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Phytoremediation of Hexavalent Chromium Polluted Soil Using *Pterocarpus indicus* and *Jatropha curcas* L.

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Abstract: This paper reports an assessment of hexavalent chromium removal from soil with and without compost amendment by *Pterocarpus indicus* and *Jatropha curcas*. Greenhouse experiment was conducted and consisted of range finding test and definitive test for various concentrations of hexavalent chromium. Result of range finding test showed that both plants were able to remediate hexavalent chromium polluted soil of less than 90 mg KgG^{1}. At a given concentration of hexavalent chromium and to achieve 50% removal, the removal half time (t-50) of Jatropha was about twice shorter than Pterocarpus. Effect concentration fifty (EC-50) of hexavalent chromium for plant dry matter (PDM) Jatropha was higher than for PDM Pterocarpus. No significant effect was found for aerial plant parts of Jatropha. Compost amendment was preferable when Jatropha was planted in hexavalent chromium polluted soil because Jatropha could remediate higher concentration than Pterocarpus. These suggested that Jatropha was more effective than Pterocarpus to remediate hexavalent chromium polluted soil.

Keywords: Hexavalent chromium removal % t-50 % EC-50 % PDM % Pterocarpus % Jatropha

INTRODUCTION

Heavy metals containing industrial wastes was found to increase environmental stress. Based on the material density, heavy metals is a general form for a group of elements with a density higher than 6 g/cm^3 such as cadmium (Cd), copper (Cu), nickel (Ni), zinc (Zn), lead (Pb) and chrome (Cr) [1]. Among the metals, the presence of hexavalent chromium was significant in Surabaya waters that might be due to industrial wastewater discharge. Industrial processes on electro plating, leather tanning, glass and canning were sources of the metal [2-4]. As the metal is non biodegradable and toxic in nature, the toxicity of metals made threats on aquatic ecosystem. Hence, removal of hexavalent chromium by means of wastewater treatment is essential and important [5] and become a major concern for protecting aquatic life. However, the treatment process produced sludge, making chromium concentrated waste. Since the sludge is collected and disposed on land, a subsequent land treatment system should be provided to save terrestrial life. Measures to metal polluted soil were emphasized towards the physico-chemical processes such as soil removal and land filling, stabilization or solidification, physico-chemical extraction, soil washing, and flushing [6]. In amendment, adsorption using low-cost adsorbents is one of the effective and economic methods [7]. Various low-cost adsorbents have been used for the removal of metals using abiotic adsorbents such as ash particles [8,9]. Biotic adsorbent using plant materials was become a major concern in developing countries [10] as well as phytoprocesses [11]. Phytoremediation represent one of the biggest economic opportunities for remediation, based on plants ability to work as phytopumping, extracting and concentrating particular solutes [12,13].

Phytoremediation of chromium polluted soil using local and potential plants poses a number of unique interlink advantages particularly for Surabaya as well as other big cities in Indonesia. Many local governments have promoted planting *Pterocarpus indicus* (local name: Angsana) for greenspace provision and *Jatropha curcas* (local name: Jarak Pagar) for biodiesel resources. *Pterocarpus indicus* is adapted to subtropical and tropical conditions [14] whereas *Jatropha curcas* is a

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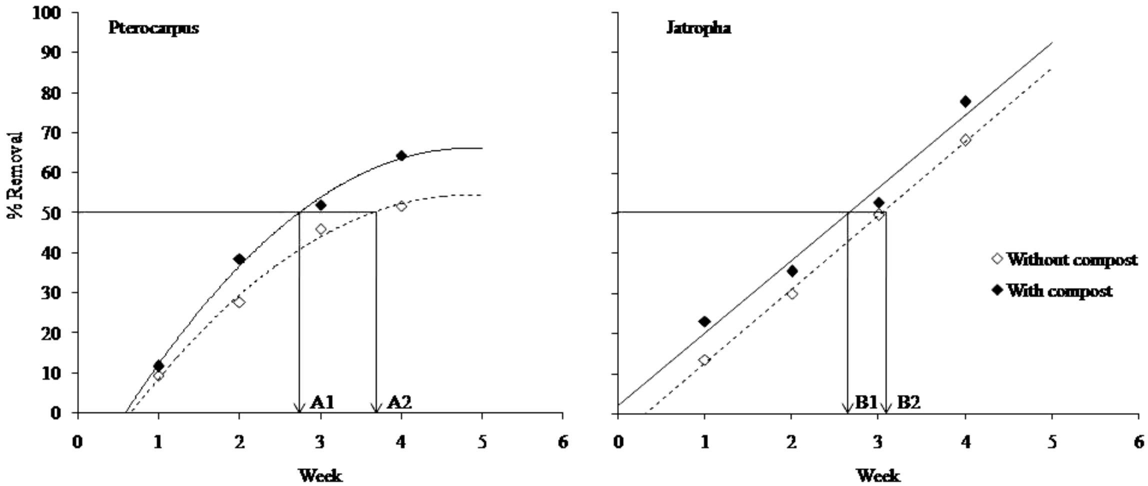

Fig. 1: Typical hexavalent chromium removal in polluted soil with and without compost amendment

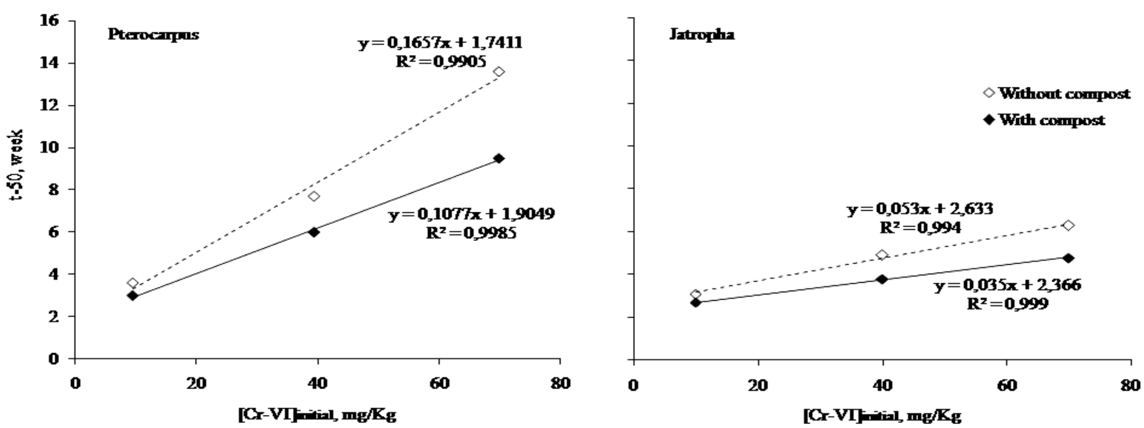

Fig. 2: Correlation between the removal half time of hexavalent chromium and the initial hexavalent chromium concentration in polluted soil with and without compost amendment

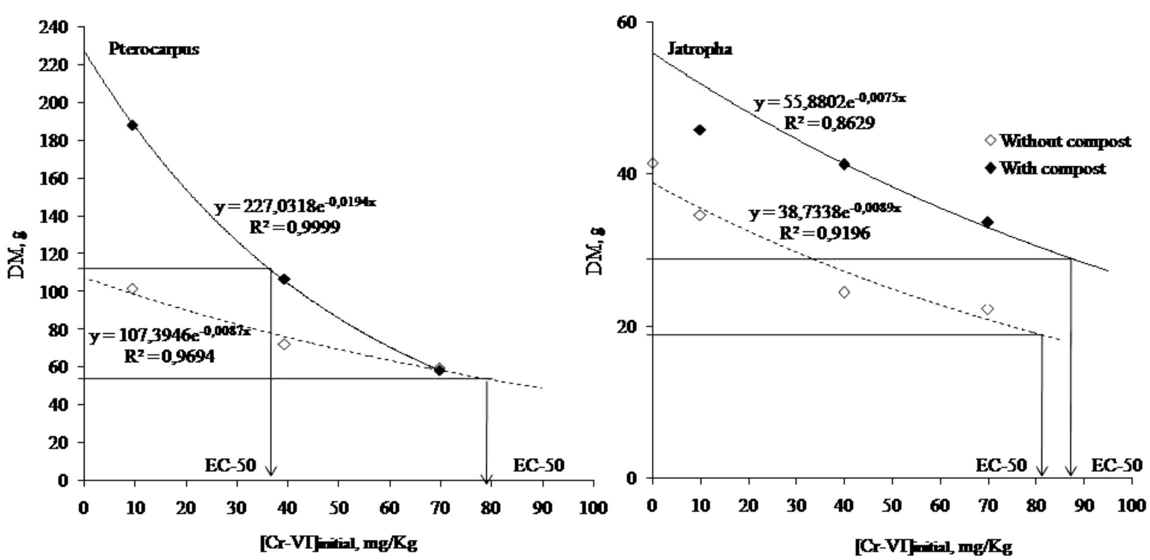

Fig. 3: Effect concentration fifty of hexavalent chromium initial concentration to plant dry matter

drought resistance and a perennial plant yielding 5-12 ton per hectare oil seed and produces 2-4 tones of biodiesel [15]. In attempt to support the program, this research aimed to assess the effectiveness of the two plants for chromium removal from soil. The effectiveness of phytoremediation was assessed by two criteria, comprising removal half time (t-50) and effect concentration fifty (EC-50). By means of a given t-50 and EC-50, one may choose which plant species is more effective than another for phytoremediation of hexavalent chromium polluted soil. Compost amendment into chromium polluted soil was also investigated for its effect on phytoremediation. Therefore, this research contributed in promoting the plants to remediate chromium polluted soil, to provide greenspace and to be an alternative source of biofuel as well as supporting compost use for phytoremediation.

MATERIALS AND METHODS

Test plants: Pterocarpus and 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: Potasium dichromate ($K_2Cr_2O_7$) solution was used as a source of hexavalent chromium. Chromium solution was uniformly mixed with air-dried soil and leave for 24 hours. The test media was organized for two compositions, i.e. 100% chromium pollued soil and 90% chromium polluted soil with addition of 10% compost (by weight). A control test medium was provided for each composition. Amendment of compost was considered to improve carbon and nitrogen sources for soil microbes, and to evaluate whether chromium was toxic towards microbe growth at a given concentration of hexavalent chromium.

Test concentrations: Range finding test was performed that consisted of 10, 30, 50, 70 and 90 mg Hexavalent chromium/Kg medium. The range finding test run for one month. The result of the range finding test was used for the definitive test to assess the effectiveness of phytoremediation.

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 HNO_3: $HClO_4$ and the hexavalent chromium was analysed using Atomic Absorption Spectrophotometer [16]. 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 °C for three days or constant weight [17]. Supporting parameters such as temperature and pH were measured using electronic probes weekly.

RESULTS AND DISCUSSION

Soil temperature and pH fluctuated in the range of 27-28°C and 5-7, respectively. No significant correlation was found between the two parameters and various concentrations of chromium polluted soil. The two supporting parameters were conducive for bioremediation of chromium polluted soil [6, 18].

Hexavalent chromium concentration and removal: Range finding test resulted in the maximum initial Hexavalent chromium concentration of less than 90 mg KgG^1 for phytoremediation using Pterocarpus and Jatropha. Typical results of hexavalent chromium removal by the two plants with and without compost amendment during montly experiment are presented in Fig. 1 for initial hexavalent chromium of 9.49 mg KgG^1. Points at A1, A2, B1 and B2 indicated the removal half time (t-50), which means the time for 50% hexavalent chromium removal from the media. Figure 1 showed that the half time of Hexavalent chromium removal in the media with compost was shorter than in the media without compost. This revealed that compost augmented phytoremediation of hexavalent chromium polluted soil using Pterocarpus and Jatropha.

The removal half time of hexavalent chromium correlated significantly with the initial hexavalent chromium concentration in the media as shown in Fig. 2. The removal half time for hexavalent chromium became longer as the initial hexavalent chromium concentration increased. The removal half time of Jatropha was significantly shorter than Pterocarpus, suggesting the Jatropha was more appropriate than Pterocarpus for phytoremediation of chromium polluted soil.

Plant response: Owing to the limited number of data on plant dry matter (PDM) that is measured at the end of exposure, therefore the response of plant due to pollutant

Table 1: Aerial plant parts response

[Cr-VI]initial polluted soil (mg Kg^{-1})	RGR Leaf area ($week^{-1}$)	RGR Plant diameter ($week^{-1}$	RGR Plant height ($week^{-1}$)
Pterocarpus			
Without compost			
9.49	0.12	0.04	0.01
39.37	0.11	0.02	0.01
69.86	0.03	0.02	0.01
With compost			
9.49	0.08	0.07	0.01
39.37	0.08	0.04	0.01
69.86	0.04	0.08	0.01
Jatropha			
Without compost			
9.49	0.05	0.02	0.01
39.37	0.03	0.01	0.01
69.86	0.04	0.01	0.01
With compost			
9.49	0.04	0.04	0.01
39.37	0.03	0.03	0.01
69.86	0.05	0.04	0.01

exposure was assessed by means of effect concentration fifty (EC-50). EC-50 was defined as the hexavalent chromium initial concentration in the soil that decreased 50% weight of PDM in non-polluted soil (Fig. 3). EC-50 PDM Pterocarpus in soil without compost and with compost was 78 and 37 mg Kg^{-1}, respectively. EC-50 PDM Jatropha in soil without compost and with compost was 82 and 88 mg Kg^{-1} respectively. EC-50s Jatropha were higher than EC-50s Pterocarpus, which means Jatropha was more resistant against hexavalent chromium than Pterocarpus. A unique result was found that the adverse effect of compost was higher towards PDM Pterocarpus than PDM Jatropha. The unique results might be due to plant characteristics that needs further study. Based on the EC-50 assessment, Jatropha was more appropriate than Pterocarpus for phytoremediation of hexavalent chromium polluted soil.

Plant response assessment on relative growth rate (RGR) was addressed for aerial plant parts consisting of leaf area, plant diameter and plant height. RGR was defined as follows:

$$RGR = \{(PPt - Ppi)/PPi\}/dt \qquad (1)$$

where; PPt is plant parameter such as leaf area at the time of measurement, PPi was plant parameter initiallly measured, dt was time of exposure. Results of RGR for aerial plant parts were shown in Table 1. Significant different ($p<0.05$) between RGR and Hexavalent chromium initial concentration was found for Pterocarpus, particularly on leaf area and plant diameter in polluted soil without compost amendment. There was no significant different between RGR for aerial plant parts and hexavalent chromium initial concentration for Jatropha.

CONCLUSIONS

Pterocarpus indicus and *Jatropha curcas* were able to remediate hexavalent chromium polluted soil of less than 90 mg Kg^{-1}. At a given concentration of hexavalent chromium and to achieve 50% hexavalent chromium removal, Jatropha was more effective than Pterocarpus and no significant effect on plant dry matter as well as aerial plant parts. Compost amendment was preferable when Jatropha was planted in hexavalent chromium polluted soil because Jatropha could remediate higher concentration than Pterocarpus. Further study is needed to investigate compost amendment into hexavalent chromium polluted soil that brought about adverse effect on plant dry matter of Pterocarpus.

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