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# Phytobarriers: Plants capture particles containing potentially toxic elements originating from mine tailings in semiarid regions

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ABSTRACT

Retention of particles containing potentially toxic elements (PTEs) on plants that spontaneously colonize mine tailings was studied through comparison of washed and unwashed shoot samples. Zn, Pb, Cd, Cu, Ni, Co and Mn concentrations were determined in plant samples. Particles retained on leaves were examined by Scanning Electronic Microscopy and energy dispersive X-Ray analysis. Particles containing PTEs were detected on both washed and unwashed leaves. This indicates that the thorough washing procedure did not remove all the particles containing PTEs from the leaf surface, leading to an overestimation of the concentrations of PTEs in plant tissues. Particularly trichomes and fungal mycelium were retaining particles. The quantity and composition of particles varied among plant species and place of collection. It is obvious that plants growing on toxic mine tailings form a physical barrier against particle dispersion and hence limit the spread of PTEs by wind.



## 1. Introduction

It has been documented that mine tailings generally represent an environmental and public health threat mainly because of the high concentrations and dispersion of potentially toxic elements (PTEs) by wind, water and percolation (Vangronsveld et al., 1995a, b; Jonathan et al., 2010). In arid and semi-arid regions the environmental conditions limit the development of a plant cover, promoting dispersion of particles containing PTEs (Mendez and Maier, 2008). Such is the case in Zimapan, Mexico, where mine tailings are located near the residential zone and are dispersed by wind.

Plant surfaces are recognized as an important sink for pollutants, like N and S oxides (Bamniya et al., 2012), polycyclic aromatic hydrocarbons (Terzaghi et al., 2013), particulate matter (Dzierżanowski et al., 2011; Popek et al., 2013) and PTEs associated to particulate matter (Fujiwara et al., 2011; Tomašević et al., 2005). Accordingly, mine tailing vegetation might also contribute to reduce PTEs dispersion. Not only by fixation of the substrate particles to roots and accumulation of PTEs in plant tissues, but also by retention of wind-transported particles on aerial plant parts. Investigations on vegetation as a sink for PTEs have been carried out in both cities and industrial areas (Litschke and Kuttler, 2008; Tomašević et al., 2005). Apparently, similar studies have not been performed in mining areas where dispersion and exposure to PTEs are conceivably high.

Particle retention varies among plant species depending on leaf characteristics (Dzierżanowski et al., 2011; Dzierżanowski and Gawroński, 2011; Popek et al., 2013; Sæbø et al., 2012; Tomašević and Aničić 2010). There is no consensus about which plant species or which leaf structure is the most efficient for particle retention. Some authors mentioned hairiness as the principal feature (Dzierżanowski and Gawroński, 2011); others stated surface roughness (Freer-Smith et al., 2004; Sæbø et al., 2012) while retention capacity is also attributed to cuticular waxes (Dzierżanowski et al., 2011; Popek et al., 2013).

Therefore, the objectives of this work were: (1) to document the retention of solid particles containing PTEs among different plant species spontaneously colonizing mine tailings; (2) to investigate

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which leaf structure(s) contribute(s) to the retention of particles; and (3) to identify which of these plant species has the highest potential to retain particles containing PTEs originating from mine residues.

## 2. Materials and methods

### *2.1. Sites of collection*

Plants were collected in the municipality of Zimapan in Hidalgo State, Mexico. It is an arid region, the annual average temperature is 18.9 °C and the annual average precipitation is 445.9 mm. Rainfall season lasts from May to August, and the dry season from November to March. Predominant wind direction is from the South, Southwest and Southeast. Wind ranged from 0.6 to 10 m $s^{-1}$ (SMN, 2015).

Two mine tailings were selected (Fig. 1): San Francisco (Site 1, S1) and Santa Maria (Site 2; S2). At both sites mine residues contained more than 800 mg $kg^{-1}$ of Cu; concentrations of Zn and Pb were higher than 4000 mg $kg^{-1}$. For Cd, 157 and 120 mg $kg^{-1}$ was reported for S1 and S2, respectively (Sánchez-López et al., 2015). Sulfide minerals such as pyrite, pyrrhotite, galena, sphalerite, arsenopyrite, chalcopyrite, bornite, marcasite dominate the mineralogy at both sites, but other common minerals are calcite, dolomite and quartz. In oxidized mine residues, like S1, gypsum, jarosite, goethite, hematite, boulangerite have been synthetized (Moreno-Tovar et al., 2009).

Site 1 is located between 20°49′32.5″ N and 99°22′20.1″ W. Heaps are constructed at the bottom of a basin and thus surrounded by hills. Despite the fact that the site is away from the urban area, several houses are located around the mine tailings and it is common to observe cattle grazing. At Site 2 (20°44′8.89″ N and 99°23′56.07″ W) the mine tailing is located in an open space close to a populated area and the houses are located along the mine tailing at a distance of 20 m.

### *2.2. Sampling and identification of plant material*

Shoots from the predominant plant species growing at the S1 and S2 locations were collected during the 2013 dry season. Species identification was done at the herbaria of Chapingo University and National Autonomous University. Young leaves, old leaves, and leaves without visible symptoms of disease or insect activity were collected. To avoid the possibility of contamination after sampling, the leaves were sealed and labeled separately in plastic containers until analysis.

### *2.3. Chemical analysis of plants*

For chemical analysis shoot samples were divided into two: one part was kept like collected in the field (unwashed; UW) and the other one was washed (W). The washing protocol consisted of 10 min tap water rinse, 5 min washing with P-free detergent Extran 2% (MA02, Merck), 5 min rinse with distilled water, 10 min immersion in diluted HCl 10%, and a final rinse with deionized water for 10 min. Samples were dried at 65 °C until constant weight. Before milling, 3 leaves were taken from W and UW samples for counting and analysis of particles.

0.5 g aliquots of powdered leaves were digested in a mixture of 1 mL of $H_2O_2$ and 4 mL of $H_2SO_4$:$HClO_4$ (4:1) for 24 h and subsequently heated until the digests developed clear appearance. Then, digests were replenished up to 25 mL and filtered (Whatman 42). Concentrations of Zn, Cd, Pb, Ni, Cu, Co and Mn in each digest were determined using flame atomic absorption spectrometry (FAAS-Perkin Elmer 3100). Blanks and certified reference material (spinach, Standard Reference Material® 1570a, National Institute of

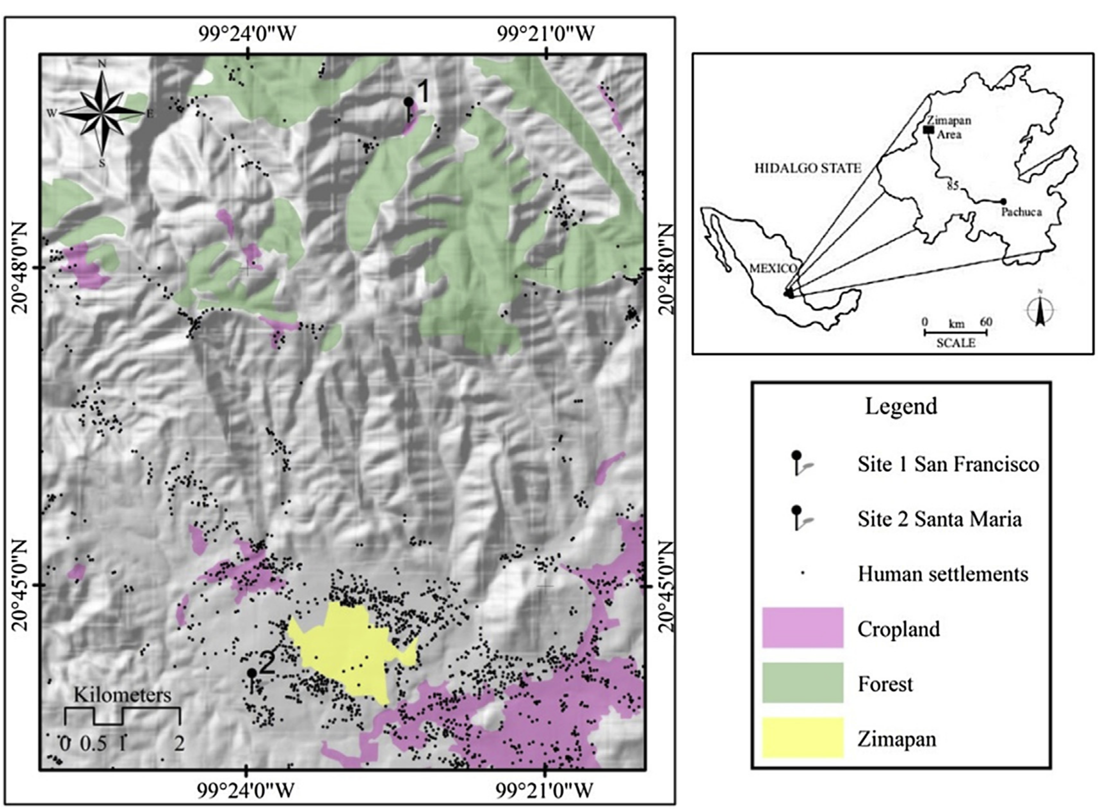


**Fig. 1.** Location of mine tailing sites where plants were collected.