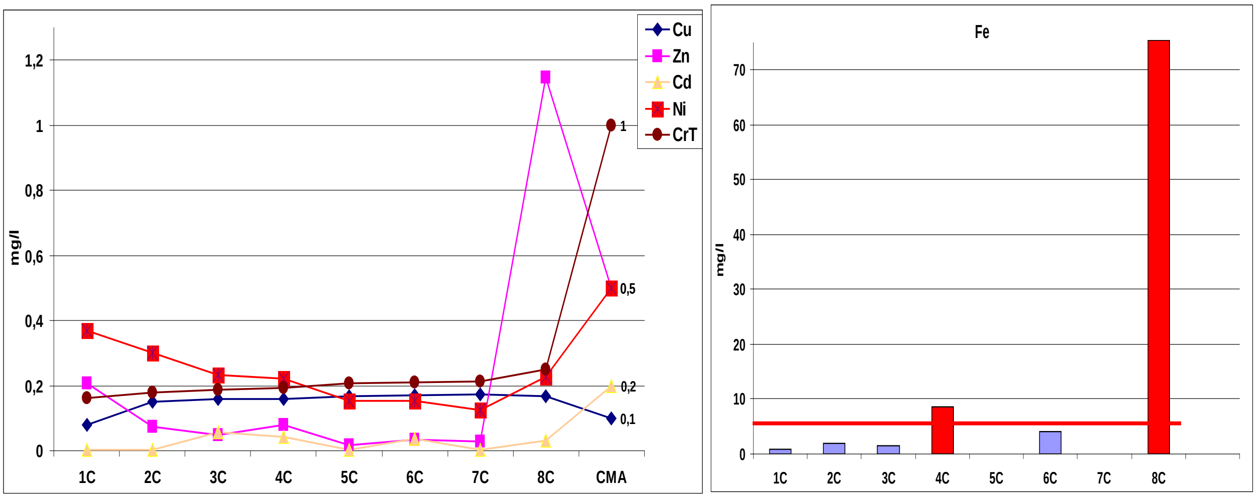

Figure. 5.23. *The heavy metals content and comparison with MCL*

The obtained data's indicate possible positive correlation between Cd - Cu, Cr - Ni and between Zn and Cd. These correlations are shown in figure 5.24.

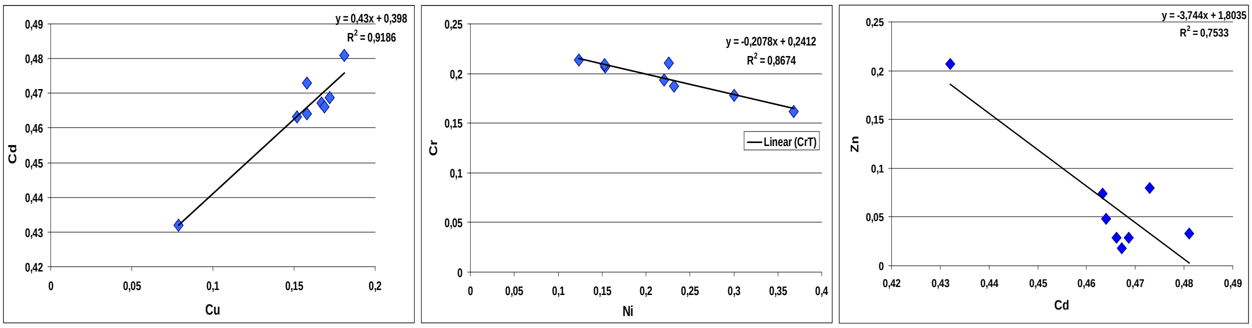

Figure no. 5.24. *Positive correlation*

Due to an inadequate reconstruction plan, water infiltrations from the precipitation in the tailings dumps cracks, continue to produce continuous surface water pollution.

Correlated with a small degree of dilution and a high acidity, in some locations the polluted water has influenced negatively the development of fauna and flora, downstream the discharge impact area and creates a specific coloration.

This coloration is given by a significant amount of Fe oxides and hydroxides. This coloration of the mine waters can be observed in figure number 5.25.

Figure 5. 25. *Acid mine drainage*

TEŞTIOARA AREA

In this area also, was exploited brown coal from the underground. The storage of tailings resulting from the implementation work was done at surface near the access in the mine.

It have been observed diving effects in areas of underground mining, at depths below 50 m, sometimes they are present as fractures or deformities, sometimes in the form of slowly sinking areas. The evolution and extension of the diving effects have been reduced by the favorable horizontal arrangement of the strata.

For waters study, from this area were taken four water samples. Sample 1T represent mine infiltration water, sample 2 T – drinking water (fountain) and sample 3T and 4T represents natural surface water from Teştioara River. These sampling points are represented in the figure 5.26.

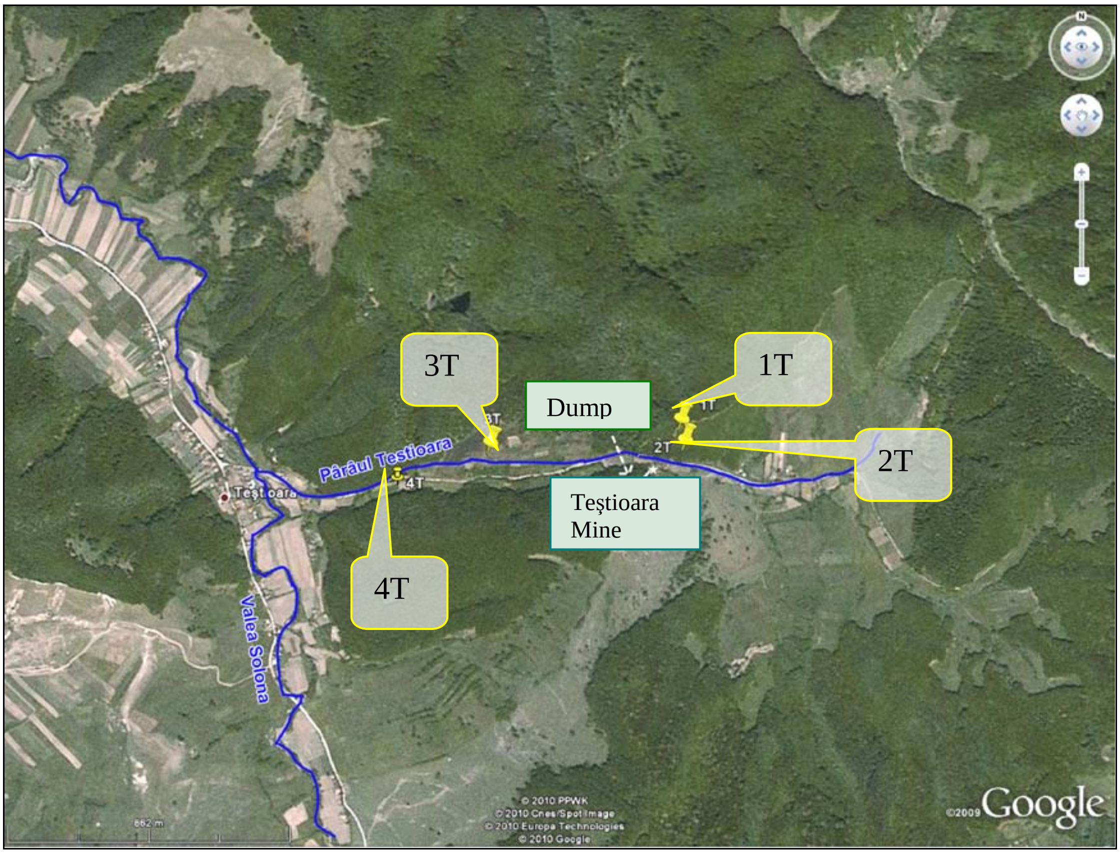

Figure 5. 26. *Teştioara area – location of the sampling points*

Figure 5. 27. *Images with collection points*

The method used in the determination and the analyzed parameters are presented above at the Cristoltel case study.

The results obtained for the waters from Teştioara area are presented in table 5.6 and 5.7.

Table 5.6. *Water quality principal parameters*

Sample	pH	ORP (mv)	T (^{0}C)	EC (µS/cm)	TDS mg/l	Salinity ‰
Date: 30.07.2010						
1T – mine water	7.28	-15.2	23	177	88.5	0
2T – drinking water	7.62	-36.7	16	777	388.5	0.1
3T –Testioara River	8.63	-97.2	19	705	352.5	0.1
4T –Testioara River	8.70	-101	19	750	375	0.1

Table 5.7. *The level of heavy metals from Cristoltel area (2010)*

Sample	Concentration mg/l					
	Cu	Zn	Cd	Fe	Ni	Cr_T
Date: 30.07.2010						
1T – mine water	**0.1781***	0.0511	**0.0480**	2.550	0.1044	0.2491
MCL sewage water	**0.1**	**0.5**	**0.2**	**5**	**0.5**	**1**
2T – drinking water	**0.1768**	0.0202	**SLD**	**0.247**	**0.1020**	**0.2304**
MCL drinking water	**0.1**	**5**	**0.005**	**0.2**	**0.02**	**0.05**
3T – Testioara River	**0.1630**	0.0175	**0.0025**	0.0414	0.0964	0.2348
4T – Testioara River	**0.1230**	0.0120	**0.0021**	0.0390	0.0751	0.2015
Quality classes	**V (bad)**	**I (v. good)**	**IV (low)**	**I (v. good)**	**IV (low)**	**IV (low)**

* With red are represent the values which exceeds the legal concentration

The level of MCL is exceeded by Cu, Fe, Ni and total Cr, in the drinking water and some metals values are much higher than the amount allowed by law (see figure 5.28).

The main source of drinking water in this area is represented by the fountain water. The spring water which rich in fountain trespass first the coal strata's and in his run dissolve heavy metals from coal. Moreover, because of this, the content of heavy metals in drinking water is very high.

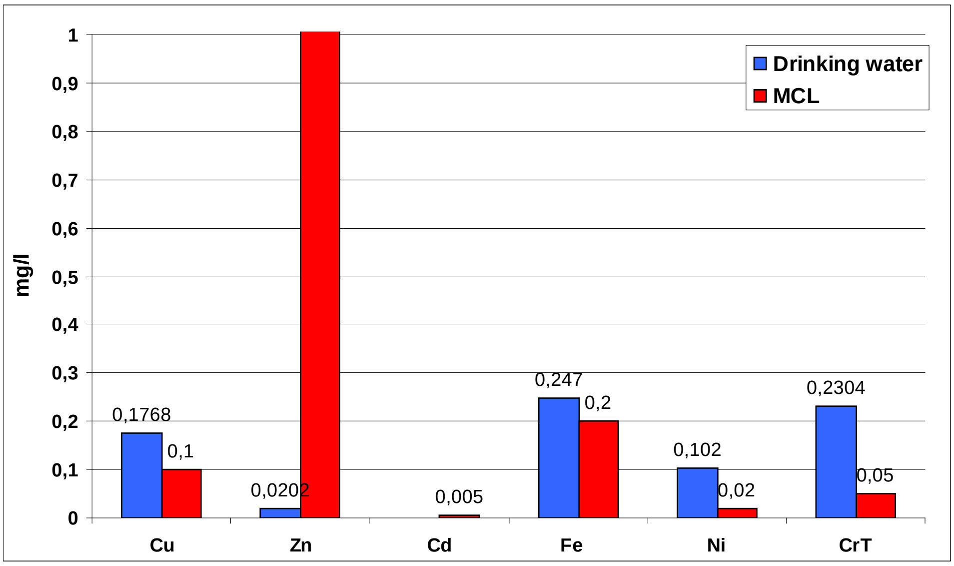

Figure 5. 28. *Heavy metals level and comparison with MCL*

For the peoples from this area, the major problem relating to coal exploitation is related to the drinking water pollution with heavy metals. This can affect in a dramatically way the health of the humans.

The positive aspect of the ecological reconstruction in this area is represented by a good stabilization of the dump and a successfully revegetation.

Figure. 5.29. *Tailing dump from Teştioara area before reconstruction (left photo) and after reconstruction (right photo)*

Chapter VI. Proposed solutions for the rehabilitation of Zăghid mining perimeter

Environmental restoration is important in a mining operation, because improves the quality of the environment (air, water, soil, vegetation) which were negatively affected by mining.

Rehabilitation of former mining areas affected by the exploitation operations should be viewed as a part of mining activity which can be defined as the methodical modelation of the areas taken into mining.

Models for the rehabilitation of the degraded mining areas are in the works of: Bradshaw et Chadwick (1980), Marshall (1982), Ma et Wu (1982) Law (1984), Hossner (1988), Chaudhury (1992), Hannan et Bell (1993), Hannan (1995), Hester et Harrison (1995), Ward et al. (1996), Loch (2000 a, b), Williams (2006), Meng (2010) etc.

Under old mining methods, once the mine became uneconomic, it was abandoned with little or no attempt to rehabilitate the land.

The rehabilitation works at *Zăghid East and West Quarry* should pursue the following steps:

1. Spatial modeling, land leveling (S = 20 ha). Main phases: shaping, smoothing, stabilization of the land with walls, fitting leaking rainwater, cover with soil and revegetation (S = 14 ha) and in some places a forestation;

2. Fitting the left side of the Zăghid Valley which is affected by landslides (S = 15 ha);

3. Zăghid riverbed clogging and roll over a length of 500 m in the area of influence of quarry.

4. Sanitation of the area, main phases: removing the residues of any kind and transportation to approved landfills.

5. Monitoring the works for at least three years, main phases: observations, measurements and tracking dynamics.

The rehabilitation works at *Zăghid I an II Mine* should pursue the following steps:

1. Closing and stabilization of all ventilation holes;
2. Disposal of the constructions and installations;
3. Land management affected by the exploitation process, to restore the forest cycle (S = 6 ha);
4. To eliminate the radioactive elements and to neutralize any chemicals which are in big concentration and exceed the concentration admitted by law;
5. To redevelop the brook points of the water in Zăghid River (L = 1000 m);
6. Monitoring of the rehabilitation actions for 2-3 years after the mine was closed.

6. 1. Rearrangement of the waste deposits

Rearrangement of the Zăghid mining tailings dump involves the following steps:

- dump planning;
- landfill surface leveling;
- topsoil deposit on the smoothed surfaces;
- improve the landfill land.

To know the characteristics and the peculiarities of those dumps, we made physico-mechanical studies regarding the content of the tailings dump. These parameters are very important in determining the stability of the dumps.

The physico-mechanical tests performed included analysis of texture, specific gravity, particle size composition, porosity, plasticity and moisture. These parameters were determined at the soil analysis laboratory of the Geo Search SRL, Cluj-Napoca.

- In terms of size, the samples (both the sterile and soil) are formed from clay that varies from sandy clay to dusty- sandy clay.
- The analyzed samples have an average porosity, having the ability to store a considerable amount of water. Soils with a total porosity of 48-60% present optimal conditions for plant growth and development.
- The soil and sterile analyzed samples have a low to medium plasticity, consistency index values are between Ic = 0.67 to 0.80. The plastic soils, under rainfall conditions do not show resistance to slip (Chatwin et al., 1994).
- The stability of wastes dumps is conditioned by the constructed angles, which have to be

adapted to local conditions and to the lithological composition of the heap. Based on analysis performed is generally recommended that the angle of inclination of the pile systems for the mining perimeter Zăghid to be approximately of 30 degrees.

Reshaping the body of the waste rock dump is a fundamental requirement in achieving long-term geotechnical stability.

The mining activity in the mining perimeter Zăghid disturbed the geological structure, causing underground collapses, whose effect was transmitted to the surface through the processes of subsidence and landslides large. This leads to the existence of a large gradient, which in turn generate associated geomorphologic processes: crumbling, ravines, superficial landslides etc.

In this scope, it was made a *water erosion analysis for the surface mining area Zăghid.*

To determine the degree of soil erosion and the amount of eroded material have been used the validated USLE method (Universal Soil Loss Equation) (Figures 6.1 and 6.2).

It is important to determine the annual amount of eroded material, to identify the measures necessary to ensure environmental and economic sustainability of the area of study.

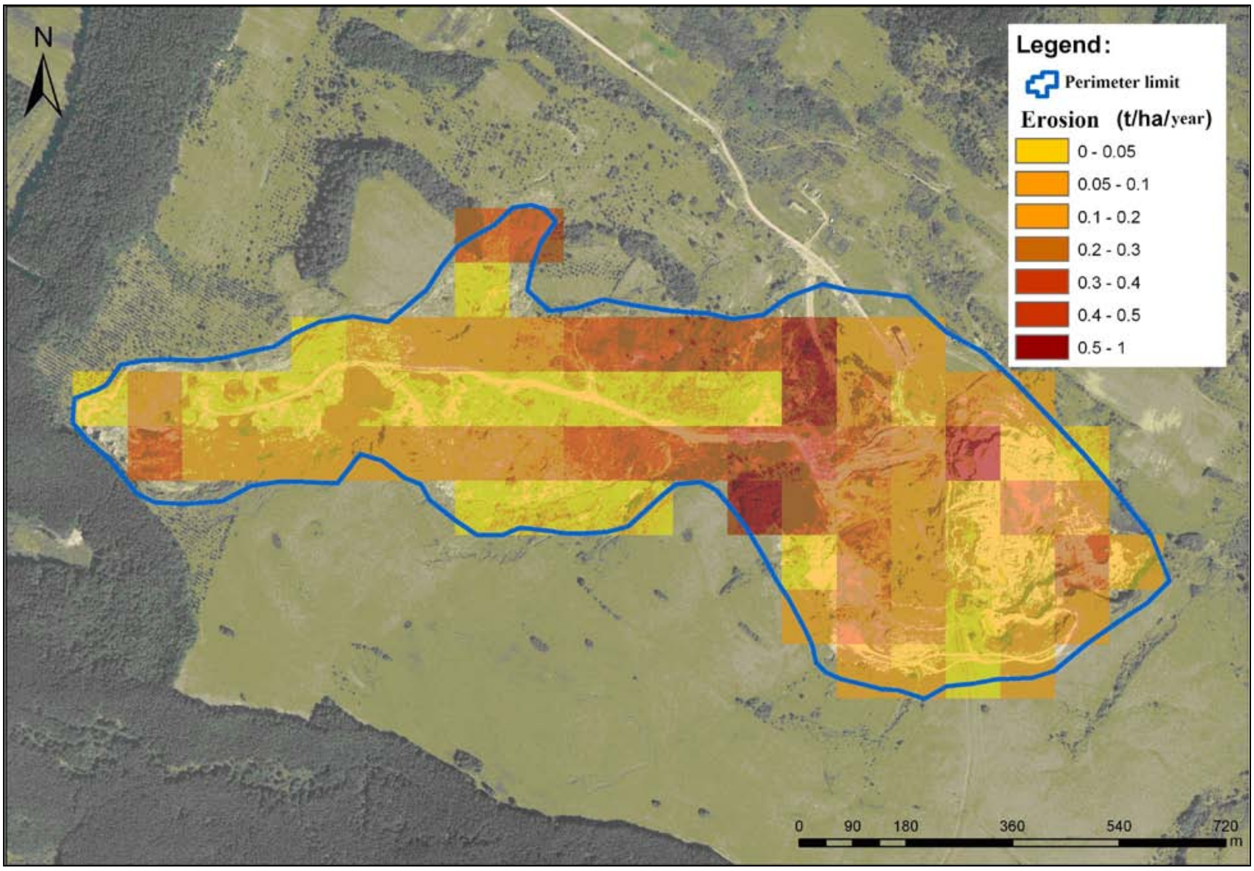

Figure 6. 1. *Soil erosion map in the study area*

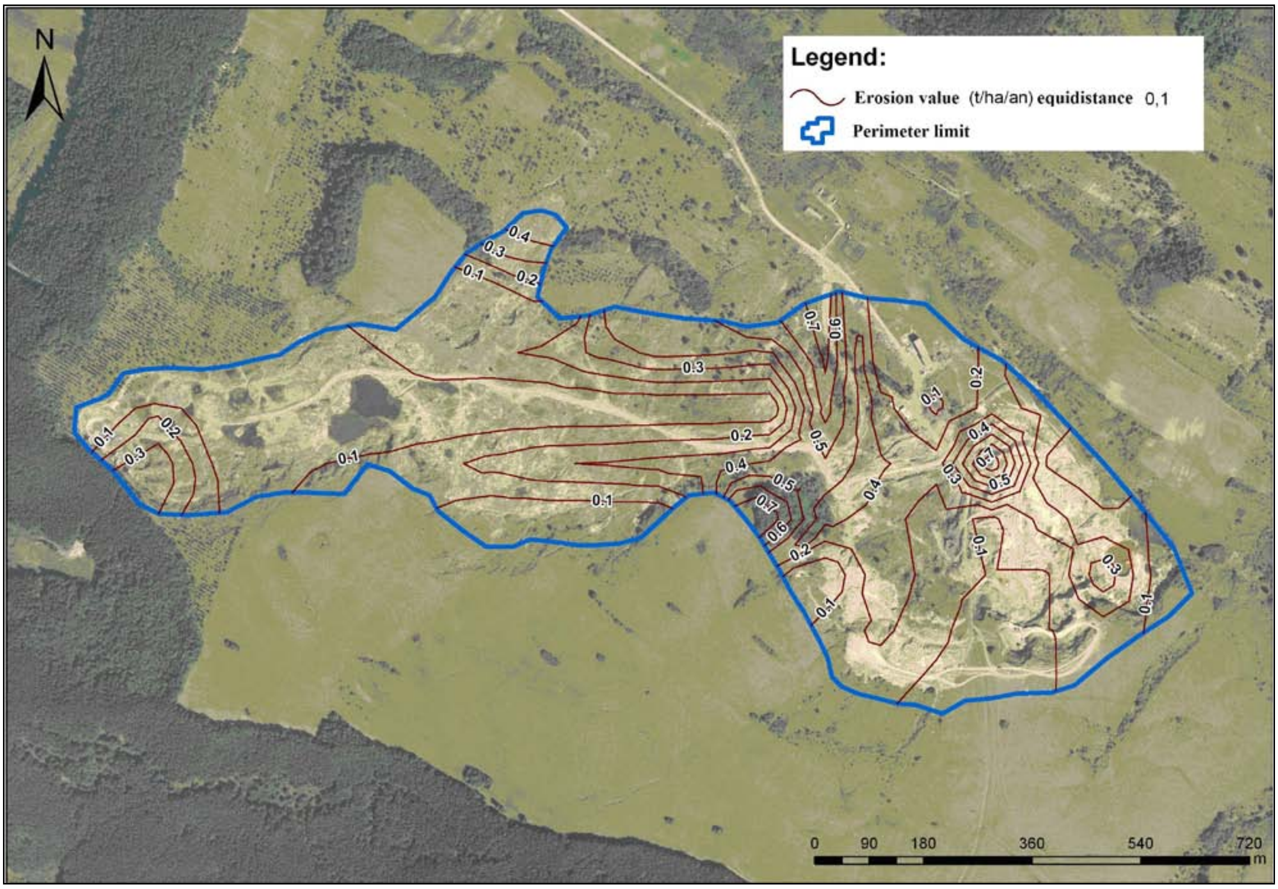

Figure 6. 2. *Erosion rate in the mining area Zăghid*

The model results show a maximum erosion rate of 0.792 t/ha/year, while the medium value for the studied area is 0.18 t/ha/year.

Revegetation in this area is recommended to be done with perennial weeds specific to this area (figure 6.3), which are unpretentious to soil conditions and are resistant to diseases.

a). Trifolium pratense *b). Trifolium repens* *c). Centaurea phrygia*

d). Festuca rubra *e). Setaria glauca* *f). Dactylis glomerata*

g). Achillea millefolium *h). Tussilago farfara* *i). Lotus corniculatus*

Figure 6. 3. *The main plant species founded in the vicinity of the Zăghid mine and recommended in the process of revegetation*

Chapter VII. CONCLUSIONS

Through our study titled *"**Brown coal mining from the Valea Almaşului Basin – Environmental Impact and Rehabilitation”*** we discuss the problems induced by mining of brown coal extraction.

The objective of this scientific approach is to assess the impact of underground mines and surface coal exploatations on the environment (water, air, soil), and designing remediation strategies for areas affected by mining, to ecological conversion of degraded areas.

In this study were analyzed the following mines:

- Zăghid mining perimeter (Zăghid I and II Mine, Zăghid East and West Quarry);
- Cristolțel mining perimeter (tailings dump 1 and 2, Old dump, Pogor dump);
- Teştioara mining perimeter.

Environmental impact assessment due to mining in Zăghid mining area was done by collecting and analyzing water samples (surface and groundwater), soil, sterile and coal samples.

• The pollution of waters from coal mines is done, especially with heavy metals and this waters have a low pH (2.44 to 7.18 pH units - at Zăghid Mine). The main source of water pollution in the area is the open coal layers (career) and the waste deposits. The high content of pyrite (FeS_2) accompanying the mineral deposits, do to the phenomenon of acid mine drainage.

• In the analyzed waters from Zăghid area were determined high values for iron and manganese, which exceeding of the legal maximum permissible concentration (1mg/l), with a maximum concentration of 3.310 mg/ l.

• The metals, which present a high risk to animal and human health, such as arsenic (As), lead (Pb), cadmium (Cd), and mercury (Hg) has no significant concentrations in Zăghid waters.

• Zăghid river quality, in terms of metal content, register an improvement downstream the pollution source due to increased intake of uncontaminated water.

To verify the accuracy and correctness of our results regarding the heavy metals from waters, we made a comparison with a RENAR accredited laboratory and from this comparison; we obtained error coefficients below 5%.

The performed analysis on soil and sterile samples regarding heavy metal concentration indicates an increased pollution in the areas where are stored the dumps. By analyzing the control samples is showed that in the near of the mining area is no soil contamination.

Coal mining in the Zăghid area presents significant radioactive activity at the radionuclides ^{232}Th and ^{40}K in comparison with other coals in other European countries.

The main observable effects on the morphology of the area are:

- occurrence of landslides on the slopes;
- occurrence of diving and field collapses due to the process of underground coal mining;
- over all waste dumps occurred driving processes; changes in the morphology of the total land area of approx. 35 ha.

The chemical tests carried out at **Cristolțel mining area** give us the field observations, regarding the environmental impacts:

- effects of land immersion, sometimes they are present in the form of deformation ruptures, sometimes as slow diving areas;
- effects due to the waste storage dumps by soil and water pollution and landscape degradation;
- hydrostatic and hydrological level changes;
- impact on surface and subsurface water quality due to discharge of mine waters by high

acidity and high concentration of metals (high concentrations of Cu and Fe, with significantly exceedings of the maximum permitted by law).

The evolution of the reconstruction work carried out at Cristolțel area shows that have not behaved properly. It may be observed serious erosion phenomena at the Pogor dump (Surduc), damages at the retaining wall and gabion pier.

At the **Teştioara mining area** it can be observed after reconstruction negative effects induced by the high concentrations of Cu over MCL in surface water and high concentrations of Fe, Cr, Cu and Ni in fountain water. The reconstruction of the dump it was made with success.

This paper can be a starting point for research projects, which aimed the remediation and reconstruction of the surrounding areas. Management and reintegration of these polluted areas are required to design and implement a system for evaluation and prioritization of intervention in these areas, and to define emergency rehabilitation. All this in the context of sustainable development of the environmental problems, which result from the analysis, made in this theme.

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