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# **Practical Aspects of Phytoextraction**

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Philosophy  
in  
Earth Science

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New Zealand

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## Abstract

Phytoextraction for heavy metals is an emerging technology that has potential application for the remediation of many contaminated sites around the world. The technology has similar application to the mining of low-grade ore bodies. Several practical aspects of the technology are addressed in this thesis.

Natural and induced-uptake phytoextraction trials have been conducted on two contaminated substrates: an area of industrial pollution in northern France, where base metals are present in an oxide and carbonate mineral phase, and an area of mine tailings in New Zealand, where base metals are present in a sulphide or sulphate mineral phase. The uptake response of several hyperaccumulator and non-accumulator plant species is described. Geochemical models are then presented that explain the observed metal uptake as a function of the predominant chemical form of metal present in the soil. Natural uptake is dependent upon the form of metal. It appears that the relative efficacy of various hyperaccumulator species to accumulate metals is also dependent upon site-specific geochemistry. The efficacy of chelating agents, in particular EDTA, to induce uptake is similarly dependent upon the chemical form of metals in the soil.

A field trial for cadmium phytoextraction was conducted on an area of pastoral land contaminated with this metal due to the application of cadmium to soil through superphosphate fertilisation. Natural uptake at this site by the hyperaccumulator species *Thlaspi caerulescens* could remove the equivalent of 17 years of annual cadmium application in one harvest. The chelating agent EDTA (ethylenediaminetetraacetic acid) did not induce significant uptake by the non-accumulator *Brassica* species. Instead, the action of this chemical was to redistribute 14% of the cadmium initially present in the 0-5 cm soil depth to the 5-10 cm depth, and to leach approximately 4% of the cadmium initially present at the site to below 10 cm in the soil profile, as shown by mass balance calculations. Phytoextraction effected by *T.caerulescens* is proposed as a management tool for cadmium in the pastoral environment.

Phytoextraction for nickel has been investigated at a field site in the central North Island of New Zealand. Hyperaccumulation was effected by two *Alyssum* species and by *Berkheya coddii*. However, the biomass of the harvested plant material was below that reported in the literature. The conclusion from this trial is that substrate modification of ultramafic soil may be necessary before phytoextraction for nickel could be implemented.

A significant obstacle hindering the practical application of phytoextraction in some environments, is the paucity of hyperaccumulator species that are native to some parts of the world. Western Australia has many sites that may benefit from phytoextraction for nickel. However, only one hyperaccumulator species is native to this region, *Hybanthus floribundus*, a species that has in the past been difficult to germinate from seed. This thesis describes a successful approach to germination, involving the use of one-year-old seeds, treated with 'Regen 2000 smoke water' and germinated under dark conditions, that may overcome this practical aspect (a limitation) of phytoextraction technology.

The most recent advance of induced phytoextraction technology has been the thioligand-induced uptake of gold by plants. The initial discovery and the geochemical rationale behind the induced uptake of gold is described. The maximum gold uptake presented is accumulation of 57 mg/kg dry weight gold by *Brassica juncea* and it is proposed that this level of uptake could make the phytomining of gold from tailings areas an economic proposition.

The conclusion of this thesis is that potential for the implementation of phytoextraction is large. Globally, the technology could offer an environmentally and economically friendly alternative to the traditional decontamination of metals from some sites. There is also potential for the phytomining of metals from low-grade ores. The social implications of phytoextraction technology in third-world countries could also be large. Phytoextraction for gold, for example, from auriferous tailings in Africa and South America, has the potential to improve both the environment and the standard of living of the local communities who live off contaminated land.

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## Chapter 12

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