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IMPACT OF THE TAILINGS IMPOUNDMENTS ON GROUNDWATER QUALITY IN BOZÂNTA AREA (BAIA MARE – NW ROMANIA) AND HUMAN EXPOSURE

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Abstract: The area of Bozânta tailings management facility, well known after the cyanide spill that occurred in the year 2000, has been evaluated from the point of view of the groundwater quality and the influence of using this resource as a drinking water source on the human exposure. Water samples were collected and analyzed in the laboratory for heavy metals and cyanides. The most intensive pollution has been noticed in the proximity of the TMFs. Notably the old tailings ponds that do not have a geomembrane underneath, seem to release important amounts of pollutants to the groundwater. Modeling of the groundwater flow and transport of contaminants has been performed by using the UnSat Suite and Visual Modflow software packages. Under steady state conditions, the ponds without an impermeable liner will produce long-term pollution of the groundwater and soil. Remediation actions will significantly diminish the transfer of pollutants to the groundwater and gradually reduce the load of contaminants in the shallow aquifer. Data on water consumption and perception of the quality of different water sources were obtained using a questionnaire administered by interviewers to each 29 children aged 7-11 years and 68 adults from Bozânta Mare. It was also investigated the chronic morbidity registered in the locality at the family doctor between 2000 and 2009. Residents of Bozânta Mare still prefer to use the water from their domestic wells for drinking and cooking, at the expense of the supplied water, whose quality is certified and monitored. The perceptions of water quality result from a complex interaction of diverse factors. In many circumstances, the estimation of water quality is mostly influenced by organoleptic properties, flavor in particular. The current general morbidity from chronic diseases for inhabitants of Bozânta Mare locality is not significantly different compared to other localities in the area or at national level. A sustained educational process in the community of Bozânta Mare will make people understand the importance of long term health risks related to the heavy metals contamination, as well as the benefits of safe water consumption.

Key words: groundwater, tailings, pollution, heavy metals, human exposure

1. INTRODUCTION

The mining and post-mining activities, as well as the ore processing industry, pose environmental and health problems to human communities all over the world. The Maramureş County is located in the northwestern part of Romania. The area is rich in gold, silver, lead, copper and salt, and there is a long history of mining and nonferrous metallurgy in the region. According to the standard international practice, waste waters and materials resulted from the extraction and processing of ore are stored in different types of tailings management facilities (TMFs). In 2010 the Environmental Protection Agency of Maramureş County identified 17 tailings ponds, 16 of them being inactive.

In some cases the negative influence of the tailings storage may be seen a very long time even after the entire productive activities stop in that area (Fodor, 2006; Modoi et al., 2010).

A number of studies have shown that the soils of Baia Mare city and its surroundings are polluted by heavy metals, especially in the proximity of smelters and tailings dams (Big et al., 2012, Lăcătuşu et al., 2002a, 2002b), representing in the mean time a significant contamination source for water and vegetables (Big et al., 2012; Lăcătuşu & Lăcătuşu, 2008; Frențiu et al., 2007).

Humans are exposed to heavy metals in different ways, but the bioavailability of metals is central to their toxicity. Some metals accumulate in selective organs and tissues and therefore have potential for chronic toxicity. In this case the past exposure is very important (Caussy et al., 2003, Gurzău E. et al., 2007). Neurological and neurophysiological effects (including behavioral alterations), kidney and reproductive toxicity, teratogenity and carcinogenity remain the main health problems related to heavy metals exposure, the most harmful being lead, cadmium and arsenic. Prevention of chemical toxicity remains a challenge for children exposed to metals, particularly lead, because they are the most susceptible non occupational population group to this type of exposure. Baia Mare city has faced important lead poisoning in children, several studies mentioning the magnitude of the phenomenon, health related effects and the correlations which were found between blood lead level and some behaviors related to hand washing, frequent wet-mopping, eating vegetables from contaminated areas and playing with soil (Verberk et al., 1992, 1996; Gurzău E. et al., 2000, 2007; Gurzău A. et al., 2002).

In a study focused on the distribution of metal contamination in private-supply groundwater in four mining-affected river catchments in Maramureş and Satu Mare Counties, Bird et al. (2009) have mentioned areas of potential concern for human health, where heavy metal concentrations exceed accepted environmental quality guidelines.

Some of the most publicized environmental disasters are associated with the mining industry and are attributed to both natural and anthropogenic related causes. Related to the transboundary impacts of the mining in general, it has been demonstrated that watercourses are the dominant vector as well as the main victim of the mining impact (Peck, 2004). The mining-contaminated sites and the affected communities at risk are important issues on the agenda of both researchers and policy makers, particularly in the former communist block countries in Eastern Europe (Dogaru et al., 2009).

The public health depends importantly on the water pollution prevention. Over 2100 contaminants have been detected in chlorinated drinking water since 1974 with 190 known or suspected to cause adverse health effects (Gurzău A et al., 2010). Realistic exposure estimates of contaminants in drinking water require detailed information on amounts and frequency of drinking water consumption during a day (Barraj, 2009). The volume of cold tap water consumed is an essential element in quantitative toxicological risk assessment.

The present study deals with the chemical quality of groundwater in Bozânta area, close to the tailings impoundments, and the related effects on human health. Three tailings management facilities located between Bozânta Mare and Săsar villages (Maramureş county) are concerned: *Aurul*, *Săsar (Bozânta Veche)*, and *Flotația Centrală*, that were used at different periods of time for storage of the tailings resulted after processing the ore. The study will mainly focus on *Aurul* TMF, where a cyanide spill that took place on 30 January 2000 has produced an ecological disaster. A breach has occurred in the dam encircling the tailings pond, probably due to a combination of factors, such as design defects, unexpected operating conditions, and bad weather (UNEP/OCHA, 2000). About 100,000 m^3 of water containing some 100 tones of cyanides have left the pond, and partly remained in the field around the TMF. The surplus has flown to the Săsar and Lăpuş rivers, moving downstream. The polluted waters eventually reached the Tisa and then the Danube rivers, producing important loss of aquatic biota. It is very likely that locally the shallow aquifer was heavily contaminated with cyanides and heavy metals at that moment. Important lessons have been drawn from this event and from some subsequent, less extended accidents. New regulations in the mining industry, especially regarding the use and management of cyanides, were setup. More effective management systems intended to improve the environmental security, and contribute to the appropriate emergency preparedness, have been designed (Balkau, 2005). However, some of the environmental consequences may be still present in the area.

2. DESCRIPTION OF THE STUDY AREA

Three rivers essentially play roles of natural boundaries of the investigated area. Lăpuş River flows from SE to NW, and receives Săsar River that flows on a NE-SW direction, in the southern part of the area. Băița River, a tributary of Lăpuş River flowing south-westward, is a smaller water course in the NW of the investigated area. The three TMFs, *Aurul, Săsar*, and *Flotația Centrală*, are located on the lowest alluvial terrace of Lăpuş and Săsar Rivers (Fig. 1).

Săsar TMF entered into operation at the beginning of the 1970's, and it is currently kept under conservation. It is extended on about 36 ha, with a total height of approximately 20 m. It has no impermeable liner underneath; just the fine-grained sediments under the topsoil cover may reduce the permeability of the bottom of the deposit. It has a drainage system that secures its structural stability. *Flotația Centrală* TMF is extended on 102 ha and is more than 30 m high. It has no bottom liner, consequently the same permeability issues occur as in the previous case. It has as well a drainage system that secures the structural stability of the tailings deposit. It is currently kept under conservation. A*urul* TMF was built for disposing of the tailings re-worked for extracting the precious metals content (Au and Ag) left into the tailings after the initial processing of the ore. It started to function in 1999. It is currently kept under conservation, and may become functional if the reprocessing of tailings will be restarted. Its area is 93 ha, and its height is between 7 and more than 10 m.

The hydrogeological context is mainly controlled by the shallow geological structure. The general structure of the shallow sediments is the following:

- a layer of soil rich in organic matter, generally more than 1 m thick;
- fine-grained sediments (mixture of clay, silt and sand) about 1.5 – 3.0 m thick. This layer has low permeability, $K \approx 5 \times 10^{-3}$ m/day;
- coarse alluvial sediments, 3.0 to 4.0 m thick, consisting of sands and gravels, with boulders locally, with high permeability, $K \approx 5$ m/day;
- Miocene compact marls, representing the impermeable bed of the shallow aquifer.

The shallow aquifer is contained in the coarse alluvial deposits and it is hydraulically connected to the rivers that border the area, being influenced by them in terms of hydrodynamics and chemical status. The watertable depth varies between 0.5 and 3.0 m.

The construction of *Aurul* TMF includes an isolating system at the bottom of the deposit, consisting of a geomembrane able to protect of pollution the groundwater and soil beneath the pond. The geomembrane is made of high density polyethylene (HDPE), with a general thickness of 0.5 mm, and 1.0 mm under the marginal dams respectively.

Generally, the geomembranes have extremely low permeability; however they are not fully impermeable. For the moment the mechanism by which the water may cross the membrane is not completely clear. It is very likely that the water flow occurs at a molecular level. The hydraulic conductivity K is about 10^{-12} cm/s. For such low values, Darcy's law is not valid anymore, and the hydrogeological modeling that is based on Darcy's law, should consider this peculiarity.

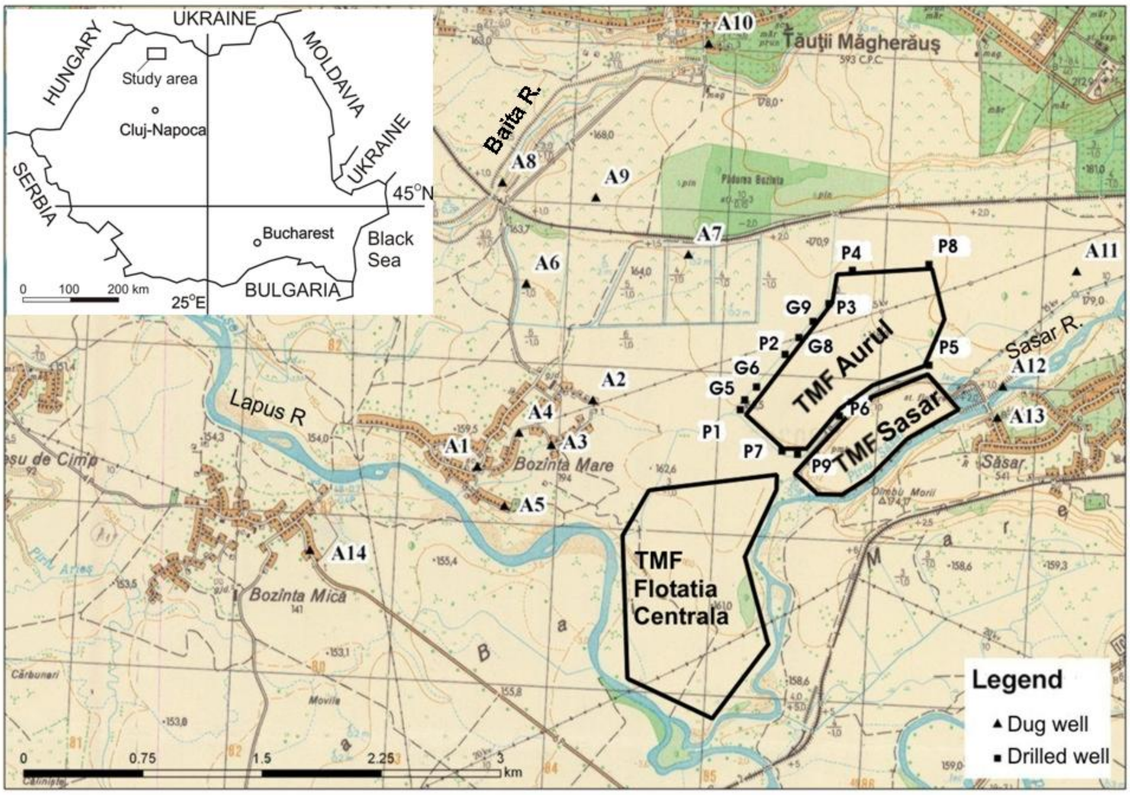

Figure 1. Map of the study area, with the position of the TMFs and of the water sampling points

Usually, this micro-permeability generates negligible flow through the membrane. Sometimes, the membrane may have manufacturing defects, as microscopic perforations, with the diameter smaller than the thickness of the membrane, called *pinholes* (Weber, 2008). The water flow through the membrane is negligible even in this case. If the welding of the sheets has not been well performed, or if the membrane was accidentally punctured during the installment, bigger holes may occur, that will allow the flow of certain water quantities through the membrane. In the case of *Aurul* TMF, there are no arguments for presuming that the membrane would be broken, or that it would have any defects allowing important water flow through it. However, it is very likely to have percolation of very low amounts of water due to the intrinsic permeability of the membrane or to the *pinholes*. The tailings have low permeability; consequently the amount of water that may be transferred to the soil and shallow aquifer would be low.

Bozanta Mare village, now a neighborhood of the town of Tautii Magheraus, is located in the northwestern part of Maramureş County, close to the three TMFs described above and has a population of over 600 inhabitants. The main economic activity of the whole area is agriculture, facilitated by the lands in the area. Some of the inhabitants are working in different sectors, as wood processing, furniture production, and building materials. The village was directly affected by the cyanide spill that took place on 30 January 2000. Consequently to this event which has impacted the quality of groundwater in the area and in the village, the water network of Baia Mare city has been extended to Bozânta Mare and most of the inhabitants have been connected to it.

3. THE RESEARCH METHODOLOGY

The underground dispersion of pollutants was investigated by using two numeric codes. The pollutants migration in the vadose zone was studied by using the VS2D/T module of the WHI *UnSat Suite Plus* 2203 package, produced by Waterloo Hydrogeologic Inc. The flow and transport in the saturated zone was performed by using the *Visual Modflow Professional* 4.3 code, produced by Schlumberger Water Services. The output given by VS2D/T simulation was used as input for the Visual Modflow model. VS2D/T is a bi-dimensional code based on solving the Richard's equation by numerical methods (finite differences). It is able to simulate the water flow and pollutants' transport in steady or transient state, in variably saturated porous media. The Visual Modflow package is intended for modeling the flow and transport in saturated porous media.

The groundwater flow direction was determined by using the Modflow software package. A general NE-SW flow direction can be noticed, with divergent pattern in the NE area, and convergent in the SW extremity. The groundwater table contour lines are marked in figure 2 by blue solid lines. The direction and speed of groundwater is marked by green vectors, perpendicular to the contour lines. The length of the vectors is proportional to the groundwater speed in the specific point. Due to the level fluctuations of the rivers in the heavy rain periods, variations of the watertable level and flow direction of the aquifer may occur. As the permeability of the tailings is low, the ponds will not substantially influence the groundwater flow.

The physical and chemical parameters of the collected groundwater samples were measured in the field (coordinates, pH, and temperature) and in the laboratory (contents of Pb, Cd, As, CN_{tot}). The contents of Pb, Cd, As were measured by atomic absorption spectrometry performed in graphite furnace using a Varian Spectra A110 equipment and the CN_{tot} was analyzed by molecular spectrometry (SR ISO 6703-1/1998) using a SPEKORD 30 device. The results of the analyses against the maximum admissible concentrations specified in the Romanian Law 458/2002 are shown in table 1.

For determination of the relationship between drinking water quality and health status of consumers, the first step of evaluation consists in determining the water consumption habits among the population. Data on water consumption and perception of the quality of different water sources were obtained using a questionnaire. The questionnaire was administered by interviewers to each person apart, the group being represented by 29 children aged 7-11 years and 68 adults from Bozânta Mare, *i.e.* approximately 16% of the total population of the locality. Subjects included in the health base-line study were adults of all ages, male and female residents in the investigated area, which were registered with chronic diseases at the family doctor between 2000 and 2009.

The investigated chronic pathology refers to tumor, blood, nervous, cardiovascular, digestive, respiratory, endocrine, musculoskeletal and renal diseases, coded according to the Australian coding standards ICD-10 PM.

4. RESULTS AND DISCUSSIONS

Upstream of the tailings ponds (points A10, A11, A12) where no alterations of the groundwater quality were observed.

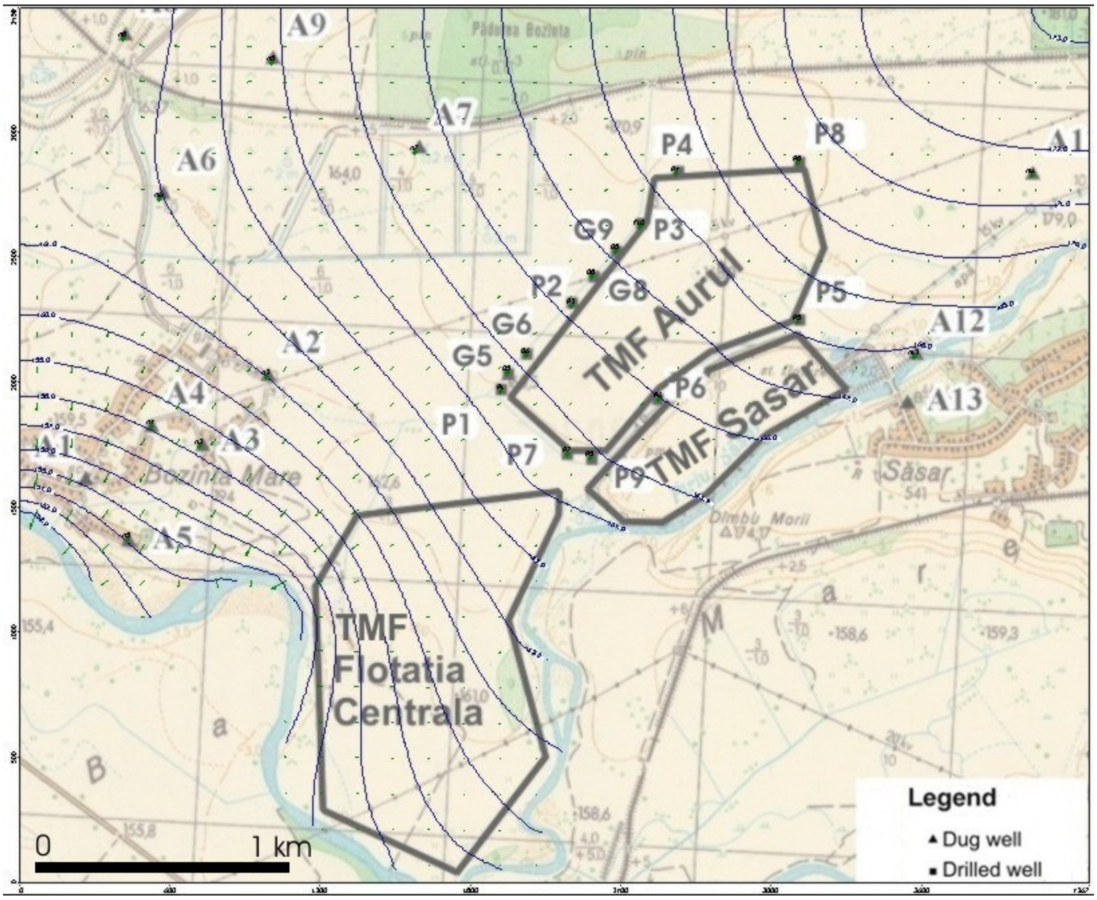

Figure 2. Groundwater flow model in the shallow aquifer in the TMFs area.

Points A13 and A14 are on the opposite bank of the river and they were not considered in the hydrogeological model. Laterally from the TMFs, in the wells generally used as drinking water supply (A1 to A7, and A9), the contaminants that were considered in the current analysis show values below the maximum admissible concentration (MAC), and very often, below the detection limit of the analytical method. In some cases, the pH may be slightly below the minimum value accepted for drinking water. The water of Băița River shows increased concentrations of heavy metals (A8). Higher contents of heavy metals were observed in the monitoring wells surrounding *Aurul* TMF, especially on the southern side of the pond.

Subsequent to the run of the flow and transport model of the shallow aquifer, a model of evolution of groundwater quality downstream of *Aurul* TMF has been obtained. We are aware that the confidence of the model is lower in the area of *Flotația Centrală* TMF due to the lack of analytical data. In the transport model, the Pb and Cd contents were taken into account. The first stage consisted of modeling the current situation by respect to the groundwater contamination (Fig. 3). The Pb content in the shallow aquifer is exceeding 200 µg/l in the contact area between the three TMFs (dark red-purple in figure 3). The cutting threshold of the dispersion model was set to 1 µg/l (the outer limit of the blue area). Cadmium distribution is similar to the Pb distribution.

The analyses that have been conducted support the hypothesis that the contaminants dispersion is currently in an equilibrium state, and the contaminants plume will not extend under steady conditions. If the TMF system will be appropriately managed by avoiding any release of contaminated water outside the area protected by the geomembrane, and if technological accidents with contaminated water discharges will not occur, the contents of the toxic elements in the shallow groundwater should decrease, or at least should remain stable.

A slow attenuation of the pollution on *Aurul* TMF site will occur after the cease of the operation. At the same time, *Săsar* and *Flotația Centrală* TMFs will produce long term pollution, being the main contaminating sources for the shallow groundwater.

The advisable solution will be the implementation of remediation actions on the two TMFs, *Săsar* and *Flotația Centrală*. In order to test the consequences of such an approach, we have analyzed the evolution of Pb contents at 4 and 10 years after the operation ceased, in the hypothesis that remediation procedures were applied on all three TMFs (Fig. 4). An important decrease of the contaminant's concentration may be noticed in time. The maximum Pb concentration would be 80 µg/l after 4 years (Fig. 4a), and 25 µg/l after 10 years (Fig. 4b).

At present, the shallow aquifer is highly contaminated in the vicinity of *Aurul* TMF. Very likely, the contamination is much more important underneath the two other ponds. The results of the analyses performed on the samples collected from the wells surrounding *Aurul* TMF (P1 to P9, and G6, G8, G9) are leading to the following general observations:

- the pH is below the minimum admissible limit for drinking water (pH=6.5) in most of the wells, only one value being above 6.5; the range of variation is between 3.17 and 6.82;
- the arsenic content is below 1 µg/l in all analysed samples;
- the most important contamination occurs in the wells P6, P7, and P9, located on the SE side of *Aurul* TMF, in the proximity of *Săsar* TMF;
- in the four large-diameter intervention wells on the western side of *Aurul* TMF, marked G5, G6, G8, and G9, the contaminants concentrations are lower than in the monitoring wells that are closer to the pond; this observation suggests that the pollutants contents are rapidly decreasing along with the distance from the pollution source, the highest concentrations occurring in the proximity of the TMF.

Table 1. Physical and chemical parameters of groundwater (and surface water: A8 – Băița River, A12 – Săsar River). In bold: concentrations exceeding the limits set by the Romanian Drinking Water Law 458/2002

Sample ID	**GPS coordinates**		**pH**	**Temp (°C)**	**Pb (µg/l)**	**Cd (µg/l)**	**As (µg/l)**	**CN (µg/l)**
	N	**E**						
A1	47 38 24.1	23 26 28.2	N/A	N/A	7.7	<1	<1	<3
A2	47 38 38.2	23 27 04.3	6.7	10.8	<1	<1	<1	4.05
A3	47 38 28.7	23 26 54.5	**6.21**	10.8	<1	<1	<1	<3
A4	47 38 31.3	23 26 40.9	6.65	10.1	<1	<1	<1	<3
A5	47 38 16.1	23 26 37.8	6.75	11.3	<1	<1	<1	<3
A6	47 39 01.1	23 26 42.1	7.19	10.4	<1	<1	<1	<3
A7	47 39 07.8	23 27 30.9	6.98	10.6	<1	<1	<1	3.3
A8	47 39 18.2	23 26 31.4	**4.25**	14.3	**15.2**	**30**	<1	<3
A9	47 39 19.1	23 27 02.8	**5.93**	12.5	<1	<1	<1	3.01
A10	47 39 50.1	23 27 35.7	6.5	9.7	<1	<1	<1	<3
A11	47 39 05.8	23 29 27.6	**6.43**	11.1	<1	<1	<1	<3
A12	47 38 40.3	23 29 02.5	6.6	13.2	<1	<1	<1	<3
A13	47 38 36.9	23 29 05.5	6.78	11.5	3.08	<1	<1	<3
A14	47 38 06.8	23 25 38.7	7.04	11.5	<1	<1	<1	<3
P6	47 38 35.5	23 28 17.9	**4.85**	12.1	**2800**	**158**	<1	4.1
P9	47 38 27.5	23 28 04.9	**3.45**	12.3	**1340**	**266**	<1	3.38
P7	47 38 28.6	23 26 00.2	**3.19**	12.7	**80**	**287**	<1	49.6
P1	47 38 36.7	23 27 47.3	**6.82**	11.5	**20.8**	<1	<1	19.5
G5	47 38 39.3	23 27 48.0	**6.01**	10.3	**80**	<1	<1	<3
G6	47 38 41.4	23 27 55.1	**5.82**	11.1	<1	<1	<1	3.5
P2	47 38 48.1	23 28 00.5	**5.49**	11	**22.9**	**515**	<1	<3
G8	47 38 52.2	23 28 05.1	**6.26**	10.6	**26.8**	1.1	<1	<3
G9	47 38 54.4	23 28 08.8	**6.14**	10.7	**26.6**	**20**	<1	<3
P3	47 38 58.2	23 28 13.6	**3.8**	11.4	**650**	**339**	<1	3.34
P4	47 39 05.0	23 28 20.4	**4.33**	11.3	**23.5**	**90**	<1	3.15
P8	47 39 06.6	23 28 43.4	**4.62**	11.1	**32.4**	**133**	<1	<3
P5	47 38 46.3	23 28 43.9	**3.17**	12.1	<1	**415**	<1	<3
MAC (Law 458/2002)			**6.5-9.5**		**10**	**5**	**10**	**50**

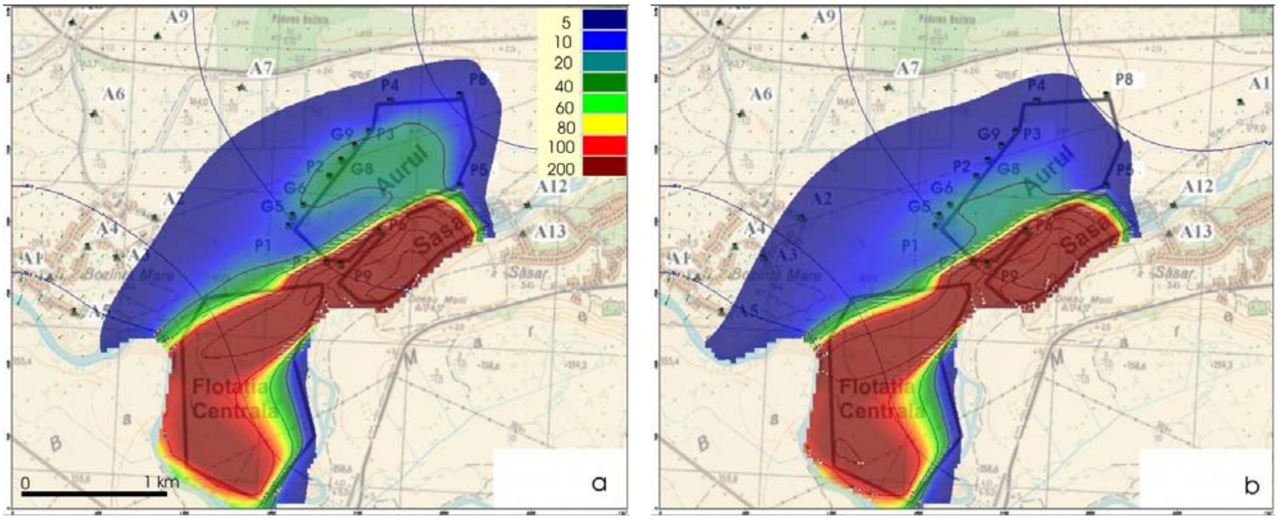

Figure 3. Distribution of the Pb concentrations (in µg/l ; a – current situation; b – 10 years after the cease of the operations).

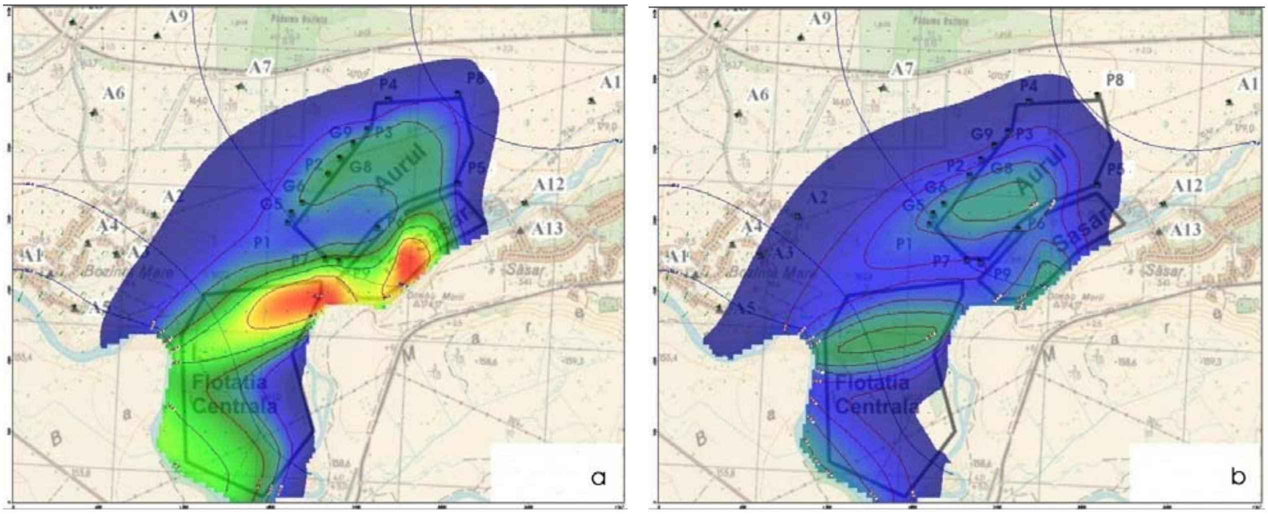

Figure 4. Distribution of the Pb concentrations in the shallow aquifer, 4 years (a) and 10 years (b) after the cease of the operation, if remediation actions will be implemented on the 3 TMFs.

Data concerning the drinking water consumption in Bozânta Mare locality were collected using individual questionnaires. Data provided by the questionnaires filled in by the parents of the investigated children pointed out (the last 10 years) major changes concerning the type of the water source in homes. Therefore, for 41% of the interviewed subjects, showed changes related to the introduction of a drinking water supply system in the locality, by extension from Baia Mare municipality, after the accident at *Aurul* pond in 2000.

Most of the wells included in the study are 5-9 m deep, being drilled 20-30 years ago, therefore their vulnerability to pollution events is getting higher.

Although the system is functional and the distributed water meets the quality criteria, 48.2% of subjects still consume water, both for drinking and cooking from their own wells, while the supply system water is mainly used for hygiene purposes (62.1%) and for cooking (41.4%). Other types of water consumption for drinking and cooking are less than 7%, and are represented by the mixed sources or spring water (Table 2).

Table 2. Water consumption at home (children) (%)

	Network	Private well	Mixed	Bottled*	Spring
Cooking	41.4	51.7	6.9		
Drinking	37.9	51.7	6.9	27.6	3.4
Other purposes	62.1	20.7	17.2		

*they use for drinking public network, private well and bottled water

Concerning the adults, the results of the questionnaire revealed similar findings regarding the predominant water sources used (well), both as frequency and quantity. Well water is used by half of the investigated subjects for drinking and cooking purposes (Table 3), Bottled water consumption is limited, 27.9% in children and adults, but always in combination with well, and tap water. Mixed and spring water consumption for drinking purposes is less frequent (10.3%, and 5.9 % respectively).

Tabel 3. The water consumption at home (adults) (%)

	Network	Private well	Mixed	Bottled*	Spring
Cooking	47.1	50.0	2.9		
Drinking	41.2	50.0	10.3	27.9	5.9
Other purposes	66.2	25.0	8.8		

*they use for drinking public network, private well and bottled water

Comparing the frequency of the main water source used by children and adults the statistical tests showed that the differences of using well and public network water is statistically significant ($p \leq 0.001$) only for personal hygiene purposes, while for both, cooking and drinking differences are not statistically significant (Table 4).

Table 4. The statistical significance of the difference in public network and well water consumption

		Cooking	Drinking	Cooking+ Drinking	Personal hygiene
Children	x^2	0.67	1.23	1.85	12.0
	p	0.41	0.27	0.17	0.001
Adults	x^2	0.12	1.16	1.0	25.29
	p	0.73	0.28	0.32	<0.001

Tabel 5. Average water consumption for drinking (liters/day)

	Children		Adults	
	Average	Standard deviation	Average	Standard deviation
Public network	1.4	0.5	2.2	0.8
Private well	1.7	0.5	2.0	0.7
Bottled water	0.4	0.3	0.9	0.5

Table 5 shows that for children the well water versus tap water is predominantly used, in terms of frequency, and also quantity, while the average water consumption for drinking and cooking is higher for well water (1.7±0.5 l/day) as compared to the tap water (1.4±0.5 l/day). A similar pattern can be noticed for the investigated adults. However, as quantity, the daily consumed bottled water is less than 500 ml in children, taking into account that not even one subject mentioned the use of bottled water exclusively.

Regarding the motivation of well water consumption as against tap water, 59.1% of the children and 56.25% of the adults put the pleasant taste on the first place. Only 6.25% of the adults prefer to use predominantly the well water because they consider it ”clean”, while the rest of the investigated subjects are really aware about the past contamination of the well and have suspicions about the well water quality. On the other hand, although 67% of children respondents and 80% of the adults consider the public network water as being safe, it is not predominantly used, probably because of the taste. About 33% and 20% respectively of the subjects identify the taste of chlorine as unpleasant. It was demonstrated that taste and smell are key variables in the people’s perception on the health-drinking water quality relation and in selection of the preferred type of water (Dupont et al., 2010, Barraj et al., 2009). A study conducted in 2010 in 3 urban areas in Transylvania demonstrated that the smell and taste of the water are the key factors in reducing or refusing the public network water consumption (Gurzău A. et al., 2010). Also these factors increase the probability to use a different type of drinking water (Dupont et al., 2010).

Concerning the groundwater quality in the area, the results of the tests performed on the samples collected in 2010 were presented above and the adequate water quality is noted in the wells from Bozânta Mare, located closest to *Aurul* TMF.

The chronic morbidity in Bozânta Mare is recording the highest prevalences as an average of a 10-year investigated period, for cardiovascular diseases 262.38‰ (hypertension – 120.46‰ and chronic ischemic heart diseases – 95.71‰), chronic digestive diseases 80.86‰, endocrine diseases 57.76‰ (diabetes 42.90%) and respiratory diseases 46.20%. The lowest prevalences were registered for anemia – 9.90‰, chronic renal diseases – 13.20‰ and musculoskeletal diseases – 14.85‰. The tumors showed an average prevalence of 21.45‰ in the studied area. The neoplasias are increasing, overall similar to the trend noticed in other cities of the county, as well as at the national level. The nervous system diseases, chronic cardiovascular pathology, digestive diseases are following an increased trend, as overall, although there are some less important decreases in some of the years.

Studies regarding the chronic pathology analysis in rural areas from Romania showed that, generally in these areas, one in four inhabitants suffers from one or more chronic diseases (Petre, 2006), and Bozânta Mare village is not an exception. At the end of the survey the adult subjects enrolled in our study were asked to mention if they are in the evidences of their family doctors with chronic disease. In total, 25% of the subjects declared a chronic disease and the hypertension was the most frequent one (41.18%), followed by ischemic heart diseases (17.65% suffering of heart diseases).

In the present we have found the well water from Bozânta Mare free of heavy metals (lead and cadmium) and cyanides. Currently, a network of monitoring wells exists around *Aurul* TMF, very close to the dam. Additionally, four large-diameter wells were drilled westward of the TMF, intended to allow the accidentally contaminated water from the aquifer to be pumped to the tailings pond. Upstream and downstream of the TMF, there are no monitoring works, with the exception of some dug wells used by the community, and that can be used for taking water samples.

Taking into account the general flow direction of the aquifer, the installment of 4 additional monitoring wells, one upstream and 3 downstream of the TMF would be a good option. The bottom of the wells should be in the impermeable layer of Neogene clays/marls, beneath the alluvial Quaternary deposits. These wells will allow the interception of the contaminated groundwater flow, if an incident will occur, and starting of the intervention procedures. Their position is sufficiently far from Bozânta Mare village, in order to ensure enough time for an effective intervention. The relevant parameters to be monitored in the proposed '*sentinel wells'* must take into account their relevance for the human health.

From the human exposure perspective, the water supply of a community which experienced an environmental disaster is a problem of major concern and should be a matter of specific assessments. Lack of risk communication from environmental/health education to common language in terms of level of perception and understanding the environmental problems the local community is still facing with, could be part of the reasons people still prefer to consume well water. On the other hand, socio – economical reasons have to be taken into account. The low income of most of the families often makes the payment of additional costs for public network supply difficult. According to the Romanian water law only the public water sources are monitored on permanent basis and the water quality of private wells is analyzed free of charge by the Public Health Authorities in the case of calamities and pollution accidents. Except these situations the owners of the wells must support the cost of the analyses, if they want to know how safe their well water is.

5. CONCLUSIONS

Bozânta area has become internationally notorious after the industrial accident in January 2000 on *Aurul* TMF, when an important amount of water contaminated with heavy metals and cyanides has been spilled on the surrounding fields, partly reaching the river system. Such events may contribute to the contamination of the shallow groundwater, however most of the pollution is very likely related to the previous operation of the TMFs and infiltration of the rainwater through the heavy metals containing tailings stored on the ponds. *Săsar* and *Flotația Centrală* ponds have no impermeable liners underneath. *Aurul* TMF has an impermeable liner at the bottom, able to block the infiltration of contaminated water to the soil and groundwater below.

A groundwater sampling campaign was carried out, and chemical analyses were performed. The UnSat Suite and Visual Modflow software packages have been used for modeling the water flow and transport of pollutants in the vadose zone and shallow aquifer respectively.

The groundwater quality is unaffected upstream of the TMFs. In the proximity of Bozânta village, westward from the TMFs, the chemical parameters of groundwater are within the acceptable limits. The pH may be slightly lower than the acceptable values in some spots. The heavy metals content is much higher in the wells surrounding *Aurul* TMF, especially in the proximity of *Săsar* TMF.

The two old TMFs Săsar and Flotația Centrală will produce a long term pollution of the shallow aquifer due to the permanent infiltration of rainwater. Remediation actions are needed, that will very much diminish the level of contamination of groundwater.

Residents of Bozânta Mare prefer to use the water from their domestic wells for drinking and cooking, at the expense of the supplied water, whose quality is certified and monitored. The perceptions of water quality result from a complex interaction of diverse factors. In many circumstances, the estimation of water quality is mostly influenced by organoleptic properties, flavor in particular.

The current general morbidity from chronic diseases for inhabitants of Bozânta Mare locality is not significantly different compared to other localities in the area or at national level.

A sustained educational process in the community of Bozânta Mare will make people understand the importance long term health risks related to the heavy metals contamination, as well as the benefits of safe water consumption.

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