Green Topics

This is an abstract from Environmental Service and Technology (Vol 32 No 20 1998) which will be of interest to South African Mining and Metallurgical Scientists, involved in chromium mining and Metallurgical processing. Maybe the scourge of our dams and reservoirs—the water hyacinth can be put to good use!

Reduction of Cr(VI) to Cr(III) by wetland plants: Potential for *in situ* heavy metal detoxification

The novel technology of phytoremediation embraces plant accumulation processes for the cleanup of toxic heavy metals and organic chemicals. Several plant species have been identified that are excellent hyperaccumulators of a number of heavy metals, e.g., *Brassica juncea* (Indian mustard) and *Thlaspe caerulescens* (Alpine pennycress). Other species including *Myriophyllum brasiliense* (Parrot's feather), *Salix* sp. (willow), and *Popullus* sp. (poplar) have also demonstrated phytoremediating abilities.

A potentially significant approach to heavy metal remediation is the use of plants that detoxify metals *in situ* through plant-based chelation, reduction, and/or oxidation mechanisms. For example, *Potamogeton pectinatus* (Sago pondweed) detoxified high concentrations of accumulated manganese when aqueous Mn(II) absorbed by the roots was oxidized to a nontoxic manganese(III) oxide in leaf tissues over the growing season. It was also demonstrated that cadmium in the xylem sap of *B. juncea* was cheleated by oxygen (organic acids) and sulfur ligands (phytochelatins) in the transport, accumulation, and detoxification of Cd. Recent studies have found that selenium detoxification in a constructed wetland receiving selenit-contaminated refinery wastewater may be due in part to wetland plant-based reduction of toxic selenite to nontoxic dimethylselenide gas.

Chromium has many industrial uses, and its unregulated application has led to the contamination of soil, sediment, surface waters, and groundwaters. Hexavalent chromium was classified as a primary contaminant because of its mobility in soil and groundwater and its reported harmful effects on organisms including humans. Within living cells Cr(VI) induces cancer and mutation by damaging DNA-protein cross-links and by causing single-strand breaks. Cr(III), on the other hand, is stable, nontoxic, and listed as an essential element for the good health and nutrition of many organisms.

Because the reduction of toxic Cr(VI) leads to the formation of stable, nontoxic Cr(III), it is important to study how this reduction may be implemented so as to achieve detoxification and therefore environmental cleanup *in situ*. Reduction of Cr(VI) can be accomplished abiotically by reactions with aqueous ions, by electron transfer at mineral surfaces, by reduction with humic substances and other organic molecules and by lyophilized plant tissues. More importantly, from the point of view of environmental cleanup, the reduction of Cr(VI) can be mediated biologically by various enzymes and nonenzymatic agents; enzymes include cytochrome P-450 reductase, NAD(P)H quinone reductase, glutathione reductase, and aldehyde oxidase.

Microbial reduction of Cr(VI) to Cr(III) has been demonstrated. A NADPH-dependent Cr reductase capable of Cr(VI) detoxification was purified from the bacterium *Pseudomonas ambigua* G-1. Several studies indicate that plants have the ability to reduce Cr(VI). Some of these studies were conducted using speciation techniques that required chemical extraction of plant materials before determination of the Cr species in the plant tissue; however, such sample preparation procedures may alter the speciation resulting in artifacts. To eliminate sample preparation artifacts, we used a synchrotron-based X-ray absorption spectroscopy technique to speciate Cr in untreated live plant tissues of *Eichhornia crassipes* (water hyacinth), a wetland plant that is frequently planted into constructed wetland treatment systems containing heavy metal-contaminated wastewater. Our objective was to determine whether *E. crassipes* and other wetland plant species can reduce toxic Cr(VI) to nontoxic Cr(III) and subsequently accumulate detoxified Cr into leaf and root tissues.

Reduction of heavy metals *in situ* by plants may be a useful detoxification mechanism for phytoremediation. Using X-ray spectroscopy, we show that *Eichhornia crassipes* (water hyacinth), supplied with Cr(VI) in nutrient culture, accumulated nontoxic Cr(III) in root and shoot tissues. The reduction of Cr(VI) to Cr(III) appeared to occur in the fine lateral roots. The Cr(III) was subsequently translocated to leaf tissues. Extended X-ray absorption fine structure of Cr in leaf and petiole differed when compared to Cr in roots. In roots, Cr(III) was hydrated by water, but in petiole and more so in leaf, a portion of the Cr(III) may be bound to oxalate ligands. This suggests that *E. crassipes* detoxified Cr(VI) upon root uptake and transported a portion of the detoxified Cr to leaf tissues. Cr-rich crystaline structures were observed on the leaf surface. The chemical species of Cr in other plants, collected from wetlands that contained Cr(VI)-contaminated wastewater, was also found to be Cr(III). We propose that this plant-based reduction of Cr(VI) by *E. crassipes* has the potential to be used for the *in situ* detoxification of Cr(VI)-contaminated wastestreams. ◆

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