Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 18 | No. 4 | pp. 1299-1304 | 2019

Original Research Paper | Open Access

Some Studies on the Removal of Chromium from Aqueous Solutions by an Adsorbent Obtained from *Terminalia chebula*

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 19-04-2019
Accepted: 31-05-2019

Key Words:
Terminalia chebula
Chromium removal
Adsorbent
Heavy metals
Drinking water

ABSTRACT

Several methods of treatment have been suggested for the removal of chromium from raw water, which include chemical precipitation, reverse osmosis, ion exchange, foam formation, etc. The main disadvantages of the above processes are that they produce a large amount of sludge and there are no possibilities of metal recovery as they are very costly. The use of plants and other plant materials for the removal of the heavy metals has already been reported in the literature as the non-conventional adsorbents. In the present work, an attempt has been made to check the suitability of *Terminalia chebula* powder for removing chromium from raw water by adsorption and for suggesting an environmental friendly as well as economically feasible solution to overcome the problems due to the presence of toxic pollutants like chromium in drinking water. Batch experiments were conducted using aqueous solution of chromium to determine the chromium removal. *Terminalia chebula* powder (commonly known as karakkaya locally) has been collected locally and used as an adsorbent for all the batch experiments. Variation of chromium removal with dosage of adsorbent and initial pollution concentration is studied.

INTRODUCTION

Chromium can exist in different oxidation states like Cr^{3+}, Cr^{5+}, Cr^{6+}. In the water environment, chromium exists primarily in the form of chromates ($Cr3^{+}$). Wastewater from industries such as chrome leather tanning, metallurgy, chrome plating, textiles, ceramics, photography and photoengraving contains moderate to excessive amounts of hexavalent chromium compounds beyond the conventional statutory limit of 0.1 mg/L. Remediation of these effluents is necessary because in humans Cr(VI) causes lung cancer, ulcers, nasal septum perforations, and damage to the kidneys (Farai et al. 2014). During the transformation of chromium in water environment, oxidation of Cr^{3+} and reduction of Cr^{6+} takes place depending upon environmental parameters. Furthermore, there is no evidence to indicate that the trivalent (Cr^{3+}) form is detrimental to human health. But, hexavalent chromium (Cr^{6+}) is a powerful oxidant which can easily penetrate the biological membranes and irritate cells. High concentration of chromium is toxic to plants, animals as well as to humans. Most of the toxic effects of the chromium to man are associated with its occupational exposure rather than its intake with diet and water. Several methods of treatments have been suggested for removal of chromium which, include precipitation, reverse osmosis, ion-exchange, foam formation, etc. The main disadvantages of the above processes are that they produce a large amount of sludge and there is no possibility of metal recovery. The use of plants and other plant materials for the removal of the heavy metal have already been reported in the literature as the non-conventional adsorbents. Ahmad et al. (2005) studied the removal and recovery of chromium from synthetic and industrial wastewater using bark of *Pinus roxburghii* as an adsorbent. They found that percent recovery of chromium from industrial wastewater by column operation and batch process are 85.8% and 65% respectively. They concluded that *Pinus roxburghii* bark can be used as a cost-effective adsorbent for removal and recovery of chromium from wastewater. Nouri Sepehr et al. (2005) studied the chromium bioremoval from tannery industries effluent by *Aspergillus oryzae*. Venkateswarlu et al. (2007) studied the removal of chromium from an aqueous solution using *Azadirachta indica* (neem) leaf powder as an adsorbent. Deng et al. (2009) studied the biosorption of Cr(VI) from aqueous solutions by non-living green algae *Cladophora albida*. They found that the abundant and economic biomass *Cladophora albida* could be used for the removal of Cr(VI) from wastewater by the reduction of toxic Cr(III). Rajor & Kunal (2013) studied the absorption of chromium and nickel from aqueous solution by bacteria isolated from electroplating unit effluent. They concluded that the bioaccumulation is efficient and cost-effective eco-friendly process and the isolated bacterial strains, which can tolerate high concentration of heavy metals, can be used for metal recovery process. Samson et al. (2016) studied the removal of hexavalent chromium from aqueous solutions by adsorption on modified groundnut hull. They found that the uptake of hexavalent chromium, being among the major pollutants from our industries, by modified and unmodified groundnut hull can be made. Krishna & Ravindhranath (2012) studied the removal of chromium(VI) from polluted waters using powders of leaves or their ashes of some herbal plants. They made an attempt to explore the surface sorption abilities of powders of leaves and their ashes of some herbal plants. Soundari et al. (2018) studied the removal of chromium from industrial waste water by adsorption using coconut shell and palm shell. They concluded that activated charcoal powder can be used to remove chromium(Cr) from tannery effluent. Dessalew (2017) studied the removal of chromium from industrial wastewater by adsorption using coffee husk. They stated that heavy metals are discharged from different industries into freshwaters and easily absorbed by fish and other aquatic organisms. Small concentrations can be toxic because heavy metals undergo bioconcentration. Chromium is an essential element that is required in small amounts for carbohydrate metabolism but becomes toxic at higher concentrations. Bahadur & Mishra (2014) studied adsorptive removal of Cr(VI) from aqueous solution by sugarcane biomass. They investigated the influence of pH, initial concentration of metal ion and contact time on maximum adsorption capacity of Cr(VI). In the present work, a study of the efficiency of removal of chromium using *Terminalia chebula* has been made.

MATERIALS AND METHODS

Terminalia chebula fruit was taken and washed with distilled water. Then the fruit was exposed to sunlight until it was completely dried. After that *Terminalia chebula* was made into small pieces and with the help of grinder those pieces were made into fine powder. A stock solution was prepared by dissolving 0.283 g of potassium dichromate in one litre of distilled water so that in 1mL, 100 μg of chromium is present. Then the working solution of different concentrations was obtained from the stock solution by appropriate dilution with distilled water for the batch experiments. Ultraviolet-visible spectroscopy or ultraviolet-visible spectrophotometer (UV-Vis or UV/Vis) refers to absorption spectroscopy or reflectance spectroscopy in part of the ultraviolet and the full, adjacent visible spectral regions. This means that it uses light in the visible and adjacent ranges. The absorption or reflectance in the visible range directly affects the perceived color of the chemicals involved. Hence, UV-Vis spectrophotometer was used to determine chromium. Batch experiments were conducted using diluted aqueous solutions of chromium with an adsorbent dosage ranging from 0.1 g to 0.4 g.

RESULTS

In the first batch experiment, different amounts of *Terminalia chebula* powder (adsorbent) were added to the chromium solution of different concentrations to find the effect of *Terminalia chebula* on % chromium removal. The results obtained are presented in Table 1 and Fig. 1. In the second batch experiment, different amounts of *Terminalia chebula* (adsorbent) powder was added to the same concentration chromium solution to estimate the most effective dosage of the adsorbent. The results obtained are presented in Table 2 and Fig. 2. In the third batch experiment, chromium solutions of different concentrations were used for the same amount of *Terminalia chebula* powder (0.1 g) to find out the effect of initial chromium concentration on percentage removal. The results obtained are presented in Table 3 and Fig. 3. In the fourth batch experiment, chromium solutions of different concentrations were used to find out the effect of adsorbent dosage on chromium removal. The results obtained are presented in Table 4 and Fig. 4.

Table 1: Results of first batch experiment

S. No.	Amount of *Terminalia chebula* powder	Initial chromium concentration (μg/L)	Final chromium concentration (μg/L)	% chromium removed
1.	0.1 g	13 μg/L	11.0 μg/L	15.38
2.	0.2 g	26 μg/L	11.5 μg/L	55.76
3.	0.3 g	39 μg/L	12.5 μg/L	67.90
4.	0.4 g	52 μg/L	12.0 μg/L	76.92

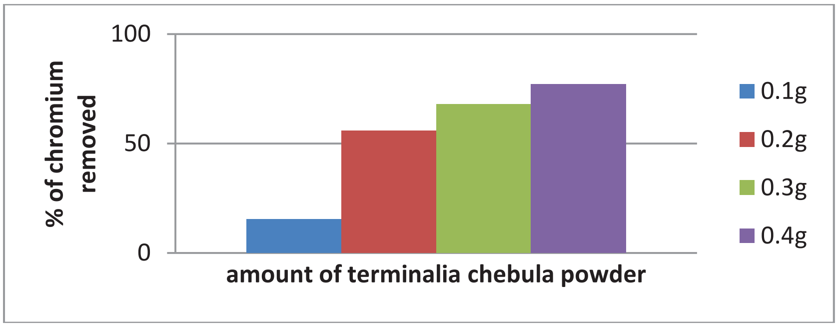

Fig. 1: Results of the first batch experiment.

Table 2: Results of the second batch experiment.

S. No.	Amount of *Terminalia chebula* powder (g)	Initial chromium concentration (µg/L)	Final chromium concentration (µg/L)	% of chromium removed
1.	0.1 g	30 µg/L	15 µg/L	50.00
2.	0.2 g	30 µg/L	11 µg/L	63.34
3.	0.3 g	30 µg/L	11 µg/L	63.34
4.	0.4 g	30 µg/L	10 µg/L	66.67

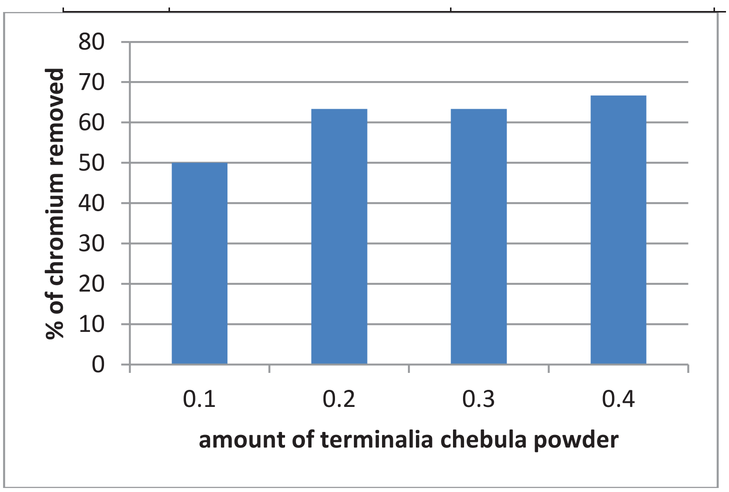

Fig. 2: Results of the second batch experiment.

Table 3: Results of the third batch experiment.

S. No.	Amount of *Terminalia chebula* powder (g)	Initial chromium concentration (µg/L)	Final chromium concentration (µg/L)	% of chromium removed
1	0.1	4	3.5	12.5
2	0.1	6	3	50
3	0.1	8	2	75.00
4	0.1	12	2.6	78

Table Cont....

S. No.	Amount of *Terminalia chebula* powder (g)	Initial chromium concentration (μg/L)	Final chromium concentration (μg/L)	% of chromium removed
5	0.1	14	3	78.57
6	0.1	16	3.34	79.125
7	0.1	18	3.03	83.12
8	0.1	22	3.64	83.43
9	0.1	24	3.04	87.33
10	0.1	28	3.02	89.21
11	0.1	32	3.36	89.5
12	0.1	34	3.5	89.7
13	0.1	36	3.001	91.66
14	0.1	38	2.74	92.78
15	0.1	42	3.08	92.85
16	0.1	44	2.81	93.62
17	0.1	46	2.89	93.7
18	0.1	48	3	93.95
19	0.1	52	3	94.23
20	0.1	56	2.8	95
21	0.1	64	2.5	96.09
22	0.1	68	2.2	96.76
23	0.1	72	2.2	96.95
24	0.1	76	2	97.36
25	0.1	84	2	97.6
26	0.1	88	1.84	97.98
27	0.1	92	1.56	98.3
28	0.1	96	1.34	98.6

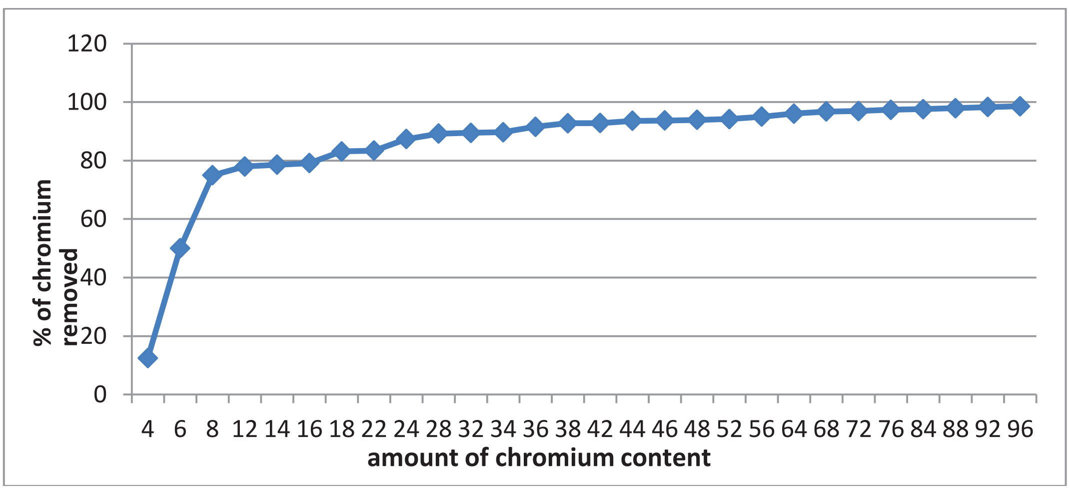

Fig. 3: Results of the third batch experiment.

Table 4: Results of the fourth batch experiment.

S. No.	Amount of *Terminalia chebula* powder (g)	Initial chromium concentration (µg/L)	Final chromium concentration (µg/L)	% chromium removed
1	0.3	8	5.5	31.25
2	0.3	12	7	41.67
3	0.3	14	8.07	42.29
4	0.3	16	8	50
5	0.3	18	8	55.56
6	0.3	22	7	68.19
7	0.3	24	7.5	68.75
8	0.3	26	7.5	71.15
9	0.3	28	6	78.57
10	0.3	32	6.75	78.9
11	0.3	34	6.97	79.5
12	0.3	36	7	80.56
13	0.3	38	7.2	81.05
14	0.3	42	7.16	82.95
15	0.3	44	7	84.09
16	0.3	46	7	84.78

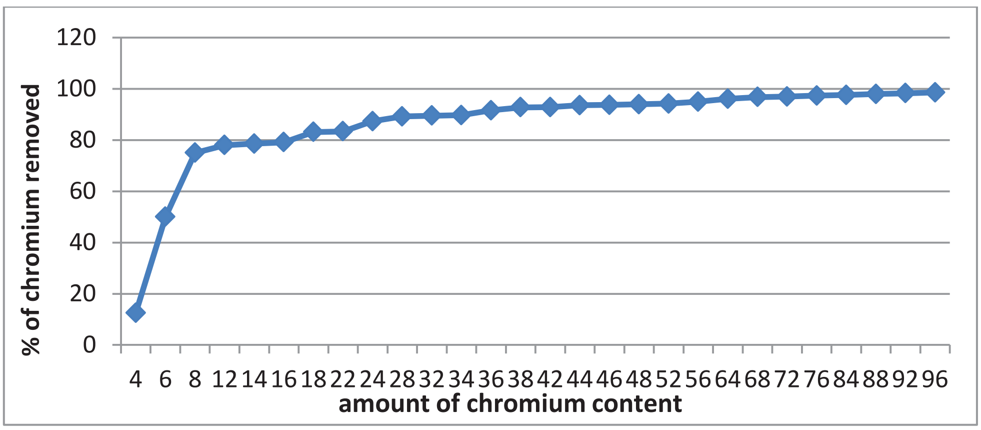

Fig. 4: Results of the fourth batch experiment.

DISCUSSION

In the first batch experiment, different amounts of *Terminalia chebula* powder were added to the chromium solution of different concentrations at the suitable dosages of the adsorbent for chromium removal from aqueous solution. It was observed that the percentage chromium removal is increased as the amount of chromium content and adsorbent dosage increase, which is evident from Fig. 1. In the second batch experiment, different amounts of *Terminalia chebula* powder were added to the same concentration chromium solution to estimate the most effective dosage of the adsorbent for chromium removal from aqueous solution. It is observed that % chromium removal is increased as the adsorbent dosage increases and effective dosage of adsorbent is 0.2 g, which is evident from Fig. 2. To find out the effect of initial chromium concentrations on percentage removal, chromium solution of different concentrations was used in the third batch experiment. It was observed that as the initial concentration is increased, the percentage of chromium removal is also increased, which is evident from

Fig. 3. To find out the effect of adsorbent dosage on percentage removal, two different dosages (0.1 g and 0.3 g) were used in the third and fourth batch experiments. It was observed that the percentage of chromium removal is increased if the adsorbent dosage is increased. But percentage removal is depended on initial concentration also.

CONCLUSIONS

Based on the results of batch experiments, following conclusions can be made.

- The percentage of chromium removal depends upon several parameters including adsorbent dosage and initial concentration of pollutant in the process of adsorption.
- Use of *Terminalia chebula* powder can be recommended as an adsorbent for safe removal of toxic pollutants like chromium. The unused *Terminalia chebula* powder in the drinking water is not harmful to public health as it is a good food supplement/medicinal plant material.
- Most of the municipalities are not able to completely purify the raw water (for drinking water) due to lack of sufficient funds. They usually follow only conventional treatment methods like sedimentation, filtration and chlorination which cannot remove most of the problematic pollutants including chromium compounds, which may be present in raw water. Lower income households can use the *Terminalia chebula* powder easily and economically for complete purification as they are not able to afford commercially available branded domestic water purifiers.

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