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CONSIDERATIONS ON THE ACID MINE DRAINAGE DISCHARGES IN NATURAL RECEPTORS, FROM THE BAIA-MARE FORMER MINING AREA

Corina Ioana NEAMȚU[1*], Elena Maria PICĂ[1]

[1] Technical University of Cluj-Napoca, Faculty of Engineering Materials and Environment, 103-105 Muncii Boulevard, Cluj-Napoca, Romania
** Corresponding author: corineamtu@gmail.com*

ABSTRACT. After more than a decade from the cessation of mining activity throughout Romania, acid mine drainage management has remained topical. The high content of heavy metals in mine water threatens the quality of surface water and groundwater, and thus the soil. Therefore, it is important to find suitable solutions to control the discharge of this water into the natural receptors, so that the environment is minimum damaged.

This paper presents the situation of five mines in Baia-Mare area, Maramureș County (Câmpurele, Tyuzoșa, Ilba Handal – near Băița village, the gallery in the central area of Cavnic and Reiner gallery from the same town) as it is in 2013, both in terms of water treatment applied methods after the evacuation from the mine galleries, and the parameters values of water samples from these five mines.

Key words: *acid mine drainage, heavy metals, pollution, pH, electric conductivity*

INTRODUCTION

The mining activities impact on the environment occurs in all phases of the production processes, beginning with the prospection of the ore deposit and intensifying with their exploitation phase (Fodor, 2006). Depending on the particularities of the area - the type of the ore deposit exploited, the topography, the soil type in the area, the area surface explored or the method of the ore extraction, the negative effects may occur over a long period of time, even after the stoppage of the mine work in the area.

The mining activities in the Baia Mare Depression begun as early as the second century A.D. The city of Baia Mare developed as a gold center in the XIVth and XVth centuries A.D., due to the existence of gold, silver and non-ferrous metals such as lead, zinc and copper, in the mountain massifs in the area (Coman et al., 2010).

In 1998, the mining area restructuring process began in Romania and the mines considered unprofitable were closed. Although greening projects for the closed mines have been developed, they were implemented only for some of them. Therefore, there are many cases of acid mine drainage discharges from the galleries in natural receptors, affecting their water quality.

Moreover, in Maramureș County area there are currently 17 tailing ponds of which 16 are inactive and about 300 mine sterile dumps, of which 74 are greened (EPAM).

Due to the mining activities, important areas of land are affected in terms of soil pollution with metals (Cu, Pb, Zn, Cd, Mn et cetera). These areas are considered by the authorities as the "hot spots" of the Maramureș County, where the soil pollution with metals is the highest: the cities of Baia Mare and Tăuții Măgherăuș, Dejani village and the mining exploitation areas of Baia Sprie, Ilba Handal, Cavnic, Băiuț, Herja, Nistru, Băița and Baia Borșa (EPAM).

This paper presents the study of the water from five mines located within Maramureș County in terms of metal concentration, pH and electrical conductivity. It also shows the way the authorities administered their closing down, as well as the accidental discharges in the past 15 years. The five studied mines are Câmpurele and Tyuzoșa from the Nistru mining exploitation area, Ilba Handal in Ilba mining exploitation area and in Cavnic city, Reiner Gallery and the gallery in the city centre.

The mines closure required an ecological process, in order to protect the environment from pollution by acid mine drainage discharges. For the greening process of four out of the five studied mines, some chemical and physical methods have been used, which are mentioned in the literature also:

- **Physical methods (the most used)** (Bejan et al., 2007; Akcil and Koldas, 2006):

- decantation of solid particles;
- electrical or magnetic treatment of water;
- coagulation.

- **Chemical methods** (Bejan et al., 2007; Akcil and Koldas, 2006; Johnson and Hallberg, 2005):

- pH neutralization;
- precipitation of cations and anions;
- extraction using ion exchange materials;
- flotation;
- reverse osmosis;
- a combination of two or more chemical methods.

- **Mechanical methods (EPAA):**

- alkaline separation technology using ultrafiltration membrane.

The current situation of the five mines in terms of their greening process and methods of mine water treating for each case are presented as follows:

- Cavnic - *Reiner Gallery* – a plating with limestone for pH neutralising and a filtering material layer for metal ions and sulphate precipitation has been used for the greening process of this gallery; the quality of the filtered water suffers a major improvement and it can be discharged in a natural receptor without affecting its quality (Fig.1).
- Cavnic – the g*allery in Cavnic city centre* – there is no water treatment plant at this gallery and no other greening method has been applied; the acid water is discharged in one of the rivers running through Cavnic;
- *Câmpurele, Tyuzoșa and Ilba Handal* mines – there are water treatment plants at these mines, which perform the following treatment operations: pH neutralization, precipitation of metal ions, flocculation, decantation of solids; however, when the quantity of precipitations increases, the water treatment plants are overloaded by the increased flow of water from the galleries, causing discharges of acid mine drainage with negative impact on the environment.

Fig. 1. *Reiner Gallery (Cavnic) (http://www.mindat.org).*

Accidental mine water discharges in Maramureş mining area

In the past 15 years, in the Maramureș mining area there have been several accidental mine water discharges that affected important areas of land by pollution of the water and the soil in the area. The most serious case was at Bozânta Mare on the 30th of January 2000, which had transboundary impact, alerting the authorities in Romania, Hungary and Yugoslavia. The negative impacts were major, the toxic discharges affecting rivers like Săsar, Lăpuș, Someș, Tisa, Danube and finally reaching the Black Sea (Fig.2) (UNEP).

Other notable accidental discharges that have occurred in Maramureş mining area are:

- March 2000 - Novăț tailing pond from Baia Borșa; 100,000 tons of sterile containing Pb, Zn, Cu and Cd are discharged in Vaser River Valley, as a result of the tailing pond pipe breakage due to heavy rainfall (*www.epmining.ro*);
- May 2010 - Purcăreț gallery, Ilba area – after heavy rainfalls, the naturally formed dam collapses and floods 6 households and clogs the wells (*www.ecomagazin.ro, www.jurnalul.ro*);

Fig. 2. *The course of toxic substances from the Aurul Bozânta Mare tailing pond, Maramureş County (1 - cyanide discharge from the tailing pond; 2 - cyanide wave reaches the Romanian - Hungarian border; 3 - Tiszalok, Hungary; 4 - Szolnok, Hungary; 5 - Hungarian - Yugoslavian border; 6 - Beograd (Perlez), Yugoslavia; 7 - Drobeta Turnu-Severin, Romania; 8 - Porțile de Fier, Romania; 9 - Danube Delta, Romania) (UNEP).*

- August 2010 - Purcăreț gallery, Ilba area – caused by the underground cavings and water and mud accumulations which have exceeded the capacity of the evacuation system (Fig.3) (*www.informatia-zilei.ro*);
- April 2013 - Câmpurele gallery - accidental discharge of acid mine drainage due to water accumulation in the underground caused by the collapsing of a few galleries. The mine water discharged in the Valea Roșie River Valley, then in its emissary - Băița river until it reached the confluence with the Lăpuș River (*www.emaramures.ro*).

Fig. 3. *Accidental discharge at Purcăreț mine, Ilba (www.ziarmm.ro)*

MATERIALS AND METHODS

Materials

In April 2013, a number of five samples of acid mine drainage were taken from five mines: Câmpurele and Tyuzoșa from Băița village area, Ilba Handal and Reiner Gallery and the gallery in Cavnic city centre, Maramureș County (Fig.4). In the first three mines, the samples were taken from a spot located before the water treatment plant. The aim of the study was to identify the concentration of nine metals and the comparison of the experimentally obtained values with the maximum allowed level for wastewater discharging in a natural receptor regulated by the Romanian law.

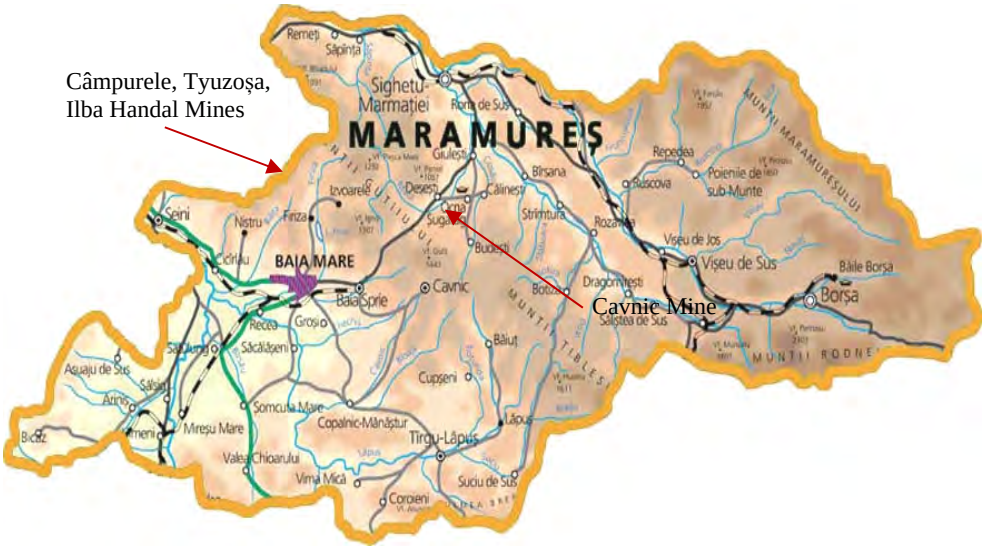

Fig. 4. *The location of the studied mines on Maramureș County map (www.turistinfo.ro).*

The concentration values of nine metals from five samples of acid mine drainage have been taken: Al, Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb. Most of the metal ions concentration values obtained experimentally exceeded the maximum allowed level for wastewater discharging in a natural receptor regulated by the Romanian law (GD no.188/2002).

In addition, pH and electrical conductivity measurements have been made in order to find the acidity level of the water.

Methods

The metal concentrations measurements were performed at Research Institute for Analytical Instrumentation from Cluj-Napoca, using an ICP Mass Spectrometer Perkin Elmer Elan DRC II.

The pH and electrical conductivity values were measured with a Seven Multi meter from Mettler Toledo company, at the Technical University of Cluj-Napoca, in the chemical research laboratory of the Department of Physics and Chemistry.

RESULTS AND DISCUSSIONS

The results of the metals concentrations found in the mine water of the five studied mines, and the pH and electrical conductivity as well are shown in Tables 1 and 2.

Table 1. *Metal concentrations values measured in the water of the five studied mines*

Metals concentration [µg/l]	Al	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb
Cavnic 1 (Reiner Mine)	11	1,875	14	4	9	3	2,890	28	1
Cavnic 2	4,828	17,191	113	32	62	896	35,027	187	117
Câmpurele	55,114	25,477	80,627	202	122	877	39,645	260	36
Tyuzoșa	22,700	8,352	35,944	105	30	147	14,142	33	174
Ilba Handal	45,116	19,701	61,448	315	124	775	101,895	452	96
Maximum value allowed level for wastewater discharged in a natural receptor (GD 188/2002)	5,000	1,000	5,000	1,000	500	100	500	200	200

The results obtained show that the limestone plating water treatment method applied at Reiner Gallery is very effective, as the metal ions concentrations are reduced, most of them falling below the maximum allowed level for wastewater discharging in a natural receptor regulated by the Romanian law. Out of the nine studied metals, only the Mn and Zn concentrations are above the maximum level regulated by law. Also, the pH is the closest to the neutral value (pH = 6). A high electrical conductivity is also noted (491 µS/cm), which means that there is a significant amount of dissolved salts, probably derived from the adsorption process of metal ions on the filtering material from the greening system of the mine.

Table 2. *pH and electrical conductivity measured in the water of the five studied mines*

Measured parameters	pH	Electrical conductivity [µS/cm]
Cavnic 1 (Reiner Mine)	6.0	491.0
Cavnic 2	3.6	1,627.0
Câmpurele	2.5	3.2
Tyuzoșa	2.6	2.1
Ilba Handal	2.6	3.8

At the gallery in the center of Cavnic (Cavnic 2), where there was no water treatment method applied, the results showed that the concentration value of Mn is 17 times higher than the maximum limit regulated by the law, the Cu value is almost 9 times higher and the level of Zn is exceeded 70 times. The value of electrical conductivity of this sample is the highest of the five samples, indicating a large amount of dissolved salts in water, probably due to the geological characteristics of the reservoir of this mine.

For Câmpurele, Tyuzoșa and Ilba Handal mines, the results showed exceeded values of the metal ions concentrations in the mine water, but the samples were taken from a spot located before the water treatment plant. However, the results obtained helped in understanding the dimensions of pollution produced by the metals in the environment, when disposed in an uncontrolled manner. The pH values for the three samples are low, which indicates a level of very high acidity of the water. The values of electrical conductivity are also low, indicating a low level of mineral salts dissolved in water.

CONCLUSIONS

Acid mine drainage represents a major threat of environmental pollution due to accidental discharges caused by environmental factors (rainfall, caving of galleries), the malfunction of the protection systems (cracks in dam walls) or by design errors. Apart from the groundwater, surface water and soil, the impact of the accidental discharges reflects on the flora and fauna as well. Regardless of the dimensions, their negative effects are maintained over long periods of time (years), affecting the life quality of the population in the area at risk.

The mines greening in Romania is a neccesity in order to prevent environmental pollution and ecological accidents, the results obtained by the authors in this study proving this fact.

The implementation in the mining areas of efficient and continuous monitoring systems of the mine water discharges, in order to reduce the environmental pollution, could be an efficient measure of prevention.

Moreover, the adoption of mine greening solutions should be made according to the particularities of each case, taking into consideration the characteristics of the mine water, water flow rate, the size of the gallery, its location and so on.

An effective way to decrease the cost of water treatment processes may be the recovery of heavy metals from the mine water, as an useful intervention method in the processes of environmental protection.

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