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Jatropha curcas L. for Phytoremediation of Lead and Cadmium Polluted Soil

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Abstract: Jatropha was investigated for its capacity to remediate cadmium and lead polluted soil in greenhaouse conditons. Various levels of single and mixed pollutants were exposed to the plant for more than one month. Range finding test was performed in order to find out the pollutant level that could be remediated. It was found that the initial concentration of lead and cadmium was about 50 mg/Kg soil without adverse effect on plant. Effect concentration fifty (EC-50) identified that cadmium was more toxic (EC-50 of 10 mg/Kg soil) than lead (EC-50 of 20 mg/Kg soil) on plant dry matter. In the presence of both pollutant, no adverse effect on plant dry matter was found that might be due to synergic effect of lead.

Key words: Jatropha . cadmium . lead . plant dry matter

INTRODUCTION

The primary source of heavy metal contamination has resulted from industrial activities such as energy and fuel production, mining and smelting of metalliferous ores and post production use that contained in wastes. There was a dramatic acceleration of heavy metal contamination in soil as a result of industrial revolution [1]. Usually, the most common heavy metal contaminants are lead, cadmium, chromium, copper, mercury and zink [2]. Lead (Pb) was noted as primary contaminant due to the ability to disperse across environmental multimedia [3-5]. Cadmium (Cd) was less toxic than mercury but it was more mobile in soil-plant system than others [5]. The current research concerned on Pb and Cd due to the mobility of both that could be magnified through food-web mechanism and threats living organisms.

Remediation of heavy metals polluted soil could be carried out using physico-chemicals processes such as ion-exchange, precipitation, reverse osmosis, evaporation and chemical reduction, however, the measures required external man-made resources and costly [6]. Attention was given to phytoremediation by which plant is applied to absorb, transform and detoxify heavy metals. The phytoremediation method was simple, efficient, cost effective and environmental friendly [7]. Investigation on the ability of plants in removing heavy metals from soil has been intensified using *Polygonum hydropiper* L., *Rumex acetosa* L. [8], *Lolium perenne* [9], *Brassica juncea* [10], *Helianthus annus* dan *Brassica napus* [11], *Streptanthus polygaloides*, *Sebertia acuminata*, *Armeria maritima*, *Aeollanthus biformifolius*, *grass*, waterhyacinth and sun flower [12]. The current research concerned on *Jatropha curcas* L. (local name in Indonesia: Jarak pagar) for at least three reasons as follows. The plant is a species of *Euphorbiaceae* family that might be effective in removing Pb and Cd as demonstrated by *Euphorbia cheirandenia* [13]. In Indonesia, the plant is able to grow under various soil conditions, it is planted as a green corridor along streets and houses and it was promoted to be a source of alternative biofuel. In addition, Jatropha was found to be able in removing hexavalent chromium [14]. Therefore, planting of *Jatropha curcas* L. could have some advantages, i.e. remediation of Pb and Cd polluted soil, provision of greenspace and source of alternative biofuel.

The objective of this research was to assess the effectiveness of *Jatropha curcas* L. for lead and cadmium, both for single and mixed pollutant removal from soil. The effectiveness consisted of the half time removal and plant growth response, leading to express a novel removal-response (RR) relationship.

MATERIALS AND METHODS

Test plant: Jatropha plants were collected from local agriculture agency. The plants were adapted under glasshouse conditions. Healthy plant with a height of 20-30cm of each was selected for the test plant.

Test media: Garden healthy soil was collected and uniformly saturated with $Pb(NO_3)_2$ and air-dried for 24

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hours. The same treatment was applied for cadmium polluted soil using $Cd(NO_3)_2$ solution and for mixtures of lead and cadmium polluted soil. The test media was organized for single pollutant and mixed pollutants, i.e. 100% lead pollued soil, 100% cadmium polluted soil and various comp ositions of lead and cadmium, ranging from Pb/Cd of 0.4 to 5.0 (by weight). A control test medium was provided for each composition.

Test concentrations: Range finding test was performed for various concentrations of lead and cadmium, ranging from 10 to 90 mg/Kg each. The range finding test run for more than one month. The result of the range finding test was used for the definitive test to assess the effectiveness of phytoremediation for single pollutant and mixed pollutant.

Test operations: Each of the test plant was grown in the test concentrations in a pot containing 2Kg medium. Experiments were carried out with three replicates. Random sampling was applied for the test medium and plant. Medium samples were taken every week. Ten grams of the medium was digested in acidic mixture of HNO3: HClO4 and the lead and cadmium was analysed using Atomic Absorption Spectrophotometer [15]. Flameless Atomic Absorption Spectrophotometry is a very ideal, sensitive and easy method in performing the measurement of the mentioned metals. The concentration of each sample was recorded at 217 nm for Cd and 283.3 nm for Pb. Plant parameters consisting of plant height, plant diameter and leaf area were measured every week at the same time as the medium sampling. Plant dry matter (PDM) was measured before and after the plant was applied in the test medium. The dry matter was measured using oven dried at 80^{o}C for three days or constant weight [16]. Supporting parameters such as temperature and pH were measured using electronic probes weekly. Soil respiration was measured using carbon dioxide evolution method [16].

RESULTS AND DISCUSSION

Soil temperature and pH fluctuated in the range of 27-28^{o}C and 5.2-7.2 respectively. No significant correlation was found between the two parameters and various concentrations of lead and cadmium polluted soil. The two supporting parameters were conducive for phytoremediation of heavy metals polluted soil [17, 18]. Range finding test resulted in weekly progress of pollutants effect on leaf necrosis and chlorosis (Fig. 1) at the initial lead and cadmium concentration of 90 mg/Kg. The following results were in conditions the maximum initial lead concentration of about 80 mg/Kg and cadmium concentrations of about 50 mg/Kg for phytoremediation using Jatropha. Monitoring on soil respiration showed that microbial activity existed in all test polluted soils.

Single pollutant removal and effect on plant dry matter: Lead and cadmium removal during one and half months exposure were converted into removal half time (t-50), which means the time for 50% lead and cadmium removal from the media. Figure 2 presented

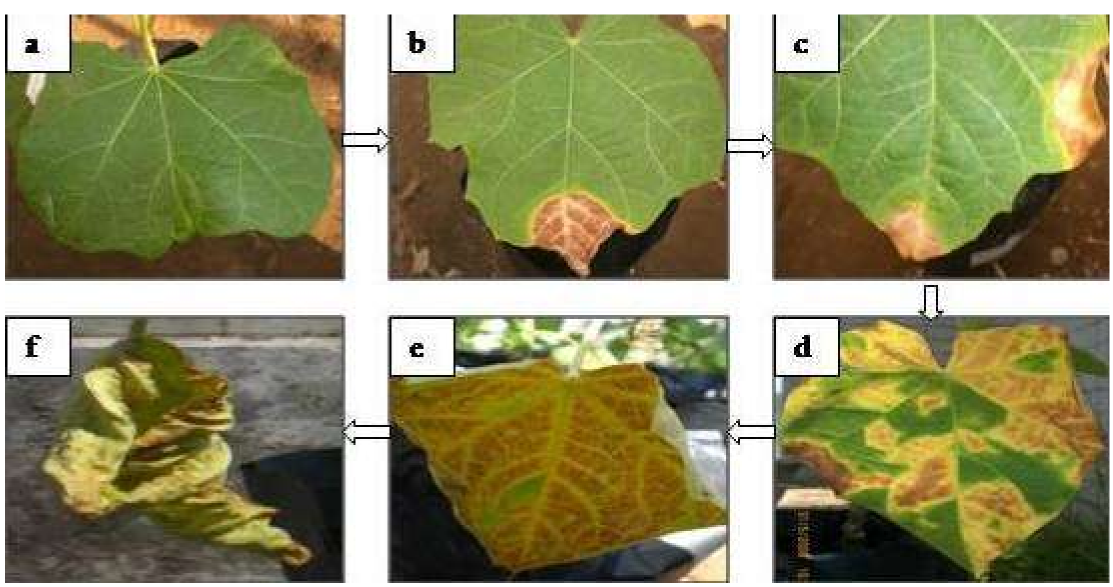

Fig. 1: Healthy leaf (a), necrosis (b, c) chlorosis (d,e) and complete destruction (f) at the initial lead and cadmium concentration in soil of more than 80 mg/Kg

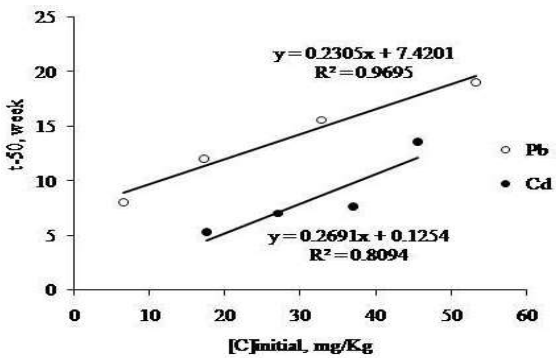

Fig. 2: Correlation between the removal half time and the initial lead and cadmium concentration in polluted soil

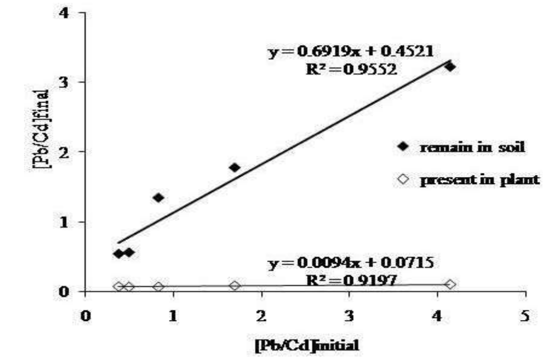

Fig. 4: Correlation between the final Pb/Cd and the initial Pb/Cd in polluted soil

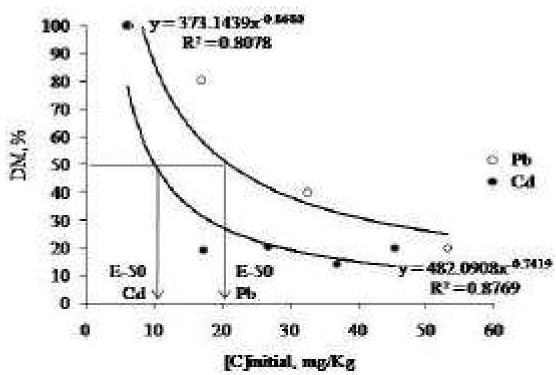

Fig. 3: Effect concentration fifty of lead and cadmium on plant dry matter

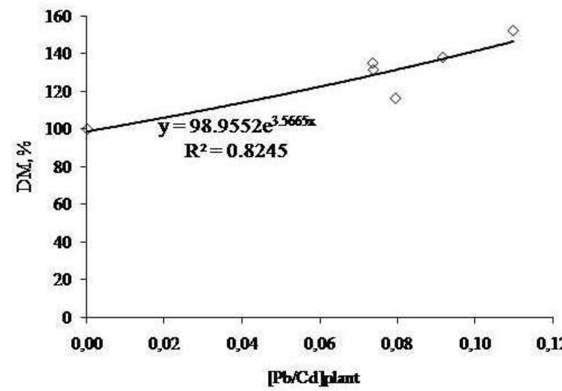

Fig. 5: Effect of Pb/Cd present in plant on plant dry matter

the half time of lead and cadmium that significantly related to their initial concentration [C] up to about 50 mg/Kg each. Based on the t-50, cadmium removal from soil was faster than lead removal. Figure 3 showed a significant reduction of plant dry matter as the initial cadmium and lead concentrations increased that was confirmed by Arvind [19] and Tomar *et al.* [20] in their work with phytoremediation of cadmium and lead. An effect criterion EC-50 was indicated in Fig. 3, representing initial pollutant concentration in soil that reduced 50% plant dry matter content relative to control. Both figures explained the pollutant removal from soil corresponded to pollutant uptake by plant that resulted in adverse effect on plant dry matter. The single pollutant removal-effect relationship revealed that cadmium was more toxic towards plant dry matter than lead.

Mixed pollutant removal and effect on plant dry matter: Various concentrations of lead and cadmium in soil were investigated on their effect on plant dry matter. Following exposure of more than one month, the levels of Pb/Cd remain in soil and in plant were correlated significantly with the initial levels of Pb/Cd (Fig. 4). The level of Pb/Cd present in plant was lower than Pb/Cd remain in soil, which means Jatropha was not a lead accumulating plant as compared to Indian mustard (*Brassica juncea*) that was able to accumulate up to 1.5% Pb in the shoots in soils containing 600 mg/Kg [19]. The low Pb/Cd in plant indicated the amount of cadmium was uptaken by plant more than lead. Even though cadmium was uptaken by plant more than lead, a significant positive effect on plant dry matter was found (Fig. 5). Recall the result of single pollutant effect that cadmium was more toxic than lead (Fig. 3), therefore, lead was the synergic pollutant for cadmium in supporting plant dry matter.

CONCLUSION

Jatropha was not an accumulator for lead and cadmium. However, the plant could be used for phytoremediation of lead and cadmium polluted soil provided the initial maximum concentration was about

50 mg/Kg each. Cadmium was more toxic on plant dry matter than lead, however, no adverse effect was found on plant dry matter in the presence of both pollutant. Lead was the synergic pollutant for cadmium on plant dry matter.

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REFERENCES

1. Nriagu, J.O., 1979. Global inventory of natural and anthropogenic emissions of trace metals to the atmosphere. Nature, 279: 409-411.
2. Kabata-Pendias, A. and H. Pendias, 1989. Trace elememts in the Soil and Plants. CRC Press, Boca Raton, FL.
3. USEPA, 1993. Clean Water Act, Sec 503, U.S. Environmental Protection Agency Washington DC, Vol: 58 (32).
4. Cunningham, S.D. and W.R. Berti, 1993. Remediation of contaminated soils with green plants: An overview", *In vitro* Cell. Dev. Biol. 29P: 207-212
5. Alloway, B.J and D.C. Ayres, 1997. Chemical Principles of Environmental Pollution, 2nd Edition, Blackie Academic and Professional, Chapman & Hall, London.
6. Lasat, M.M., 2002. Phytoextraction of toxic metals: A review of biological mechanisms. J. Environ. Qual., 31: 109-120.
7. Schnoor, J.L. and S.C. McCutcheon, 2003. PHYTOREMEDIATION Transformation and Control of Contaminants, Wiley-Interscience Inc, USA.
8. Wang, Q.R., Y.S. Cui, X.M. Liu, Y.T. Dong and P. Christine, 2003. Soil contamination and plant uptake of heavy metals at polluted sites in China. J. Environ. Sci. Health, 38 (5): 823-838.
9. O'Connor, C.S., N.W. Leppi, R. Edwards and G. Sunderland, 2003. The combined use of electro-kinetic remediation and phytoremediation to decontaminate metal-polluted soils: laboratory scale feasibility study. Environ. Monit. Asses, 84 (1-2): 141-158.
10. Bennet, L.E., J.L. Burkhead, K.L. Hale, N. Terry, M. Pilon and E.A. Pilon-Smits, 2003. Analysis of transgenic Indian mustard plants for phytoremediation of metal-contaminated mine tailings. J. Environ. Qual., 32 (2): 432-440.
11. Solhi, M., M.A. Hajabbasi and H. Shareatmadari, 2005. Heavy Metals Extraction Potential of Sunflower *(Helianthus annus)* and Canola *(Brassica napus)*. Isfahan Agricultural Research, Soil and Water Department, College of Isfahan, Isfahan University of Technology, Isfahan.
12. Ghosh, M. and S.P. Singh, 2005. A Review on Phytoremediation of Heavy Metals and Utilization of Its Byproducts. Appl. Ecol. Environ. Res., 3 (1): 1-18.
13. Chehregani, A. and Behrouz E. Malayeri, 2007. Removal of heavy metals by native accumulator plants. International Journal of Agriculture and Biology, 9 (3): 462-465.
14. Mangkoedihardjo, S., R. Ratnawati and N. Alfianti, 2008. Phytoremediation of Hexavalent Chromium Polluted Soil Using *Pterocarpus indicus* and *Jatropha curcas* L. World Applied Sciences Journal, 4 (3): 338-342.
15. Standard Methods, 1995. Standard Methods for the Examination of Water and Wastewater. American Public Health Association/American Water Works Association/Water Environmental Federation, Washington DC, 19th Edition.
16. Mangkoedihardjo, S., 2006. The Kinetics of biodeconcentration for nitrate: Case study for microbial denitrification and plant absorption. Malaysian Journal of Soil Science, 10: 67-75.
17. Hossain, M.A., M. Kumita, Y. Michigami and S. Mori, 2005. Optimization of parameters for Cr-VI adsorption on used black tea leaves. Adsorption 11 (5-6): 561-568.
18. Jeyasingh, J. and L. Philip, 2005. Bioremediation of chromium contaminated soil: Optimization of operating parameters under laboratory conditions. Journal of Hazardous Materials, B118: 113-120.
19. Arvind P., 2004. Zinc protects chloroplasts and associated photo-chemical functions in cadmium exposed *Ceratophyllum demersum* (L.) a fresh water macrophyte. Plant Science, 166 (4): 1321-1327.
20. Tomar, M., Kaur, I., Neelu and A.K. Bhatnagar, 2000. Effect of enhanced lead in soil on growth and development of *Vigna radiata* (L.) Wilezek. Indian J. Plant Physiol., 5 (1): 13-18.
21. Blaylock, M.J., D.E. Salt, S. Dushenkov, O. Zakharova, C. Gussman, Y. Kapulnik, B.D. Ensley and I. Raskin, 1997. Enhanced accumulation of Pb in Indian mustard by soil-applied chelating agents. Environmental Science and Technology, 31: 860-665.