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Experimental Study of Vetiver Phytoremediation on Compost Clay with Chromium (Cr) and Cadmium (Cd) Contaminant

A. Zubair[1*], M. Selintung[2], L.Samang[2] and H. Usman[3]

[1]Student of Doctoral in Civil Engineering Hasanuddin University, Indonesia
[2]Department of Civil Engineerig, Hasanuddin University, Indonesia
[3]Department of Chemistry, Hasanuddin University, Indonesia
*email: achmad.zubair@gmail.com

ABSTRACT

A study was conducted to analyze the absoption and reduction capacity of cadmium and chromium metal in clay soil and clay soil plus compost artificiallly polluted with several Cd and Cr concentrations after phytoremediation process using several number of vetiver (*Vetiverazizanioides*) plants/ pot growing. The study testing 18 treatment combinations which were consisted of three Cr concentration (400, 6000, and 800 ppm), three number of vetiver plants (3, 6, and 9 plants/ pot), two growing media (clay and 80% clay + 20% compost). The more number of plants and the higher concentration of metals Cd, the higher capacity reduction Cd metals in the soil and the higher Cd metal absorption by vetiver plants. The higher number of vetiver plants grown the higher Cd and Cr in clay and clay plus compost media were absorbed and reduced. The levels of Cd and Cr in clay and clay plus compost media absorbed were followed by the more reduction of Cd and Cr

Keywords: Cadmium; chromium; phytoremediation; reduction capacity; vetiver

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1. INTRODUCTION

Heavy metals are important environmental pollutant. Cadmium and chromium are toxic and harmful heavy metals [1]. Their toxicity is a problem to ecology, nutrition and environment [2]. Environmental pollution by metals become extensive as mining and industrial activities increased, and some of these activities include mining and smelting of metals, burning of fossil fuels, use of fertilizers and pesticides in agriculture, production of batteries and other metal products in industries, sewage sludge, and municipal waste disposal [3]. The growth and yield of plants growing on heavy metal polluted soils show a reduction due to changes in their physiological and biochemical activities [4, 5]. Most of the reduction in growth parameters of plants growing on polluted soils can be attributed to reduced photosynthetic activities, plant mineral nutrition, and reduced activity of some enzymes [6]. Continued decline in plant growth reduces yield which eventually leads to food insecurity. Therefore, soil polluted by heavy metal needs to be remediated.

Using plants for the treatment of polluted soils is a more common approach in the bioremediation of heavy metal polluted soils. Bioremediation encourages the establishment of plants on polluted soils. It is

a widely accepted method and an environmentally friendly approach because it is achieved via natural processes. Bioremediation is also an economical remediation technique compared with other remediation techniques [7]. Bioremediation is the use of microorganisms and/ or plants for the treatment of polluted soils.

Effort to remedy soil condition polluted heavy metal is needed in order soil condition save to utilized. Remediation of soil polluted can be achieved through phytoremediation i.e. leaching the pollutant using plant, including tree, grasses, and water plant. Leaching including decomposition, inactivation or mobilization of pollutant into save form [Chaney *et al.*,1995 in 8].Phytoremediation is an aspect of bioremediation that uses plants for the treatment of polluted soils. It is suitable when the pollutants cover a wide area and when they are within the root zone of the plant [9]. Plants used to remedy soil condition polluted by should have characteristics: rapid growth rate, high biomass, extensive root system, and ability to tolerate high amounts of heavy metals [10]. Vetiver (*Vetiveriazizanioides*) is a hyper accumulator plant which have great potency to remedy. Utilization of vetiver in phytoremediation process is intended to remedy the polluted soil quality faster, easier lower cost compared with without phytoremediation process or compared with utilization other method engineering based, such as chemical leaching or scraping. Utilization of vetiver is also aimed to conserve the environment involved biotic diversity [11].

The objectives of this study were to analyze the absoption and reduction capacity of cadmium and chromium metal in clay soil and clay soil plus compost artificially polluted with several Cd and Cr concentrations, after phytoremediation process using several number of vetiver plants/ pot.

2. MATERIAL AND METHOD

In this study, vetiver (*Vetiveriazizanioides*) used to remedy the soil media growing polluted with cadmium (Cd) and chromium (Cr). Vetiver grew on clay and clay plus 20% compost.

A.Time and Location

The experiment was carried out in February to March 2015. Acclimatization of vetiver plant, preparation of artificial waste of Cd and Cr, soil sampling and soil analyzing before and after treatment were done in Laboratory of South Sulawesi Agricultural Technology Assessment in Maros Regency.

B. Design and Data Collection

Clay used in this experiment was taken from experimental farm of South Sulawesi Agricultural Technology Assessment in Maros Regency, while vetiver seedling was taken from Soppeng Regency. Compost for plant media came from cattle/ poultry farm,

and heavy metal of Cd and Cr was industrial waste diluted pollution.

B1. Material and Instrument

Experimental material such as clay, compost, polluter of heavy metal Cd and Cr, vetiver plant seedling were prepared suitable with requirement.

Instruments and the complementary were:

- Instrument for analyzing chemical properties of soil: composition of chemical element and compound, scales, injector, ruler.
- Instrument to detect Cd and Cr heavy metal: Atomic Absorption Spectrophotometer (AAS).
- Complementary instrument: green house, spade, reactor pot process.

B2. Treatment

The experiment had 2 x 3 x 3 = 18 treatments, consisted of:

- Heavy metal of injected at concentration of 40, 60, and 60 ppm for Cd, and 400, 600, and 800 ppm for Cr
- Vetiver planted were 3, 6, dan 9 plants/ pot.
- Media for growing vetiver used were clay and 80% clay + 20% compost.
- Phytoremediation was observation at 0, 7, 14, 21, and 28 days after vetiver planting for clay; and 0, 7, 14, 21, 28, and 35 days after vetiver planting.

B3. Data Analysis

The study was conducted at laboratory scale using in process reactor pot to identify the interaction of variables studied. Data collected were calculated to determine the absorption capacity of Cd and Cr, and reduction capacity of Cd and Cr from vetiver during phytoremediation process. The absorption level of heavy metal Cd and Cr on growth media during phytoremediation was calculated using formula (1) as follows:

$$KAv = \frac{\text{Concentration of Heavy Metal for Vetiver}}{\text{Initial Concentration of Heavy Metal of Planting Media}} \times 100\% \quad [1]$$

Reduction capacity of heavy metal Cr of growth media during phytoremediation was calculated using formula (2) as follows:

$$KRt = \frac{\text{Reduction of Heavy Metal Concentration of Planting Media}}{\text{Initial Concentration of Heavy Metal of Planting Media}} \times 100\% \quad [2]$$

3. RESULTS AND DICUSSION

A. Absorption Capacity

A.1. Absorption Capacity of Cadmium in Clay

The ability of the vetiver plants in absorbing metal Cd as a whole reflected their ability to remedy polluted soil. Calculation of the absorption capacity was based on the Cd concentration absorbed by plants during 28 days after planting and plant dry weight. In Figure 1 showed that three absorption capacity of the metal cadmium by varying the number of plants/pot in the clay media.

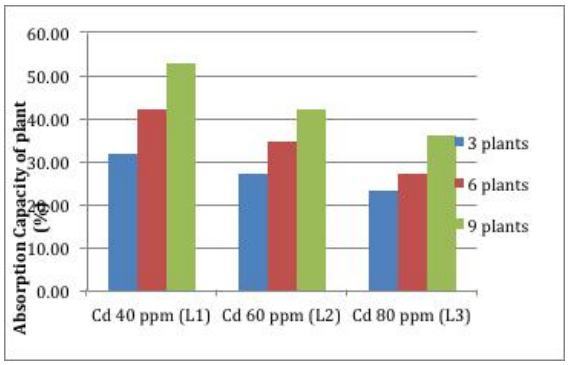

Figure1.Cadmium absorption in clay

Based on Figure1 can be seen that at concentration of 40 ppmCd, the highest Cd metal absorption by plants found in 9

plants/pot , as well as at concentration of 60 ppm and 80 ppm . This shows that the more the number of plants/pot, the more levels of metals absorbed on the plant. But the more number of plants/ pot will be the little metal absorption capability/ plant. This is because the more the number of plants will be needed much nutrients. As a result, there is competition in plants to obtain nutrients [12].

The highest Cd absorption capacity was found in 9 plants/ pot with a value of 53.03 % at a level of 40 ppm Cd metal contaminant. This suggests that the vetiver plants had the ability to absorb metals Cd well, because these plants have much volume and long roots, so that the plant roots permeate the soil that had been contaminated by Cd. The more the number plants, the higher the value of their absorption capacity.

A.2. Absorption Capacity of Cadmium in Clay plus Compost

The ability of the vetiver plant in absorbing metal Cd as a whole can be seen from the absorption plant. Calculation are based on the absorption rate of Cd concentrations absorbed byplants for 35 days and plant dry weight as presented in Figure 2.

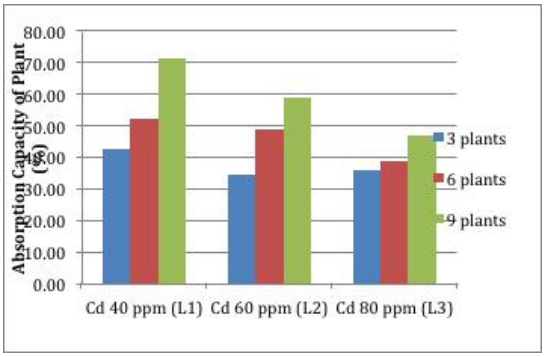

Figure 2. Cadmium absorption capacity in clay plus compost

Based on Figure 2, can be seen that Cd metal absorption capacity by varying the number of plants on the clay plus compost media. At a concentration of 40 ppm Cd, the highest Cd metal absorption capacity at 9 plants/pot, as well as at a concentration of 60 ppm and 80 ppm. The highest absorption capacity Cd metal contained in plants with 9 plants/pot with a value of 71.54 % at a level of 40 ppm Cd metal pollutant, and at a concentration of 60 ppm with a value of 58.82 % and 47.07 % for concentration 80 ppm. This shows that the more the number of plants/pot, the higher the level of absorption capacity[13].

A.3. Absorption Capacity Chromium in Clay

The ability of vetiverplant in absorbing Cr metal was reflected by plant absorption. The calculation of absorption rate based on Cr concentration absorbed by plant and the dry weight of plant. The absorption of Cr was calculated using formula (1).

At Figure 3 seen that the highest Cr absorption was at 9 number of vetiver plants/pot, either treated with 400, 600, or 800 ppm Cr.The increasing number of vetiver plants/pot totally increased the absorption of Cr, but decreased the absorption of Cr individually of vetiverplant.That was due to the increasing number of plants/pot increased intake of nutrient, and as a result the plant compete in intake of nutrient. The highest

absorption/plant was observed at growing 3 vetiver plants/pot [14].

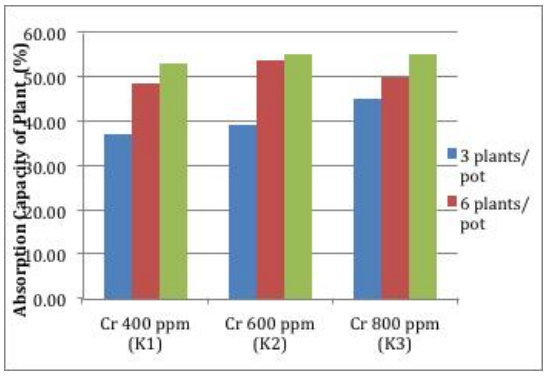

Figure3. Chromium absorption capacity inclay

The highest Cr absorption capacity of 55.28% was observed at 9 vetiver plants/pot and treated 800 ppm Cr. And lowest Cr absorption of 37.01% was observed at 3 vetiver plants/pot and treated with 400 ppm Cr. It indicated that vetiver had the ability to absorb chromium.

A.4. Absorption Capacity Chromium in Clay plus Compost

In Figure 4 presented that the highest Cr absorption capacity per pot of 13.30 ppm/day was observed at growing 9 vetiver plants/pot and treated 800 ppm Cr. But highest Cr absorption per plant of 3.50 ppm/day was observed at 3 vetiver plants/pot and treated with 800 ppm Cr.

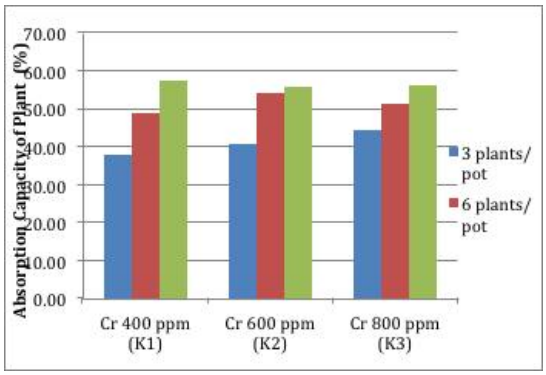

Figure 4.Cadmium absorption capacity in clay plus compost

In Figure 4 shown that the highest Cr absorption capacity of 57.47% at planting 9 vetiver plants/potand treated 400 ppm Cr. It was indicated that vetiver had the ability to absorb Cr effectively. The greater number of vetiver plants/pot, the higher level of its absorption capacity.

B. Reduction Capacity

B.1. Cadmium Reduction Capacity in Clay

The reduction of cadmium by vetiver plants in clay growing media had decreased over time. Continued decline occurred during a span of 28 days in pots with 3, 6, 9 plants/pot. Cadmium content in the clay polluted with 40 ppm Cd and grown 3 vetiver plants/pot decreased up to 34.60 ppm, while grown 9 vetiverplants/pot decreased up to 26.35 ppm. For media polluted with 60 ppm Cd, the growing 3 vetiverplants/pot had decreased Cd concentration up to 27.92 ppm at 28 days after planting, while the growing 9 vetiverplants/pot decreased Cd concentration up to 17.95 ppm. For media polluted with 80 ppm Cd, the growing 3 vetiverplants/ pot decreased Cd concentration up to 29.17 ppm, while the growing 9 vetiverplants/pot decreased Cd concentration up to 25.07 ppm. This showed the influence of the number of plants in decreasing the level of the metal cadmium in the soil.The more number of

plants/pot then the greater reduction of metals in the soil.

The graph of reduction capacity of metal content in phytoremediation on clay soil contaminated with metals Cd is presented in Figure 5.

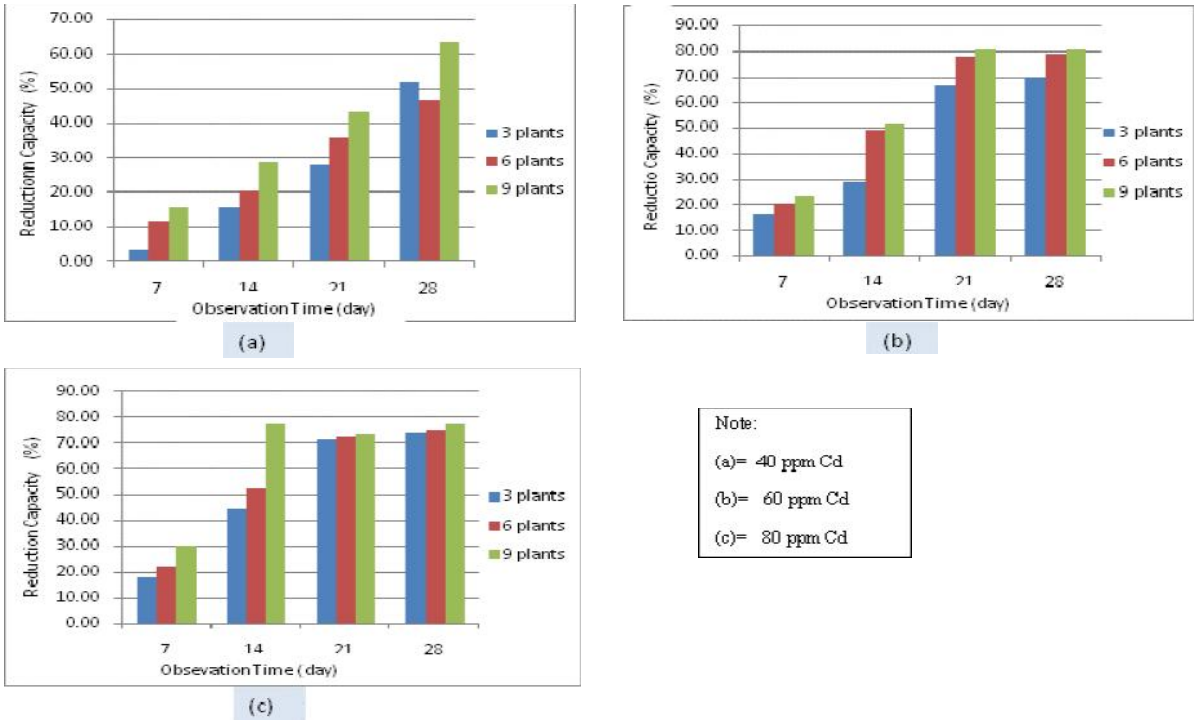

Figure 5. Reduction capacity of Cd in clay.

In Figure5seen that Cd metal reduction capacity by varying the number of plants in the clay media. For the provision of 40 ppm Cd metal obtained the largest metal reduction capacity at the treatment of 9 plants/ pot of 63.42%. For the provision of 60 ppm Cd metal also gained the largest metal reduction capacity at 9 plants/ pot of 80.50 %. As for the provision of 80 ppm Cd metal also gained the largest metal reduction capacity at 9 plants of 77.62 %. This suggestthat there was influence between the length of time of observation and the number of plants of the reduction capacity of metals in the soil.

Cadmium metal reduction capacity of the largest average in the clay media growing in treatment of 90 ppm Cd by 57.45%.A decrease in concentration with increasing observation time due to the ability of plants to absorb heavy metals Cd up to a certain time limit before the saturation point. Saturation point is the maximum time limit that can be tolerated in the plants to absorb contaminant. Once past the saturation point, the ability of plants to absorb heavy metal declined even heavy metal concentrations in soil can increase because the plant can release metal that has been absorbed.

B.2. Reduction Capacity in Cadmium in Clayplus Compost

The reduction of the metal cadmium by the number of plants on clay plus compost media continue to decline that occurred over a span of 35 days either in pots with 3, 6 or 9 vetiver plants/pot. For 40 ppm Cdtreatment with 70.45 ppm metal initial concentration, the growingof3 vetiverplants/pot reduced up to 20.73 ppm Cd, while the growing of 9 vetiver plants/ pot reduced up to 18.63 ppm Cd. For 60 ppm Cd treatment with 90.45 ppm metal initial concentration, the growingof3 vetiverplants/pot had decreased up to 21.47 ppm Cd, while the growing 9 vetiverplants/ pot had decreased up to 17, 62 ppm Cd. For 80 ppm Cd treatment with 120.45 ppm metal initial concentration, the growingof3 vetiverplants/pot had decreased up to 24.60 ppm Cd, while the growing 9 vetiver plants/ pot reduced up to 25.40 ppm Cd.

Cadmium metal content reduction in clay plus compost media presented in Figure6 .

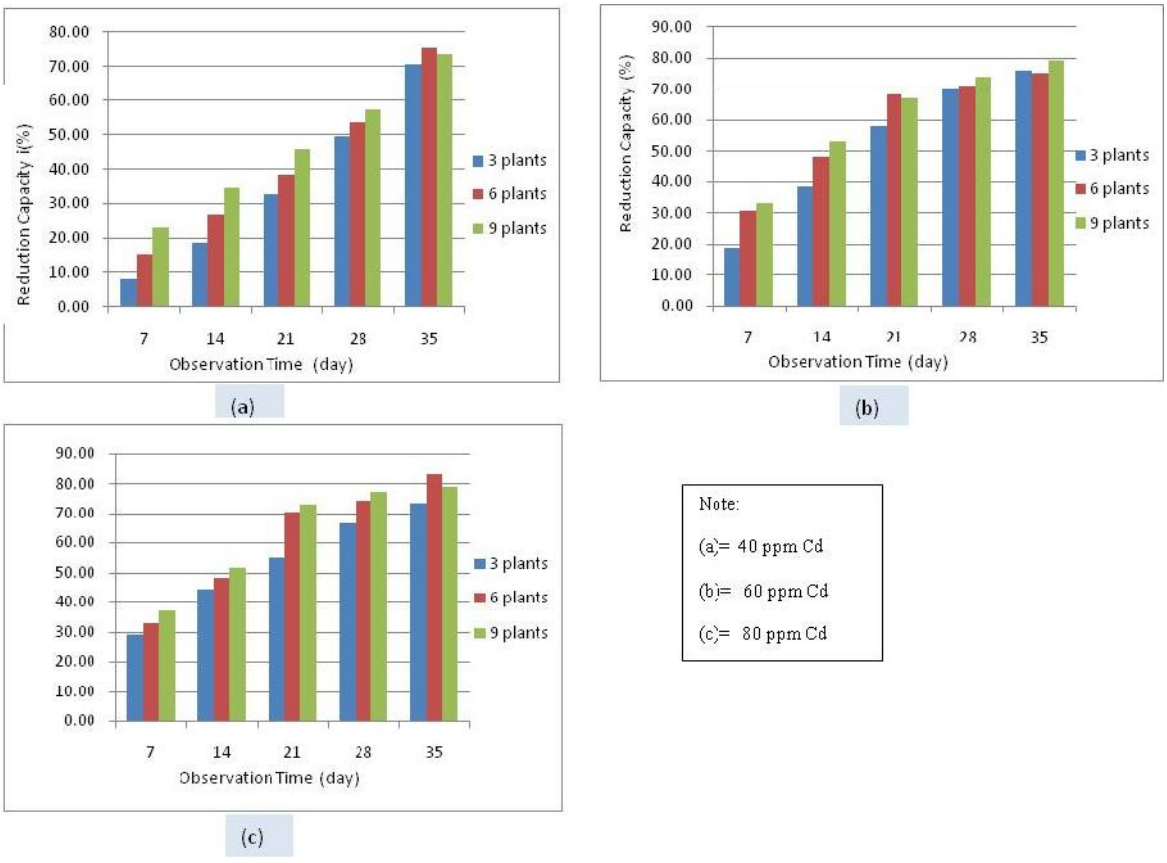

Figure 6. Reduction capacity of cadmium in clay plus compost

The largest metal reduction capacityof 75.27% was observed at 6vetiver plants/pot with 40 ppm Cd treatment. However, at 60 ppm Cd with 9 vetiver plants/ pot treatment, the reduction capacity was 80.52 %. As for the provision of 80 ppm Cd metal also gained

the largest metal reduction capacity at the 9 plants/pot of 83.09 %. From these data it can be seen the highest reduction in the reduction capacity of 40 ppm and 80 ppm grown with 3 vetiverplants/pot.

B.3. Reduction Capacity of Chrom in Clay Soil

Reduction of Cr metal at several number of vetiver plants on clay media Cr, while at 9 plants vetiver/ pot Cr concentration reduced 149.54 ppm. At treatment of 600 ppm Cr, reduction of Cr was 186.72 in pot planted with 3 plants vetiver, and Cr reduction was 136.59 ppm in pot planted with 9 plants vetiver. At treatment of 800 ppm Cr, reduction of Cr was 199.25 ppm in pot planted with 3 plants vetiver, and Cr reduction was 171.73 ppm in pot planted with 9 plants vetiver.

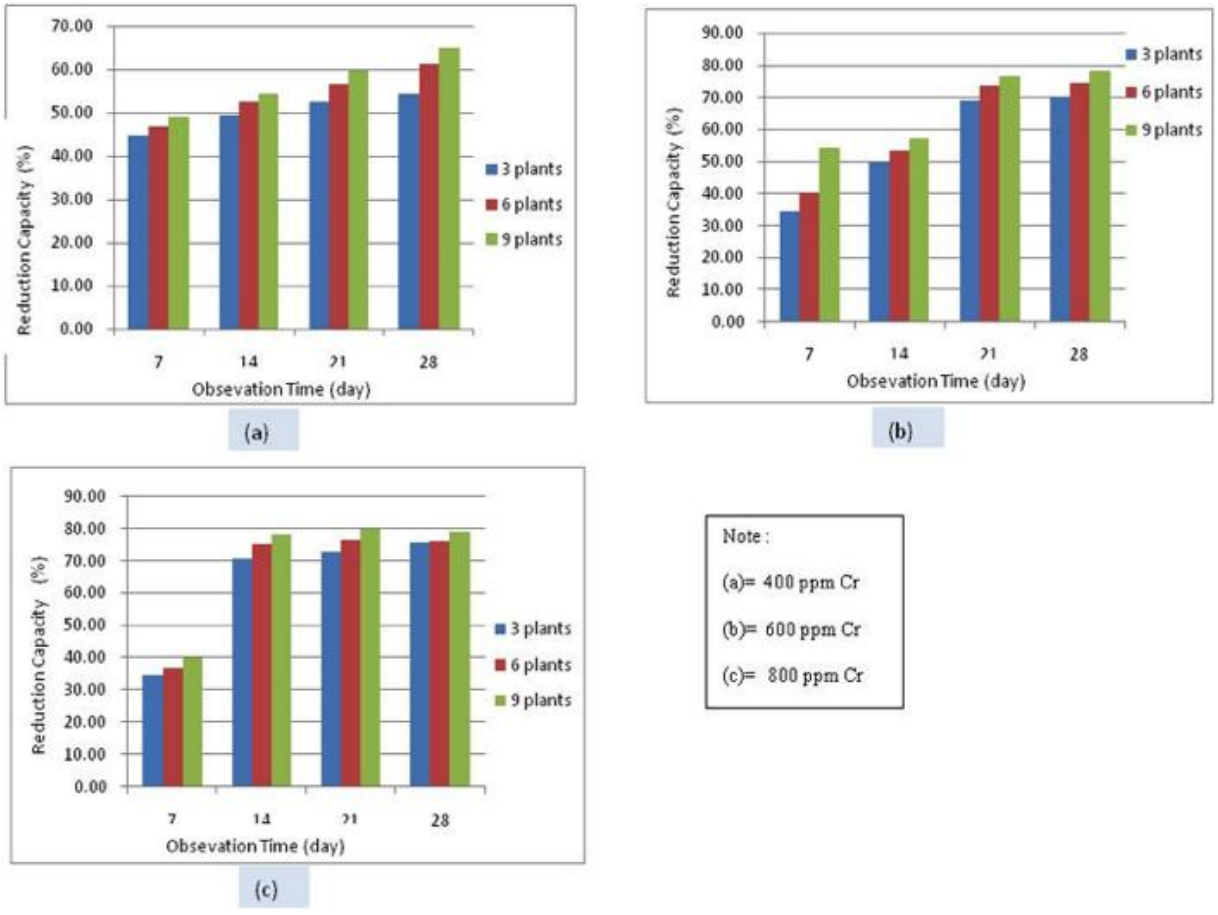

Figure 7. Reduction capacity of chrom in clay

decreased from 0 to 28 days after vetiver planting, and the decreasing observed at 3, 6, and 9 plant vetiver plants/pot. In that 28-day period, Cr concentration reduced 194.41 ppm at 3 plants vetiver/ pot and treated 400 ppm

B.4. Reduction Capacity of Chrom in Clay plus Compost

Reduction of Cr metal at several number of vetiver plants on clay plus compost was presented in Figure 8. Reduction of Cr metal at several number of vetiver plants on clay compost media decreased from 0 to 35 days after vetiver planting, and the decreasing observed at 3, 6, and 9 plant vetiver plants/pot. In that 35-day period, Cr concentration reduced of 152.63 ppm at 3 plants vetiver/pot and treated 400 ppm Cr, while at 9 vetiver plants/pot Cr concentration reduced 96.27 ppm. At the treatment of 600 ppm Cr, reduction of Cr was 158.71 ppm in pot planted with 3 vetiver plants, and Cr reduction was 151.40 ppm in pot planted with 9 vetiverplants. At treatment of 800 ppm Cr, reduction of Cr was 151.40 ppm in pot planted with 3 vetiverplants, and Cr reduction was 140.20 ppm in pot planted with 9 vetiverplants.

In clay media, the highest reduction capacity was obtained at growing 9 vetiver plants/pot, and on treatment of 400, 600, and 800 ppm Cr, found the highest reduction capacity of 64.87%, 78.17%, and 79.20%, respectively. The data shown that number of vetiver plant and the level of Cr concentration affected the reduction capacity.

omparation of Figure 5 and 7 with Figure 6 and 8, seen that reduction capacity of vetiver in clay plus compost was lower compared with reduction capacity of vetiver in clay alone. Organic matter had been shown to decrease heavy metal availability through

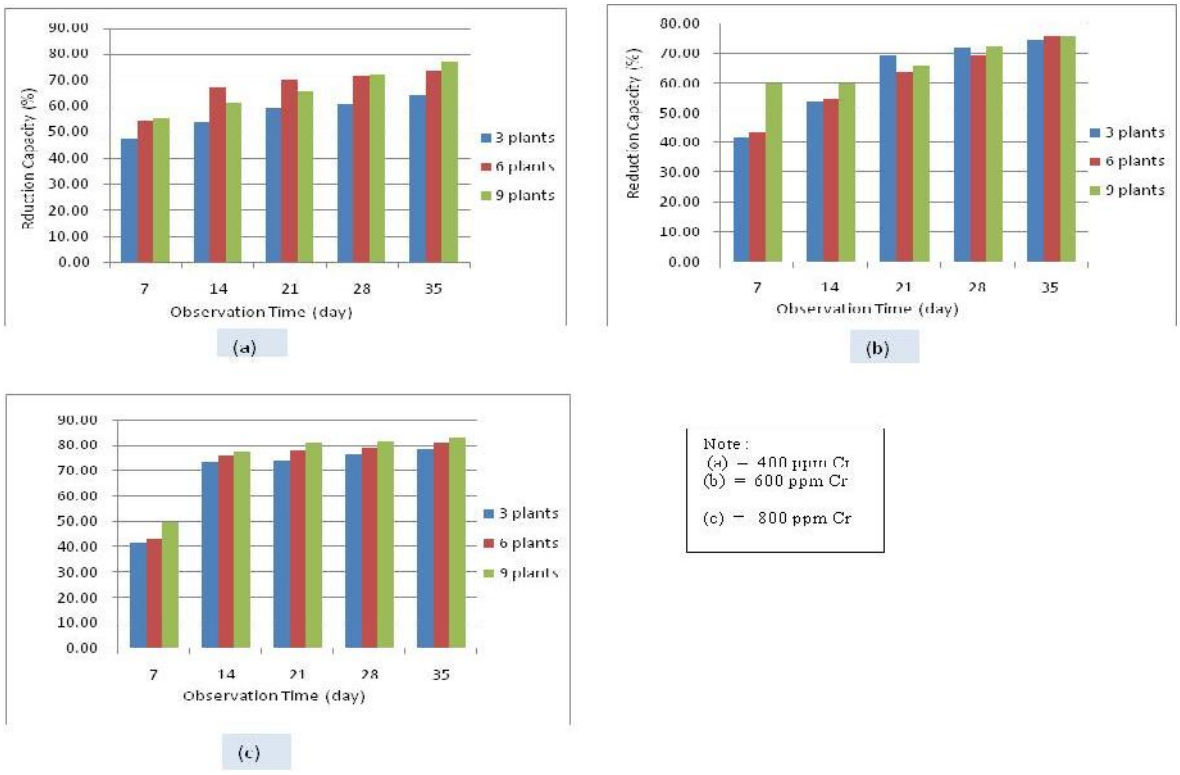

Figure 8. Reduction capacity of chrom in clay plus compost

immobilization of the metals [15]. Biostimulation involves the addition of nutrients in the form of compost or other organic amendments which serve as Cr source for microorganisms present in the soil. The added nutrients increase the growth and activities of microorganisms involved in the remediation process and thus this increases the efficiency of bioremediation. Although biostimulation is usually employed for the biodegradation of organic pollutants [16], it can equally be used for the remediation of heavy metal polluted soils. It is well known that the addition of organic materials reduces the pH of the soil [17]; this subsequently increases the solubility and hence bioavailability of heavy metals which can then be easily extracted from the soil [18].

4. CONCLUSION

Increasing the number of vetiver plants per pot increased absorption capacity of Cd and Cr in clay and clay plus media. The highest Cd and Cr absorption was obtained on growing 9 vetiver plants per pot at 400, 600, and 800 ppm Cd and Cr. Increasing Cd concentration treatment decreased the Cd absoption of the vetiver plant, but increasing Cr concentrationalmost not affected the Cr absoption of the vetiver plant.

Reduction capacity of Cr in clay and clay plus compost media increased with the increasing number of vetiver plants per pot.

Reduction capacity of vetiver in clay plus compost was lower compared with reduction capacity of vetiver in clay alone

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