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

**A thesis in partial fulfilment of the requirements for the degree of
Master of Science at Massey University.**

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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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Table of Contents

Abstract	i
Acknowledgements	iv
Table of Contents	v
List of Figures	viii
List of Tables	x
Chapter One - The Science of Phytoextraction	1
1.1 Introduction	1
1.2 Hyperaccumulators	3
1.3 Phytoextraction.....	5
1.4 Heavy Metal Bioavailability.....	7
1.5 Laterite Formation	11
1.6 Gold Phytotechnology.....	13
1.7 Industrial support to my research	16
1.8 Research Outline.....	18
1.9 Materials and Methods.....	19
1.9.1 Artificial Nickel and Cobalt Substrates.....	19
1.9.2 Artificial Gold Trials	20
1.9.3 pH Determination.....	21
1.9.4 Biomass Analysis	21
1.9.5 Ore Quality Determination.....	21
1.9.6 Total metal determination.....	21
1.9.7 Bioavailable metal determination.....	22
1.9.8 Chelator potential metal determination.....	22
1.9.9 Artificial Induced Gold Phytoextraction Trials	23
1.9.10 Laterite Induced Gold Phytoextraction Trial.....	23
Chapter Two - Nickel and Cobalt Phytoextraction using Artificial Substrates ...	1
2.1 Introduction	1
2.2 Aims of the experiment.....	5
2.3 Phytoextraction of Nickel and Cobalt by <i>Berkheya coddii</i> from Artificial Metalliferous Substrates.....	6
2.3.1 Nickel accumulation in <i>Berkheya coddii</i> vs ammonium acetate extractable nickel from a nickel-only substrate.....	7
2.3.2 The relationship between a nickel-only substrate and biomass production in <i>Berkheya coddii</i>	8
2.3.3 Cobalt accumulation in <i>Berkheya coddii</i> vs ammonium-acetate-extractable cobalt from a cobalt-only substrate	9
2.3.4 Biomass production of <i>Berkheya coddii</i> on cobalt-only substrate.....	10
2.3.5 Nickel accumulation in <i>Berkheya coddii</i> vs ammonium-acetate-extractable nickel from a mixed nickel-cobalt substrate	10
2.3.6 Biomass production of <i>Berkheya coddii</i> on nickel-cobalt mixed substrate.....	14

2.4	Phytoextraction of Nickel and Cobalt by <i>Alyssum bertolonii</i> from Artificial Metalliferous Substrates.....	15
2.4.1	Nickel uptake by <i>Alyssum bertolonii</i> and ammonium-acetate-extractable nickel in a nickel-only substrate.....	16
2.4.2	The relationship between a nickel-only substrate and biomass production in <i>Alyssum bertolonii</i>	17
2.4.3	Cobalt accumulation by <i>Alyssum bertolonii</i> and ammonium-acetate-extractable cobalt from a cobalt-only substrate.....	18
2.4.4	The relationship between substrate cobalt content and biomass production in <i>Alyssum bertolonii</i>	19
2.4.5	Nickel accumulation in <i>Alyssum bertolonii</i> and ammonium-acetate-extractable nickel for a mixed nickel-cobalt substrate.....	19
2.4.6	Cobalt accumulation in <i>Alyssum bertolonii</i> and ammonium-acetate-extractable cobalt for a mixed nickel-cobalt substrate.....	20
2.4.7	The relationship between substrate cobalt and biomass production in <i>Alyssum bertolonii</i>	21
2.5	Conclusions.....	22
2.6	Further research arising from this investigation.....	25

Chapter Three - Induced Gold Accumulation using an Artificial Gold

Substrate	27	
3.1	Introduction.....	27
3.2	The source of free thiosulphate.....	28
3.3	Laterite Gold Mobility.....	29
3.4	The Biochemical Pathway of Gold.....	30
3.5	Gold thiosulphate uptake constraints.....	31
3.6	Cyanogenesis and Chelation.....	31
3.7	Aims of this experiment.....	34
3.8	Results and Discussion.....	35
3.9	Induced Accumulation of Gold by <i>Berkheya coddii</i> using Ammonium Thiocyanate as a Chelator.....	36
3.10	Induced Accumulation of Gold by <i>Berkheya coddii</i> using Ammonium Thiosulphate as a Chelator.....	37
3.11	Induced Accumulation of Gold by <i>Iberis intermedia</i> using Ammonium Thiocyanate as a Chelator.....	37
3.12	Induced Accumulation of Gold by <i>Iberis intermedia</i> using Ammonium Thiosulphate as a Chelator.....	38
3.13	Conclusions.....	39

Chapter Four - Nickel and Cobalt Phytoextraction from Laterite Substrates...41

4.1	Introduction.....	41
4.2	Objectives of this experiment.....	42
4.2.1	Heavy-Metal Bioavailability.....	42
4.2.2	Heavy Metal Chelation.....	42
4.2.3	Substrate Preparation and Final Metal Concentrations.....	43
4.3	The Boddington Consignment.....	44
4.3.1	Introduction.....	44
4.3.2	Laterite Descriptions.....	44
4.3.3	Ore Quality.....	45
4.3.4	Nickel Bioavailability as Determined by Solvent Extractions.....	46
4.3.5	Cobalt Bioavailability as Determined by Solvent Extractions.....	48
4.3.6	Gold Bioavailability as Determined by Solvent Extractions.....	49

4.4	The Anaconda Consignment	51
4.4.1	Introduction and Laterite Descriptions	51
4.4.2	Ore Quality.....	51
4.4.3	Nickel Bioavailability as Determined by Solvent Extraction.....	52
4.4.4	Cobalt Bioavailability as Determined by Solvent Extractions	54
4.4.5	Gold Bioavailability as Determined by Solvent Extractions.....	54
4.4.6	Lateritic Chelator-available Gold	55
4.5	Nickel and Cobalt Accumulation by <i>Alyssum bertolonii</i> grown on Lateritic Substrates	56
4.5.1	Nickel Accumulation in <i>Alyssum bertolonii</i> grown on Lateritic Substrates.....	56
4.5.2	Cobalt Accumulation in <i>Alyssum bertolonii</i> grown on Lateritic Substrates.....	58
4.5.3	The General Accumulation Response of <i>Alyssum bertolonii</i> when grown on Metalliferous Laterites from Western Australia	59
4.6	Nickel and Cobalt Phytomining – A best-case scenario	60
4.7	Nickel Accumulation by <i>Berkheya coddii</i> grown on Lateritic Substrates.....	61
4.7.1	Cobalt Accumulation of <i>Berkheya coddii</i> grown on Lateritic Substrates.....	63
4.7.2	The General Accumulation Response of <i>Berkheya coddii</i> when grown on Metalliferous Laterites From Western Australia	64
4.7.3	Nickel and Cobalt Phytomining – A best-case scenario	66
4.8	Conclusions	66
4.8.1	Further research arising from this project.	70
 Chapter Five - Ammonium Thiocyanate Induced Gold Accumulation using Lateritic Substrates.....		73
5.1	Introduction	73
5.2	Induced Gold Accumulation – Pretreatment Experiment	75
5.2	Results and Discussions	77
5.3	Ammonium-Thiocyanate-Induced Gold Accumulation using Lateritic Substrates	79
5.3.1	Ammonium-Thiocyanate-Induced Gold Accumulation on Boddington B5 Laterite	80
5.3.2	Ammonium-Thiocyanate-Induced Gold Accumulation on Boddington M4 Laterite	84
5.3.3	Ammonium-Thiocyanate-Induced Gold Accumulation on Boddington Z1 Laterite	86
5.4	Gold accumulation in <i>Acacia longifolia</i> – uptake versus transportation	88
5.5	Acidity, chelation and gold accumulation.....	90
5.6	Cyanogenesis and Ammonium Thiocyanate-Induced-Gold Accumulation	91
5.7	A Phytomining Scenario - Induced Phytoextraction of Gold from Laterite Gold Ore using <i>Linum usitatissimum</i>	92
5.7.1	Further work arising from this study.....	93
 References		95

List of Figures

Chapter One – The Science of Phytoextraction

- Figure 1.** The possible uptake responses of plants to heavy metals in soils. Source Robinson 1997.....2

Chapter Two - Nickel and Cobalt Phytoextraction from Artificial Substrates

- Figure 2.** Trunk of *Sebertia acuminata*. Bark has been removed to reveal this species' vivid blue-green high-nickel-content sap. Photo by T. Jaffré.....3
- Figure 3.** The cobalt hyperaccumulator *Crotalaria cobalticola* growing over copper/cobalt-rich soils in Zaïre. Photo by R R Brooks.4
- Figure 4.** Nickel accumulation (solid line, diamond symbol) and biomass (dashed line, circle symbol) production for *Berkheya coddii* (n=8) vs ammonium acetate extractable nickel from an artificial nickel-only substrate8
- Figure 5.** Cobalt accumulation (solid line, diamond symbol) and biomass production (dashed line, circle symbol) vs ammonium-acetate-extractable cobalt in a cobalt-only substrate.9
- Figure 6.** Nickel accumulation response (solid line, diamond symbol) and biomass production (dashed line, circle symbol) vs ammonium-acetate-extractable nickel from a nickel-cobalt mixed substrate..... 11
- Figure 7.** Cobalt accumulation (solid line, diamond symbol) and biomass production (dashed line, circle symbol) vs ammonium-acetate-extractable cobalt from a nickel-cobalt mixed substrate..... 12
- Figure 8.** Nickel uptake (solid line, diamond symbol) by *Alyssum bertolonii* and biomass production (dashed line, circle symbol) vs ammonium-acetate-extractable nickel in a nickel-only substrate. 17
- Figure 9.** Cobalt accumulation (diamond symbol, solid line) and biomass production (circle symbol, dashed line) vs ammonium-acetate-extractable cobalt from a cobalt-only substrate..... 18
- Figure 10.** Nickel hyperaccumulation (solid line, diamond symbol) and biomass production (circle symbol, dashed line) vs ammonium-acetate-extractable nickel for a nickel-cobalt mixed substrate.....20
- Figure 11.** Cobalt hyperaccumulation (solid line, diamond symbol) and biomass production (dashed line, circle symbol) vs ammonium-acetate-extractable cobalt from a nickel-cobalt mixed substrate.....21

Chapter Three - Induced Gold Accumulation using an Artificial Gold Substrate

- Figure 12.** *Iberis intermedia* growing in an outdoor plot at the Plant Growth Unit, Massey University, Palmerston North, New Zealand. Note *Alyssum bertolonii* in the background and *Thlaspi caerulescens* in the foreground. Photo by author.....27
- Figure 13.** Chelator induced gold accumulation for *Berkheya coddii* (solid diamond = SCN, open diamond = S₂O₃) and *Iberis intermedia* (solid circle = SCN and open circle = S₂O₃).36

Chapter Four - Nickel and Cobalt Phytoextraction from Laterite Substrates

Figure 14. Nickel hyperaccumulation (n=8) by *Alyssum bertolonii* grown on Western Australian laterites. Error Bars are Standard Error of the Mean.. 57

Figure 15. Cobalt accumulation (n=8) by *Alyssum bertolonii* grown on Western Australian laterite. Error Bars are the Standard Error of the Mean. 58

Figure 17. Nickel hyperaccumulation by *Berkheya coddii* grown on Western Australian laterite (n=8). 62

Figure 18. Cobalt hyperaccumulation by *Berkheya coddii* grown on Western Australian laterite (n=8). 64

Chapter Five - Ammonium Thiocyanate Induced Gold Accumulation using Laterite Substrates

Figure 19. Acidified ammonium-thiocyanate-induced gold accumulation for species grown on Boddington B5 laterite. 81

Figure 20. Acidified ammonium-thiocyanate-induced gold accumulation for selected species grown on Boddington M4 laterite. Concentrations in $\mu\text{g}/\text{kg}$ 85

Figure 21. Acidified ammonium-thiocyanate-induced gold accumulation for selected species grown on Z1 laterite. Concentrations in $\mu\text{g}/\text{kg}$ 87

List of Tables

Chapter One – The Science of Phytoextraction

Table 1. Normal elemental concentrations in plants and the lower limits for hyperaccumulation. (After Reeves et al., 1995 and Anderson et al., 1998). Concentrations in mg/kg.....	3
Table 2. Species investigated in this study	19

Chapter Two - Nickel and Cobalt Phytoextraction from Artificial Substrates

Table 3. Average nickel and cobalt accumulation (n=8), including standard error of the mean. <i>Berkheya coddii</i> grown on artificial substrates.....	6
Table 4. Average plant hyperaccumulation response to nickel and cobalt.	15
Table 5. ANOVA statistics for <i>Alyssum bertolonii</i> hyperaccumulation response under artificial conditions. S** = very highly significant, NS = not significant.	16

Chapter Three - Induced Gold Accumulation using an Artificial Gold Substrate

Table 6. Induced gold accumulation (n=5) using ammonium thiocyanate (NH ₄ SCN) and ammonium thiosulphate ((NH ₄) ₂ S ₂ O ₃). All concentrations (mean and standard deviation) in mg/kg.	35
--	----

Chapter Four - Nickel and Cobalt Phytoextraction from Laterite Substrates

Table 7. Final substrate metal concentrations (mg/kg) of laterite growth medium. ...	44
Table 8. Ore quality of Boddington Gold Mine samples. Concentrations are in mg/kg (ppm), n=5.....	45
Table 9. Nickel extractability (n=4) as determined by end-over-end solution extractions using (RO) water, 1 M ammonium acetate and 1% ammonium thiocyanate and ammonium thiosulphate. Concentrations are in mg/kg (ppm), Standard Errors is approx. ±15%.....	46
Table 10. Total and extractable nickel from the Boddington Gold Mine samples (n=4) expressed as a percentage of the total metal concentration, in mg/kg (ppm). Standard Errors is approx. ±17%.....	47
Table 11. Cobalt extractability (n=4) as determined by end-over-end solution extractions using (RO) water, ammonium acetate, ammonium thiocyanate and ammonium thiosulphate. Concentrations are in mg/kg (ppm). Standard Errors is approx. ±22%.....	48
Table 12. Gold extractability (n=4) as determined by end-over-end solution extractions using (RO) water, ammonium acetate, ammonium thiocyanate and ammonium thiosulphate. Concentrations are in mg/kg (ppm). Standard Errors is approx. ±40%.....	49
Table 13. Ore quality for nickeliferous material supplied by Anaconda Nickel Mine. Concentrations are in mg/kg (ppm), n=4. Standard Errors is approx. ±18%.	52

Table 14. Nickel extractability (n=4) as determined by end-over-end solution extractions. Concentrations are in mg/kg (ppm). Standard Errors is approx. $\pm 15\%$ 52

Table 15. Cobalt extractability (n=4) as determined by end-over-end solution extractions. Concentrations in mg/kg (ppm). Standard Errors is approx. $\pm 15\%$ 54

Table 16. Gold extractability (n=4) as determined by end-over-end solution extractions using deionised water, ammonium acetate, ammonium thiocyanate and ammonium thiosulphate. Concentrations are in mg/L (ppm). Standard Errors is approx. $\pm 42\%$ 54

Chapter Five - Ammonium Thiocyanate Induced Gold Accumulation using Laterite Substrates

Table 17. Revised gold concentrations for media used in an induced gold accumulation pot trial, including pH. Concentrations in $\mu\text{g}/\text{kg}$. Standard Errors is approx. $\pm 15\%$ 74

Table 18. Induced gold accumulation experiment pretreatment (n=3) using 2M HCl (T1), 1% NH_4SCN (T2) and a combination of both (T3), including total substrate gold and pH. Concentrations are in $\mu\text{g}/\text{kg}$ (ppb). Standard Errors is approx. $\pm 68\%$ 77