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THE EFFECTS OF ACID MINE DRAINAGE UPON VEGETATION IN THE BOZANTA TAILINGS POND (MARAMUREŞ COUNTY)

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ABSTRACT. Owing to the procedures of processing non-ferrous ores, from Baia Mare mining district, containing Au, Ag, Cu, Pb and Zn, resulted large amounts of flotation tailings, which were deposited in Bozânta tailings pond (located between the villages Săsar and Bozânta Mare, 4 km west of Baia Mare town). Due to the presence of minerals containing metal sulphides (mainly pyrite), the acid rock drainage (ARD) has become very active, catalyzed by iron- and sulphur-oxidizing bacteria, especially those of the genus *Acidithiobacillus ferrooxidans*, *Leptospirillum ferrooxidans*, *Acidithiobacillus thiooxidans*, *Thiomonas intermedia* and *Starkeya novella*, which naturally occur in these sites. Bacterial oxidation of these minerals leads to the production of acid rock drainage, contaminating the environment with heavy metals. In this study we investigated the effects of ARD on the tailings, but also on plantations of acacia (*Robinia pseudoacacia*) from sector 5 (were the tailings was not covered with soil) compared to sectors 1-4 (where the tailings were covered with soil). On the surface of the tailings pond, in sector 5, a non-homogeneous appearance of the flotation tailings can be noticed, with different oxidation stages; landslides; ravines up to 100 cm deep; driftings of tailings and seepage solutions areas. Dependent on the age of the tailings, and the action time of the ARD phenomena, the pH value decreased from 7.7 to 2.9. The decrease in pH below 5 caused the vegetation to die. When additional countermeasures of covering with soil the tailings were taken in the sectors 1-4 of the tailings pond, the effects of the ARD phenomena were diminished and helped vegetation flourish.

Key words: *tailings pond, flotation tailings, ARD, A. ferrooxidans.*

INTRODUCTION

Baia Mare Mining Basin is a significant example of anthropical pollution caused by the mining activities and ore processing (Mihali et al., 2013; Roba et al., 2015a; 2015b). Here are deposited non-ferrous minerals (Cu, Pb, Zn, Au, Ag etc.) on an area of approximately 122 km2, in the counties of Maramures, Satu Mare and Bistrita-Năsăud.

As a result of the activities of mining and mineral processing to obtain useful mineral elements, 250 mine tailings (volume ~5.7 mil. m^3) and 26 flotation tailing ponds (152 mil. tonnes with a surface of ~592 ha) resulted. The dumps are located on the slopes of the mountains, at elevations between 300 and 1800 m, having direct polluting influence on the system/network basins; ponds are located near ore preparation plants, a short distance from human communities (NAEP, 2007).

Under the catalysts influence of iron- and sulfur-oxidizing bacteria, naturally present in the tailings of these deposits, triggered physical and chemical transformations were triggered. The transformations are known as bacterial leaching, acid mine drainage - AMD, or acid rock drainage - ARD (Bond et al., 2000).

In tailing ponds and mine waste dumps, bacterial leaching - the biooxidation of metal sulfides (especially pyrite) to soluble metal sulfates and sulfuric acid, is done mainly by three species of mesoacidophilic, chemolithotrophic bacteria: *Acidithiobacillus ferrooxidans*, *Acidithiobacillus thiooxidans*, and *Leptospirillum ferrooxidans* (Schippers and Sand, 1999). *A. ferrooxidans* oxidizes reduced sulfur compounds to sulfate and iron(II) to iron(III) ions, *A. thiooxidans* is able to oxidize only reduced sulfur compounds, where as *L. ferrooxidans* can oxidize only iron(II) ions (Sand et al., 1995; Garrity et al., 2005). *Starkeya novella* and *Thiomonas intermedia* are all sulfur-oxidizing bacteria, but *S.novella* is a facultatively chemolithoautotrophic and methylotrophic bacterium (Kelly et al., 2000) and *T.intermedia* is an moderately acidophilic, facultatively heterotrophic bacterium, exhibited the capability to use terationate under oxic and anoxic conditions (Wentzien and Sand, 1999; 2004).

Natural phenomena of ARD are characteristic since all deposits of tailings (mining and flotation) resulting from the exploitation of non-ferrous minerals (Jelea, 2014). They place over decades and alter environmental factors in the long term, causing serious ecological imbalances (Schippers et al., 2000; Jelea et al., 2007).

The aim of the present research was: highlighting ARD phenomena (bacterial biocatalyzed) in the tailing on Bozanta pond terraces and the effects on vegetation.

MATERIALS AND METHODS

Bozânta tailings pond site

Bozânta, Săsar and Transgold ponds (for example Aurul) can be found between Săsar and Bozânta Mare villages, north of the confluence of Săsar Creek with Lapus River, at a distance of 4 km west of Baia Mare (Modoi et al., 2010).

The Săsar Pond secured the storage of flotation tailings from the Săsar Processing Plant, resulted from gold cyanidation processing of the ore extracted from the Săsar Mine in the period of 1970-1975.

The Transgold Pond contains flotation tailings resulted from gold cyanidation processing from Meda Pond, processed and stored in the period of 2000-2005.

The Bozânta Pond functioned between 1976 and 2007. The pond has a surface of 105 ha (120 ha with annexes). The pond is built in four terraces by depositing tailings from the base inwardly by upstream method - whereby the embankment crest moves progressively upstream.

It has a maximum height between 22 to 31 m.

The area is divided into 11 sectors (figure 1):

- In the 1976-1980 period, in all sectors (S 1-11) was deposited tailings coming from U.P. Central Flotation Plant, resulting from Cu, Pb, Zn ore processing; the tailings forms Terrace 1, at the bottom of the pond;

- Sectors S 1-4 continued the deposition of tailings from UP Central Flotation Plant until the closure of the pond in 2007;

- In Sectors S 5-11 tailings from Sasar Flotation Plant have been deposited, starting with 1980.

In 1980, in terrace T_1 - at the bottom of the pond, in all sectors (S 1-11) was set up a plantation of acacia (*Robinia pseudoacacia*) by planting holes with topsoil; the tailing surface from sectors S 1-4 was coated with a layer of 5-10 cm of topsoil.

In sectors S 1-4 terrace T_2 (with Central Flotation UP tailings) in 1985, they continued planting acacia and continued covering the area with topsoil. On the upper terraces T_3 and T_4, they made no vegetation plantations.

In the same year, 1985, in the west of sector S 5 on terrace T_2 (with UP Săsar tailings) they planted ornamental species of ornamental acacia, *Robinia hispida*, and in the eastern half and in the sectors S 6-11, *R. pseudoacacia* without topsoil cover. In 1994, on the terrace T_3 acacia trees were planted directly into stailings without covering the surface with topsoil. On the terrace T_4, there was no vegetation planting.

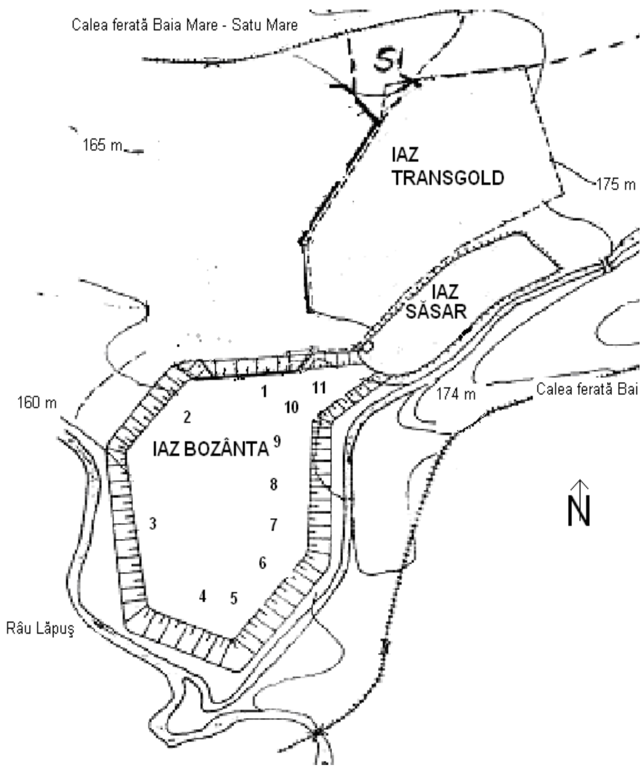

Fig.1. *Bozânta, Săsar and Transgold ponds, site.*

Field observations

Field observations were made using comparison on the sectors of the terraces S4 and S5 from August to November 2013 in order to analyse the vegetation status and the degree of tailings alteration.

The degree of tailing alteration is judged by its color: the tailings that is deposited relatively recent and that is not altered has a gray colour; as the ARD phenomena intensifies, tailings turns yellow (due to sulfur oxidation and the formation of sulfuric acid), fawn (due to the start of the processes of oxidation of iron in pyrite) or bright red (when the iron oxidation is highly active and runs over a long period of time).

Tailings sampling

20 samples of tailings were taken at half the width of each terraces and 5 samples from the pond (10 m inboard from the top) from the 4 terraces T_1-T_4 of the sector S5 (5 average samples up to a depth of 25 cm) in September of 2013.

Analysis

Were analyzed humidity and pH samples of tailings (the aqueous extract 1/5, solid:water w/v).

For iron and sulphur-oxidizing bacteria, to quantify cell numbers, use the most-probable number (MPN) technique, in which a series of serial dilutions is made in selective liquid media: *Acidithiobacillus ferrooxidans* and *Leptospirillum ferrooxidans* - Mackintosh medium (Mackintosh, 1978); *Acidithiobacillus thiooxidans* - Hutchinson medium (Hutchinson et al., 1965); *Thiomonas intermedia* and *Starkeya novella* was aerobically grown in a culture medium, containing thiosulphate (Matin and Rittenberg, 1971).

RESULTS AND DISCUSSIONS

On the surface of the pond terraces, heterogeneous aspect of the flotation tailings are noticed, with different oxidation stages; landslides; ravines; drifting tailings; areas with solution exfiltrations.

Tailings oxidation, degradation and destruction of vegetation

Tailings beach and the top of the pond (embankment crest)

Following the ceasing of activity in 2007, the mirror of the lake that covered the tailings retreated to the center, resulting in a huge area (figure 2).

Fig. 2. *Tailings beach.*

The winds have blown the tailings that formed the top of the lake scattered in on the lower terraces.

Results are: mirror lake withdrawal, the beach area growth and the absence of the scattering of fine tailing particles at a considerable distance. They often end up in neighbouring towns, especially in the two villages, as a result of prevailing winds in NE-SW direction.

In the absence of the mirror lake, the tailings from beach surface is subject to the process of acid rock drainage. Being a process that is performed in the presence of aerobic bacteria, the process is more active in the superficial layers:

- in the 0-5 cm layer the pH of the tailings are 4.5; the number of the sulfoxide neutrophil bacteria *Thiomonas intermedia* and *Starkeya novella*, that initiates the oxidative processes (from slightly alkaline pH to 4) is 10^7 bact./g, as *A.thiooxidans* (which is active in the pH range from 1 to 7); ironoxidizing bacteria of the *A. ferrooxidans* type, which require a more acidic pH (2-3) can be found in the number of 10^6 bact. /g;

- the tailings from layers between 5-25 cm, with pH from 6.8 to 7.9, is particularly found under the action of the sulfoxidante species: sulfoxide neutrophil species are a number of 10^4, while *A.thiooxidans* is between 10^5 in the layers 5-15 cm and 10^3 in the layers 15-25 cm. Given the unfavourable pH, *A.ferrooxidans* species was present with values between 93 and 10^3 bact./g.

On the surface of the beach area, it is not observed the presence of plant species that appeared spontaneously.

S4 sector

The acacia trees in terrace T_1, planted more than 30 years ago, are vigorous and show no signs of depreciation of their condition. The grassy vegetation appeared spontaneously and developed normally. Spontaneously, on this terrace, three species of wood were also installed: one species of tree - turkey oak (*Quercus cerris*); a shrub - wild rose (*Rosa canina*) and dewberry (*Rubus caesius*).

On the terrace T_2, alongside the acacia, tree five species of wood installed: four species of trees - tatarian maple (*Acer tataricum*), black poplar (*Populus nigra*), oak (*Quercus robur*), willow (*Salix pentandra*) and dewberry.

On the upper terraces, T_3 and T_4, where no vegetation planting or topsoil coating, ravines were formed, sometimes more than 150 cm deep (figure 3) and drifting tailings are common. On the basis of the terrace T_3, strong exfiltrations can be noticed.

The yellow-red colour of the tailings, and also the presence of the reed clumps (*Phragmites communis*), plants which living in excessive humidity, is due to the presence of a high and permanent humidity on the surface of the tailings, due to some preferential exfiltrations of solutions from the lake in the middle of the pond to the surface of the terraces.

The phenomenon is a reason of concern because the exfiltration solutions in the lake start and maintain the processes of acid mine drainage in the terraces of the pond, causing damage in their stability, which can cause landslides of surfaces or dam breaking, unless appropriate measures are taken to fix the problem by draining the solutions in the pond.

On the terraces T_3 and T_4, right under the superficial layer, the colour of the tailing is red, as a result of intense phenomena of chemical and bacterial oxidation.

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Fig. 3. *Ravines on terraces T_3.*

On the terraces T_3 and T_4, right under the superficial layer, the colour of the tailing is red, as a result of intense phenomena of chemical and bacterial oxidation.

S5 sector

In the sector S5, where the surface of the tailings was not covered with soil, different degrees of degradation phenomena manifestation of tailings and vegetation can be observed.

On the terrace T_1 with adult acacia trees, aged over 30 years, it can be noticed the drying of ~ 80% of the trees planted, while for the remaining trees the degradation is manifested by dry twigs at the base of the stems or the more advanced stages such as the drying branches at the peaks.

Spontaneously, several pieces of birch (*Betula pendula*) appeared, this species being acidophile. The grassy vegetation is underrepresented and dries in summer.

On the surface of the terrace the runoff formed deep ravines from a few centimeters to 100 cm (figure 4), transporting tailings to the bottom of the pond, in the guard ditch, covering it. Here the reed grew in abundance, which prevents the collection and the disposal of the solutions. The solutions, acid and heavy metal, cross the auxiliary road around the pond, affecting the vegetation in the vicinity.

Although the tailings are oxidized completely, and the solutions are very acid, the adult woody plants from the base of the terrace survive if some of the roots develop in the layer of embankment dam of the belt (starter dike) (figure 5).

The vegetation in the upper area of the terrace was destroyed due to the thick layer of oxidized tailings where the roots are mainly found.

The grassy vegetation grows in spring from seeds spread by wind, but quickly disappears as a result of chemical conditions, of tailings slides under the influence of rainwater and because of the wind or of the lack of moisture. The tailings layer, with a sandy texture, cannot hold water. Strong insolation and rising temperatures lead to rapid elimination of the humidity in the superficial layer.

Fig. 4. *Ravines on T_1 terrace.*

Fig. 5*. The layer of embankment dam of the belt (starter dike).*

On the terrace T_2 in the ornamental acacia trees area, the majority of the shrubs disappeared, resisting only a few specimens (figure 6). Also, the trees of acacia are almost dried totally. The drying of the green vegetation and of the trees on the upper terrace surfaces T_2 is the result of massive mobilization of tailings from the upper terraces T_3 and T_4 caused by wind and rain in the spring and fall.

Fig. 6. *The ornamental acacia in T_2 terrace.*

The ravines have dimensions that reach 30-40 cm. The tailings are oxidized, reddish.

On the terrace T_3 where acacia trees were planted directly into the tailings dumps without the application of topsoil on the surface, the green vegetation is missing and the trees are mostly dry; the plants still living show obvious signs of drying branches and shoots (figure 7).

Fig. 7. *T_3 terrace.*

The tailings is oxidized and the superficial layer is always swept away by the wind or driven by the runoff waters.

On this terrace, numerous ravines are present, caused by rainwater runoff from the upper terrace. The erosion phenomena caused numerous landslides of the tailings, leading to its destruction of vegetation.

On the terrace T_4, there was no acacia planting.

Terrace T_4 offers particularly arid conditions as a result of intense solar exposure and as a result of hydraulic erosion and permanent wind erosion.

Completely isolated, there were shown a herb - twitch (*Agropyron repens*) and several pieces of birch that appeared spontaneously.

The results of physical tests

The physical test results are shown in table 1.

The tailings have higher moisture in the beach (between 8 and 22%) than in the terraces (2-16%). The higher moisture in tailings on the beach is due to the lake from the centre of the pond.

The lowest moisture is in terrace 4 (containing un-oxidized tailings).

Oxidized tailings (terraces 1-3) are fine-grained and retain water better.

Table 1. *The pH values and the moisture contents of the samples*

Areas	Samples	Depth of sampling (cm)	The moisture of samples (%)	pH
Tailings beach	1	0-5	15.8	4.45
	2	5-10	22.8	3.65
	3	10-15	8.2	6.77
	4	15-20	10.3	6.96
	5	20-25	8.0	7.95
Terrace 4	6	0-5	1.9	7.36
	7	5-10	3.5	7.50
	8	10-15	4.3	7.45
	19	15-20	5.2	7.50
	10	20-25	6.7	7.71
Terrace 3	11	0-5	14.0	2.88
	12	5-10	10.2	3.63
	13	10-15	9.5	3.66
	14	15-20	11.2	3.63
	15	20-25	8.9	3.76
Terrace 2	16	0-5	9.1	3.59
	17	5-10	11.2	3.67
	18	10-15	13.0	3.59
	19	15-20	15.0	3.54
	20	20-25	16.5	3.79
Terrtace 1	21	0-5	6.8	3.06
	22	5-10	8.6	3.74
	23	10-15	8.8	3.93
	24	15-20	12.3	4.91
	25	20-25	12.3	4.90

The pH has acid values in the samples taken from the terraces with the oldest tailings.

In the old terraces (1-3) longer ARD processes were held.

As ARD processes are aerobic, the oxidized samples are in the surface layers (tailings beach and terraces 1-3).

The results of microbiological analysis

The microbiological test results are shown in table 2.

Microbiological test results from samples taken from the tailings beach illustrate the most relevant mechanism of a continuous ARD process, having passed through the first stage, initiation of the process.

T. intermedia and *S. novella*, which firstly install as a result of an initial neutral or alkaline pH, are present in the 0-5 cm layer in very large numbers: 1.1 x 10^7 bact./g tailings. Their number is 10^5 bact./g tailings in the 5-10 cm layer and drops to 10^4 bact./g in the tailings from the layer 10-25 cm, but remain numerically dominant, in relation to other species.

Table 2. *The MPN values of the samples*

Areas	Samples	Depth of sampling (cm)	MPN/g		
			A. ferroox. *L. ferroox.*	*A. thioox.*	*T. int.* *S. nov.*
Tailings beach	1	0-5	1.5×10^6	1.1×10^7	1.1×10^7
	2	5-10	1.1×10^7	1.5×10^5	2.3×10^5
	3	10-15	1.5×10^3	2.3×10^5	4.3×10^4
	4	15-20	4.3×10^2	2.3×10^3	1.5×10^4
	5	20-25	93	4.3×10^3	4.3×10^4
Terrace 4	6	0-5	0	2.3×10^3	1.5×10^4
	7	5-10	0	2.3×10^3	4.3×10^4
	8	10-15	0	1.2×10^3	9.3×10^4
	9	15-20	0	2.3×10^3	2.3×10^5
	10	20-25	0	3.6	7.5×10^4
Terrace 3	11	0-5	2.3×10^5	1.5×10^4	4.3×10^2
	12	5-10	9.3×10^2	9.3×10^2	9.3×10^2
	13	10-15	1.5×10^3	9.3×10^2	4.3×10^2
	14	15-20	2.3×10^2	2.3×10^3	2.3×10^2
	15	20-25	9.3	23	3
Terrace 2	16	0-5	9.3×10^2	4.3×10^4	3.9×10^2
	17	5-10	2.3×10^2	4.3×10^2	93
	18	10-15	2.3×10^2	4.3×10^2	9.3×10^2
	19	15-20	43	1.5×10^3	43
	20	20-25	4.3×10^2	2.3×10^3	4.3×10^3
Terrace 1	21	0-5	43	9.3×10^3	0
	22	5-10	9.3×10^2	2.1×10^3	2.3×10^3
	23	10-15	2.3×10^4	3.9×10^3	23
	24	15-20	3.6	4.3×10^4	1.6×10^3
	25	20-25	23	4.3×10^4	1.2×10^4

Sulfur-oxidizing bacteria *A. thiooxidans*, which has a pH which varies from neutral or slightly alkaline to strongly acid, is found in huge numbers, 1.1×10^7 bact./g in 0-5 cm and 5-15 cm layers, with 10^5 bact./g. In samples from 15-20 cm and 20-25 cm, their numbers are 10^3 bact./g.

Iron-oxidizing species *A. ferrooxidans* and *L. ferrooxidans*, are also present in large numbers in the first two layers: 1.5×10^6 bact./g in the 0-5 cm layer and 1.1×10^7 bact./g in the 5-10 cm layer.

In the case of these two species, which prefers an acidic pH environment, their number increases as the pH decrease - in this case, from the first layer of 4.45 to 3.56 in the second.

With increasing depth, pH values above 6, their numbers are decreasing at 10^3, 10^2 and 93 bact./g, in the 20-25 cm layer, where the pH is around 8. In this layer with alkaline pH, both species survive, though it is possible that their metabolic activity is reduced. It is possible that, during heavy rains, acidic solutions resulting from metabolic activities of sulfur-oxidizing bacteria in the upper layers would provide conditions of survival for them.

In T_4 terrace, where the most recent tailings is stored (2006-2007) in relation to the terraces 1-3, bacteria belonging to the thiosulphate oxidizing species (*T. intermeia* and *S. novella*) are dominant numerically: 10^4 and 10^5 bact./g tailings.

Sulfur-oxidizing species *A. thiooxidans* is present: 10^3/g of bact./g tailings.

Taking into consideration that the value of pH over 7 (7.3-7.7) of sterile samples, in the samples on the terrace were not isolated the two iron-oxidizing species, A. ferrooxidans and L. ferrooxidans, whose optimum pH is 1.8-2.2.

The tailings from this terrace can be found in the first stage of initiation of the ARD process, which is characterized by the following features: alkaline values of pH, the presence of sulfur-oxidizing bacteria - especially thiosulphate-oxidizing, absence of iron-oxidizing bacteria, as well as the appearance of the samples.

In tailings samples from the terrace T_3, showing values of acidic pH (2.88-3.76), the number of thiosulphate-oxidizing species (*T. intermedia* and *S. novella*), is smaller, 10^2 bact./g tailings compared to the terrace T_4.

Sulfur-oxidizing bacteria of the genus *A. thiooxidans* are more numerous, 10^4 bact./g, in the 0-5 cm layer, while other samples are 10^2 bact./g tailings.

Iron-oxidizing bacteria *A. ferrooxidans* and *L. ferrooxidans*, are dominant in the 0-5 cm layer, with 10^5 bact./g, while in greater depth the number drops to 10^2 bact./g tailings.

The tailings this terrace presents iron- and sulfur-oxidizing bacteria species perform metabolic activities of bioleaching of sulfides (mainly pyrite), having the effect of lowering the pH and the oxidation of iron. As a result of those processes, the number of thiosulphate-oxidizing bacteria decreases, and the tailings acquires a reddish-intense color, especially in tailings with a pH of 3, due to the precipitation of $Fe^{3+.}$

The terrace T_2, with pH samples that range between 3.6-3.8, presents ARD processes which take place under the influence of sulfur-oxidizing bacteria *A.thiooxidans* present in all samples, with values between 10^4 bact/g tailings in the top layer and 10^2-10^3 bact/g in others.

Iron-oxidizing bacteria of the species, *A. ferrooxidans* and *L ferrooxidans*, are present at the value of 10^2 bact./g tailings.

Regarding thiosulphate-oxidizing species*, T. intermeia* and *S. novella*, their presence is heterogeneous: alternating layers with values of 10^2-10^4 in the number of bacteria, with numbers below 100 bact./g tailings.

The existence of heterogeneous numerical variations of thiosulphate-oxidizing bacteria, may be due to acidic pH or maybe even because of running out of nutritional or energy sources or appropriate for this group.

T_1 terrace presents a vertical heterogeneity in the number of thiosulphate-oxidizing bacteria *T. intermedia* and *S. novella*: alternating layers with a number of very different bacteria. The largest number is present in the 15-20 cm layer and 20-25 cm layer, with 10^3, 10^4 bact./g tailings, while in others the number is very small.

Sulfur-oxidizing bacteria *A. thiooxidans* are present in all samples, the largest number being in the samples 15-20 cm and 20-25 cm, 10^4 bact./g.

The number of bacteria of the species *A. ferrooxidans* and *L. ferrooxidans* is very different in layers: layers alternating with a number under 100 bact./g tailings with values reaching 10^2 or 10^4 bact./g tailings.

The tailings from this terrace has a pH value of 3-4 in surface layers (0-15 cm) and 5 in deeper layers (15-25 cm). Analyzing the pH values and the number of bacteria there, at first glance, there is a tendance to associate the phenomena of ARD from the terraces T_2 and T_1.

However, it is possible, taking into account the age of the tailings from the terrace T1, as in this case, the processes of AMD can be found in a very advanced stage, due to running out of the main energy sources for iron- and sulfur-oxidizing bacteria: pyrite.

This hypothesis is based on theoretical knowledge concerning the metabolic activity and the evolution of the number of bacteria in this type of tailings. Confirmation of this hypothesis may be achieved only by chemical and geological analysis and the identification of pyrite in tailings samples.

However, it should be taken into account the presence of other factors which intervened at this stage:

- the substrate consisting of rocks and soil with alkaline pH which were used for the realization of the starter dyke;
- the presence of organic substances derived from the degradation of foliar mass with effects of inhibition of the metabolism of iron- and sulfur-oxidizing, chemolithoautotrophic bacteria;
- "washing" the superficial layers of the initial tailings by water drained from the upper terraces;
- tailings transport, in varying degrees of oxidation, on the upper steps, either by waters or either by wind.

CONCLUSIONS

Depending on the length of tailings depositing, and the time of action of ARD phenomena, the pH value decreased from 7.7 (in the 'fresh' tailings, stored in the period 2001-2007) to 2.9 (in deposited tailings pond at the base of ~ 35 years ago).

The decrease in pH below 5 led to the death of vegetation (*Robinia pseudoacacia* plantation).

Lowering the pH and the death of the vegetation show that only the tree planting measure is not effective to stop the ARD phenomena, in S5.

Additional countermeasures (soil cover or organic material) taken on sectors 1 to 4 of the pond decreased the ARD phenomena.

REFERENCES

Garrity, G.M. (Ed in chief), Brenner, D.J., Kreig, N.R., Staley, J.T. 2005. *Bergey's Mannual of Systematic Bacteriology*, 2nd Edition, Vol. 2: The Proteobacteria, Part A: Introductory Essays, Springer, Berlin.

Hutchinson, M., Jonstone, K.J., White, D. 1965. The taxonomy of certain thiobacilli. *J. Gen. Microbiol.*, **41**, pp.357-366.

Jelea M., Jelea S.G., Kovacs Zs.M., Gheţa D.E. 2007. Research concerning the oxidation degree of the sulphidic tailings from the Novaţ tailings storage facility. *Carpath. J. Earth Env*., **2**(2), pp.45-55.

Jelea O.C., 2014. Drenajul acid al rocilor şi efectele poluante asupra mediului. *BIO-ME*, **6**, 19-29.

Kelly, D.P., McDnald, I.R., Wood, A.P. 2000. Proposal for the reclassification of *Thiobacillus novellus* as *Starkeya novella* gen. nov., comb. nov., in the alpha-subclass of the *Proteobacteria*. *Int. J. Syst. Evol. Microbiol*., **50**, pp.1797-1802.

Mackintosh, M.E. 1978. Nitrogen fixation by *Thiobacillus ferrooxidans*. *J. Gen. Microbiol.*, 105, pp.215-218.

Matin, A., Rittenberg, S.C. 1971. Enzymes of carbohydrate metabolism in *Thiobacillus* species. *Journal of Bacteriology*, **107**(1), pp.179-186.

Mihali C., Oprea, G., Michnea, A., Jelea, S.G., Jelea, M., Man, C., Şenilă, M., Grigor, L., 2013. Assessment of Heavy Metals Content and Pollution Level in Soil and Plants in Baia Mare Area, NW Romania. Carpathian Journal of Earth and Environmental Sciences, **8**(2), pp.143-152.

Modoi, O.C., Ozunu, Al., Stezar, I.C. 2010. Risks Associated to Soil Pollution in the Proximity of Tailing Facilities in the Western Area of Baia Mare. *ProEnvironment*, **3**, pp.352-358.

Roba, C., Rosu, C., Piştea, I., Baciu, C., Costin, D., Ozunu, A. 2015a. Transfer of heavy metals from soil to vegetables in a mining / smelting influenced area (Baia Mare - Ferneziu, Romania), *Journal of Environmental Protection and Ecology*, 16(3), pp.891-898.

Roba, C., Roşu, C., Piştea, I., Ozunu, A., Baciu, C. 2015b. Heavy metal content in vegetables and fruits cultivated in Baia Mare mining area (Romania) and health risk assessment. *Environmental Science and Pollution Research*; 1-12, JUN. 2015. (on line).

Sand, W., Gehrke, T., Hallmann, R., Schippers, A. 1995. Sulfur chemistry, biofilm, and the (in)direct attack mechanism - a critical evaluation of bacterial leaching. *Appl. Microbiol. Biotechnol*., **43**, pp.961-966.

Schippers, A., Jozsa, P-G., Sand, W., Kovacs, Zs.M., Jelea, M. 2000. Microbiological Pyrite oxidation in a Mine Tailings heap Its Relevance to the Death of Vegetation. *Geomicrobiology Journal*, **17**(2), pp.151-162.

Schippers A., Sand W., 1999, Bacterial Leaching of Metal Sulfides Proceeds by Two Indirect Mechanisms via Thiosulfate or via Polysulfides and Sulfur. *Appl Environ Microbiol.* **65**(1), pp.319-321.

Wentzien S., Sand W., 1999, Polythionate metabolism in *Thiomonas intermedia* K12. 1999. In: *Process Metallurgy*, Vol. 9A; No. Biohydrometallurgy and the Environment toward the Mining of the 21st Century, Pt. A, pp.787-797.

Wentzien S., Sand W., 2004, Tetrathionate Disproportionation by *Thiomonas intermedia* K12. *Engineering in Life Sciences*, **4**(1), pp.25-30.

***National Agency for Environmental Protection (ANPM). 2007. Annual report on the environmental situation in Romania.
http://www.anpm.ro/files2/5%20SOL_20081219742413.doc