Research Article

Brassica juncea (Indian Mustard Plant) as A Phytoremediator for Chromium

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ABSTRACT

Water pollution is the most serious environmental problem due to overpopulation, urbanization, and industrialization. An emerging technology gaining momentum to remove toxic contaminants from wastewater and soil such as phytoremediation. Different concentrations like 1ppm, 2ppm, 3ppm, 4ppm and 5ppm of simulated chromium wastewater and Tannery effluent from Leather Industry were used to determine the uptake and accumulation of chromium by Brassica juncea - Indian mustard plant by pot studies. The chromium concentrations in the mustard plants and the soil were estimated using inductively coupled plasma mass spectrometry (ICP-MS) after 45 days. The total accumulation of simulated chromium water in mustard plants were 9.90 µg/g, 20.54 µg/g, 58.53 µg/g, 61.65 µg/g, 65.34 µg/g and the concentrations of chromium in the soil were 21.90 µg/kg, 44.67 µg/kg, 66.95 µg/kg, 89.15 µg/kg & 110.98 µg/kg respectively. Similarly, the chromium from the tannery wastewater accumulation in plants were 18.65 µg/g, 29.06 µg/g, 43.66 µg/g, 58.48 µg/g, 60.42 µg/g and the concentrations of chromium in the soil were 20.76 µg/kg, 43.26 µg/kg, 66.26 µg/kg, 88.45 µg/kg, 112.74 µg/kg respectively. The chromium removal from the simulated water as well as the tannery effluent experiments was similar. The effective phytoremediation efficiency of chromium by Indian mustard (Brassica juncea) proves that it can be used as a potential phytoremediator

Keywords: Chromium, Wastewater, Indian mustard, Inductively coupled plasma mass spectrometry.

INTRODUCTION

Water pollution is the most serious environmental problems due to overpopulation, urbanization, industrialization. The tanning industry is a potential industry which is responsible for the large scale of pollution. It is one of the major consumers of water, and about 90% of the used water is discharged as the waste[1]. Chromium is the toxic metal from industrial effluents from electroplating industries and leather processing industries. In our earlier research work, the effect of chromium exposure on freshwater fish *Catla catla* was evaluated, and chromium bioaccumulation has caused the DNA damage and other nuclear abnormalities [2]. Present technologies for remediation of chromium are expensive and require sophisticated instruments for clean-up. Phytoremediation is an environmentally friendly, low maintenance cost, with less waste disposal requirement (Dushenkov and the cost effective technology for clean up the contaminated soils [3]. Earlier from our studies, we have proved that *Chrysopogon zizanioides* as effective uranium hyperaccumulator by simulation studies. It was observed that uranium concentration in the plants was found to increase with time and mostly the uranium is accumulated in roots [4]. Lotfy et *al.,*(2013) has tested five different plants for phytoremediation, he has reported sunflower plants has exhibited the higher remediation potential [3]. Cunningham *et al.,* (1997) has reported that the total amount of chromium accumulated by *Azadirachta indica* in which 95.16% was accumulated in shoots and 4.63% in roots**.** It has been identified that Indian mustard (*Brassica juncea*) as a high biomass rapidly growing plant with an ability to accumulate Nickel and Cadmium in its shoots and as a promising plant for phytoremediation [5.] So, the presence study has been proposed to investigate the feasibility of chromium removal using Indian mustard (*Brassica juncea)* from simulated wastewater and also from partially treated tannery effluent.

MATERIALS AND METHODS

Plant Material

The present study was carried out to investigate the efficiency of *Brassica juncea* to remediate the chromium. The healthy Brassica juncea seeds were collected from the local market. All the selected seeds were of uniform size. Indian mustard belong to Brassicaceae family which is perennial herbs, root depth is 90-120 cm, and seeds were uniform in size were collected and used for the experiment.

Experimental Design for simulated chromium water

The garden soil preferred to conduct the experiments. The pots were taken 2kg of garden soil and 100 numbers of mustard seeds in each pot. The various concentration of chromium solution was prepared by dissolving potassium dichromate ($K_2Cr_2O_7$) in the double distilled water. The simulated wastewaters were prepared at a higher concentration of chromium such as 5ppm, 10ppm, 20ppm, 30ppm, 50ppm, and 70ppm, whereas at lower concentrations of chromium were 1ppm, 2ppm, 3ppm, 4ppm, and 5ppm. 50ml of each concentration were used every day for the growth of the Indian mustard seeds for a period of 45 days. The influence of chromium on the growth of the plant regarding shoots, roots, leaves is carried out. In addition to that, a control blank set of experimental pot was maintained.

Collection and characterization of treated tannery effluent

The partially treated tannery effluent samples were collected from a Central Leather Research Institute (CLRI) at Tamil Nadu, India. The collected samples were brought to the laboratory within 2 hours of sampling with the help of icebox. The estimation of different physicochemical parameters like pH and Electrical Conductivity (EC) were analyzed on the site of collection, and the other parameters such as dissolved oxygen (DO) [6], total hardness (TH) [7], and sulfates were analyzed in the laboratory. The dissolved oxygen was determined by titration against sodium thiosulphate, total hardness (TH) was analyzed by titration using a standard EDTA solution; with eriochrome black T as an indicator [8].

Experimental Design for treated tannery effluent

Similar to the above mention experimental design, the pots were taken 2kg of garden soil and 100 numbers of mustard seeds in each pot. The various concentration of treated tannery effluent was prepared such as 1ppm, 2ppm, 3ppm, 4ppm, and 5ppm. 50ml of each concentration of treated tannery effluent were used each day for the growth of the Indian mustard seeds for 45 days. The effect of tannery effluent water on the growth of the plant regarding shoots, roots, leaves was carried out, and a control set of experimental pot was maintained.

Analysis of Soil, Plant and water Samples for Chromium

Processing of soil, plants and water samples were carried out using the earlier methods reported by Arunachalam *et al.,* (2014)[9]. The Processed samples were analyzed using Inductively Coupled Plasma Mass Spectrometry (ICPMS; Agilent Technologies, USA) with detection limit: 10ng/L±5% [9]. Internal reference standards were run regularly (in duplicate for every eight samples), and the measurements were accepted when the concentration of the internal standards was within 5% of the known concentration of chromium [2].

RESULTS AND DISCUSSION

Characterizations of Treated Tannery EffluentThe characteristic features of partially treated tannery effluent were analyzed, and the results for physicochemical characteristics of the treated tannery effluent were tabulated in Table 1. The present data clearly showed that the prominent heavy metal in the tannery effluent is chromium (VI) of 250 mg/L which exceeded the permissible limit for discharge of industrial wastewater into the environment.

Table 1: Physicochemical characteristics of the tannery effluent

S. No.	Parameters	Characteristics of partially treated wastewater
1	pH	7.5
2	BOD	29
3	COD	250
4	Ammoniacal nitrogen	30
5	TSS	50
6	Cr (VI)	250

Note: All the units are mg/L except pH

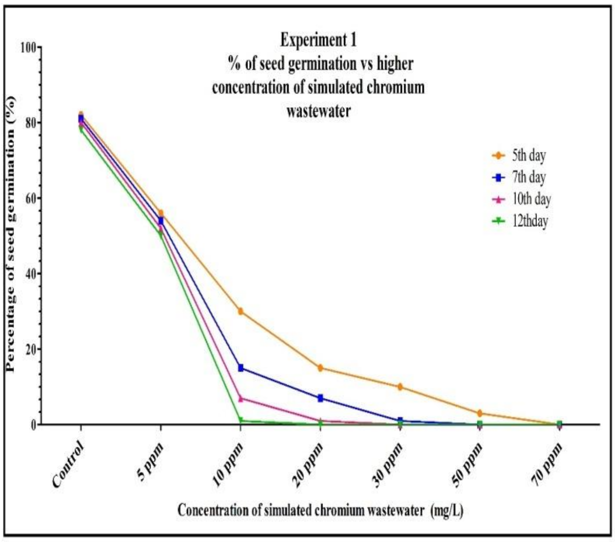

Figure 1: Percentage of seed germination at higher concentration of simulated chromium water

Simulated water and Tannery water used for seed germination

The Indian mustard seeds were allowed to germinate in soil, and various concentrations of chromium (5ppm, 10ppm, 20ppm, 30ppm, 40ppm, 50ppm and 70ppm) of 50 ml were added every day. Percentages of seed germination were reduced at higher concentrations of chromium (10-70ppm), and all the plants were dead, so the chromium concentrations were reduced to 1, 2, 3, 4, and 5ppm. The percentages of seed germination at various concentrations of simulated chromium wastewater and tannery effluent are calculated at the end of the 45th day as shown in Fig: 1, 2 and 3.

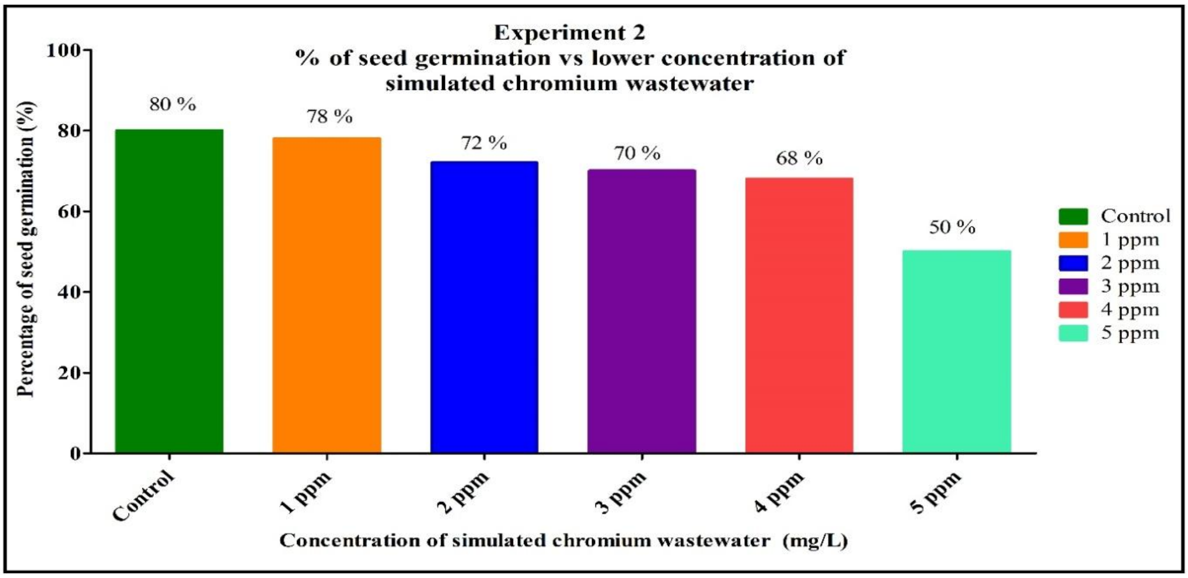

Figure 2: Percentage of seed germination at a lower concentration of simulated chromium water.

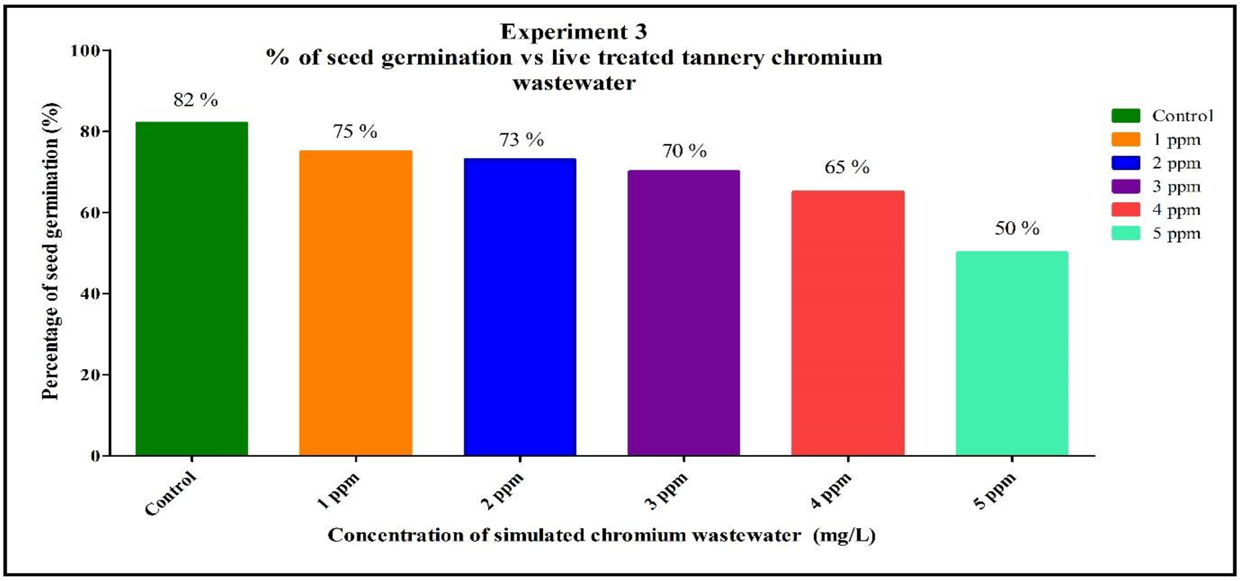

Figure 3: Percentage of seed germination at a lower concentration of Tannery effluent

Effects of Simulated chromium water and Tannery effluent on plant after 45 days by pot study

Indian mustard plants were treated with the various concentrations such as 1ppm, 2ppm, 3ppm, 4ppm and 5ppm of simulated chromium water as well as Tannery effluent for 45 days. The growth of the plants after 45 days for stimulated chromium water showed 12 cm for control, 11.8 cm for 1ppm, 9.1 cm for 2ppm, 8.2 cm for 3ppm, 7 cm for 4ppm and 6.1 cm for 5ppm. Similarly for Tannery effluent it showed 12 cm for control, 11.7 cm for 1ppm, 8.5 cm for 2 ppm, 7.8 cm for 3ppm, 6.7 cm for 4 ppm and 6 cm for 5ppm. It showed the gradual decrease of growth in the plant size. However, both the simulated chromium treated water and tannery treated water showed similar results (Figure: 4,5 and 6).

Figure 4: Plants growth at different concentration of chromium: A) Control, B) 1ppm, C) 2ppm, D) 3ppm, E) 4ppm and F) 5ppm.

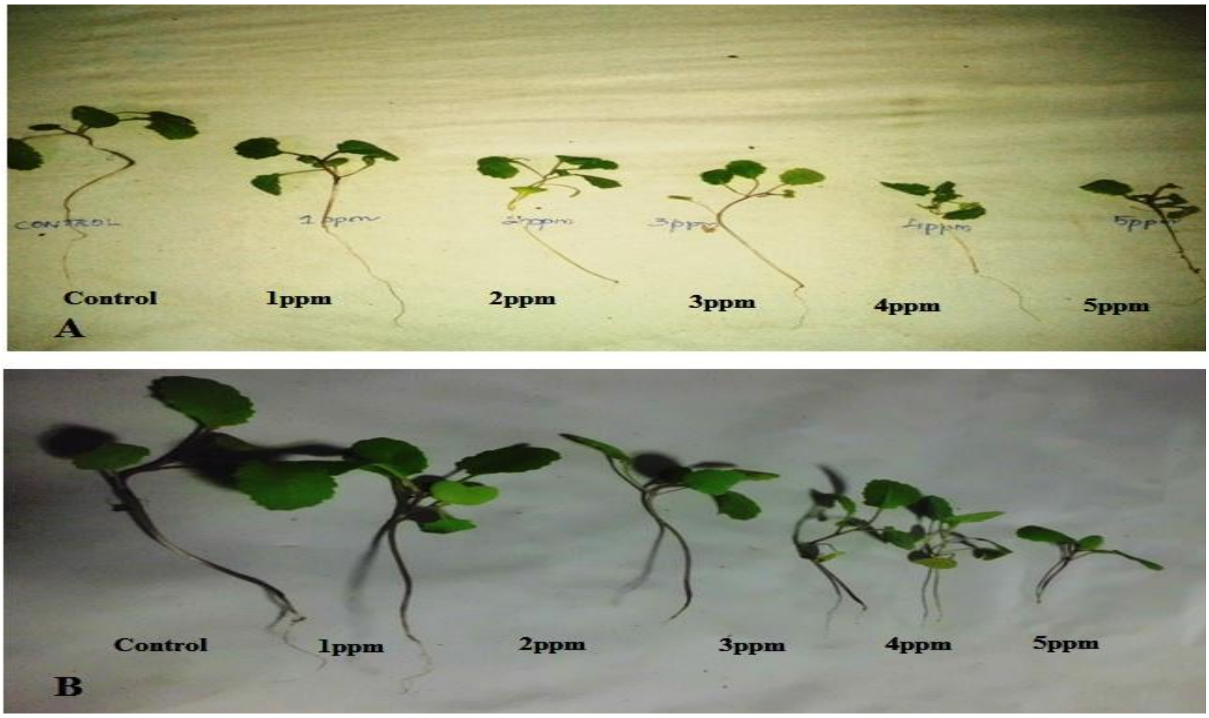

Figure 5: Plant growth after 45 days: A) Simulated chromium water and B) Tannery effluent.

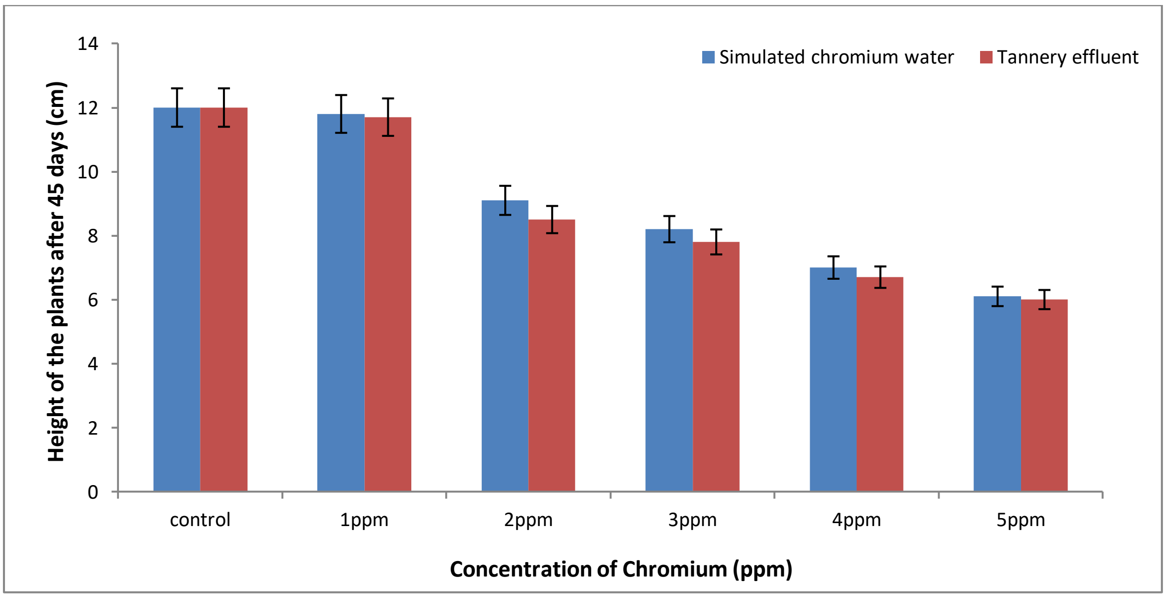

Figure 6: Effect of Plant Growth in Simulated Chromium water and Tannery effluent after 45 days.

Accumulation of Chromium from Simulated Chromium water and Tannery effluent

Indian mustard treated with different concentrations of simulated chromium water and tannery effluent such as 1ppm, 2ppm, 3ppm, 4ppm & 5ppm which showed that the total accumulation of Chromium in Indian Mustard Plant were 9.90 µg/g, 20.54 µg/g, 58.53 µg/g, 61.65 µg/g, 65.34 µg/g and accumulation of chromium in the soil were 21.90 µg/kg, 44.67 µg/kg, 66.95 µg/kg, 89.15 µg/kg & 110.98 µg/kg respectively. Similarly, for Tannery effluent it showed 18.65 µg/g, 29.06 µg/g, 43.66 µg/g, 58.48 µg/g, 60.42 µg/g in plants and accumulation in the soil were 20.76 µg/kg, 43.26 µg/kg, 66.26 µg/kg, 88.45 µg/kg, 112.74 µg/kg respectively (Table: 2 and 3). Han et al., (2004) has reported that when the concentration of chromium in soil is 500 mg/kg the concentration in the leaves and the roots are 650 and 1800 mg/kg which is inline with the present study [10]. This larger amount of chromium uptake by the plants is through the passive uptake through the broken cell membranes. Where as the Vazquez et al., (1989) has confirmed that the chromium uptake is by active mechanisms in the roots of the plants [11].

Table 2: Accumulation of Chromium (µg/g fresh weight) from simulated Chromium water in Indian mustard during the experimental period

Sample	Concentration of chromium in simulated wastewater	Experimental period	Total accumulation in plant (µg/g)	Total accumulation in soil (µg/kg)
1	Control	45 days	0	0
2	1 ppm		9.90±0.01	21.90±0.03
3	2 ppm		20.54±0.01	44.67±0.01
4	3 ppm		58.53±0.05	66.95±0.02
5	4 ppm		61.65±0.03	89.15±0.01
6	5 ppm		65.34±0.00	110.98±0.01

Table 3: Accumulation of Chromium (µg/g fresh weight) from partially treated tannery wastewater in Indian mustard during the experimental period

Sample	Concentrations of chromium in treated tannery effluent	Experimental period	Total accumulation in plant (µg/g)	Total accumulation in soil (µg/kg)
1	Control	45 days	0	0
2	1 ppm		18.65±0.01	20.76±0.00
3	2 ppm		29.06±0.02	43.26±0.01
4	3 ppm		43.66±0.02	66.26±0.03
5	4 ppm		58.48±0.04	88.45±0.04
6	5ppm		60.42±0.01	112.74±0.02

CONCLUSION

This study examined the efficiency of Indian mustard (*Brassica juncea*), in the removal of heavy metal contaminants. Conventional remediation technologies like chemical precipitation, reverse osmosis, ion exchange and Solvent extractions have disadvantages including incomplete Metal removal, quite expensive and generation of toxic Sludge which requires disposal. Phytoremediation technology has proved to be a viable option to purify water contaminated with trace elements since it is cost-effective. However, both the simulated chromium water as well as partially tannery treated water experiments showed similar results. So, the effective phytoremediation efficiency of chromium by Indian mustard (*Brassica juncea*) proves that it can be used as a potential phytoremediator.

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