Available online at
www.proenvironment.ro

ProEnvironment

ProEnvironment 3 (2010) 352 - 358

Original article

Risks Associated to Soil Pollution in the Proximity of Tailing Facilities in the Western Area of Baia Mare

MODOI O.Cristina*, Al. OZUNU, I.C. STEZAR

Babes Bolyai University, Faculty of Environmental Science, Fântânele Street no. 30, 400 294 Cluj - Napoca, Romania

Received 12 September 2009; received and revised form 29 September 2009; accepted 30 November 2009
Available online 25 December 2009

Abstract

Baia Mare town is situated in Northern side of Romania and it is well known for the old mining activities deployed in the area. The hazardous waste landfills positioning directly on the soil without other protection it is known as being a source of pollution for the underground, and the wastes resulted from ore processing are included in the hazardous waste category, due to their hazardous substances content and their large quantities. This study presents the soil pollution in the near vicinity of the tailing dams: Aurul, Bozânta Nou and Bozânta Vechi. Soil samples located in the proximity of the tailing dams as well as samples from inside the tailing dams were analysed in order to determine the acid water drainage. For the soil samples were determined the concentrations for As, Cd, Cu, Pb, Mn, Zn, total cyanide and the pH values. The results were compared with the maximum admissible threshold values in the Romanian environmental protection regulations, for less sensitive soils. Exceeding concentrations for the analyzed elements were determined, especially in the proximity of the Aurul tailing dam pump station used to recycle the water inside the dam. It can be possible that these high concentrations for the analyzed elements are due to some local leakage. The cyanide concentration did not exceed the thresholds values in any of the analyzed sample. The following metals and metalloids had concentration values above the maximum threshold value: Pb, As, Cd, Cu, and Zn. For the pH indicator the minimum value was also determined in the area of the water recycling pumps inside the Aurul dam. (3.99). The risks associated to soil pollution in the near vicinity of the analyzed tailing dams consist of soil alteration including the farming land, the possibility of pollutant migration in the groundwater, with a direct impact on it and on the human health of the inhabitants in the villages nearby who use the groundwater for several housing chores, including as drinking water.

Keywords: risk, soil pollution, mining waste, groundwater pollution, threshold values

1. Introduction

Ore capitalization industry is highly connected to Baia Mare, locality situated at the downhill of the volcanic mountains Gutâi, „the richest in silver-gold ores in all our volcanic mountains". From here have been extracted, for several centuries, ores with contents of precious metals, like gold, silver, but also other metals as valuable as the others, like the lead, copper, zinc, antimony, the wealthy underground resources favouring the ore formation in this area [3]. Therefore the mining was for Baia Mare and the inhabitants there one of the most important subsidence sources, and at the same time a traditional occupation from ancient times.

The specific activities for the mining industry are susceptible of causing accidents with catastrophic impact on the environment [1] and

* Corresponding author.
Tel.: +40 264 583378; Fax: +40 364 816 647
e-mail: cmodoi@yahoo.com

sometimes of favouring the appearance of these accidents through the inherent modifications for the natural environment. Thereinafter these activities need sometimes scraping of the vegetal soil, of the cover and waste intercalations and direct exposure of the rocks in the geological layers to the action of the meteorological factors, deforestation actions, creation of underground gaps, that can form subsidence phenomena, acid drainage generation through the sulphide minerals exposure to the action of oxygen and atmospheric water, creation of new anthropogenic positive landscape by depositing the tailing material in dumps which also can create stability problems,, and being at the same time under the erosion of the meteorological factors.

The tailing facilities derived from the capitalization of the mineral resources located on the administrative territory of the Baia Mare town, occupy important land surfaces that were taken out from the agricultural and forestry circuit for long periods of time. The mining wastes in the analysed area have in their composition tailings from the preparation plants, ore marks with various particle sizes, different compositions and often potentially dangerous. These deposits represent a continuous pollution source for the environmental factors in the analysed region, as well as a potential risk source for the environment and the human community of the area.

2. Location analysis and the conceptual site model

Baia Mare is located in a depression, bordered on the northern, western and eastern sides by hills. The terrain in the area of the town is relatively plain, with a general inclination from the north east towards south west. In the context of the general inclination, the terrace of the Sasar River, river that crosses through the town from west to east, determines local inclinations of the land towards the river's bed.

The main waste deposits created by ore capitalization in Baia Mare area are the waste dams. These were formed from the waste that appeared from the specific works in the Processing Plant.

The tailing dams are deposits of processed waste with small size particles and very small, exposed to the atmospheric agents, under the influence of which suffer physical transformations (rain and wind erosions) or chemical transformations (the precipitations and the oxygen alter/ oxidize the minerals in their composition). The rain waters that leach this tailing deposits or that flow on the external embankments charge with pollutants (mobile phase metals, because of the low pH values) that are being transported in the nearby area [8].

This paper wants to underline the study of soil pollution in the vicinity of the three tailing dam facilities situated in the western side of Baia Mare, at about 2900 m of the town's constructed area, respectively the dams Aurul, Bozânta Nou and Bozânta Vechi.

The terrains in the area of Aurul tailing dam have in their composition a mixed material that can be sorted in two layers as follows:

- at the surface, beneath the soil layer, a package of smaller particle materials of different clays, dusts and fine sands, with a variable thickness of 0.5 to 3 m and relatively low permeability K = $6x10^{-3}$ m/day.
- next is a package of thicker materials, which is made of sands, gravels, and from place to place even small rocks; the thickness of this layer is of about 4 m and the permeability is of about K = 5 m/day.

The two layers described above are settled on a base rock practically impermeable constituted of clay and shale.

The litological structure of the area has been determined when borehole drills were made for the site of the tailing dam UP Central Flotation, Bozânta [13]. The tailing dams in the western side of the Baia Mare town are settled on an almost plain surface, the terrain has a shallow inclination from the north east towards south west. The closest water sources are Lapus River, tributary of Somes River (and receptor of Săsar River) which flows on the western and southern side of the assembly created by the three tailing dams, being also the receptor of the waters coming from the tailing dams and Sasar River, which flows close to the eastern side of the three tailing dams assembly (fig. 1.).

The three tailing dam assembly neighbours on the cardinal point direction, on a distance up to 500 m with agricultural lands, pastures, surface waters, and at more than 1400 m with villages located in the vicinity of Baia Mare town, as follows:

- *to the north* – pasture and at about 1400m, the southern limit of Tăuții Măgherăuşi village;
- *to the east* – agricultural;
- *to the south-east* – Săsar River (at about 400 m), Lăpuş River (The closest point at about 1200 m) and at about 800 m, the western limit of Săsar village;
- *to the south* – Săsar River, agricultural lands, and at about 2800 m the northern limit of Lăpuşel village;
- *to the west* – agricultural lands, pasture, and at about 2000 m, the eastern limit of Bozânta Mare village.

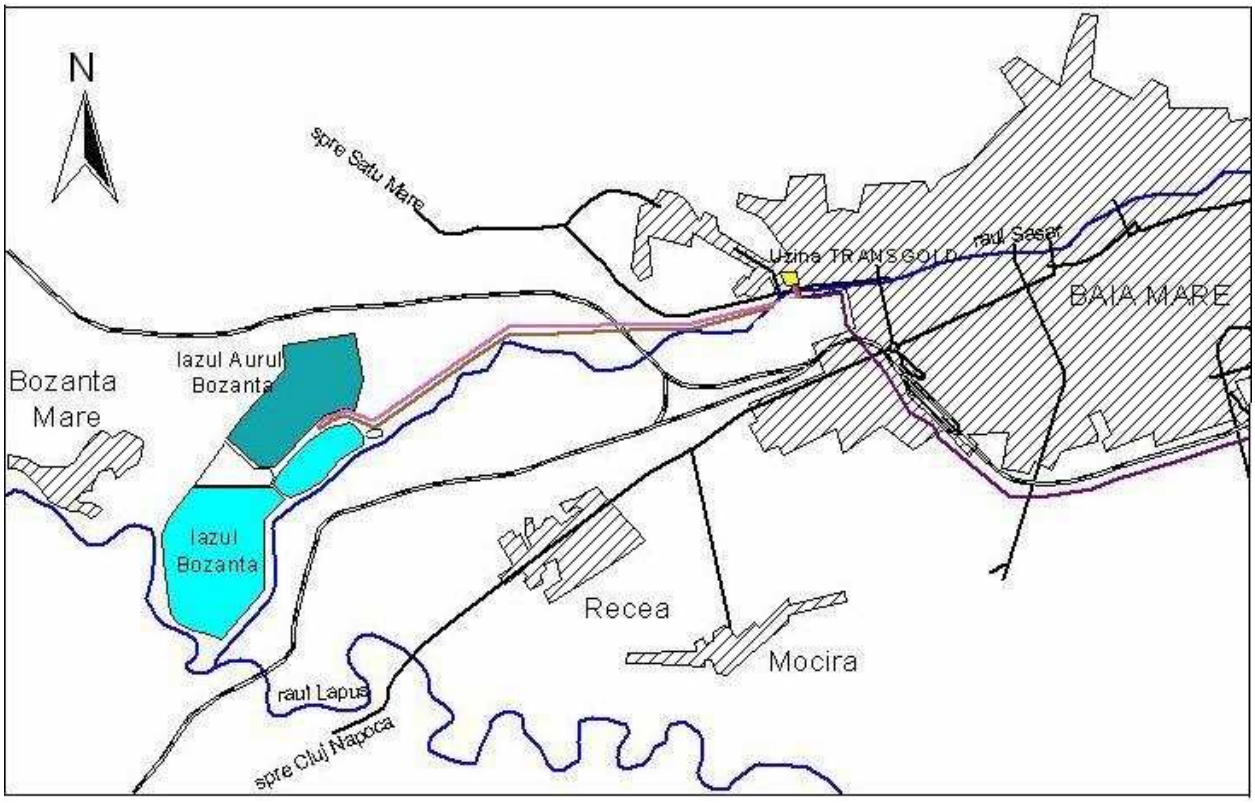

Figure 1. Location of the analysed sites/objectives

The collective feature of the tailing dam facilities located in the area of Baia Mare town and in the vicinity of it is their location on a flat terrain (plain dams), where they have no natural support because on each of the four sides of the dams exists an embankment. Nevertheless, all the tailing dam facilities that were previously described are located in an area of river terraces, this being a natural drainage and being favourable for the assurance of the dam's stability [6] on one hand, but also for the rain water infiltration that migrates the dam's body or flows on the embankments of the dam on the other hand, achieving like this the transport of pollutants towards the aquifer [9].

The tailing dam facilities represent around 50 % of the prejudices that the mining industry has on the environment [12].

Aurul tailing dam, plain dam with interior development, is the only dam from the ones described previously with impermeable basis, with geo-synthetic membrane. The drainage system of the dam includes the contour drainage and pumping station for the drained water back to the dam.

The tailings deposited on the Aurul dam comes from the exploitation of the Meda tailing dam facility, located on the territory of Baia Mare town, to the south of the Processing Plant, from which was separated by the access road and the pipeline corridor for slurry (the tailings in suspension brought in order to be processed in the plant).

Aurul dam has a designed capacity of 15 million tons, and by 2006 (when it has been temporarily set out of action) a volume of 5.3 million tons of tailings has been deposited, meaning about one third of the designed capacity.

The terrain where the *Aurul* tailing dam was made had before an agricultural use. Nearby, on the south-south eastern direction, are located the Bozânta Nou and Bozânta Vechi tailing dam facilities.

At the moment the dam is kept in conservation, is visually monitored daily, and the exfiltrations from the dam that are being collected are recycled (back in the dam) with the pump station it has. Since 2006 no slurry was deposited on the dam [13, 9].

Bozânta Nou tailing dam is also a plain dam built with hydro-cyclones.

On the Bozânta Nou tailing dam were deposited, since it was built and until 2006, the following types of residues: flotation tailings and residual technological waters from the Processing Plant, mine waters from E.M. AURUM, the overflow from the Aurul tailing dam and in the last period the sludge from the waste water treatment plant of Baia Mare town [13, 9].

Bozânta Vechi tailing dam (Săsar) is a plain dam built by hydro-cyclones, upstream method, without the waterproofing works of the base. At the moment is covered by thick vegetation, including on the superior embankment and almost all the beach, the present surface of the water shine being restricted and difficult to get to it, because of the thick vegetation on the dam. On the exterior embankment of the tailing dam facility there can be seen different species of trees (locust tree, birch, sporadic pine and others), and the inside vegetation specific for the humid soils (cane, rush).

On the Bozânta Vechi tailing dam was deposited tailing from the Central Flotation and technological waters with basic pH (corrected), from the Sasar Flotation Processing Plant. The present situation of the dam is that it is in a conservation state. It was put out of action in 1982 [9, 13].

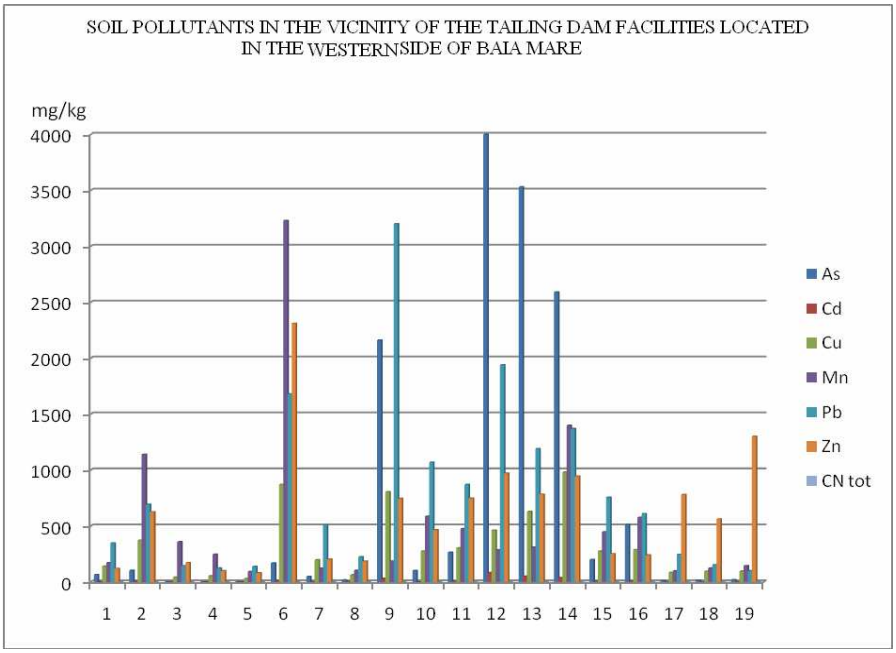

Figure 2. Pollutant concentrations in the soils in the vicinity of the tailing dam facilities in the Western area of Baia Mare

The illustration of the pollutant concentration variations has been made in figure 2. It can be seen an overtaking for the concentrations for the majority of the analysed indicators in the area of the pump station which does the recycling of water in the Aurul tailing dam.

The lead indicator has high values in all the soil samples that were analysed, the maximum value being in the same area, the area of the slurry recycling pumps. The same situation is for the indicators: As, Cd, Cu, and Zn that have maximum values in the area of the recycling pumps. It is possible that these overtaking in the area of the recycling pumps are due to some potential leakages of waters from the pump station that makes the recycling of the slurry in the dam.

The total cyanide parameter does not cross the pollution threshold limit values, for none of the analysed samples. The manganese has just one value above the alert threshold limit value in the north-eastern area of the Aurul dam. The variation of the pH values in the soil samples in the vicinity of the tailing dam facilities in the western area of Baia Mare (fig. 3) is between a minimum of 3.99, also in the vicinity of the slurry recycling pumps, and a maximum value of 6.65, in the eastern area of the Aurul tailing dam.

The soil samples from the vicinity of the dams in the western area of Baia Mare (Aurul, Bozânta Nou and Vechi) present overtaking of the concentrations for the analysed elements, mostly in the vicinity of the pump station used to recycle the waters in the Aurul tailing dam facility. It is possible that these overtaking are due to the local leakages in the area [16]. Are being noticed overtaking for the following elements: Pb, As, Cd, Cu, Zn. For the pH indicator, the minimum value was also determined in the area of the water recycling pumps in the Aurul tailing dam (3.99). The soil's pH values are between the minimum 3.99 and 6.65, in the eastern area of the Aurul tailing dam. All in all, the pH values are lower in the southern area of the Aurul tailing dam, respectively on the northern, for the Bozânta tailing dam facilities located in the vicinity.

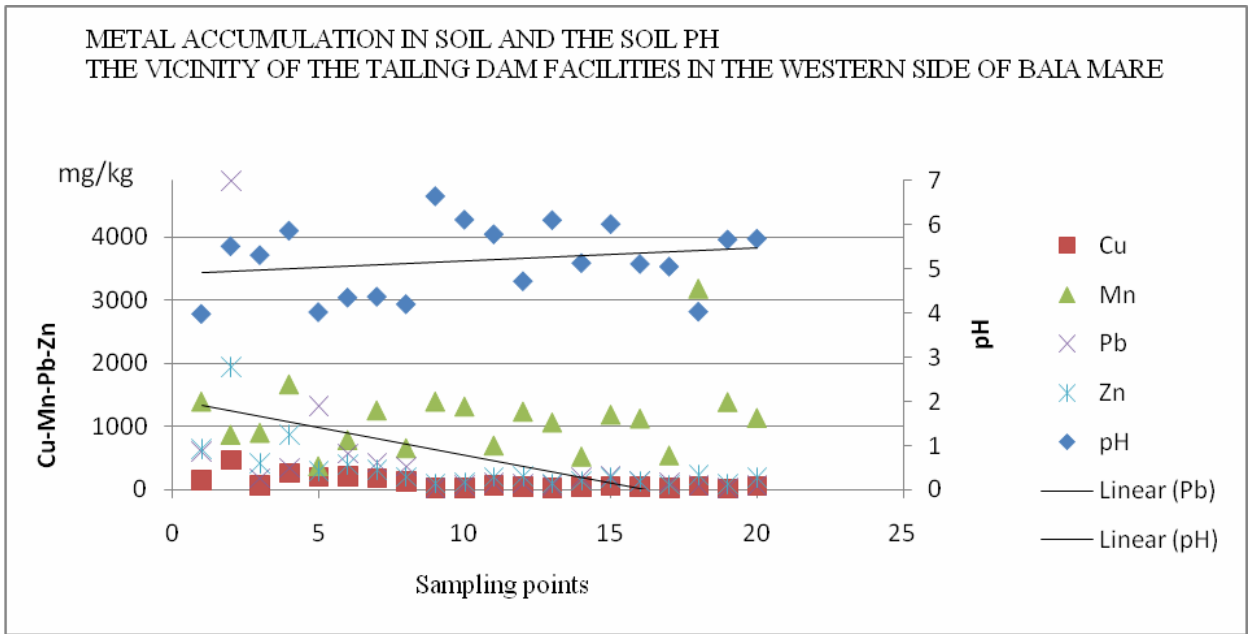

Figure 3. pH variation and metal accumulation in the soils in the vicinity of the tailing dam facilities in the Western area of Baia Mare

3. Risk assessment

The analysed tailing dam facilities have in their content plenty of sulphides and the important quantities of mineral sulphides are exposed in the tailing dams to the action of the oxygen and other meteorological and natural factors (humidity, rain, snow, UV radiations, etc.) [8].

The localization of the tailing dam facilities in the analysed area determines a growth of the area's susceptibility, by being exposed to the pollution generated due to the action of the meteorological factors (by pluvial erosion, leakages, wind erosion and air masses movement) of several particles on the surface of the tailing dams and depositing them in the vicinity [17].

The acid drainage in the tailing dam facilities provokes the pollution of environmental factors in the vicinity and even the transport and migration of pollutants on long distances [2]. There also exists the possibility of landslides of the dam embankments which can lead to the damage of the terrain in the vicinity, modification of water flows in the vicinity and biodiversity damage in the area and in the vicinity.

The conceptual site model regarding the hazards and risks induced by the tailing dam facilities is presented in fig. 4.

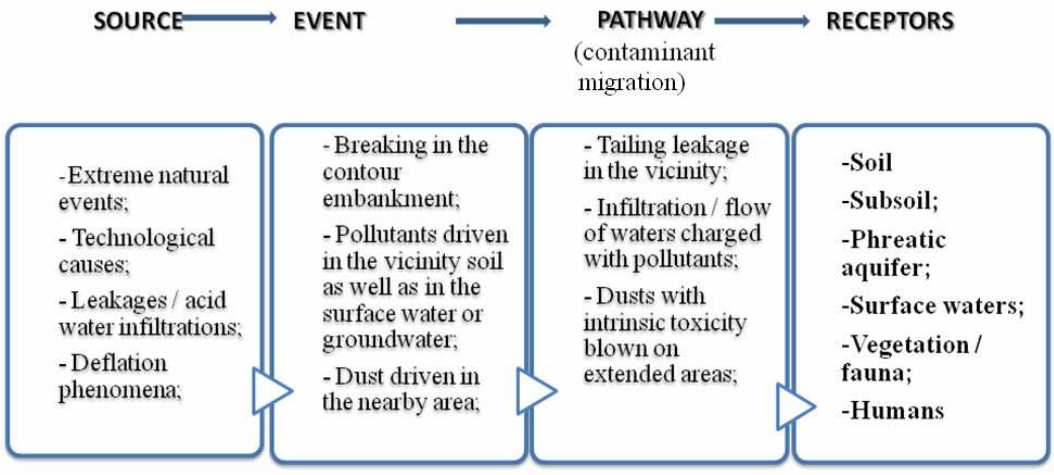

Figure 4. The conceptual site model of the hazards and risks induced by the tailing dam facilities

The damages triggered by an eventual accident at the tailing dam facilities in the analysed area are: pollution of the environmental factors, (soil, subsoil, phreatic water and surface water, terrestrial and aquatic biocoenosis). The human community is less probable to be directly affected due to the sufficiently large distance between the tailing dams and the closest houses, but it would be for sure indirectly affected due to the pollution of the environmental factors and contaminant transport on distances of several kilometres.

The example of the accident that took place at the Aurul tailing dam in 2000 is an unfortunate benchmark in this issue, during the accident the contaminant migration having also a trans-frontier impact.

Trans-frontier pollutions due to the accidents at the mining waste facilities cause for the owner company together with the inherent costs also prejudices related to their reputation, in the communities from the affected countries, also having an impact on the general image of the mining industry which is therefore perceived as an industry that generates a global pollution..

The risks generated by the tailing dam facilities are not just due to some accidents related to the physical stability, with such high and extended consequences.

Acid drainage and its leakage in the vicinity as well as the infiltration by deflation phenomena (wind) of dusts with hazardous pollutant for the environment and human health content towards the nearby areas represent risks with a very high probability of occurrence.

Therefore even though the gravity of them to occur is not that high, because of the high probability of occurrence this type of risks can be treated as major risks. The consequences of accumulation with time of the pollutants in the soil and water in the vicinity, bioaccumulation of pollutants in the vegetal tissues, their transport to other species through the food chain generates unwanted consequences both on the environmental factors as well as for the people, respectively for human health, due to their hazardous and toxic character [10].

The risks on the human health generated by the waters that have a high content of pollutants that leak from the dams or because of the dusts with a high content of hazardous substances, are mostly generated by the existence of some cultivated lands in the vicinity of the tailing dam facilities (at distances below 1000 m) as well as the infiltration of pollutants in the phreatic aquifer [7, 4], being known the fact that part of the inhabitants in the villages in the vicinity use drinking water from the wells that are supplied from the phreatic aquifer.

The measures needed in order to diminish the risks for the tailing dam facilities consist in the first place of a correct monitoring and as complete as possible of their behaviour during time. Correct and rapid interpretation of the monitoring data is the basic element in the process of decision making in order to reduce the risks [15]. The European document BREF (2004) for mining waste management and the Romanian legislation in order, also require a monitoring program of the waste facilities for a period of minimum 30 years after their closure [14].

The monitoring actions of the physical stability are done with corresponding geodesic benchmarks. The chemical stability is monitored on the basis of the chemical analyses of the samples taken on certain time periods. The acid waters from the tailing dam facilities can be treated by passive methods that assure their neutralisation and heavy metal precipitation, respectively taking them into insoluble states in natural conditions [11].

A complete monitoring program of the tailing dam facilities includes both the measures taken for the environment and human health protection as well as measures to reduce the hazards and risks on the site to an acceptable level.

4. Conclusions

The presence of the tailing dam facilities in the analysed area generates risks with consequences on the environmental factors (soil, subsoil, phreatic water and surface water, biodiversity), but also for human health. It mainly focuses on the population that has agricultural lands in the vicinity of the tailing dams, respectively the population that uses as drinking water source the water in the phreatic aquifer.

The risks generated by the tailing dam facilities can be due to the loss of their physical stability (collapse), accidents with major consequences, both as spatial dimension as well as generated pollution and consequences for the biocoenosis. The movement of the fine dusts with pollutant content on the tailing dams by deflation phenomena and the transport of pollutants by the meteoric waters towards the nearby areas are also risk generating, with low gravity but with possible major consequences. Reduction of risks generated by the tailing dam facilities is based on a correct monitoring of them, both from the point of view of the physical stability as well as from the point of view of the chemical stability (acid water drainage).

References

[1] Baciu C., D. Costin, 2008, Geologie ambientală, Casa Cărții de Știință, Cluj-Napoca

[2] Banks D, P.L. Younger, R.T. Arnesen, E.R. Iversen, S.B. Banks, 1997, Mine-water chemistry: the good, the bad and the ugly. Environ Geol 32, 157 – 174

[3] Bălănescu S., V. Achim, A. Ciolte, 2002, Istoria conducerii mineritului, a metalurgiei neferoase prețioase din Nord-Vestul României, Ed. Gutinul, Baia Mare

[4] Benciu F., 2007, Poluarea cu metale grele, Editura Didactică și Pedagogică R.A. București

[5] Bird G., M.G. Macklin, P.A. Brewer, S. Zaharia, D. Bălteanu, B. Driga, M. Serban, 2009, Heavy metals in potable groundwater of mining-affected river catchments, northwestern Romania, Environ Geochem Health 31, 741 – 758

[6] Florea I., 1996, Stabilitatea iazurilor de decantare, Ed. Tehnică, București

[7] Frențiu T., S.N. Vlad, M. Ponta, C. Baciu, I. Kasler, E. Cordos, 2007, Profile distribution of As (III) and As (V) species in soil and groundwater in Bozânta Area, Chem. Pap. 61(3), 186 - 193

[8] Lottermoser B.G., 2007, Mine Wastes: Characterization, Treatment, Environmental Impacts, Second Edition, Springer Verlag Berlin Heidelberg

[9] Modoi O.C., 2010, Managementul integrat al deșeurilor rezultate din valorificarea minereurilor asociate provinciei metalogenetice Baia Mare – teză de doctorat

[10] Saniz A., J.A. Grande, and M.L. Torre, 2003, "Odiel River, Acid Mine Drainage and Current Characterization by Means of Univariate Analysis." Environment International 29, 51 - 59

[11] Younger P.L., 2004, Wetland treatment of mine waters, Newcastle University, Department of Civil Engineering, UK, Groundwater Management in Mining Areas, Proceedings of the 2nd image-train, Advanced Study Course, Pécs, Hungary, 72 – 101

[12] ***, Australian Government, 2007 Department of Industry, Tourism and Resources – Managing Acide and Metalliferous Drainage

[13] ***, 2001 – 2009, APM Maramureș, Rapoarte de monitorizare anii

[14] ***, 2004, BREF Reference Document of Best Available Techiniques for Management of Tailing and Waste-Rock in Mining Activities, 2004). Edificio Expo, Sevilla Spain

[15] ***, 2001, BRGM, Management of mining, Quarrying and Ore-Processing Waste in the European Union

[16] ***, 2000, UNEP Report, Cyanide spill at Baia Mare, România, Geneva

[17] ***, 2010, US EPA, http://yosemite.epa.gov