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Summary – PhD thesis

Constructed wetlands and their performance for treatment of water contaminated with arsenic and heavy metals

Constructed wetland models were investigated for removal of As and heavy metals from different wastewaters.

In batch models of wetland systems, the performances of As and heavy metal removal from artificial wastewater varied with the type of the constructed wetland. The subsurface wetland (SSW) and free surface wetland (FSW) removed heavy metals better than hydroponic system (HP) and algae pond (AP). The combination of gravel bed and plants (e.g. *Juncus effusus*) resulted in a high removal rate. The heavy metals mostly accumulated in the plant roots. The remaining amounts were bound to the gravel, precipitated, attached to or incorporated into the cells of micro-organisms and adsorbed on sediment to the bottom.

Also a two step constructed wetland system with continuous flow, consisting of HP and FSW was tested for the removal of As, Zn and Cr from an artificial wastewater. A high removal rate was observed in the first phase of the experiment, when a high load of carbon source was supplied, which enhanced anaerobic conditions. Zn, As and Cr probably precipitated with iron and S^{2-}, which were present in the systems. As(V) could precipitate as $FeAsO_4$ or be immobilized on hydrated iron oxides. Under anaerobic conditions, As(V) was reduced to As(III), which could precipitate with S^{2-}. The average removal efficiencies of the HP decreased in the sequence Cr ≈ Zn > As (118, 114 and 18 mg/m^{2}d, respectively).

As the toxicity and the environmental behaviour of As strongly depends on the species in which it is present; also the As speciation was investigated in the experiments described above. The data show that methylated arsenic species occurred under reducing conditions. In particular, As(III) was found in compartments with low concentration of oxygen, i.e. near the bottom of the SSW and FSW wetlands, and in the HP of the two-step constructed wetland. Methylated arsenic was also found in the AP due to the appearance of algae which could transform toxic As(V) to other non-toxic As species.

The planted FSW in a field test was highly effective for treatment of acidity and metals from acid mine drainage, with a removal capacity for acidity of about 34-51 mmol NaOH/m^{2}d, for Zn of about 4-10 mg/m^{2}d and for Fe of about 73-122 mg/m^{2}d. SSW and HP also remove acidity and metals, although to a lower extent. The hydroponic systems had significantly less capacity for the removal of all parameters than the systems containing soil material.

The plants in the system promoted the neutralization and took up metals from wastewater. In both FSW and SSW, Zn and Fe were accumulated in the roots and at the root surface rather than in the shoots. Soil materials were found to accumulate Fe rather than Zn, especially in the planted FSW.

In conclusion, constructed wetland systems with a combination of gravel/soil matrix and plants have a high removal rate of heavy metals in both lab models and a field test system.