Arsenic removal through rhizofiltration by *Eleocharis macrostachya*

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1 ABSTRACT

Technologies currently available for the remediation of arsenic-contaminated sites are expensive and environmentally disruptive. Rhizofiltration, a strategy of phytoremediation that uses plants to clean up contaminated water, has been successfully applied in this study to remove arsenic from contaminated water. Proper plant selection is key to ensuring the success of rhizofiltration as a water cleanup strategy. Therefore, the aim of this study was to analyze the behavior of *Eleocharis Macrostachya* in the removal of arsenic from water. The experiment was performed by duplicate in constructed wetland prototypes. Results indicate that *E. Macrostachya* was able to tolerate and accumulate in its roots significant amounts of arsenic from water (47mg-kg^{-1} dry weight). The number of individual plants doubled during the experiment, showing that the presence of the metalloid had no effect on growth. The removal efficiency of arsenic from water in the system ranged from 90 to 99% for an input concentration of 0.1 and 0.5 mg-L^{-1}, respectively.

2 INTRODUCTION

Arsenic (As) may be found in underground water which has been in contact with arsenic-rich rocks. Severe health effects have been observed in populations drinking arsenic-rich water over long periods in countries worldwide. Since groundwater serves as the principal source of drinking water for the majority of the population in Mexico, the presence of arsenic in water sources is of great concern. The US Environmental Protection Agency and the World Health Organization established a concentration of 0.01 mg/L total As in water as the maximum permissible limit. In Mexico, the maximum concentration of total As in water destined for human consumption is 0.025 mg/L (NOM-127).

Common technologies available for treating As-contaminated water include coagulation/filtration, reverse osmosis, lime softening, adsorption into ferric oxides and activated alumina. All these technologies have several disadvantages and can be expensive for rural comunities. Nanotechnology, specifically the use of nanoscale iron particles (1–100 nm) to remove As, represents a new technique; however, the processes are still under development, the cost of generating these small particles must be optimized and their human impact analysed (Colvin, 2007).

A promising alternative to these conventional cleanup methods is rhizofiltration, a phytoremediative technique designed for the removal of metals in aquatic environments. The process involves several steps, starting with the selection of the most promising plants capable of removing the contaminant from water and retaining it in their roots. The plants are then transplanted into a constructed wetland, where arsenic from the polluted water will be removed. The plants in this process mainly absorb and concentrate the metals in their roots, but also translocate some low quantities to their shoots. (Dushenkov et al. 1995). Previous studies have shown that *E. Macrostachya* has the potential to function as a biofilter to clean up As-contaminated groundwater (Alarcón-Herrera et al., 2007. However, the behavior of the plant and its efficiency at arsenic removal from water in constructed wetland conditions is not known. The objective of the present study was to determine the behavior *E. macrostachya* as a rhizofiltrator of arsenic in a constructed wetland prototype under the local environmental conditions of a semi-arid region northern Mexico (Chihuahua).

3 MATERIALS AND METHODS

Plants were collected from native environments, propagated and transplanted into pots with coarse sand as substrate, always covered with 5cm of water to simulate flood conditions for 50 days. After that, the plants were transplanted into the constructed wetland prototypes and acclimated for 5 weeks.

Experimental design: The study was conducted over a period of 7.5 months in a system consisting of three prototypes of constructed wetland (Units: P-H1, P-H2, P-H3) all operating in parallel with sub-surface flow. The support medium was lime sand. Two of the units (P-H1 and P-H2) were planted with *E. macrostachya* plants, with a plant density of 4000 plants/m^2. The third unit was used as a control (P-H3), with a similar lime sand substrate but no plants. Two influx arsenic concentrations (0.1 and 0.5mgL^{-1}) and two retention times (2.3 and 1.0 d^{-1}) were used during the experiment. Arsenic solutions were prepared using sodium arsenite (NaAsO2 100%) from Fisher Scientific laboratories. This salt was diluted in water, which comes from underground water wells in Chihuahua City.

Sampling and analysis: To determine the As removal by the system, water samples were collected at the entrance and exit of the wetland units daily throughout the time of the experiment. At the end of the experiment, a sampling of soil and plants was performed on the wetland units in order to determine the total arsenic content retained by plants and soil. Arsenic concentrations in the plants' structure was determined for both the aerial parts and the roots. Both sections were first washed with drinking water and then with tridistilled water. Next, they were placed in paper bags and dried at 40 °C for 7 days until constant weight. From each plant's dry material, 0.5 g samples were subjected to acid digestion with nitric acid (HNO_3) for 12 hours at laboratory ambient temperature (20 °C). Digestion then proceeded in a microwave oven, in accordance with the method recommended by CEM (2002). Concentration analyses of the samples with low concentrateons were then performed with an atomic absorption spectrophotometer equipped with a BGC Avanta Sigma hydride generator. A plasma emission spectrophotometer (ICP-OES) was used for the soil and plant analysis, as well as that of samples with high arsenic concentrations.

Monitoring the tolerance of E. macrostachya to arsenic: Counts of the number of individuals per wetland were used to determine the level of tolerance and reproduction of the plant. Regular measurements were performed on 81 previously identified individuals at different stages of the experiment in order to determine the height of the plants.

4 RESULTS AND DISCUSSION

The number of *E. Macrostachya* individuals in the wetland units doubled during the experiment, and they reached in average a length of 1.6 m.

At the end of the experiment, the average arsenic concentrations in the plants' roots and in the system soil were 48 and 13 mg-kg^{-1}, respectively, indicating that the plant retained 3.7 times the amount of As retained by the soil around it. These results indicate that *E. Macrostachya* acted during the experiment as an efficient rhizofiltrator, retaining a great quantity of arsenic in its roots. This can be attributed to the fact that *E. Macrostachya* is a terrestrial plant that has a long fibrous root system with a large surface area for metal sorption.

According to the literature, the ideal plant for rhizofiltration is one that is able to accumulate and tolerate significant amounts of the target metals while in conjunction with easy handling, low maintenance cost, and a minimum of secondary waste requiring disposal (Dushenkov et al., 1995). After the experiment, we observed that *E. macrostachya* has complied with most of these requirements. Remaining to be analyzed are the maintenance and disposal costs.

Arsenic removal from the treated water showed an efficiency of 99%, for the test period with the highest As feedwater concentration (0.5mgL^{-1}), and 89% efficiency for the test stage with the lowest As concentration (0.1mgL^{-1}). Based on these results, one can deduce that the concentration at the system entrance has a heavy influence on the system's operation efficiency; higher entry concentrations lead to higher arsenic removal efficiency. The arsenic removal efficiency from water of the wetland with no plants (P-H3) was of only 23% at the end of the experiment, which shows the importance of the plants in arsenic removal.

5 CONCLUSIONS

Eleocharis macrostachya is an arsenic-tolerant plant with the capability of rhizofiltrating arsenic from water under constructed wetland conditions with sub-surface flow. No negative effects were observed during the 7.5 months with the studied As concentrations. The removal efficiency of arsenic from water in the units with plants ranged from 90 to 99% for an input concentration of 0.1 and 0.5 mg-L^{-1}, respectively.

6 REFERENCES

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