The Economic Significance of the Phytoextraction of Nickel, Cobalt and Gold from Metalliferous Soils.

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Abstract

Phytoextraction of heavy metals is a relatively new technology that has potential applications for the remediation of many contaminated sites around the world. The technology has significant applications in the minerals industry for the treatment of low-grade ores and metalliferous mine waste.

This study concerns the investigation of the potential to remove heavy metals, in particular nickel, cobalt and gold, from artificial and lateritic substrates. Four experiments comprise this study of the phytoextraction of nickel, cobalt and gold using both accumulator and non-accumulator species. Nickel and cobalt bioavailability was determined by ammonium acetate extraction for both artificial and laterite substrates. It was found that ammonium acetate extractability was predictive for nickel accumulation from a nickel-only artificial substrate. Cobalt bioavailability did not predict the accumulation response of either *Alyssum bertolonii* or *Berkheya coddii* grown of artificial substrates.

The potential for phytoextraction of nickel and cobalt was investigated using the known nickel hyperaccumulators *A. bertolonii* and *B. coddii*, grown on artificially prepared substrates. The substrates were nickel-only (4 mg/kg to 1000 mg/kg), cobalt-only (4 mg/kg to 1000 mg/kg) and nickel-cobalt mixed (1:1 ratio, 4 mg/kg to 500 mg/kg) amendments of sulphates to commercial potting mix. Hyperaccumulation from nickel-only and cobalt-only substrates resulted in typical logarithmic metal uptake by both species. The cobalt-only substrates were phytotoxic to *B. coddii* above a concentration of 15-20 mg/kg. Phytotoxicity significantly reduced biomass production in *B. coddii* without effecting the bioaccumulation coefficient. No corresponding cobalt phytotoxicity was observed in *A. bertolonii* over the experimental range, although biomass production appears to favour substrate concentrations below 30 mg/kg. The bioavailability and hyperaccumulation of cobalt from the mixed nickel-cobalt substrates dramatically reduced the nickel accumulation potential of both species at substrate concentrations below 300 mg/kg. At higher substrate metal concentrations both species return to nickel dominant hyperaccumulation.

Induced gold accumulation in *B. coddii* and *Iberis intermedia* was investigated using, sequential ammonium thiocyanate and ammonium thiosulphate chelation to, a 5 mg/kg gold artificial substrate. An attempt to determine gold bioavailability by ammonium thiocyanate and ammonium thiosulphate extraction was made on the substrate. It was found that neither chelator extraction could be correlated with plant accumulation induced by the same concentration of the reagent. Ammonium thiocyanate induction resulted in plant gold accumulation at or below the substrate concentration. Ammonium thiosulphate induced gold accumulation in *I. Intermedia* reached 48.8 mg/kg when treatment with a 1% solution. *B. coddii* accumulated 9.3 mg/kg gold for the same treatment.

Five consignments of metalliferous lateritic materials from Western Australia were investigated. Three substrates originated from Project Murrin Murrin nickel and cobalt mine operated by Anaconda Nickel Ltd. and two substrates originated from Boddington Gold Mine operated by Worsley Alumina Ltd. Nickel and cobalt accumulation by *A. bertolonii* and *B. coddii* was found to be significantly lower than observed using artificial substrates. Nickel and cobalt bioavailability, determined by ammonium acetate extraction, failed to predict the accumulation responses from laterite substrates. This is attributed to elemental interference by, and possibly ammonium acetate chelation of, other mobile heavy metals in these substrates. A hypothesis deserved of further research. Hyperaccumulation of nickel was observed for both species on the Anaconda Nickel Ltd. SAP substrate only. Appreciable cobalt accumulation (≈90 mg/kg) was observed on the SAP substrate for both species and on the Boddington Gold Mine B5 substrate for *B. coddii*. Phytomining scenarios were determined for both species grown on the SAP substrate. *A. bertolonii* could produce 13 kg of nickel and 0.8 kg of cobalt per hectare with a value of US$ 163. *B. coddii* could produce 23.8 kg of nickel and 2.1 kg of cobalt per hectare at a value of US$ 319. These levels of production could be improved by fertilisation and/or substrate acidification.

A preliminary investigation into induced gold accumulation from laterite substrates by *I. Intermedia*, *A. longiflora*, *Brassica juncea* and *Linum usitatissimum* was made using the acid biased chelator ammonium thiocyanate. It was found that an acidified amendment of ammonium thiocyanate greatly improved the

phytoaccumulation of gold from the lateritic substrates. An amendment of 2M HCl produced appreciable gold mobility and phytoaccumulation and indicates that gold solubility is the primary control on plant uptake. Analysis of various plant tissues indicated that *Acacia longiflora* stored significant gold in its roots compared to foliar components. All plant-substrate combinations indicated a trend towards increasing acidification and gold phytoaccumulation. No plant-substrate-treatment combination produced an economically viable phytomining scenario.

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