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ORIGINAL ARTICLE

Chromium Removal from Industrial Wastewater Using Aquatic Plant (*Phragmites australis*)

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ABSTRACT
Among various methods of wastewater treatment, constructed reed beds are known as successful systems for municipal and industrial wastewater treatment which are very affordable in terms of energy and manpower costs. Constructed reed bed systems are the systems which can effectively refine various contaminants in different kinds of wastewater by using aquatic plants and appropriate substrate. In this research, plant species of Phragmites australis was used for cultivation in three systems with different substrates in different particle diameter sizes as 2-5, 5-10, 10-15 mm in order to treat constructed wastewater containing chromium with inlet concentration of 10 mg/lit and the removal efficiency was compared with retention times of 1, 3, 5, and 10 days. The results of the research showed that the effect of retention times on removal efficiency was significant at 5% level and also the effect of different substrates on removal efficiency was significant at 1% level. The highest efficiency of chromium removal by 99.98% was observed at 10day retention time. Considering the type of substrate, the highest removal efficiency by average of 99.92% belonged to fine sand substrate and the lowest efficiency by the average of 93.17% belonged to coarse sand substrate.
Keywords: *aquatic plants, chromium, industrial wastewater*

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INTRODUCTION

Heavy metals in a large scale enter the environment through man-made or natural resources. The rate of heavy metals entrance to the environment is far beyond the rate which is made by natural processes. Therefore, the accumulation of heavy metals in environment is considerable. Aquatic systems are naturally the ultimate receiver of such metals. Pollutants found in water result from domestic and industrial wastewater, chemicals discharge, pesticides, insecticides, herbicides, industrial discharge, radioactive waste, oil and colored hydrocarbons [1]. The use of constructed wetlands for natural treatment of industrial, urban, and agricultural wastewater has increased recently which not only decreases economic costs but also contributes to environment reform. These systems were first in the 1950s in West Germany. Then, a lot of research was conducted on wetland systems in different countries which have still continued. The results of these studies show that such systems are very suitable for industrial wastewater treatment [2]. Countries such as Denmark, The U.S.A, Australia, and England have used lots of these systems.

Municipal and industrial wastewater with toxic metal ions is an environmental concern. Such rare mineral pollutants, due to their non-biodegradable nature, too much toxicity, cumulative and carcinogenic effects are highly emphasized. Discharging wastewater containing industrial heavy metals is not only harmful and poisonous for marine life and other creatures, but also makes natural waters unsuitable for drinking. Containing heavy metal ions such as chromium, copper, zinc, cadmium, lead, etc., and due to their high toxicity, these effluents cause a lot of environmental problems. Presence of metal ions in water due to their known toxic effects on life cycle and plants and animals makes numerous environmental problems for human being. With regard to the serious damage which has incurred, wastewater treatment and the removal of heavy metals from water resources are crucial factors for protecting the environment and improving human health.

MATERIALS AND METHODS

This research was conducted in May 2013, at Faculty of Agriculture, Islamic Azad University, Dezful. Young plant 109samples were collected from the bank of Dez River. 9 fully sealed galvanized cells in dimensions of 1×0.35×0.35 m with an outlet on the floor were made and each substrate was equipped with a 200-liter tank of constructed wastewater. The cells have outlets in the bottom and the wastewater overflows after passing the substrate and samples are taken. Figure1 displays a schematic view of a constructed wetland system.

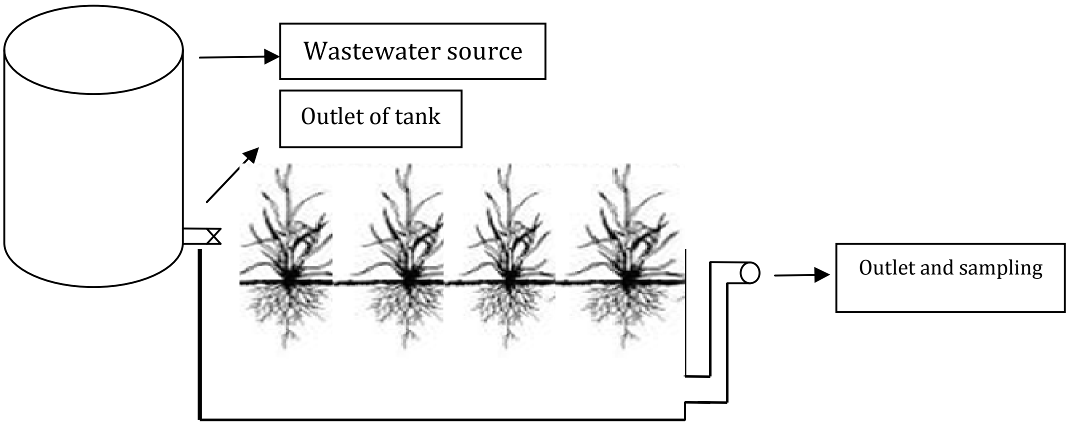

Figure 1: A schematic view of constructed wetland system

In this research, three different substrates with particle diameter of 1-5, 5-10, 10-15 mm were used in order to get the best substrate and efficiency for the reed (*Phragmites australis*) for the removal of chromium. The required substrates for the experiment were prepared and transferred to the experiment site, so that the plants collected from the bank of the Dez River could be planted in the cells. Hydraulic features of all three types of substrates are described in Table (1).

Features/type of substrate	Fine sand	Medium sand	Coarse sand
Diameter (mm)	0-5	5-10	10-20
Hydraulic conductivity (cm/min)	1.795	18.6	25
Uniformity coefficient	3.7	1.8	1.5
Porosity (%)	34.5	41.3	45.67
Bulk density	1.510	1.43	1.35

Table (1): Hydraulic features of substrate

For each cell one 220-liter tank and totally 9 tanks were prepared and installed in the right place. 200 liters wastewater was constructed with Cr and Zn concentration of 10 and 30 mg/lit, respectively. Each tank was equipped with a valve regulating outflow discharge so that it was possible to carry out the experiment within the desired retention times. The experiment was done within the retention times of 1, 3, 5, and 10 days and within two successive replications.

Table (2) displays the calculated volume and discharge with regard to retention time of the experiment.

Retention time	V(1)	Discharge (L/d)	Surface load (l/d.m^2)
1	59	59	198
3	69	23	77
5	80	16	53
10	100	10	35

Table (2): Volume, discharge, and surface load of systems' input wastewater

All tanks were calibrated so it was possible to calculate outflow discharge and to observe the volume of consumed wastewater at different retention times. Then, at the end of each retention time, samples were taken from the cells output within sterile test tubes, and the samples were kept at a temperature of 5°c

and after taking the samples they were transferred to the central laboratory of Shahid Chmran University and were measured via atomic absorption method.
So, 10 mg concentrated nitric acid (65%) was added to 1 g powder (root and shoot). The samples were placed in Bain-Marie bath at 65°c for two hours. Then, 3 ml hydrogen peroxide (20%) was added to them. After the samples got cool, they were filtered and their volume increased to 30 ml by distilled water and then they were measured by flame atomic absorption spectrometer (Perklim Elmer Analyst 700).
Chromium removal efficiency is calculated via the following equation:

$$\frac{(\text{Outlet concentration} - \text{inlet concentration} \times 100}{\text{Outlet concentration}}$$

In this research, EXCEL software was used to do all data analysis and calculations, and to draw required diagrams and SPSS diagram was used to do statistical calculations.

RESULTS

This research was done with three different substrates as the main treatments (with three replications) and retention times of 1, 3, 5, 10 days as the sub treatments. Diagram (1) displays chromium removal percentage within fine sand bed and retention time of 1, 3, 5, and 10 days. As it is observed in this diagram, removal efficiency increased when the retention time increased. Chromium removal time at retention times of 1, 3, 5, and 10 days was 72, 98, 65, 99, 92, 99, 98, 99 percent respectively.

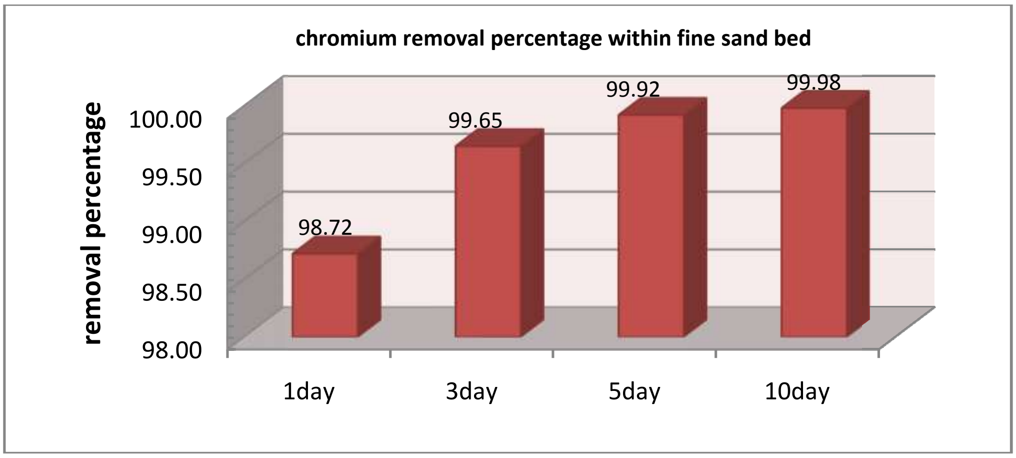

Diagram (1): chromium removal percentage within fine sand bed

Diagram (2) displays chromium removal percentage within medium sand bed and different retention times. Like fine sand bed, in medium sand bed retention time alteration affects chromium removal percentage. According to Diagram (2) the optimal retention time within medium sand bed and with regard to removal efficiency is 5-day retention time because after this retention time wetland has been able to decrease chromium concentration up to 99.84%.

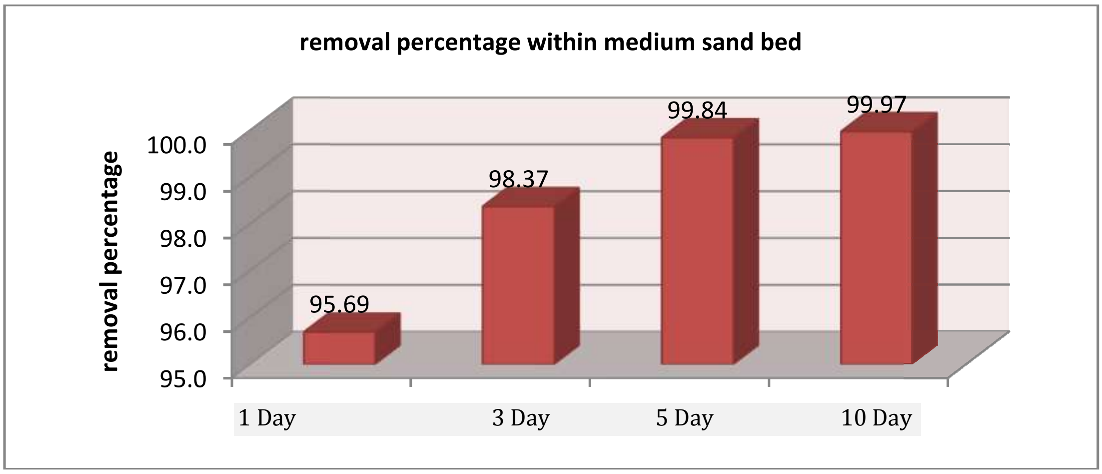

Diagram (2):): chromium removal percentage within medium sand bed

Diagram (3) displays chromium removal percentage within coarse sand bed and different retention times.

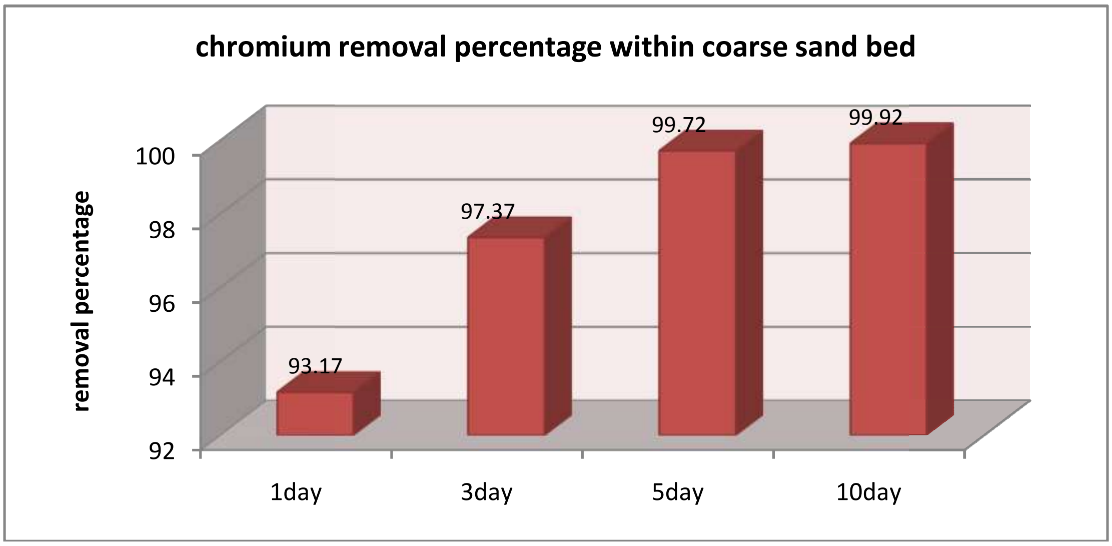

Diagram (3) chromium removal percentage within coarse sand bed

The highest chromium removal efficiency by 99.98% was observed in 10-day retention time. Considering the type of substrate, the highest efficiency of chromium removal belonged to fine sand bed by 99.92% and the lowest efficiency belonged to coarse sand bed by 93.17%. The results also showed that the interactive effect of retention time and type of substrate on removal efficiency was significant at 5% level. Diagram (4) displays the interactive effect of substrate type and retention time on chromium removal efficiency.

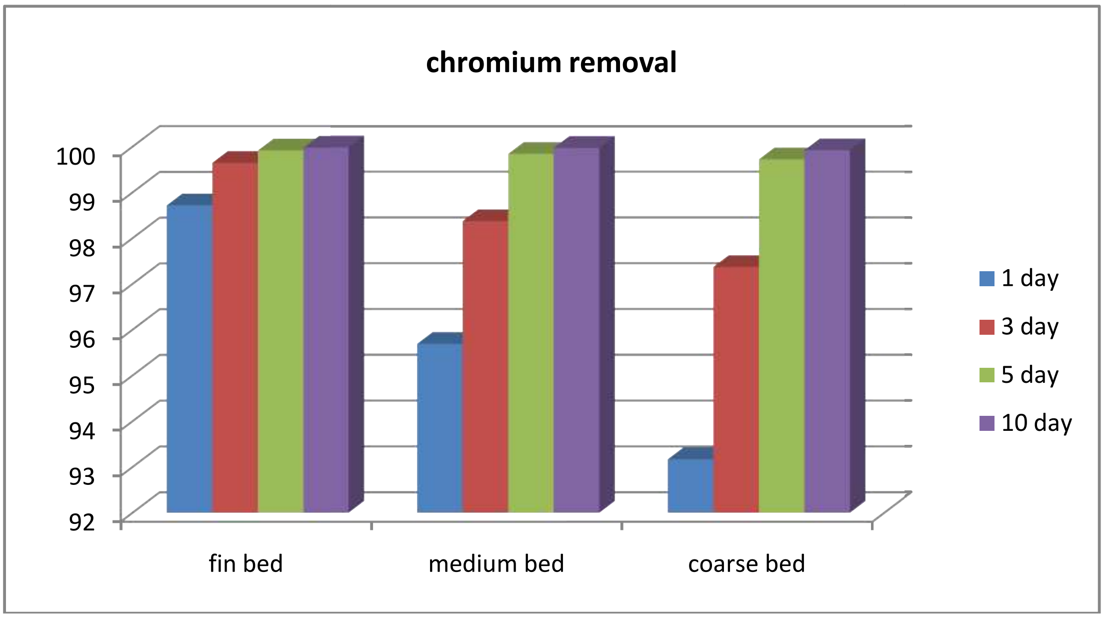

Diagram (4): the interactive effect of substrate type and retention time on chromium removal efficiency

The following results can be obtained from this diagram:

1. As retention time increases, chromium removal efficiency increases, too.
2. Optimal retention time by removal of more than 99% of chromium concentration belonged to 3-day retention time and medium sand bed, and also 5-day retention time and coarse sand bed.
3. The best type of substrate which reaches optimal removal efficiency within less time is fine sand bed.

DISCUSSION AND CONCLUSION

A lot of research has been done on chromium removal efficiency from different wastewaters some of which are referred to in this study and the results are compared with the findings of other researchers.

Borghei et al. [3] investigated treatment of industrial wastewater of Esfahan Refinery in wetland method. Therefore, a semi-industrial system of constructed wetland with horizontal sub-surface flow (SSF) was used. The tested plant was the reed of *Phragmatis Australis* which had grown in sand beds. The research was carried out in several sections with regard to the following hypothesis:

1. Biological method ability to treat wastewaters contaminated with oil products was satisfactory.
2. Constructed wetlands are able to treat wastewaters contaminated with refinery's oil products. The results obtained at different stages of the research are as the following:

a. Initial studies showed that COD removal efficiency in wastewater was about 86%.

Comparison of construct wetland performance and control wetland showed that constructed wetland was highly capable of reducing contamination load of wastewater polluted with oil materials due to the presence of reeds, so that in this research removal efficiency of P-PO6, COD, TNK was reported as 79.62, 67.3, 57.22% respectively.

b. Constructed wetland efficiency showed that pollution load changes have well tolerated industrial wastewater. So that during the experiments, COD removal efficiency with input concentration of 50 and 100 mg/l increased from 75.5 to 85.6% and in the wetland with input concentration of 270 mg/l and retention time of 3 days, COD removal efficiency was 82.3% [4-5].

Samples of water, sediment, and plant in the input and output of constructed wetland system during 8 years were taken. Plants were sowed in three successive phases and three different patterns of pollutant retention time were considered. During the cultivation of Eichhornia crassipes species, pollutants remained mainly in plant organs and by adding Typha to previous stage, pollutants mainly remained in sediments and organs of Typha. Pollutant removal efficiency for ammonia and other nutrients was not significantly different during three different stages. Using subsurface flow constructed wetlands with reed (*Phragmites Australis*) during 2 years in order to reduce chromium concentration to acceptable limit in receiving waters. The research was conducted in a textile factory and wastewater directly entered the beds cultivated with reeds. The research showed that this method decreased chromium concentration up to 72% and reduced output concentration to1.6 μg/l which was consistent with Italian legal limits for water reuse. It also showed that Cr VIII in textile effluents were accumulated in plant organs and were removed.

A lot of research has been done on aquatic plants efficiency in removing heavy metals from wastewater some of which will be reviewed in the following and their results will be compared with the findings of this research.

According to the obtained results the highest percentage of removal efficiency was related to zinc by 99.3% with 3-day retention time and the lowest removal efficiency belonged to cobalt by 54.6%.

The inlet and outlet wastewater samples were measured and the removal of 50% lead, 91.9% cadmium, 74.1% iron, 40.9% nickel, 89%chromium, and 48.3% copper was recorded.

The obtained results showed that there was a significant difference between the removal efficiency of copper and zinc at different retention times. The best zinc removal efficiency by 96% belonged to 4-day retention time and the best copper removal efficiency by nearly 100% belonged to 30day retention time.

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