ENVIRONMENTAL IMPACT OF CLOSING MINING ACTIVITIES - A CASE STUDY FROM BALAN, ROMANIA

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ENVIRONMENTAL IMPACT OF CLOSING MINING ACTIVITIES - A CASE STUDY FROM BĂLAN, ROMANIA

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ABSTRACT

Mining activities have played an important role in the development of human communities and in the economic growth of societies. However, in many cases, the exploitation of the resources was carried out in an unsustainable manner and contamination of the environment or ecological accidents occurred, which lately led to increased financial efforts for the remediation of contaminated sites. The negative effect on the environment of the entire technological process of exploration, exploitation and preparation of ores is continued with the impact of closing the mines. The aim of this paper is to study the environmental impact of the Bălan mining industry, Romania, on the receptors, before and after closing. In the Bălan area the mines were closed in 2004, but the restoration of the mining area began only in 2011, so, meanwhile the population and the environmental system were affected.

A tailing pond was created in the southern area of the mining perimeter, where all the residues from the flotation of the ore were pumped. During the period in which the plant was running, the material in the tailing pond was humid and had the consistency of mud. Since the mine was closed, though, and no fresh material was added, the water started to evaporate and, especially during summer, the finest particles from the tailing pond are easily carried away by wind, ending up in people's yards and gardens.

For this study, soil samples were collected from the area of the tailing pond, both in 2004, when the mine was closed, and in 2011, when the remediation began. Total heavy metals in soil were analyzed by X-ray fluorescence spectrometry and pseudo-total metals were extracted using aqua regia assisted by microwave procedure and the concentrations were determined by atomic absorption spectrometry. The results showed that, because of the large period of time between ending of the mining activities and beginning of the restoration, heavy metals accumulated in the soil around the tailing pond, due to atmospheric deposition of particles containing trace metals from the pond.

Keywords: trace metals, soil, mining activities, pond drying

1. INTRODUCTION

Heavy metals are an ill-defined group of elements, with arsenic, cadmium, zinc, chromium, copper, lead, mercury and nickel most commonly found at contaminated sites [1]. Soils may become contaminated with these metals by atmospheric deposition, industrial emissions, disposal of wastes, mine tailings, and agricultural application of fertilizers, manures, sewage sludge and pesticides [2]. Soils are a major sink for heavy metals released into the environment [3]. Unlike organic contaminants, most metals do not undergo microbial or chemical degradation [4], and their total concentration in soils persists for a long time after the pollution moment and, in time increases, if the source of contamination has not been removed [5]. However, changes in their chemical forms (speciation) and bioavailability are possible and they take place very often. Heavy metal contamination of soil can be hazardous for humans and the ecosystem by inhalation of soil particles, ingestion (oral bioavailability), dermal contact, drinking of contaminated groundwater, by negatively influencing the food chain and reduction of food quality or decrease in land suitability for agriculture [6].

Mining activities coupled with ore processing industries left the legacy of wide distribution of metal contaminants in soil. Tailings (particles heavier than the element of interest, settled at the bottom of the flotation cell) are directly discharged into natural depressions, resulting in large surface tailing ponds with elevated concentrations of associated heavy metals [7]. Modern mining exploitations produce waste materials with low reactivity to weathering processes. However, tailings from old exploitations – due to the low efficiency of reagents and equipment – are heterogeneous, highly reactive, have a high degree of alteration and high trace element content. Moreover, the affected areas also suffer from severe erosion caused by wind and water run-off, enhanced by the texture of the tailings, landscape topography and regional and local meteorological conditions [8].

The increased tendency of stopping mining activities in the past two decades has led to the abandonment of numerous mines without proper restoration efforts. Although mine galleries and many ore processing plants have been closed, that issue still require a lot of attention regarding the sterile deposits and the tailing ponds. In many cases, the containing material is not covered, immobilized or isolated in any way, thus becoming a hazardous source of PM (particulate matter) and heavy metal contamination. Trace elements contained in the residues from mining and metallurgical operations are often dispersed, included in particulate material or in aqueous solution by wind and/or water after their disposal [9] Three types of pollution could be described, function of the type of transport: i) primary contamination, formed by residues deposited near the sources; ii) secondary contamination, due to trace element dispersion away from its production perimeter, by water or wind; iii) tertiary contamination, involving trace element mobilization (e.g. crops uptake) [10].

The aim of this study was to evaluate the trace metal content in soil in the area of Bălan-Harghita County, in Romania and to assess the effect of mines closing on the accumulation and dispersion of heavy metals. Here, mining activities were ceased in 2004 and they left behind a huge tailing pond containing heavy metals and residues from the flotation processes. The fine particles were easily carried away by the wind, extending the contaminated perimeter outside of the mining are and outside of the area polluted while operating, because, until the restoration process began in 2011, nothing was done to control this phenomenon.

2. MATERIALS AND METHODS

Twelve soil samples were collected from the area upstream and downstream the tailing pond, as well as from the eastern zone, which is inhabited and the soils are commonly used for agriculture. The first series of soil was sampled in 2004, after the mine closing. GPS data was used to identify the same location and collect comparative samples in

2011, right before the beginning of the restoration works. About 300 g of soil was collected from the top layer of soil, air dried, grinded and sieved for the specific analysis.

Total Cu, Pb and Zn concentrations were determined using 10 g of soil sieved to pass through a 0.5 mm mesh and analyzed by X-Ray Fluorescence spectroscopy (MiniPal 4, PAnalytical).

The soil pseudo-total content of Cu, Zn and Pb was determined by microwave acid digestion method using 5 mL *Aqua Regia* ($HCl:HNO_3$ 3:1 v/v) and 0.5 g of soil sieved to pass through a 0.5 mm mesh. Te soil and the reagent were digested at in a Teflon beaker in a microwave oven at 180°C for 20 min. The mixture was then transferred quantitativley to a graduated tube and made up to 14 mL with deionized water. The metals were analysed by flame Atomic Absorbtion Spectrometer (Zeenit 700, AnalytikJena). All the analyses were carried out in duplicate and the results were accepted when the coefficient of variation was within 5%.

3. RESULTS AND DISCUSSIONS

Lead is not an essential element and is a potentially toxic chemical because it can accumulate in individual organisms, but also in entire food chains. Moreover, lead was classified by REACH Regulation (EC) 1907/2006 as being probable human carcinogen. The most important human exposure pathway to lead from soil is through direct ingestion (eating) of contaminated soil or dust. In general, plants do not absorb or accumulate lead. However, in soils testing high in lead, it is possible for some lead to be taken up. Pb accumulates in the body organs, which may lead to poisoning or even death. Children exposed to lead are at risk for impaired development, lower IQ, shortened attention span, hyperactivity, and mental deterioration. Adults usually experience decreased reaction time, loss of memory, nausea, insomnia, anorexia, and weakness of the joints caused by lead exposure [11].

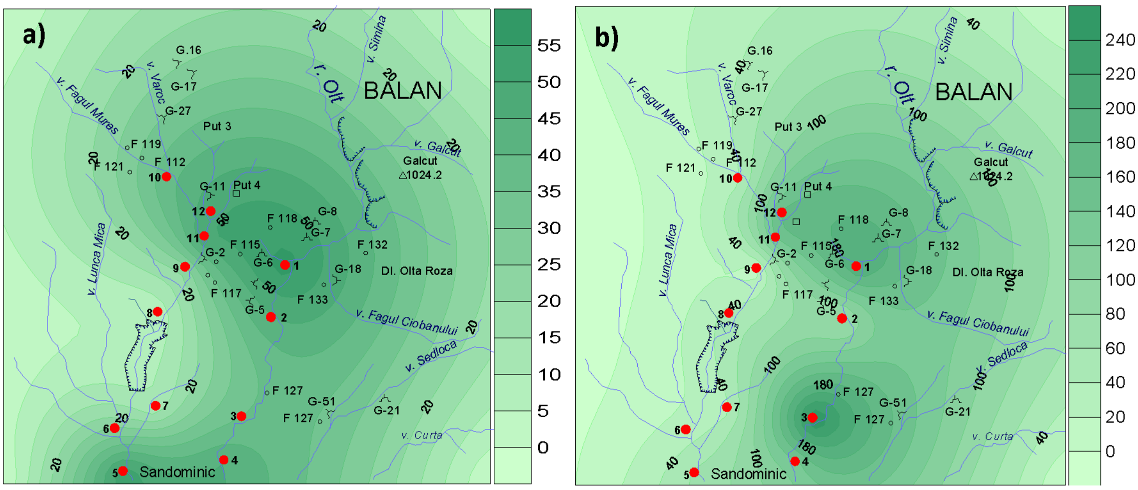


Figure 1. Spatial distribution of Pb in the area, in 2004 (a) and 2011 (b)

Copper is an essential micronutrient required in the growth of both plants and animals. In humans, it helps in the production of blood hemoglobin. In plants, Cu is especially important in seed production, disease resistance, and regulation of water. Copper is indeed essential, but in doses above tolerably daily intake it can cause anemia, liver and kidney damage, and stomach and intestinal irritation. Unlike some man-made materials, Cu is not magnified in the body or bioaccumulated in the food chain. In the soil, Cu strongly complexes to the organic implying that only a small fraction of copper will be found in solution as ionic copper, Cu(II). The solubility of Cu is drastically increased at pH 5.5 [12], which is rather close to the ideal farmland pH of 6.0–6.5 [13].

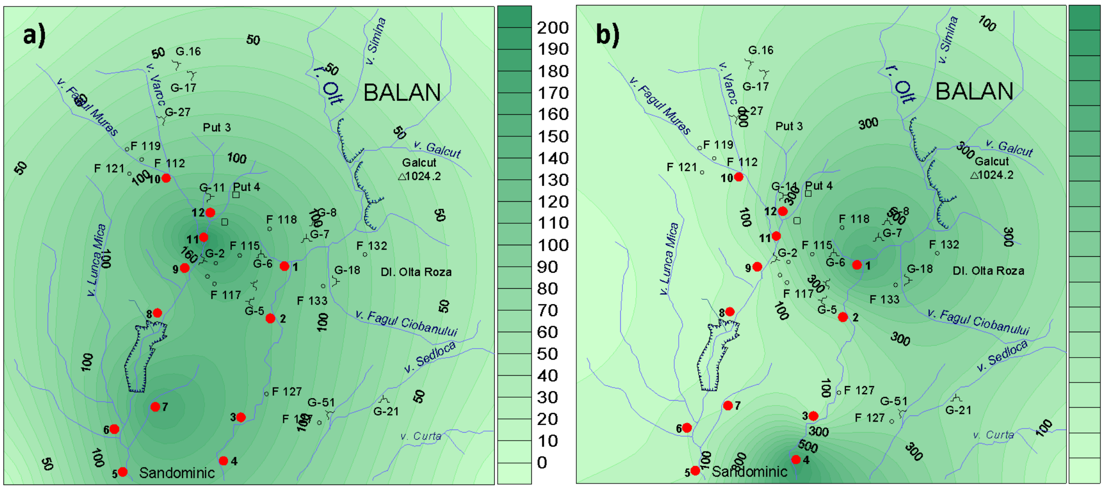


Figure 2. Spatial distribution of Cu in the area, in 2004 (a) and 2011 (b)

Soil is polluted with zinc during industrial activities, such as mining, coal, waste combustion and steel processing. Zinc is a trace element that, as copper, is essential for human health. Zinc shortages can cause birth defects. Water-soluble zinc that is located in soils can contaminate groundwater. Plants often have a Zn uptake that their systems cannot handle, due to the accumulation of Zn in soils. Finally, Zn can interrupt the activity in soils, as it negatively influences the activity of microorganisms and earthworms, thus retarding the breakdown of organic matter. Some fish can accumulate Zn in their bodies, when they live in Zn-contaminated waterways. When Zn enters the bodies of these fish, it is able to biomagnify up the food chain [14].

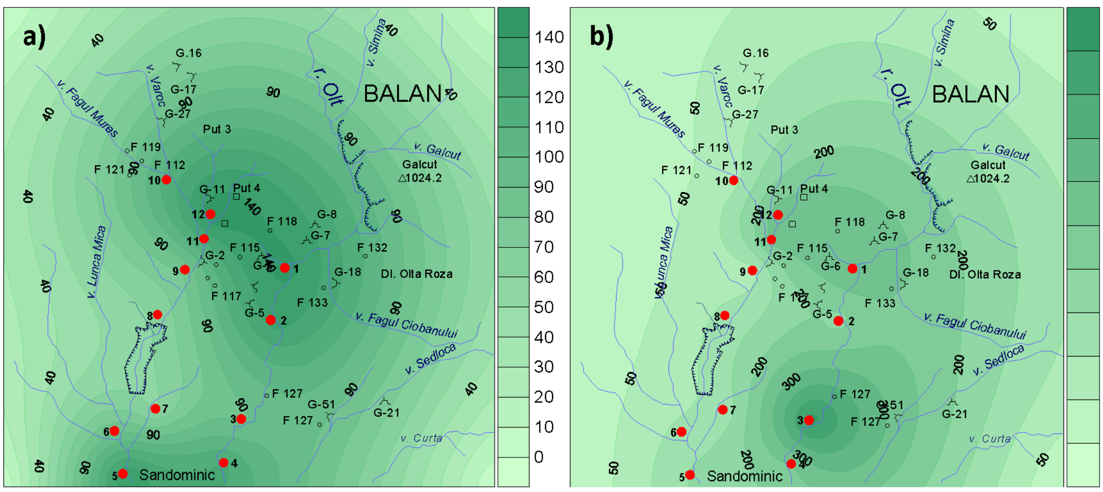


Figure 3. Spatial distribution of Zn in the area, in 2004 (a) and 2011 (b)

The spatial distribution of metals shows the trend of lead (figure 1), of copper (figure 2) and of zinc (figure 3) accumulation in soil in the 2004-2011 period. After drawing the distribution maps it was revealed that the initial point source pollution become diffuse.

Table 1. Pseudo-total concentration of heavy metals in the soils collected in 2004 and in 2011.

Sample	**Pb, mg·kg^{-1}**		**Cu, mg·kg^{-1}**		**Zn, mg·kg^{-1}**	
	2004	**2011**	**2004**	**2011**	**2004**	**2011**
1	15,0	95,6	16,9	324,0	53,6	130,7
2	0,1	30,9	17,2	115,3	55,3	81,5
3	5,7	109,1	19,7	42,3	43,8	231,7
4	5,4	80,6	27,2	551,5	54,1	123,6
5	4,2	19,0	18,2	21,0	55,5	71,4
6	1,0	11,5	14,4	28,7	42,4	54,3
7	12,3	11,7	58,6	35,1	31,1	50,3
8	1,4	32,9	12,0	19,5	32,6	52,8
9	0,0	27,8	34,0	14,0	45,7	34,3
10	13,0	24,4	23,6	35,3	51,3	38,1
11	21,4	33,1	70,5	107,2	52,5	100,8
12	28,8	44,7	26,6	165,5	72,5	100,2

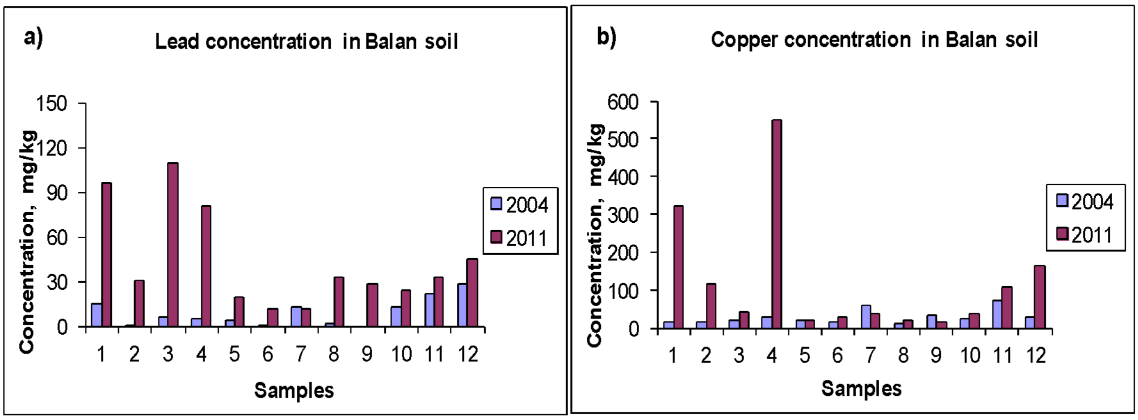
The results of Aqua Regia extraction underline that pseudo-total trace metals concentration in soil increased between 2004 and 2011 (table 1). Although in 2004 no sample was above alert limit for sensitive use (table 2), in 2011 the situation was totally changed. Three samples exceeded lead alert limit, 5 samples had copper concentrations above alert limit and two of them exceeded even intervention limit. In the case of zinc all samples had concentrations below alert limit, but an increase in the 2004-2011 period were reported. Surprisingly, closing mining activities, proved to be not environmental friendly as it may be assumed.

Table 2. Alert and intervention concentrations for Pb, Cu, Zn according to Romanian legislation

Sample	**Pb, mg·kg^{-1}**	**Cu, mg·kg^{-1}**	**Zn, mg·kg^{-1}**
Alert limit (sensitive use)	50	100	300
Intervention limit (sensitive use)	100	200	600

[15]

After mine closing, the slag humidity decreased, the material became non-cohesive, and, particularly in summer, the polluted material is carried by wind far from the initial polluted area. The pseudo-total concentrations show that after 7 years since pollution was stopped, trace metal content is higher. (figure 4) The hazard is increasingly mostly for east gardens where the soil is used for vegetables grow.



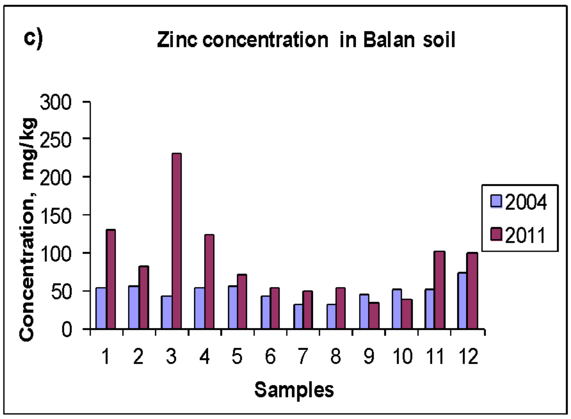


Figure 4. Comparison of heavy metal pseudo-total concentration in soil (2004 and 2011)

Pb (a), Cu (b) and Zn (c).

4. CONCLUSIONS

Health is a key to human development and is increasingly considered the environment as a key factor determining human health. [16]

The paper highlights that closing mining activities is not enough for decreasing the exposure risk for humans.

The initial hypothesis was confirmed by both sets of results: X Ray Fluorescence analysis and Aqua Regia microwave extraction.

So, future activities on mining closing should be made only after a polluted area remediation plan is prepared because of the high potential hazard posed by pollutants to humans and ecosystems.

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