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Antimony in the Contaminated Site of El Triunfo, Baja California Sur, Mexico

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Abstract. Antimony has properties similar to arsenic with some of its compounds toxic to humans. Therefore it is necessary to control the wastes accumulated by anthropogenic activities, such as mining, where it is in tailings to be released to the environment. According to the Environment Protection Agency, the maximum value in sediments is 11.2 mg Sb kg^{-1} and the Earth´s crust average is 0.2 mg Sb kg^{-1}. In this semiarid area, the drainage basin El Carrizal is impacted with wastes of an abandoned gold mine at the Mining District El Triunfo (MD – ET) which have tailings with 17,600 mg kg^{-1} of antimony. In the main dry river (arroyo), the Sb content is between 0.6 and 122 mg kg^{-1}. This element is transported from the source throughout the fluvial basin to discharge into the Pacific Ocean. In the arroyo mouth we collected one sedimentary core and the sediment from dunes (28.6 – 45.7 and 6.43 – 7.74 mg Sb kg^{-1}). This research concluded the antimony is enriched in this semiarid system, with Normalized Enrichment Factors severely enriched mainly in arroyo sediments close to the MD-ET

Key words: Antimony, gold mine, contamination, trace elements

Introduction

Antimony is a metalloid considered toxic to most organisms at elevated concentrations (Filella et al., 2007). It is a naturally occurring element that belongs to group 15 of the periodic table of the elements, along with N, P, As, and Bi. It is not an essential element in plants or animals. Its bioavailability and toxicological effects depend on its chemical form and oxidation state, with the trivalent compounds more toxic than the pentavalent compounds, similar to arsenic (WHO, 2006).

Study Area

The hydrographical basin El Carrizal is a fluvial coastal system influenced by wastes of an abandoned gold mine. It is located in Baja California Sur, Mexico, about 40 km from La Paz (Fig. 1). Small towns such as El Triunfo, and El Carrizal are in this hydrographical basin where their inhabitants are exposed to tailings and ash with high concentrations of Potential Toxic Elements (PTE) such as arsenic, mercury, lead, and zinc (Carrillo, 1996, Volke-Sepúlveda et al., 2003; Marmolejo- Rodríguez et al., 2011).

Materials and Methods

The overbank tailings (n =19), arroyo sediments (n = 26), cores (n = 34), and dunes (n = 6) were sampled from the study area to determine the major and trace element contents in these semiarid environments. For antimony determinations, the sediment was digested with acid using four acids (HCl, HNO_3, $HClO_4$, and HF). For these digestions the determination was made with an ICP-MS. (Inductively coupled-plasma mass spectrometry) The results were higher than the detection limits (>500 mg Sb kg^{-1}) therefore, the samples where measured again with Neutron Activation Analysis (INAA). The methods were validated with certified reference materials (PACS-2 and MESS-3). The results of this validation can be seen in Figure 2.

Results and Discussion

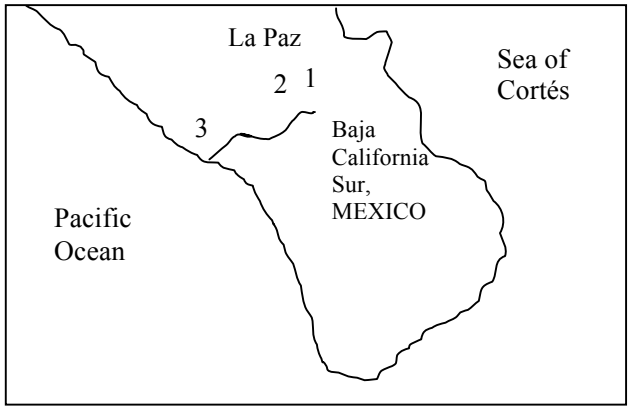

Fig. 1. Sampling site in the study area (1) El Triunfo town with abandoned gold mine overbank tailings, (2) Overbank tailings, and (3) Sediment core and dunes.

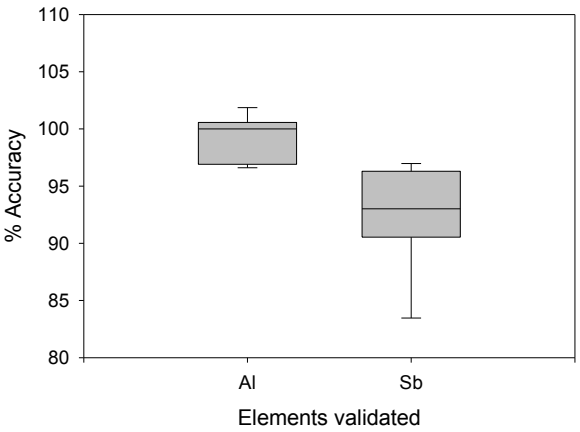

Fig. 2. Method validation with certified materials (PACS-2 and MESS-3). Accuracy corresponds to the certified material.

The grain-size analyses indicated that the sediment texture of the contaminated site is sand and silt-clay.

The results for the Sb in tailings, ash, arroyo, sediment core, and dunes are in Table 1.

The antimony concentrations in the different sampling sites studied here are compared with the Earth´s Crust average (0.3 mg Sb kg^{-1}; Wedepohl, 1995), and indicate that Sb is the severely enriched PTE in the study area. The results of Sb in tailings were extremely high and are in comparison with others determined in the vicinity of the study area (Volke-Sepúlveda et al., 2003; Posada-Ayala 2011). The validated results of the tailings in this study can be compared with those found in Sb mines (Wang et al., 2011; He et al., 2012; Hiller et al., 2012). The Sb in arroyo surface sediments decreases to the arroyo mouth at the Pacific Ocean, though the results show an accumulation in the core and dune sediments at the arroyo mouth.

The results of British soils (Flynn et al., 2003) show contents of 700 mg kg^{-1} of Sb was found to be biologically unavailable over a wide range of pH values, indicating that Sb is relatively unreactive and immobile in the surface layers of the soil. This suggests that soil contamination by Sb caused by mining and smelting operations is not a severe risk to the environment or human health. This is good for the surface sediment results (Figure 3). However, the contents in the mining areas >10,000 mg Sb kg^{-1}(Table 1) suggest the mine wastes would have a great potential to contaminate the downstream environment.

Table 1. Results of mg Sb kg^{-1} in tailings, ash, surface sediment, core sediment, and dunes in the hydrographic basin El Carrizal, B.C.S., Mexico.

Matrix	**Range (mg Sb kg^{-1})**
This study	
Tailings overbank	1.2 – 17,600
Ash	5,300 – 5,400
Surface sediment	0.6 – 122
Core sediment	28.6 – 45.7
Dune sediments	6.43 – 7.74
Other studies in the same area	
Soils[2]	1.6 – 352
Tailings[2]	600 – 2063
Ash[2]	2330 – 16,057
Sediments[3]	<0.1-18
Other international studies	
Soils of Great Britain[4]	11.89 – 709.84
Soil in mining areas [5]	10.4 – 5045
Background sediment[6]	11.2
Sb mine sediment[7]	57 – 7316
Sb mine sediment[8]	15,000
Earth Crust average[9]	0.31

[1]This study; [2]Volke-Sepúlveda et al., 2003; [3]Posada-Ayala, 2011; [4]Flynn et al., 2003; [5]He et al., 2012; [6]Reimann et al., 2010; [7]Wang et al.,2011; [8]Hiller et al., 2012; [9]Wedepohl, 1995.

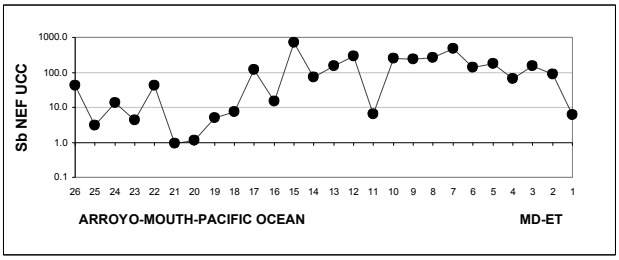

Fig. 3. Normalized Enrichment Factor (NEF) of Antimony in the surface sediment of the Arroyo Hondo-Las Gallinas-El Carrizal. NEF was calculated and compared with the Earth Crust (Wedepohl, 1995).

The abandoned mine wastes could contaminate water such as in Slovakia (Hiller et al., 2012), a similar scenario with the tailing wastes of this study area. Therefore, cleaner technologies must be developed and effectively

implemented in the abandoned mining areas to avoid negative human health effects.

Conclusion

Our results indicate that exposure to tailings, ash, and sediments close to the MD-ET is potentially hazardous. Results from tailings are compared with antimony ore mines and their waste concentrations. It is necessary to remove the tailings or to extract most of the antimony contents in the tailings and ash to clean the zone. For the remediation of the fluvial system after removing the EPT, it is necessary to clean close to the abandoned installations of the inactive gold mine.

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