Phytoremediation of Cr and Pb from Soil Irrigated by Wastewater

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ABSTRACT
In order to evaluate the effect of agricultural crops, such as kenaf *(Hibiscus Cannabinus L.),* corn *(Zea Mays),* and barley *(Hordeum vulgare*), in the removal of Cr and Pb from soil irrigated with wastewater, an experimental pot was conducted at Green House of University of Technology. Three levels of water were used for irrigation included tap water (control) (T1), 50% of wastewater+50% of tap water (50%WW) (T2) and 100% wastewater (100%WW) (T3). The obtained results, indicated that kenaf, and barley have been an effective plant in removal of Cr and Pb due to its high removal efficiency. Maximum values of removal efficiency were recorded in August 2015 for the (100%WW) and found 85.59%, 82.77, 93.27% of Pb and 85.67, 93.85, 87.24% of Cr for corn, kenaf and barley, respectively. Minimum removal efficiencies recorded at (50%WW) treatment for Pb were (5.66, 4.48, 0.99%) and at control treatment for Cr were (0.99, 1.51, 2.37%) for Cr in May 2015 for corn, kenaf and barley, respectively. From the results obtained, kenaf, and barley were effective in removal of Cr and Pb due to its high removal efficiencies.
Keywords: Phytoremediation; Heavy metals; Soil; Wastewater

INTRODUCTION
Contaminated soils with heavy metals can potentially lead to the uptake and accumulation of these metals in the edible plant parts causing a risk to human and animal health [1]. Solid waste disposal, wastewater irrigation, sludge application and industrial action are the major source of heavy metals pollution, and an increased metals uptake by food crops grown on such contaminated soil is not uncommon [2].

The rapid increase in population coupled with fast industrialization growth causes serious environmental problems, including the production and release of considerable amounts of toxic waste materials into environment [3].

There are many methods that used to remove heavy metals from polluted soil and water, such as chemical precipitation, ion exchange and reverse osmosis, etc., but these methods are more expensive so that, phytoremediation technique was used for this purpose.
phytoremediation has been considered a natural process, first identified and proved more than 300 years ago [4]. At the current time, Phytoremediation technique, was applied in using of several types of plants to remove, extract, absorb and accumulate toxic elements from the soils. However, phytoremediation was described as a cost-effective, environmentally friendly approach, applicable to large areas [3,5,6].

The aim of this research study was to determine the effectiveness of phytoremediation technique in the removal of heavy metals such as Cr and Pb by using of kenaf *(Hibiscus*

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Cannabinus L.), corn *(Zea Mays),* and barley *(Hordeum vulgare* from soil irrigated with wastewater.

Materials and Methods

Experimental Work

In order to evaluate the effect of agricultural crops, such as kenaf *(Hibiscus Cannabinus L.),* corn *(Zea Mays),* and barley *(Hordeum vulgare*), in the removal of Cr and Pb from soil irrigated with wastewater, an experimental pot was conducted from May 2015 to August 2015. The study was carried out at the University of Technology in Baghdad city, Iraq.

The experiment was arranged for four months to evaluate the effect of agricultural crops, such as kenaf *(Hibiscus Cannabinus L.),* corn *(Zea Mays),* and barley *(Hordeum vulgare*) as shown in Figure 1, in the removal of heavy metals (Pb and Cr) from soil irrigated with wastewater. Three levels of water were used for irrigation included tap water (control) (T1), 50% of wastewater+50% of tap water (50%WW) (T2) and 100% wastewater (100%WW) (T3). The selected plants were planted on in plastic pots (6 plant per pot; 25 cm length × 25 cm width × 25 cm height) filled with a 8 kg of sandy loam soil. The pots were kept in the greenhouse of University of Technology.

The wastewater samples were collected from sewage nearby the experimental site in polyethylene bottle. Potable water also collected from tap water nearby the experimental site. Wastewater, tap water, soil and plant samples were collected from monthly to determine the concentration of Cr^{+3} and Pb.

The soil was air-dried, powdered, sieved through a 2 mm sieve and heavy metal concentration was measured. The total concentration of soil Pb and Cr measured using wet digestion method. While wastewater samples were collected in acid washed plastic containers. 100 mL of wastewater sample has been filtered using Whatman filter paper (0.45 μm pore size) for estimation of dissolved heavy metals (Cr^{+3} and Pb). Another 100 mL of the sample have been digested with (3:1) of Hydrochloric acid (HCl) and Nitric acid (HNO_3) to determine total heavy metals. Procedures followed for analysis have been in accordance with the standard methods for examination of water and wastewater [8]. Analysis of the total and dissolved of heavy metal was performed with a flame atomic absorption spectrophotometer (AA6300, Shimadza, Japan).

Results and Discussion

Table 1 and 2 shows the concentration of $Cr^{+3}$and Pb that found in the plant parts which was irrigated with wastewater during the experimental period (four months). Table 1 illustrated the concentration of Cr^{+3} in corn, kenaf, and barley plants where the minimum value (1.01mg/kg) was found in the stem of corn plant in May in the control treatment and maximum value (18.21 mg/kg) which was observed in the stem of the kenaf plant in the (100%WW) in August. While the minimum value of Cr^{+3}(1.21 mg/kg) founded in the roots of corn plants at a control treatment in May and maximum value was recorded in kenaf 17.29 mg/kg in August. However, the experimental results indicated that the Kenaf plant can be considered as an effective plant to remove the Cr^{+3} from soil irrigated with wastewater.

Figure (1): Picture of plants that tested in this study

Table 2 demonstrated the results of concentration of Pb in the stem and root of corn, kenaf and barley. The results clarified that the minimum value (3.09 mg/kg) was observed in May for the control treatment in the stem of barley plant and maximum value (19.65 mg/kg) was observed in the stem of the barely plant in July. For root of plant, the highest and lowest value was observed in May for barely plant (2.12 mg/kg) when the plant was irrigated by (50% WW) and (19.65 mg/kg) for kenaf plant at (100%WW). These results showed the uptake of heavy metals from soil that irrigated with wastewater were increased with time.

Table (1): Chromium concentration (mg/kg) in the selected parts during the experimental study

Plant name		Corn			Kenaf			Barley		
Plant parts	Study periods	T1 (Control)	T2 (50%WW)	T3 (100%WW)	T1 (Control)	T2 (50%WW)	T3 (100%WW)	T1 (Control)	T2 (50%WW)	T3 (100%WW)
Stem	May	**1.01**	3.98	7.24	1.35	5.15	18.4	3.15	6.69	17.23
	June	4.85	6.01	11.05	2.12	5.25	8.13	4.98	5.56	10.97
	July	5.85	5.29	13.19	5.65	5.65	14.22	4.29	5.56	12.45
	August	5.99	9.16	16.45	5.39	9.21	**18.21**	8.01	9.12	15.29
Root	May	1.15	2.41	7.48	1.98	6.58	16.56	1.99	6.38	15.37

	June	3.98	4.25	12.98	**1.21**	4.85	10.38	3.45	6.98	11.39
	July	4.75	7.51	14.56	3.74	5.51	14.97	5.61	6.91	13.86
	August	7.09	10.35	17.22	7.34	7.34	**17.29**	6.29	10.15	14.12

Table (2): Lead concentration (mg/kg) in the selected parts during the experimental study

Plant name		Corn			Kenaf			Barley		
Plant parts	Study periods	T1 (Control)	T2 (50%WW)	T3 (100%WW)	T1 (Control)	T2 (50%WW)	T3 (100%WW)	T1 (Control)	T2 (50%WW)	T3 (100%WW)
Stem	May	4.5	4.24	8.01	4.01	3.79	7.9	**3.09**	3.41	7.2
	June	7.23	8.11	14.5	5.34	9.98	13.98	8.54	10.21	13.75
	July	5.25	12.01	16.85	5.12	13.89	15.98	6.28	12.89	**19.78**
	August	5.76	7.21	17.01	6.34	8.12	16.55	5.79	7.79	18.85
Root	May	6.31	3.41	5.21	6.31	2.27	6.95	7.79	**2.12**	7.8
	June	6.65	10.25	13.5	7.45	9.44	14.03	5.22	10.05	13.59
	July	7.28	8.35	17.48	7.01	11.44	**19.65**	7.28	11.87	18.55
	August	5.98	8.45	18.53	5.78	7.29	15.25	6.62	8.98	17.34

Removal Efficiency

The percent of removal efficiency of each metal was calculated as follows:

$$\text{Removal Efficiency (\%)} = \left(\frac{C_i - C_f}{C_i}\right) \times 100 \qquad \ldots(1)$$

Where

C_i = initial concentration of heavy metal (mg/kg), C_f = final concentration of heavy metal (mg/kg).

Figures 1 and 6 show the removal efficiency in the level of heavy metals in plants for all treatment. The percentage of removal efficiency of Cr^{+3} and Pb in the plants (corn, kenaf and barley) for all the treatment was calculated for every month. The results are as the following**.**

From Figure 1, it can be observed at the end of the experiment (August 2015) that the percentage of removal efficiency of Pb by corn plant for T1, T2, and T3 was 63.59 %, 36 % and 85.59 % respectively. The removal efficiency of Pb by the kenaf plant recorded as (82.77%) (Figure 2), while barley plant displays the maximum percentage of removal efficiency of Pb (93.27 %) (Figure 3).

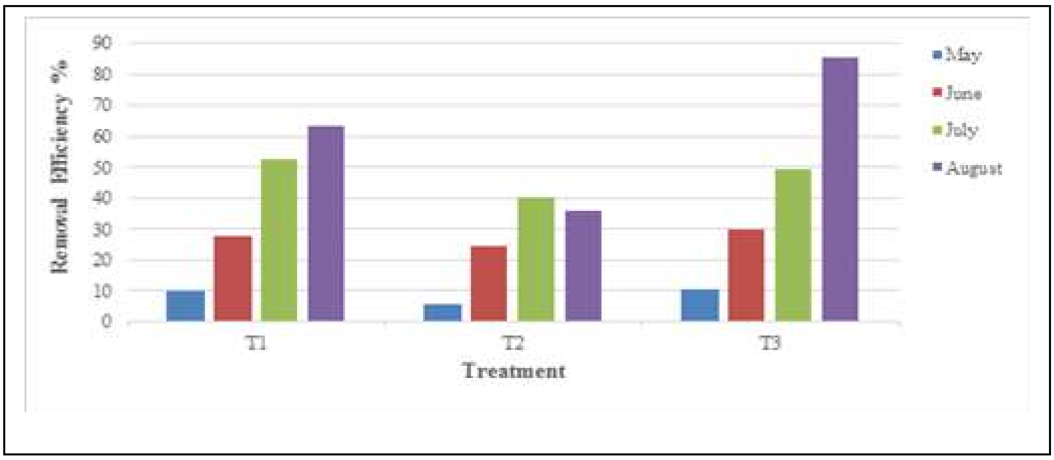

Figure (1): Removal Efficiency (%) of lead from soil by corn plant

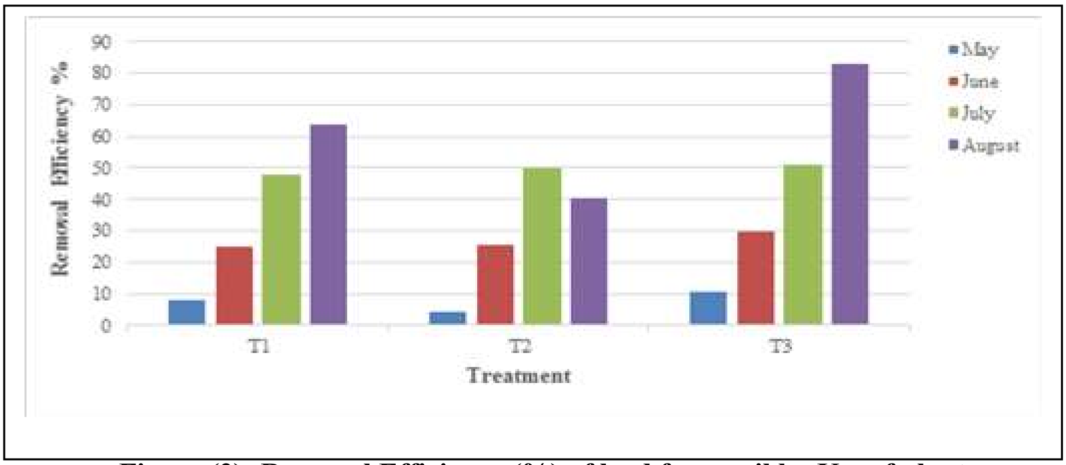

Figure (2): Removal Efficiency (%) of lead from soil by Kenaf plant

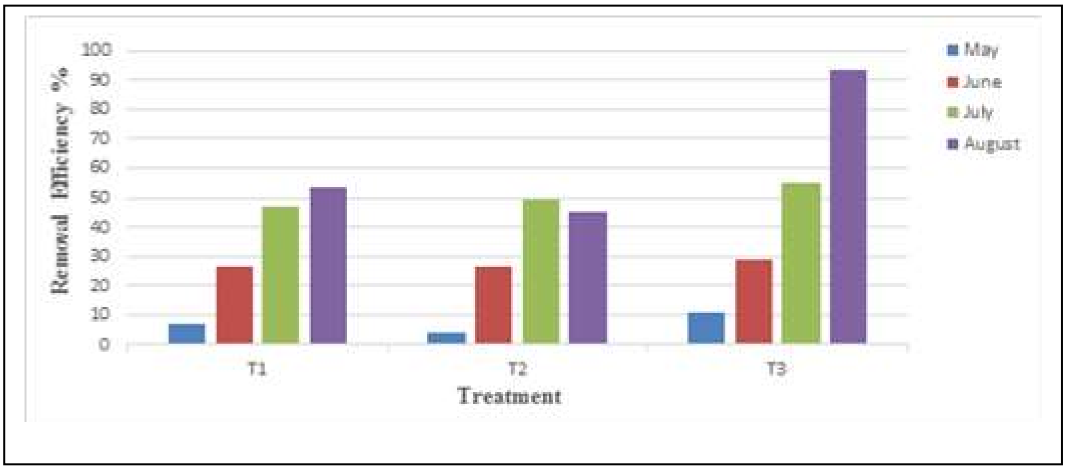

Figure (3): Removal Efficiency (%) of lead from soil by Barley plant

Figure 4, illustrated that the percentage of removal efficiency at the end of the experiment (August 2015) of Cr^{+3} by the corn plant for T1, T2, and T3 was 30.57 %, 56.68 % and 85.67 % respectively. However, It can be observed that the removal efficiency of Pb by the barley plant recorded as (97.24 %) (Figure 5), while kenaf plant displays the maximum percentage of removal efficiency of Pb (98.8 %) (Figure 6).

The results of this research study indicated that Pb has been the highest absorbance rate by the root for all the experiments. The results also pointed out that the level of the Pb and Cr^{+3} by the root were more than in the stem of all the plants that used in this study.

From the results obtained, it show there was a steady increase in the levels of Pb and Cr in all the experimental treatment and an increase in the levels of these metals in the stem and root of the corn, kenaf and barley plant. The increase in the levels of these metals in the plant sample can be attributed to two major transport mechanisms: convection and diffusion [9]. When the metal concentration in the soil had been increased, the amount of accumulated metal in the aerial parts and the roots increased significantly [10].

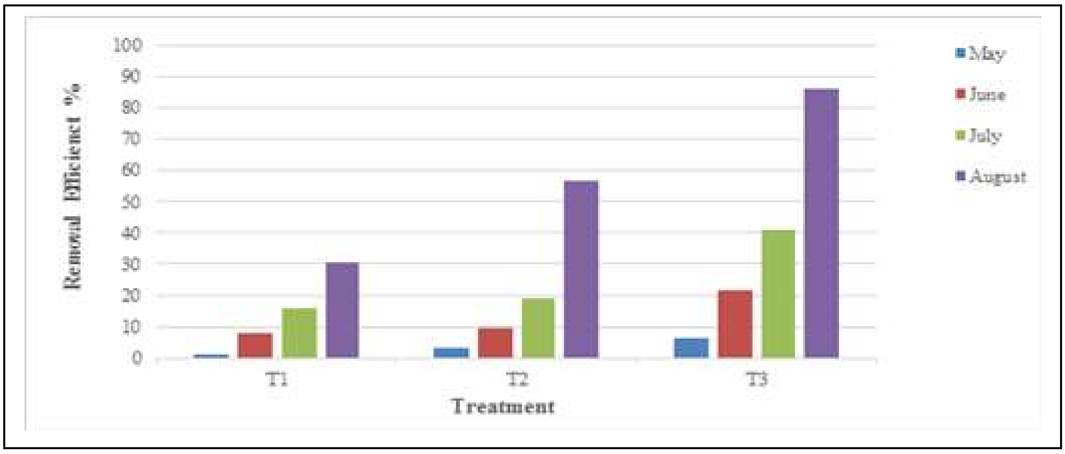

Figure (4): Removal Efficiency (%) of chromium from soil by corn plant

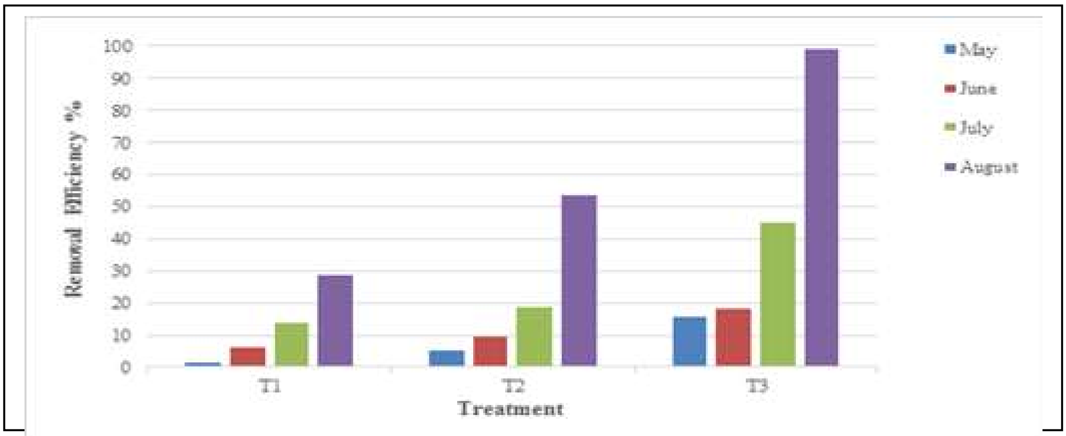

Figure (5): Removal Efficiency (%) of chromium from soil by kenaf plant

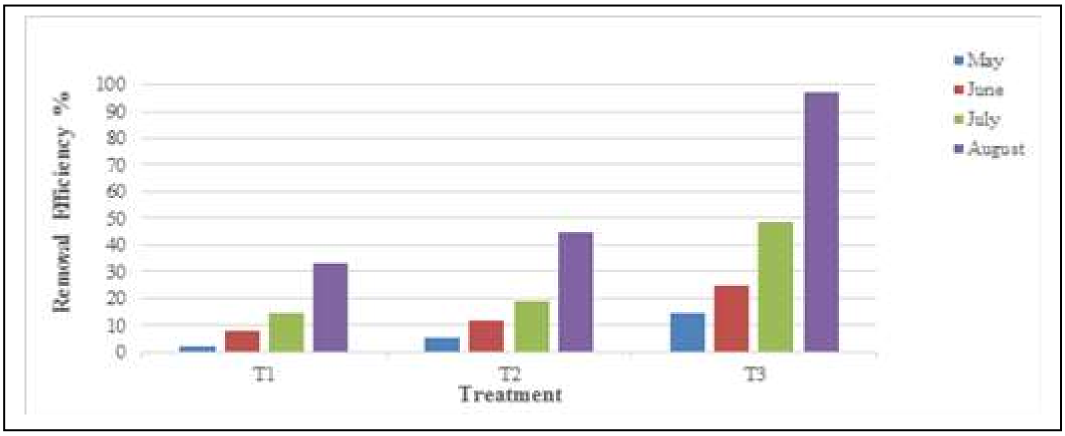

Figure (6): Removal Efficiency (%) of chromium from soil by corn plant

CONCLUSIONS

From the results obtained from this study, it can be concluded that the plants that used in this study were very effective in the removal of Cr^{+3} and Pb because of their percentage of removal

efficiency at the end of the experiment of Pb has been higher for the treatment of (100%WW) and it was 85.59%, 82.77% and 93.27% for corn, kenaf, and barley, respectively, and for Cr was observed as 85.67%, 98.85% and 97.24% for or corn, kenaf, and barley respectively.
Finally, it can be concluded that these plants (corn, kenaf, and barley) were a hyper accumulation of heavy metals.

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