Arsenic Removal Processes for Groundwater in a Treatment Wetland

M.T. Alarcón-Herrera[a], M.C. Valles-Aragón

[a] Center for Advanced Materials Research. CIMAV. Miguel de Cervantes 120., Chihuahua C.P. 31109, MEXICO. teresa.alarcon@cimav.edu.mx

INTRODUCTION

Arsenic pollution in groundwater is a worldwide issue due to its toxicity and chronic effects on human health. This problem has generated an increasing interest in the use of different treatment technologies to remove arsenic from contaminated groundwater sources. Treatment wetlands are a cost-effective natural system successfully used for removing different organic and inorganic pollutants and have shown high capability for removing arsenic. In this study, the main contaminant removal processes occurring in subsurface-flow treatment wetlands treating groundwater were reviewed. The redox conditions, pH and temperature, prevailing in the treatment wetlands were analyzed and linked to elucidate the possible arsenic removal processes.

METHODS

The study was conducted with three constructed wetlands prototypes. Two planted (HA and HB) with *Eleocharis macrostachya* and *Schoenoplectus americanus* respectively; other one (HC) remained unplanted as a control (Figure 1). The system was fed with synthetic water, prepared with groundwater added with Sodium Arsenite ($NaAsO_2$) in order to reach As values of 90 ± 15µg/L. Redox potential (Eh): was continuously monitored by a digital equipment (Hach, PC SC and RC model: Sc 1000), with a range of 0 ± 2000mV and ±20mV of accuracy. pH was measured, three times per week in every sampling well. Water temperature was automatically monitored every hour using a conductivity data logger (HOBO U24-00) in a range of -2 up to 36ºC and 0.1 ºC of accuracy. Environmental temperature was monitored using temperature sensors (HOBO, Light Logger UA-002-64) in a temperature range of -20 up to 70 ºC and ± 0.54°C of accuracy.

Arsenic determinations

Samples were taken from the water inflow and outflow every week. Arsenic determinations were carried out using an atomic absorption spectrophotometer with hydride generator GBC Avanta Sigma equipment. Duplicate samples, certified standards (traceable at National Institute of Standards and Technology, NIST), and blanks were analyzed. Arsenic recovery from analyzed controls was 96% ± 3% for all samples. Arsenic quantification limit was 5µg/L.

RESULTS AND DISCUSSION

Results shown that oxidized conditions from 87 to 516mV were presented during 84 and 90% of the days in the hot and warm seasons respectively; while reduced conditions where reported the rest of the time (up to -539mV). On the cold season, only oxidized conditions were observed. Eh values fluctuated as a consequence of weather conditions (the lower the temperature, the higher the Eh). pH values were lower than 8, which indicate that $HAsO_4^{2-}$ was the main As specie. Under this circumstances it was assumed, that As can be retained by precipitation/absorption onto Fe^{3+} and Mn^{5+} oxyhidroxides (at pH≥6.5 and Eh>0), since high pH and oxidize conditions enhance the oxides-arsenic affinity (Marchand et al., 2010).

During the experiment, pH values in every wetland sections, ranged from 7.0 to 8.0 on HA and HB. Higher pH values (8.0 to 8.5) were registered for HC. Other authors reported the same tendency with pH values in a range from 7.2 to 8.1 in planted wetlands, whereas unplanted wetlands range was from 8.1 to 8.5 (Zurita et al., 2012).

Arsenic retention was around 87% in the planted system, compared to 46% in the unplanted. According to these results, root activity is highly involved on As immobilization on planted wetlands (Rahaman et al., 2011). The lower As retention in the unplanted prototype, was attributed to alkaline pH prevailing in the mesocosms (pH>8.5). At this conditions As desorption was theoretically due to the negative charge on the mineral surface (Frohone et al., 2011).

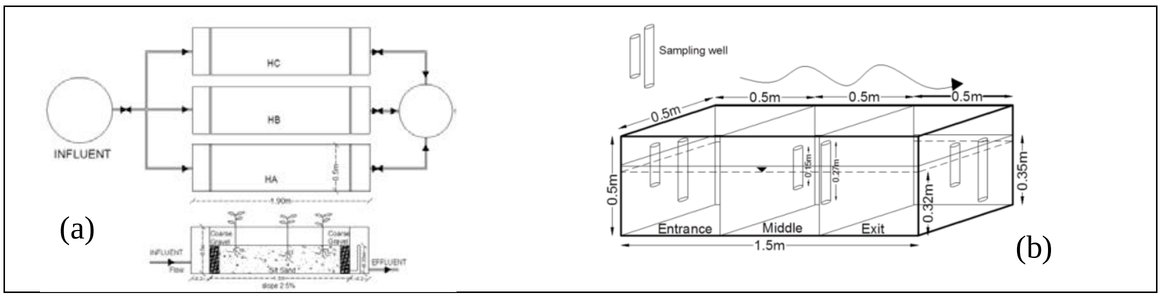

Fig. 1.-Diagram of experimental design: a) HA and HB: prototypes with plants, HC: no plants. b) monitoring and sampling wells.

CONCLUSIONS

The increased capacity of the soil to retain As in the mesocosms prototypes was attributed to the plants. Rhizosphere oxygenation through plants promoted oxidized conditions in the mesocosms most of the operational time. Under this conditions, the arsenic removal as As^{+5} was propitiated by precipitation and its adsorption onto oxyhidroxides (Fe^{+3} and Mn^{+5}) present in the soil.

ACKNOWLEDGEMENTS

This research has been supported by the Spanish Agency for International Development Cooperation (AECID) through the projects 10-CAP1-0631 and 11-CAP2-1583. This study has also been co-funded by the Spanish Ministry of Economy and Competitiveness and the European Union through the European Regional Development Fund.

REFERENCES

Frohne, T., Rinklebe, J., Diaz, R., Du Laing, G. (2011). Controlled variation of redox conditions in a floodplain soil: Impact on metal mobilization and biomethylation of arsenic and antimony. Geoderma, 160 pp. 414 - 424.

Marchand, L., Mench, M., Jacob, D., Otte, M. (2010). Metal and metalloid removal in constructed wetlands, with emphasis on the importance of plants and standardized measurements: A review. Environmental Pollution, 158 pp.3447-3461.

Rahman, K., Wiessner, A., Kuschk, P., Afferden, M., Mattuschc, J., Müllera, R. (2011). Fate and distribution of arsenic in laboratory-scale subsurface horizontal-flow constructed wetlands treating an artificial wastewater. Ecological Engineering. 37 pp. 1214–1224.

Zurita, F., Del Toro-Sánchez, C., Gutierrez-Lomelí, M., Rodriguez-Sahagún, A., Castellanos-Hernandez, O., Ramírez-Martínez, G., White, J. (2012). Preliminary study on the potential of arsenic removal by subsurface flow constructed mesocosms. Ecological Engineering, 47 pp. 101-104.