



**UNIVERSITI PUTRA MALAYSIA**

**EVALUATION OF FOUR PLANT SPECIES FOR PHYTOREMEDIATION  
OF CADMIUM- AND COPPER-CONTAMINATED SOIL**

**PARISA AHMADPOUR**

**FH 2011 13**

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**By**

**PARISA AHMADPOUR**

**This Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Fulfilment of the Requirements for the Degree of Master of Science**

**December 2011**

## DEDICATION

*I would like to dedicate this thesis to my  
mother, father and sisters, for their  
infinite love and support*



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

**EVALUATION OF FOUR PLANT SPECIES FOR PHYTOREMEDIATION OF CADMIUM- AND COPPER-CONTAMINATED SOIL**

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**PARISA AHMADPOUR**

**December 2011**

**Chairman : Arifin Abdu, PhD**

**Faculty : Forestry**

Application of weeds and leafy wild vegetables for phytoremediation of cadmium (Cd) - and copper (Cu)-contaminated soils is well documented; however, limited research has been conducted on forest trees. Cd and Cu are known as the most dangerous pollutants, particularly at higher concentrations. This thesis reports two studies on the phytoremediation of Cd- and Cu-contaminated soils using four forest species, namely *Jatropha curcas*, *Acacia mangium*, *Dyera costulata*, and *Hopea odorata*. Randomized completely block design (RCBD) with four replications was used in a factorial arrangement in each study. The aim of this study was to assess the phytoremediation potential of the four tested species for Cd- and Cu-contaminated soil and then to recommend the most suitable species for phytoremediation of the soil contaminated with Cd and Cu.

In the first study, cadmium chloride ( $\text{CdCl}_2 \cdot 2 \cdot 5\text{H}_2\text{O}$ ) was used as a source of Cd. The growth media were prepared using soil mixed with different levels of Cd. The different levels of growth media (soil + different levels of Cd) were Cd<sub>0</sub> (control soil), Cd<sub>1</sub> (soil + 25 mg kg<sup>-1</sup> Cd), Cd<sub>2</sub> (soil + 50 mg kg<sup>-1</sup> Cd), Cd<sub>3</sub> (soil + 75 mg kg<sup>-1</sup> Cd), Cd<sub>4</sub> (soil + 100 mg kg<sup>-1</sup> Cd), and Cd<sub>5</sub> (soil + 150 mg kg<sup>-1</sup> Cd). For the second study, copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) was used as a source of Cu. The different levels of growth media were Cu<sub>0</sub> (control soil), Cu<sub>1</sub> (soil + 50 mg kg<sup>-1</sup> Cu), Cu<sub>2</sub> (soil + 100 mg kg<sup>-1</sup> Cu), Cu<sub>3</sub> (soil + 200 mg kg<sup>-1</sup> Cu), Cu<sub>4</sub> (soil + 300 mg kg<sup>-1</sup> Cu), and Cu<sub>5</sub> (soil + 400 mg kg<sup>-1</sup> Cu). The pots were filled with growth media, and the seedlings of the four plant species were transplanted after one month. The parameters monitored and analyzed were soil physico-chemical properties, growth variables (basal stem diameter, height and number of leaves), plant dry biomass (dried biomass of leaves, stems, and roots), and heavy metal concentrations both in the growth media and in the plant parts (leaves, stems, and roots).

The results of the first study revealed that higher levels of Cd significantly ( $p \leq 0.05$ ) influenced both growth variables and plant dry biomass. The growth variables of the four tested species decreased with increase in the level of Cd. Increasing Cd levels also disaffect production of dry biomass. There was significant difference ( $p \leq 0.05$ ) in total Cd concentration (Cd concentration in leaves + stems + roots) among plant species grown under different Cd levels. Among seedlings exposed to Cd<sub>5</sub>, *J. curcas* showed the highest total Cd concentration (1125.68 mg kg<sup>-1</sup>). Cd removal efficiency (RE), bioconcentration factor (BCF), and translocation factor (TF) were significantly different ( $p \leq 0.05$ ) among plant species grown under different Cd levels. Among seedlings exposed to Cd<sub>5</sub>, *J. curcas* exhibited the highest Cd removal (0.64%).

The BCFs of Cd in plant species were  $>1$  under various Cd levels, except in control media. Plant species grown in control media showed the high TFs ( $>1$ ), whereas the plant species grown in the media treated with different Cd levels exhibited low TFs ( $<1$ ). Among plant species exposed to Cd<sub>5</sub>, the highest BCF (7.17) and TF (0.61) were recorded in *J. curcas* and *H. odorata*, respectively.

As for the second experiment, the growth variables and dry biomass of the four tested species were significantly influenced ( $p \leq 0.05$ ) by different Cu levels. Higher Cu levels significantly decreased ( $p \leq 0.05$ ) the growth performance and the production of dry biomass. Total Cu concentration in tested species increased significantly ( $p \leq 0.05$ ) with increase in the Cu level. Among seedlings exposed to Cu<sub>5</sub>, *J. curcas* showed the highest total Cu concentration (665.04 mg kg<sup>-1</sup>). The Cu removal efficiency, BCF, and TF were significantly different ( $p \leq 0.05$ ) among plant species grown under different Cu levels. *J. curcas* attained the highest Cu removals within each level of Cu. The BCFs of Cu were  $>1$  within each level of Cu and in control media. Plant species grown in the control media showed TFs  $>1$ , whereas plant species grown in the media treated with various levels of Cu exhibited very small TFs ( $<1$ ). Among plant species exposed to Cu<sub>5</sub>, the highest RE, BCF, and TF (0.23%, 1.76, and 0.33, respectively) were found in *J. curcas*.

In general, the highest total Cd and Cu concentration and the maximum Cd and Cu removal efficiency among plant species were observed in *J. curcas*. In addition, most parts of Cd and Cu accumulated in roots of the four tested species in both experiments. As a conclusion, *J. curcas* was the most effective species in both studies for phytoremediation of Cd- and Cu-contaminated soils through phytostabilization.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**PENILAIAN EMPAT JENIS TUMBUHAN BAGI FITOREMEDIASI  
PENCEMARAN TANAH OLEH KADMIUM DAN KUPRUM**

Oleh

**PARISA AHMADPOUR**

**Disember 2011**

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Penggunaan rumpai dan sayur-sayuran berdaun yang tumbuh secara liar di hutan telah digunakan untuk tujuan fitoremediasi di tanah yang telah dicemari kadmium (Cd) dan kuprum (Cu) telah banyak didokumenkan; namun, terdapat kekurangan dalam penyelidikan terhadap pokok-pokok hutan. Cd dan Cu dikenali sebagai pencemaran yang amat bahaya, terutamanya apabila berkepekatan tinggi. Tesis ini menjalankan dua kajian fitoremediasi di atas tanah yang telah dicemari dengan Cd dan Cu dengan menggunakan empat spesis pokok hutan, iaitu *Jatropha curcas*, *Acacia mangium*, *Dyera costulata* dan *Hopea odorata*. Susunan corak blok secara rawak (RCBD) dengan empat replikasi telah digunakan. Tujuan kajian ini adalah untuk mengkaji potensi spesis ini untuk fitoremediasi dan mengesyorkan spesis yang paling sesuai digunakan bagi tujuan fitoremediasi tanah yang telah dicemari Cd dan Cu.

Dalam kajian pertama, Kadmium klorida ( $\text{CdCl}_2 \cdot 2.5\text{H}_2\text{O}$ ) telah digunakan sebagai sumber Cd. Media pertumbuhan telah disediakan dengan menggunakan tanah yang dicampurkan dengan kuantiti Cd yang berbeza-beza (tanah + tahap Cd yang berbeza) ialah  $\text{Cd}_0$  (kawalan),  $\text{Cd}_1$  (tanah +  $25 \text{ mg kg}^{-1}$  Cd),  $\text{Cd}_2$  (tanah +  $50 \text{ mg kg}^{-1}$  Cd),  $\text{Cd}_3$  (tanah +  $75 \text{ mg kg}^{-1}$  Cd),  $\text{Cd}_4$  (tanah +  $100 \text{ mg kg}^{-1}$  Cd), and  $\text{Cd}_5$  (tanah +  $150 \text{ mg kg}^{-1}$  Cd).

Untuk kajian yang kedua, kuprum sulfat ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) telah digunakan sebagai sumber Cu. Tahap media pertumbuhan yang berbeza ialah  $\text{Cu}_0$  (kawalan tanah),  $\text{Cu}_1$  (tanah +  $50 \text{ mg kg}^{-1}$  Cu),  $\text{Cu}_2$  (tanah +  $100 \text{ mg kg}^{-1}$  Cu),  $\text{Cu}_3$  (tanah +  $200 \text{ mg kg}^{-1}$  Cu),  $\text{Cu}_4$  (tanah +  $300 \text{ mg kg}^{-1}$  Cu), and  $\text{Cu}_5$  (tanah +  $400 \text{ mg kg}^{-1}$  Cu). Pasu-pasu telah diisi dengan media pertumbuhan, dan anak-anak pokok telah ditanam dalam pasu selepas satu bulan. Ciri-ciri fizikal-kimia, variasi pertumbuhan, biomass kering tumbuhan dan kuantiti Cd dan Cu di media pertumbuhan dan di bahagian-bahagian pokok telah dianalisis dan diukur.

Keputusan kajian pertama telah menunjukkan bahawa terdapat kuantiti Cd yang ketara ( $p \leq 0.05$ ) telah mempengaruhi pertumbuhan dan biomass tumbuhan kering. Pertumbuhan keempat-empat spesis berkurang manakala kuantiti Cd bertambah. Pertambahan kuantiti Cd juga mempengaruhi biomass tumbuhan. Terdapat perbezaan kuantiti Cd yang ketara ( $p \leq 0.05$ ) diantara spesis-spesis yang ditanam. *J. curcas* menunjukkan kuantiti Cd yang tertinggi ( $1125.68 \text{ mg kg}^{-1}$ ). Kecekapan penyingkiran Cd (RE), biokonsentrasi faktor (BCF) dan translokasi faktor (TF) terdapat perbezaan yang ketara ( $p \leq 0.05$ ) diantara spesis-spesis yang telah ditanam. *J. curcas* paling tinggi mengeluarkan Cd dari media pertumbuhan (0.64%). BCF bagi Cd diantara spesis adalah  $>1$ , mengikut kuantiti-kuantiti yang berbeza, kecuali media



kawalan. Spesies tumbuhan di media kawalan menunjukkan TF yang tinggi ( $>1$ ), dan spesies yang ditanam di media yang ada Cd menunjukkan TF yang rendah ( $>1$ ). Diantara spesies yang terdedah dengan Cd, BCF yang tertinggi ialah (7.17) dan TF (0.61) telah direkodkan bagi *J. curcas* dan *H. odorata*.

Bagi kajian kedua, pertumbuhan dan biomass kering mengalami perbezaan yang ketara ( $p \leq 0.05$ ) mengikut kuantiti Cu yang berbeza. Cu yang kuantiti tinggi mengurangkan pertumbuhan dan biomass kering bagi kesemua spesies. Jumlah kepekatan kuprum dalam tanaman yang diuji meningkat ketara bersama dengan tahap kuprum yang ditambah. Diantara spesies dalam kajian ini, *J. curcas* menunjukkan kuantiti Cu yang tertinggi ( $665.04 \text{ mg kg}^{-1}$ ). RE, BCF dan TF menunjukkan perbezaan yang ketara ( $p \leq 0.05$ ) diantara spesies. *J. curcas* mencapai kadar penyingkiran Cu yang tertinggi, mengikut kuantiti Cu yang ditambah kedalam media pertumbuhan. BCF bagi Cu adalah  $>1$  bagi setiap media pertumbuhan. Spesies yang ditanam pada media kawalan menunjukkan  $TF > 1$ , dan spesies tumbuhan di media pertumbuhan yang terdapat Cu menunjukkan TF yang amat rendah ( $< 1$ ). Diantara spesies yang dikaji, RE, BCF dan TF tertinggi (0.23%, 1.76, dan 0.33) terdapat pada spesies *J. curcas*.

Secara amnya, kuantiti Cd dan Cu tertinggi terdapat pada spesies *J. curcas*. Cd dan Cu paling banyak didapati pada akar-akar kesemua spesies. *J. curcas* merupakan spesies yang paling efektif dalam kedua-dua kajian fitoremediasi bagi tanah yang dicemari Cd dan Cu.

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I certify that an Examination Committee has met on 28<sup>th</sup> December 2011 to conduct the final examination of Parisa Ahmadpour on her MSc thesis entitled “Evaluation of Four Plant Species for Phytoremediation of Cadmium- and Copper-Contaminated Soil” in accordance with the Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science degree.

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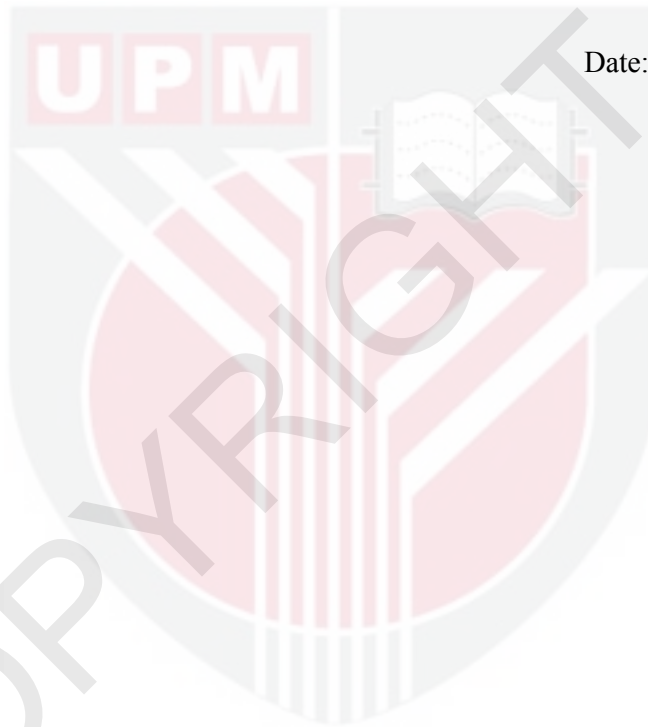
## DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

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**PARISA AHMADPOUR**

Date: 28 December 2011



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