Phytoremediation of arsenic using a chemical stabilizer and *Eleocharis macrostachya* in a contaminated mining soil

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ABSTRACT: Arsenic (As) is a highly toxic metalloid that occurs naturally in the environment, however, anthropogenic activities have also caused this element occurrence in water and soil. The objective of this study was to evaluate phytoremediation capacity of *Eleocharis macrostachya* to remove As from the mining soils using cryptomelane (KMn₈O₁₆) as a chemical stabilizer. Experiment was established under greenhouse conditions during 70 days (10 weeks) using 20 pots with capacity of 3 kg of soils. 15 pots were applied 5 g of cryptomelane, while five pots were considered as a blank. The variables determined were soluble and total As in soil and plant (root and stem). 89% of the As was retained in the root and the rest in stem. The arsenic concentration, both in root and stem, was higher in the control soil than that with cryptomelane addition, which confirms that the chemical stabilizer retains or maintains less bioavailable arsenical compounds.

1 INTRODUCTION

Arsenic (As) is a highly toxic metalloid that occurs naturally in the environment, however, anthropogenic activities have also caused this element occurrence in water and soil (Han *et al.*, 2003; Hettiarachchi *et al.*, 2000). Once in the ecosystem, As affects the quality of soils and waters used for various productive activities (Singh *et al.*, 2015). In contrast to conventional treatments (physicochemical), which require long periods of time, involve high costs and can generate residual compounds, phytoremediation that develops the stabilization, transformation and degradation of pollutants, has the characteristics of being an ecological alternative, implemented in situ and have social acceptability (Wani *et al.*, 2017; Singh *et al.*, 2015). The objective of this study was to evaluate phytoremediation capacity of *Eleocharis macrostachya* to remove As in the mining soils using cryptomelane (KMn₈O₁₆) as a chemical stabilizer.

2 METHODS/EXPERIMENTAL

2.1 Soil sampling and experimental

The soil collected for this study was taken from the surroundings of Avalos smelter (28°37'17.32" N, 106°00'12.73" W). Soil samples were taken at 0.30 m of depth from six points near to the tailing dam. Experiment was under greenhouse conditions during 70 days (10 weeks) an experiment of 20 pots with capacity of

3 kg of soils, 15 pots were applied 5 g of cryptomelane (KMn₈O₁₆) chemical stabilizer while 5 pots were used as control. After ten days of the stabilizer addition in the soil, *Eleocharis macrostachya*, collected of natural wetland in Chihuahua, Mexico, was planted. The variables that were measured are soluble and total As in soil and plant (root and stem).

2.2 Arsenic analysis

Arsenic concentrations in soil and plant were analyzed after 70 days of the experiment. The samples were analyzed for total and soluble arsenic by atomic absorption spectrometer (AAS) according NMX-AA-132-SCFI-2016, using HACH® spectrometer model DR2000™.

3 RESULTS AND DISCUSSION

3.1 Total and soluble arsenic in soil

Table 1 shows the average concentrations of total and soluble As determined in soil at the end of the experiment.

3.2 Roots and stem

89% of the As stabilized by soil was retained in the root and the rest in stem, both for the samples treated with the stabilizer and for the control targets. When stabilizer was used, the average As concentration in

Table 1. Total and soluble As concentrations in soil after 70 days.

Treatment	Total As (mg kg ⁻¹)	Soluble As (μg L ⁻¹)	U.S. EPA Permissible limit (mg kg ⁻¹)
Initial As concentration in soil	2,796.62	8.07	24 mg kg ⁻¹
As concentration in soil (after stab.)	2044.47	N/D	—
As concentration in soil (after phyt. + estab.)	2409.97	7.97	—

Table 2. Descriptive statistics of concentrations of As in roots (a) and stem (b) of *Eleocharis macrostachya*.

(a) Roots					
Treatment	n	mean	SE	min	max
Phytoremediation (stabilizer)	15	779.26	135.61	361.69	1119.55
Phytoremediation (without stab.)	5	877.72	122.45	173.18	1869.01
*SE: Standard Error					
(b) Stem					
Treatment	n	mean	SE	min	max
Phytoremediation (stabilizer)	15	105.17	15.80	25.58	252.30
Phytoremediation (without stab.)	5	77.66	20.87	27.34	154.47

*SE: Standard Error

Figure 1. The average As concentrations in roots and stem after stabilizer apply.

the root was 779.26 mg kg⁻¹, while for the stem it was 105.17 mg kg⁻¹ (Fig. 1). In the controls average As concentration in root was higher than plants with stabilizer, with an As concentration of 877.72 mg kg⁻¹.

It is important to mention that reproduction and development of plants in both treatments were

Figure 2. Reproduction of *Eleocharis macrostachya* in both treatments.

similar (Fig. 2). Tendency was positive during experiment (70 days or 10 weeks).

4 CONCLUSIONS

The maximum decrease in the soluble arsenic concentration was presented with the application of the chemical stabilizer. The concentration of arsenic after phytoremediation in the control targets and in the soil samples treated with the stabilizer was similar. On the other hand, the arsenic concentration, both in root and stem, were higher in the plants planted in the control soil, which confirms that the chemical stabilizer retains or maintains less bioavailable arsenical compounds.

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