Arsenic Retention and Distribution in Treatment Wetlands

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ABSTRACT: Arsenic (As) can be removed from water through its retention in constructed wetlands. The aim of this study was to analyze the arsenic retention in treatment wetland prototypes, as well as its distribution along the flow gradient in a treatment wetland mesocosmos. Experiments were carried out in laboratory-scale wetland prototypes, two planted with *E. macrostachya* and one without plants. Samples of water were taken at the inlet and outlet of the prototype during the testing period. At the end of the experiment, plants and soil (silty-sand) from each prototype were divided in three equal segments (entrance, middle and exit) and analyzed for their arsenic content. Results revealed that the planted wetlands have a higher As-mass retention capacity (87- 90% of the total As inflow) than prototypes without plants (27%). As-mass balance in the planted wetlands revealed that 78% of the total inflowing As was retained in the soil bed. Nearly 2% was absorbed in the plant roots. In the prototype without plants, the soil retained only 16% of As-mass, 72% of the arsenic was accounted for in the outflow. The plants retained only 2% of the total arsenic mass in their roots; however its presence was determinant for arsenic retention in the wetland soil medium. Therefore, it can be assumed that treatment wetlands are a suitable option for treating As-contaminated water.

Keywords: Arsenic, water, treatment wetlands.

1 INTRODUCCION

Treatment wetlands (TWs) are an innovative technology in water treatment, which has proven to be both effective and affordable. Some species of aquatic macrophytes can be used for water treatment, due to the great extent to which they accumulate arsenic from water. The behavior of metals and metalloids in aquatic systems is complex and may include interactions among or between major wetland compartments: above-ground plant parts, roots, litter, biofilms, soil, and water (Kadlec and Knight,1996). Chemical reactions, such as acid–base, precipitation, complexation, oxidation/reduction, and sorption, all play a role in removing metal ions from the water column, resulting in a metal-ion complex more or less rapidly settling in the sediments (Yong, 1995). To understand As-retention capacities, it is necessary to analyze the specific behavior of arsenic during uptake by plants, as well as the influence of media (soil) retention (Frohne et al. 2011). The mass balance of As in treatment wetlands, both in the presence and absence of wetland plants, could yield insights on the capacity of treatment wetlands (TWs) to retain arsenic from water. Therefore, the objectives of this study were: a) to investigate the arsenic retention capacity of subsurface-flow TWs prototypes with and without plants, and b) to investigate the distribution of total arsenic in main wetland compartments (plants and soil bed) and in three segments (entrance, middle and exit) of each prototype along the flow path.

2. MATERIALS AND METHODS

Laboratory-scale prototypes; Three wetland prototypes built with acrylic (length: 150cm, width: 50cm, height: 50cm) were used in this study. The prototypes were uniformly filled with 200 kg of silt sand (porosity of 31%, and hydraulic conductivity of $6.89X10^{-4}$ cm/s). Two prototype wetlands (W1 and W2) were planted with *E. macrostachya*, and one prototype remained unplanted (W3) as a control.

Arsenic mass balance. After 4 months of operation, the experiment was ended. An arsenic mass balance was performed in each prototype unit and within the three segments by considering the total As-mass input, the total As-mass output, and the total As retained in the soil and plant biomass. The remaining (loss or gain) of arsenic from the mass balance was considered to be unknown. The total As-mass input and output in each unit was calculated from the cumulative total As-mass inflow and outflow during the whole operation time period.

Sample collection and analysis. Throughout the experiment, water samples were taken before the entrance and after the exit of the three units. Samples were preserved for later digestion and measurement of arsenic content. At the end of the experiment, plant biomass samples were collected. For plant sampling, each prototype (W1 and W2) was divided into three equal segments (entrance, middle and exit). Plant samples, were prepared to be analyzed for arsenic content according to EPA method 200.2.

For soil sampling, the wetland units (W1, W2 and W3) were divided into three equal segments. Soil samples were digested according to the SW-3051 EPA method and analyzed for arsenic content.

3. RESULTS

Arsenic retention by plants. The prototypes with plants showed greatest arsenic retention in the exit section of prototype, reaching root arsenic dry weight concentrations of 33±1.37 and 47±1.42 mg/kg. The entrance sections retained 17±0.70 and 27± 1.01 mg/kg in W1 and W2, respectively.

Arsenic retention in soil. As concentration in soil decreased between the entrance and exit segments from 13.05±0.75 to 5.86 ± 0.26 mg/kg (dry weight). In the un-planted prototype W3, the arsenic concentration values presented the same trend but also significantly lower concentrations in all three segments (4.91±0.30, 1.86 ± 0.20 and 0.14 ± 0.05 mg/kg (dw) for the entrance, middle and exit segments, respectively). Arsenic retention in the soil of the prototypes showed an inverse behavior to that of the plants. A better retention of Arsenic was obtained at the entrance section of each unit. The obtained arsenic concentrations show a great difference between the retention of arsenic from the soil of the units with and without plants.

Arsenic mass balance and distribution. The total mass balance showed that the soil with the plants is the main source of As retention system in units W1 and W2. The mass of arsenic that was retained in the units with plants was 1210 and 1044 mg for W1 and W2, respectively, while the unit without plants (W3) retained only 230 mg. The units with plants (W1, W2) presented a smaller quantity of arsenic in the exit water (182 and 140 mg, respectively) than the unit without plants W3 (1034 mg). The plants' retention of arsenic was very small (2%) in comparison to that obtained from the soil-bed of units W1 and W2, which retained 84 and 72%, respectively. Like in natural wetlands, a TW's environment is very complex. However, it is known that plants add to the wetland environment a high capacity of arsenic retention through different physical-chemical mechanisms like precipitation, adsorption, chelation, and complexation among others.

4. CONCLUSIONS

In a treatment wetland, As is mainly retained by soil. However, plants play an important role in the arsenic retention capacities of wetland systems, making the whole system able to retain arsenic better than unplanted wetland systems.

5. BIBLIOGRAPHY

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