Environmental Resources Research
Vol. 4, No. 1, 2016

GUASNR

Impact of mine tailings on surrounding soils: Case study of Draa Lasfar mine, Marrakech-Morocco

Y. Barkouch[*1,2], A. Pineau[2]
[1]Laboratoire de Toxicologie et d'hygiène Industrielle, 1 rue Gaston Veil, 44035, Nantes Cedex, France
[2]Laboratoire Régional du diagnostic épidémiologique et d'hygiène du milieu –Marrakech – Maroc.

Received: February 2015 ; Accepted: December 2015

Abstract

The present study represents a first insight into the Draa Lasfar mine (Marrakech - Morocco) to assess the degree of polymetallic pollution caused by anthropogenic activities (like mine extraction) and consequently the possible diffusion of heavy metals and to predict the risk of their mobility in the surroundings of the mine area. The edaphologic parameters pH and electrical conductivity (EC) were measured according to standard methods, whilst heavy metals concentration was atomic absorption spectroscopy (AAS). Contamination factors (CF) and pollution index (IP) were calculated in order to estimate the anthropogenic contribution of target pollutants determining Cd, Cu, Pb, and Zn as the main pollutants in this region. The results showed that the polluted areas at the vicinity of the mine especially two rural communities (Ouled Bou Aicha and Tazakourte) of about 5790 ha are probably linked to increasing mine activities and the lack of appropriate measures to counteract its effects causing a progressive pollution of water and soil with heavy metal emissions in the region under study.

Keywords: Contamination, Heavy metals, Soils, Mine area, Mine tailings, Marrakech – Morocco.

[*]Corresponding author; yassirbark@yahoo.fr

1. Introduction

Environmental pollution especially by chemicals is one of the most effective factors in the destruction of the biosphere components. Among all chemical components, potentially toxic metals are believed to be of a specific ecological, biological, and health significance.

Mining is one of the industrial activities that causes the greatest and most persistent alterations in the nature (Passariello *et al.,* 2002). It affects relatively small areas, but could have a significant impact on the environment representing a potential danger to the health of human populations residing in the vicinity of these mining areas. The pre-existing ecosystems in mining areas become subjected to such disturbance and the most common consequences is their disappearance; the territories in the vicinity are very vulnerable and usually very much affected (Marqués *et al.,* 2001).

During and following mine activity, the tailings are disposed into surrounding soils leading to their exposure to environmental factors (El Khalil *et al.,* 2008). The emissions from the mine activity are generally transported by air masses up to some km from the pollution source and are deposited in the ground leading to an increase of heavy metal concentration in the upper layer of soil.

Soil is characterized as a complex and dynamic system which is constituted of several layers that differ in relation to the physical, chemical, mineralogical, and biological nature and are influenced by the climate and activities of the living organisms. Besides contributing to the maintenance of all forms of life that occur in the terrestrial surface, soil plays an important role in protecting the groundwater acting as a collector filter of organic and inorganic residues helping in sequestering possible toxic compounds (Sousa *et al.,* 2008).

Excess heavy metal accumulation in soils is toxic to humans and other animals; exposure to heavy metals is normally chronic (exposure over a longer period of time) due to food chain transfer. Also, acute (immediate) poisoning from heavy metals is rare through ingestion or dermal contact, but is possible (Sharma *et al.,* 2007). This present study investigated the issue of Draa Lasfar mine tailings as a potential source of trace elements contamination in adjoining agricultural soils at this mine.

2. Materials and methods

2.1. Site Description

Draa Lasfar mine involves a deposit of pyrite mineral located 10 km northwest of Marrakech city (Figure 1) that can pose a risk for the environment due to discharge of tailings all around the mine area (Avila *et al.,* 2012).

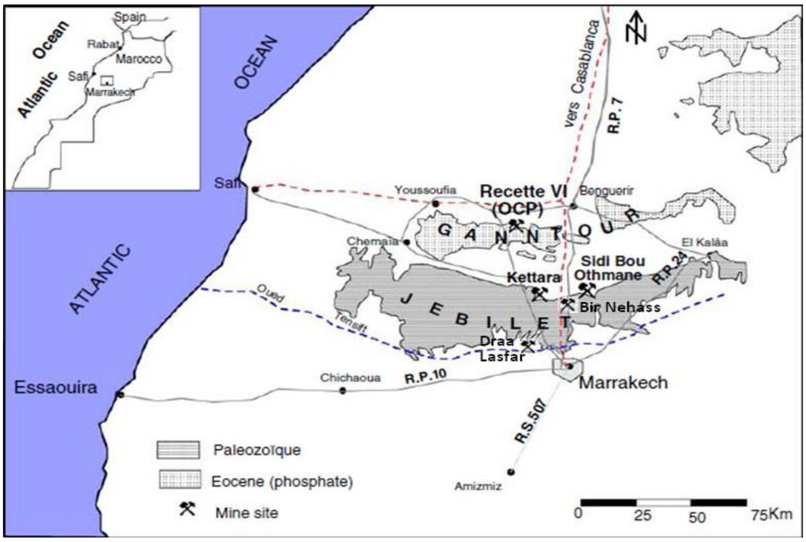

Figure 1. Geographic situation of Draa Lasfar mine in Marrakech region.

Draa Lasfar mine is located a few hundred meters from the Tensift River close to two rural communities (Ouled Bou Aicha and Tazakourte) of about 5790 ha of which 65% are occupied by farmland (Figure 2). The climate is Mediterranean, bordering arid, and semi-arid with an average annual precipitation of 231 mm (10 years). Temperatures are characterized by great daily and seasonal variation with an average value of 11.5 °C in January and 36.8 °C in July.

Figure 2. Geographic situation of Ouled Bouaicha and Tazakourte rural communities.

2.2. Sampling Description

In order to assess the impact of the Draa Lasfar mine on the surrounding environment, a total of 120 samples were collected in the vicinity of the mine covering 230 ha through 8 sampling lines oriented towards specific receptor media (Tensift river creek, Tazakourte village, Ouled bouaicha village, farms, etc.). Two samples were taken at the other side of Tensift River at 1 km from the mining site as control soils in order to avoid mining contamination. Samples were taken every 50 meters from the upper 20 cm after removing the first layer of surface soil (2 cm) within an area of 100 cm^2.

2.3. Soil Samples Analysis

The soil samples from the various sampling sites (Ouled Bouaicha=SOB, Tazakourte=ST and Tensift River=STR) were all taken at a depth of 0 to 20 cm each with the help of garden shovel cleaned with concentrated nitric acid and three (3) samples were taken from each sampling site during 12 months. The soil samples were collected into plastic containers which had all been pre-cleaned with concentrated nitric acid; the reason was to remove any traces of heavy metal contaminant (Brigden *et al.,* 2008).

All samples were dried and passed through a 2-mm sieve. Aliquots of about 1g were digested with 5 ml 65% HNO3 in a microwave digestion system for the determination of the HNO3-soluble fraction of heavy metals. The concentrations of Cd, Cu, Pb and Zn were determined by means of a graphite furnace atomic absorption. Soil pH was measured in soil-H2O suspension (1:2.5, w/w) and electrical conductivity was measured in a 1:5 soil to water suspension using a HI 9828 Multiparameter portable (HANNA instruments). Organic matter content was determined by the Walkley and Black procedure (Nelson and Sommers 1982).

Soil samples were dried at 60 °C for 75 h, then each sample was crushed, sieved (<325μm), homogenized, and weighed and its particle size distribution was measured using the hydrometer method (Allen *et al.,* 1974). Carbonate content was determined following Horton and Newson (1953) methodology.

3. Results and Discussion

Textural characteristics of the studied soils are showed (table 1) according to the classification of Shepard (Shepard and Moore, 1954). These results showed that coarse sand (2.0-1.0 mm) and fine sand (MS 0.250-0.125 mm) were dominant fractions in all agricultural soils samples with ranges from 25.3 to 27.7%, 23.4 to 25.2% in Tazakourte (ST) and Ouled Bou Aicha (SBA) soils respectively, and silty clay (< 0.031 mm) with 21.4 to 25.3% in SBA and ST in turn.

Table 1. Mean values (%) of the grain-size analysis of different soils in Draa Lasfar region.

	SBA	ST	STR	Control soil
Clay	21.4 ± 2.1	25.3 ± 3.1	23.2 ± 1.2	26.4 ± 2.5
Fine silt	16.1 ± 1.7	16.5 ± 2.7	26.9 ± 2.1	31.6 ± 3.7
Coarse silt	9.2 ± 1.4	8.7 ± 1.5	25.7 ± 1.5	20.1 ± 1.2
Fine sand	25.2 ± 2.9	23.4 ± 3.1	13.8 ± 4.6	5.2 ± 0.7
Coarse sand	27.7 ± 2.5	25.3 ± 2.8	8.2 ± 3.1	5.1 ± 0.4

pH, EC and carbonate content (De Matos et al, 2001) are geochemical soil characteristics and able to provide sufficient information to understand the soils capacity to retain heavy metal pollutants. Numerical values on pH, EC, and $CaCO_3$ for each analyzed sample can be found on Table 2.

Table 2. Geochemical characteristics of different soils in Draa Lasfar region.

Parameters	SBA	ST	STR	Control soil
pH	8.1 ± 0.6	7.8 ± 0.7	5.6 ± 0.4	7.8 ± 0.2
C.E (ms/cm)	1.5 ± 0.4	1.7 ± 0.4	2.7 ± 0.4	1.0 ± 0.2
CEC (meq/100g)	31.6 ± 3.1	35.2 ± 2.7	10.6 ± 1.5	16.4 ± 1.7
OM (%)	4.7 ± 1.0	5.5 ± 0.7	6.7 ± 1.5	4.3 ± 0.8
OCC (%)	2.7 ± 0.6	3.2 ± 0.4	3.9 ± 0.9	2.5 ± 0.5
S %	0.5	0.7	3.4	1.6
Cl-	< 0.1	< 0.1	< 0.1	< 0.1

Results obtained for the soil pH measurements revealed that, in general, all sampled points presented a neutral reaction to alkaline pH ranging from 7.8 to 8.1, similar to control samples.

pH variations are presumed to be related to heterogeneous deposits of sulfidic residues at the surroundings of the mine which can cause a decrease of the pH by corresponding oxidation and formation of sulfuric acid (STR). Among the factors influencing the accumulation of nutrients, particle size played a significant role. Fine grained soils often show higher concentrations of nutrients due to their greater surface-to-volume ratio and enrichment of organic matter (OM) (Wang *et al.*, 2004).

Mean organic matter contents in the studied soils were in the range of 4.7 in SBA and 6.7% dw in Tensift River soil (STR). The results showed that the anthropogenic contribution from discharge of domestic sewage in the Draa Lasfar region was an important source of OM in this mining zone; high values of organic content were due to agricultural activities around Tensift River. The organic carbon content (OCC) ranged from 2.7% dw in SBA to 3.9 % dw in STR.

Organic carbon concentrations increased in STR reflecting a corresponding decrease of the soil grain size. The highest organic carbon contents occurred at the soils that had the lowest sand and the highest silt and clay contents (Table 1). Table 3 shows the results of total estimate concentrations for the following elements in soils: Cd, Cu, Pb, and Zn. All the results are expressed in mg/kg.

Table 3. Mean concentrations of heavy metals in different soils in Draa Lasfar region.

Metals	SBA	ST	STR	Control soil
Cd (mg/kg)	1.1 ± 0.7	2.2 ± 0.2	0.8 ± 0.2	0.2 ± 0.0
Cu (mg/kg)	227.8 ± 225.3	330.5 ± 22.8	86.7 ± 20.9	40.7 ± 0.7
Pb (mg/kg)	184.0 ± 27.1	255.3 ± 24.0	61.3 ± 14.6	11.8 ± 1.4
Zn (mg/kg)	648.0 ± 174.3	890.5 ± 101.0	223.0 ± 134.6	133.9 ± 2.0

The concentrations of heavy metals were higher in Tazakourte soil that was identified as hotspots. Heavy metal concentrations in these soils are strongly determined by local geology or anthropogenic influences. The weathering of minerals is one of the major natural sources while anthropogenic sources include the use of fertilizers and herbicides, irrigation, and industrial effluent. In this agricultural area, mining extract activities are likely to be the major contamination sources. The results show significant spatial variations; compared to the control soil (CS), the contents of other metallic micro soils show a significant increase and the highest levels were observed in the ST village.

The contamination factors (CF) were calculated (Table 4) and displayed the extent of this increase. The pollution index (PI) is the arithmetic mean of CF of analyzed metals (Gonçalves *et al.*, 1992; Gonçalves *et al.*, 1994; Sanchez *et al.*, 1994) and it allows an assessment of the degree of polymetallic pollution of analyzed soil samples. With a value greater than 1, it indicates that the analyzed sample had a metallic contamination caused by human activities.

Table 4. Contamination factors (CF) and pollution index of different soils in Draa Lasfar region.

		Soil samples		
	Elements	SBA	ST	STR
Contamination factors	Cd	6,0	11,9	4,3
	Cu	5,6	8,1	2,1
	Pb	15,8	21,9	10,5
	Zn	4,8	6,6	1,7
Pollution Index		8.05	12.03	4.65

The pollution index (Table 4) showed that soil SBA and ST villages have a high metal contamination because their IP are well above the legal limit pollution that is equal to 1. In addition, ST and SBA are clearly highly polluted as their respective IP (12.03 and 8.05) are high (Table 4). These high metal concentrations in agricultural soils can be justified by the reuse of Draa Lasfar mine wastes for irrigation in the region.

4. Conclusion

Draa Lasfar mine area has been characterized by determining various physico-chemical parameters of edaphological importance, including pH, electrical conductivity (CE), and organic carbon content (OCC). Anthropogenic pollution has been assessed by the use of contamination factors (CF) and pollution index (IP). Thus, Cd Cu, Pb, and Zn can be distinguished as the main pollutants of the mine area.

References

Allen, S.E., Grimshaw, H.M., Parkinson, H.M., and Quarmby, J.A. 1974. Chemical Analysis of Ecological Materials. Blackwell Scientific publications, Oxford.

Avila M., Perez G., Esshaimi M., Mandi L., Ouazzani N., Brianso JL., and Valiente M., 2012 Heavy Metal Contamination and Mobility at the Mine Area of Draa Lasfar (Morocco). The Open Environmental Pollution and Toxicology Journal. 3 (Suppl 1-M2): 2-12.

Brigden, K., Labunska, I., Santillo, D., and Johnston, P. 2008. Chemical contamination ate-waste recycling and disposal sites in Accra and Korforidua, Ghana. Greenpeace Research Laboratories Technical Note. Greenpeace International, Amsterdam, the Netherlands.

De Matos, A.T., Fontes, M.P.F., Da Costa, L.M., and Martínez, M.A. 2001. Mobility of heavy metals as related to soil chemical and mineralogical characteristics of Brazilian soils. Environmental Pollution. 111: 429-35.

El Khalil, H., El Hamiani, O., Bitton, G., Ouazzani, N., and Boularbah, A. 2008. Heavy metal contamination from mining sites in South Morocco: monitoring metal content and toxicity of soil runoff and groundwater. Environmental Monitoring and Assessment. 136:147–160.

Figueroa, F., Castro–Larragoitia, J., Aragón, A., and García–Meza, J. 2010. Grass cover density and metal speciation in profiles of a tailings-pile from a mining zones in Zacatecas, North-Central Mexico. Environmental Earth Sciences. 60(2): 395-407.

Gonçalves, E.P.R., Boaventura, R.A.R., and Mouvet, C. 1992. Sediments and aquatic mosses as pollution indicators for heavy meatls in the Ave River Basin (Portugal). Science of the Total Environment. 114: 7-24.

Gonçalves, E.P.R., Soares, H.M.V.M., Boaventura, R.A.R., Machado, A.A.S.C., and Esteves Da Silva, J.C.G. 1994. Seasonal variations of heavy metals in sediments and aquatic mosses from the Cavado river basin (Portugal). Science of the Total Environment. 142: 143-156.

Horton, J., and Newson, D. 1953. A Rapid Gas Evolution for Calcium Carbonate Equivalent in Liming Materials. Soil Science Society of America Proceeding. 17: 414-415.

Marqués, M.J., Martínez-Conde, E., Rovira, J.V., and Ordóñez, S. 2001. Heavy metals pollution of aquatic ecosystems in the vicinity of a recently closed underground lead-zinc mine (Basque Country, Spain). Environmental Geology. 40: 1125-1137.

Nelson, D.W., and Sommers, L.E. 1982. Total carbon, organic carbon and organic matter. In Page, L. (Ed.), Methods of Soil Analysis. Part 2. Agronomy 9. American Society of Agronomy, Madison, WI, pp. 279-539.

Passariello, B., Giuliano, V., Quaresima, S., Barbaro, M., Caroli, S., Forte, G., Garelli, G., and Iavicoli, I. 2002. Evaluation of the environmental contamination at an abandoned mining site. Microchemical Journal. 73: 245–250.

Sanchez, J., Vaquero, C., and Legorburu, I. 1994. Metal pollution from old lead-zinc mine works: biota and sediment from oirtzun valle, Environmental Technology. 15: 1069-1076.

Sharma, R.K., Agrawal, M., and Marshall, F. 2007. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicology and Environmental Safety. 66(2): 258-266

Sousa, A., Pereira, R., Antunes, S.C., Cachada, A., Pereira, E., Duarte, A.C., and Gonçalves, F. 2008. Validation of avoidance assays for the screening assessment of soils under different anthropogenic disturbances. Ecotoxicology and Environmental Safety. 71: 661-670.

Wang, G.P., Liu, J.S., and Tang, J. 2004. The long-term nutrient accumulation with respect to anthropogenic impacts in the sediments from two freshwater marshes (Xianghai Wetlands, Northeast China). Water Resources. 38(20): 4462-4474.