Potential of Arsenic Removal in Constructed Wetlands

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INTRODUCTION

Arsenic in groundwater poses one of the most important environmental health risks of the present century. In many parts of the world, groundwater resources naturally contain high levels of arsenic. The technologies of arsenic removal include conventional co-precipitation, lime softening, filtration, ion exchange, reverse osmosis and membrane filtration. Bulky sludge, high energy requirements and cost, as well as the excessive use of chemicals, keep these techniques from being cost-effective, especially at small scales and in rural communities. Because of this, there is an urgent need for innovative low-cost water purification techniques (Jiang, 2001). Constructed wetland models have been created for the removal of As and heavy metals from different wastewaters, but until now they have not been considered for the treatment of drinking water. The performance of As and heavy-metal removal from artificial wastewater varied with the type of the constructed wetland. Subsurface wetlands and free surface wetlands removed heavy metals better than hydroponic systems and algae ponds (Buddhawong et al., 2004). There are several plant species with promising results in arsenic phytoremediation. Although hyperaccumulators are mostly considered for the phytoextraction of As from soil and water in contaminated sites, accumulators and tolerators can be very useful in the phytostabilization and rhizofiltration of polluted water with the metalloid. Constructed wetland systems with plants and a combination gravel/soil matrix have the potential to remove arsenic from contaminated water; therefore, the purpose of this study was to determine the system behaviour in a prototype subsurface wetland.

METHODS

This study was conducted in a subsurface wetland prototype system, with three units operated in parallel under a continuous flow. Prepared water with an As concentration of 1mg L^{-1} was used as influent. The design of the prototype was created based on the hydraulic factors of the system, considering a piston flux. The hydraulic retention time of the solution in the wetlands was 8 days. The test period was 38 days. Plant rhizomes of *Schoenoplectus americanus* were planted in the units. Two months of adaptation in the support medium allowed the plants to develop roots and invade the wetland prototypes.

Sampling and analytical determination

The influent and effluent of the systems were monitored throughout the experiment. Plants and soil were analysed at the end of the experiment. The soil and water samples were submitted to acid digestion following the EPA methodology (EPA-SW–846–3051 and 3015). All plants were separated into aerial part and roots for the As determination. Total As determinations were performed in an Inductively Coupled Plasma Optical Emission Spectometer (ICP/OES) and in an atomic adsorption spectrophotometry apparatus model Avanta Sigma GBC, equipped with a GBC hydride generation system model HG 3000. The validation of the analytical method for the determination of total As was performed with certified standards (High Purity Standards). For the plant samples, a certified tomato leaf standard was used (NIST 1573a). The precision was 95.5%, uncertainty 3.3%, error 6.8%, and recovery 112%.

RESULTS AND DISCUSSION

The removal of As in the 3 units during the time of the experiment was around 90%. The analysis of variance indicates that there were no significant differences between the values obtained in the three units (95% confidence interval).

As retention in plant tissues

Schoenoplectus americanus successfully developed in the test units with no apparent physical deterioration. The amounts of As retained in the plant structure at the end of the period were 188, 128 and 203 mg kg^{-1} of dry biomass for the plants of units CW–1, CW–2, and CW–3, respectively. The greatest retention was at the root level, which confirms along with previous studies that *Schoenoplectus americanus* is a highly tolerant plant.

Arsenic retention in the medium (gravel) of the units

During the experiment, an average of 431mg per unit of As was accumulated in the gravel of the system. A general balance of the amounts of arsenic retained in the 3 test units is presented in Table 1; as can be observed, 86% of the As retention occurred in the medium (gravel). Plants retained only 1% of the arsenic; however, it is considered that they contributed in conjunction with the micro-organisms and the physical conditions created in the complex system to promote the precipitation and retention of this metalloid in the medium that resulted in a general removal of 90%. It is considered that this efficiency of arsenic removal in the system can be further improved by optimizing the critical variables, but this required a lot more experimentation.

Table 1. Balance of the amount of arsenic retained in the test units.

Unit	Influent	Gravel	Plants	Effluent	As retention (%)
			As, mg		
CW–1	489	423	5	49	90
CW–2	514	438	3	54	89
CW–3	496	433	6	49	90
Average	500	431	4	51	90

CONCLUSIONS

Constructed wetland systems with a combination of specifically As-tolerating plants and a gravel matrix have the potential to remove arsenic from contaminated water. In this study, a removal efficiency of 90% was achieved.

The use of artificial wetlands as an alternative for the removal of arsenic from water is an important technique that has proven useful in prototype systems and should be considered for pilot projects working at lower concentrations and aimed at treating water intended for human consumption.

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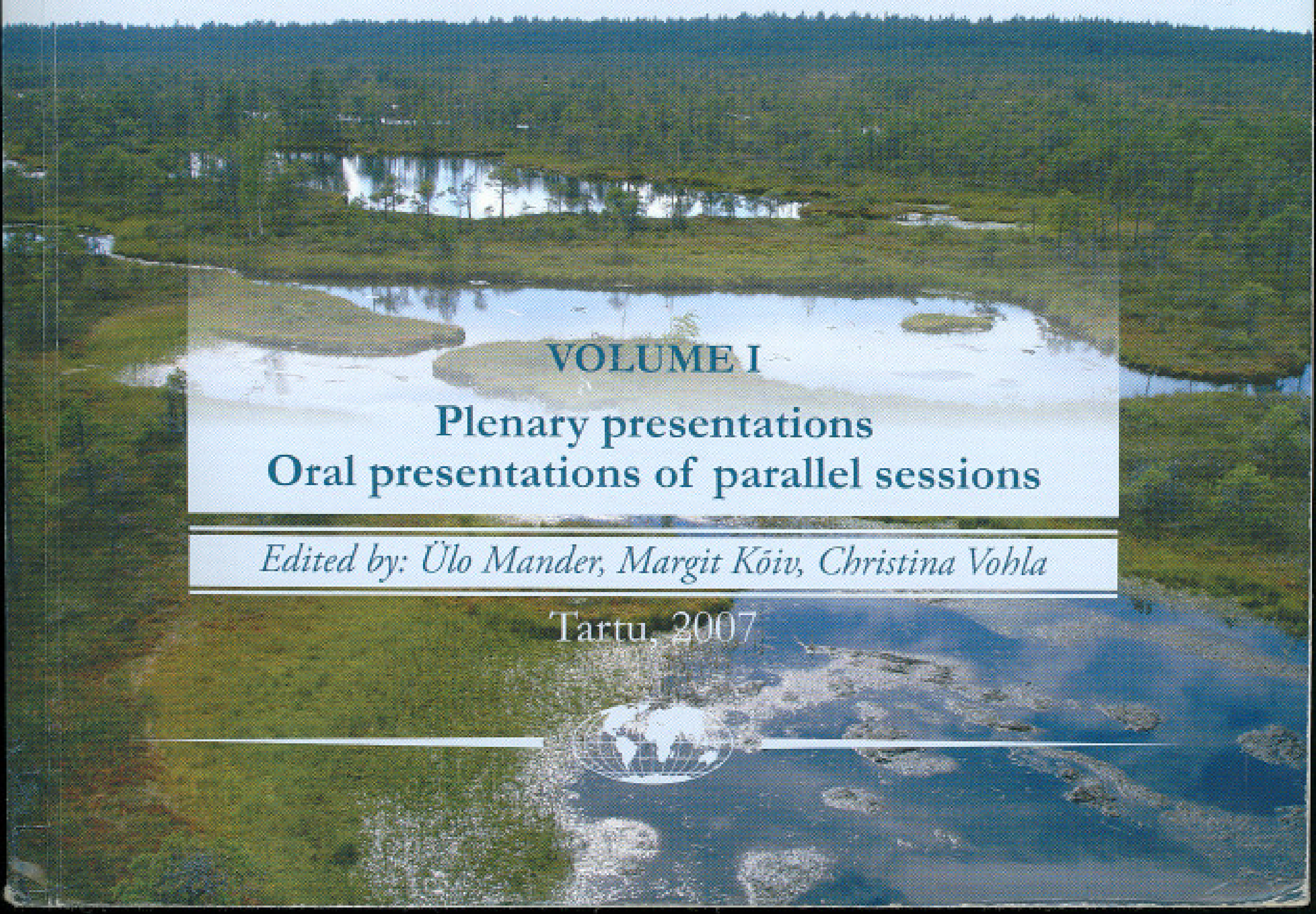

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