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## Studies on hexavalent chromium removal from aqueous solution in a fixed column using saw dust as an adsorbent

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### ABSTRACT

In the present work, studied the performance of an adsorbent such as saw dust, which is less in cost and easily available. The saw dust was used for the removal of chromium (VI) from an adsorbate solution, which was prepared as the quality of effluent of both electroplating industry and tannery industry. The adsorbent material was found to be an efficient media for removal of Chromium (VI) ion in continuous mode using the fixed bed isothermal adsorption column. A comparative study has been done on the adsorption capacity of different sizes of saw dust.

The column studies were conducted with column diameter of 7 cm and bed height of 40 cm. The flow rate of solution passing through the adsorbent bed was maintained at a constant rate of 1litre/min. It was found that the percentage removal of Chromium (VI) ion decreased initially further it was increased with the decrease in initial concentration of chromium (VI). It was also observed that the order of adsorption capacity of different sizes of saw dust for Chromium (VI) was as follows: 0.353mm > 0.767mm > 1.379mm. The results were shown that the sawdust is an efficient adsorbent for the removal of Cr (VI) from industrial effluent. The percentage removal of chromium reaches 95% with increasing contact time.

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### KEYWORDS

Saw dust;  
Adsorption;  
Chromium (VI),  
Continuous fixed column.

### INTRODUCTION

Chromium exists usually in both trivalent and hexavalent forms in aqueous systems. The two oxidation states of chromium have different chemical, biological and environmental characteristics. Cr (III) is relatively insoluble and required by microorganisms in small quantities as an essential trace metal nutrient, while Cr (VI) is a great concern because of its toxicity. Cr (VI) has been reported to be a primary contaminant to

humans, animals, plants and microorganisms and it is known to be carcinogenic. Chromium is used in a variety of industrial applications; hence, large quantities of chromium are discharged into the environment.

Sources of chromium waste leading to water pollution includes electroplating, steel fabrication, paints and pigments, mining, leather tanning, textile dyeing, aluminum conversion coating operations, plants producing industrial inorganic chemicals and wood treatment units. Due to environmental concern, discharge

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limits of both Cr (III) and Cr (VI) have been instituted by most industrial countries. Their concentration in industrial wastewaters ranges from 0.5 to 270mg/L<sup>[1]</sup>. The tolerance limit for Cr (VI) for discharge into inland surface waters is 0.1 mg/L and in potable water is 0.05 mg/L<sup>[2,3]</sup>. The Ministry of Environment and Forest (MOEF); Government of India has set minimal national standards (MINAS) of 0.1 mg/L for safe discharge of effluent containing Cr(VI) in surface water<sup>[4]</sup>. In order to comply with this limit, it is essential that industries treat their effluents to reduce the Cr (VI) concentration in water and wastewater to acceptable levels before its transport and cycling into the natural environment

Therefore, the level of chromium in final effluent has to be reduced by the application of appropriate technology. In wastewater treatment, various methods are utilized to remove Chromium. These include reduction followed by chemical precipitation, ion exchange, electrochemical precipitation, reduction, adsorption, solvent extraction, membrane separation, concentration, evaporation, reverse osmosis and bio-sorption and emulsion per traction technology.

Adsorption is by far most versatile and effective method for removing any contaminants like heavy metal, especially, if combined with appropriate regeneration steps. This solves the problem of sludge disposal and renders the system more economically viable, especially if low cost adsorbents are used. In the last few years, several approaches have been reported in this direction utilizing inexpensive and effective adsorbent for removal of Cr(VI) from aqueous solutions. The advantages of the low-cost adsorbents over the conventional adsorbents are as follows:

- 1 The efficiencies of various non-conventional adsorbents towards adsorbate removal vary generally between 50% and 90% depending on the characteristics and particle size of the adsorbent, and the characteristics and concentration of the adsorbate, etc. Hence, low-cost adsorbents can be employed efficiently in removal of heavy metals.
- 2 Non-conventional adsorbents are much cheaper relative to conventional adsorbents, and when readily available locally lead to much reduced transportation costs.
- 3 Non-conventional adsorbents require simple alkali/ and or acid treatment for the removal of lignin before application in order to increase their efficiency.
- 4 Non-conventional adsorbents require less maintenance and supervision.

The materials developed for this purpose range from industrial wastes to agricultural waste products, biomass and various solid substances. Some examples are hydrous concrete particles, paper mill sludge, seaweed biosorbent, tannin gel particles, sugar beet pulp, wheat bran, leaf mould, coniferous leaves, activated groundnut husk carbon, coconut husk and palm pressed fibers, coconut shell, wood and dust coal activated carbons, coconut tree sawdust carbon, used tyres carbon, cactus, olive stone/cake, wool, charcoal, and pine needles, rice husk carbon, moss, sphagnum moss peat, hazelnut shell carbon, almond shell carbon, corncob, cow dung carbon, agricultural wastes, waste slurry, carbon slurry, Lignocellulosic solid wastes, charred rice husk and activated charcoal and eucalyptus bark have been reported in literature. However, to cover this problem, more work and investigations are needed to deal with other locally available and economically viable adsorbents to eliminate Cr (VI) from aqueous solutions having different composition and characteristics. In this project we have studied the efficiency of saw dust available locally in the removal of Cr (VI) from solution. A comparative study has also been done on the adsorption capacity of saw dust of different particle sizes.

### EXPERIMENTAL METHODS

#### Preparation of adsorbate solution

The stock solutions of Cr(VI) of concentration 1000 ppm was prepared by dissolving 0.2828 grams of analytical grade of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in 100ml of RO distilled water. The stock solution was further diluted with RO distilled water to desired concentration for obtaining the standard solutions for absorbance measurement. The sample solutions which were to be treated with the adsorbent were also prepared similarly by dissolving required quantity of the above mentioned salt in RO distilled water.

#### Preparation of adsorbent

Raw saw dust locally was obtained from nearby saw mill. It was then screened to get particles of three different sizes i.e 0.353mm, 0.767mm, 1.379mm.

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Figure 1: The average particle sizes of saw dust: 0.353mm, 0.767mm, 1.379mm

The above fractions of saw dust were washed with sufficient quantity of RO distilled water until it gave a clear transparent solution. Only then the prepared Cr (VI) solutions were passed through them in the bed to study their adsorption capacity. The particles having diameter greater than 1.5mm were not used in the present study as they were found to be inconvenient due to excessive channeling effect & formation of paste like substance respectively.

### EXPERIMENTAL SET UP

#### Column studies

The fixed-bed column had 7.0 cm internal diameter and was 50 cm in height. The bed length used in every experiment was fixed at 40 cm. The bed was filled with the saw dust upto the specified height of the column and different size of the adsorbent was used as specified for each experiment. In every experiment the metal solution of a known concentration was pumped at a fixed flow rate of 1 litre/min to the column filled with known bed height of adsorbent. The above fixed flow rate into the fixed column was maintained with the help of monitoring a bypass stream. The samples solution after passing through the adsorbent in the fixed bed column was again recycled back into the sample reservoir tank so that there is a continuous adsorption of Chromium ion. Samples for analysis of Chromium ion concentration were collected at a regular interval of 30 minutes from the bottom of the sample reservoir tank. The saw dust used inside the fixed bed column was replaced by a fresh batch of saw dust at the beginning of each of experiment.

The metal uptake capacity (amount of removal of chromium ion) and the adsorption capacity (percentage of chromium ion removal) were calculated using the

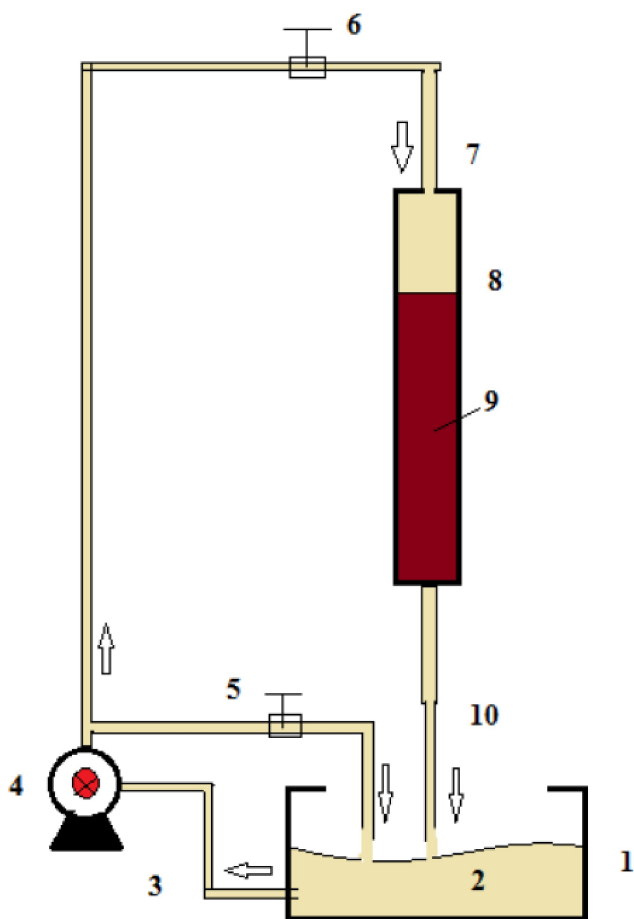
following equations: Metal Uptake Capacity = Initial Chromium ion conc. – Final Chromium ion conc. Adsorption Capacity (%) = (Metal Uptake Capacity X 100) / Initial Chromium ion concentration.

#### Measurement of Cr (vi) in aqueous solutions

There are some components within the sawdust that may reduce the Cr (VI) to Cr (III). Therefore, oxidation of Cr (III) within the samples to Cr (VI) is necessary before the analysis of each sample. Cr ions within the samples were oxidized by using potassium permanganate in acidic medium. The violet color that forms as a result of the reaction between the Cr (VI)



Figure 2 : Photograph of experimental set up



1. Sump tank 2. Chromium solution 3. Pump inlet 4. Pump 5. Bypass valve 6. Flow control valve 7. Column inlet 8. Glass column of 50 cm height 9. Adsorbent bed of 40cm height 10. column outlet (sample collection point)

Figure 3 : Schematic diagram

ions and 1,5-diphenyl carbazide in acidic medium, was measured by using UV/VIS – Spectrophotometer at 540 nm. The lowest limit of this method is 0.01 mg/L and the best suitable measurement range is 0.5 - 5.0 mg/L (ppm). For samples containing concentrations in the range 5.0 – 100.0 mg/L, the absorbance of pure K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution at 313nm was taken as standard. The samples were diluted before the measurements and the measured values were multiplied by the dilution factor.

**RESULTS AND DISCUSSIONS**

**Study of adsorption capacity**

- Bed height of adsorbent = 40 cms
- Adsorbent size (average) used = 0.353 mm
- Flow rate of solution through the bed = 1 litre/min

For 1st run: Initial Cr+6 solution concentration. = 500 ppm (14.14 Gms of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in 10 litres of RO distilled water)

Calculations:

Metal Uptake Capacity = 500ppm-348ppm=152ppm;

Adsorption Capacity = (152/500) x100=30.4%

S.No	Time (hrs)	Concentration, ppm	Concentration, ppm	Concentration, ppm
1	0.5	467.2	348.1	236.3
2	1	440.5	341.3	230.1
3	1.5	432.7	336.2	225.5
4	2.0	426.9	328.9	221.4
5	2.5	397.1	324.5	217.1
6	3	390.3	317.8	210.4
7	3.5	385.2	310.6	203.5
8	4	379.8	304.1	196.8
9	4.5	366.4	297.4	185.2
10	5	363.2	290.6	180.4
11	5.5	361.7	280.9	172.7
12	6	359.9	271.1	163.0
13	6.5	355.1	261.3	157.5
14	7	352.5	253.7	150.7
15	7.5	351.3	244.2	143.3
16	8	348.6	236.5	134.2

**Overall graph for 3 runs**

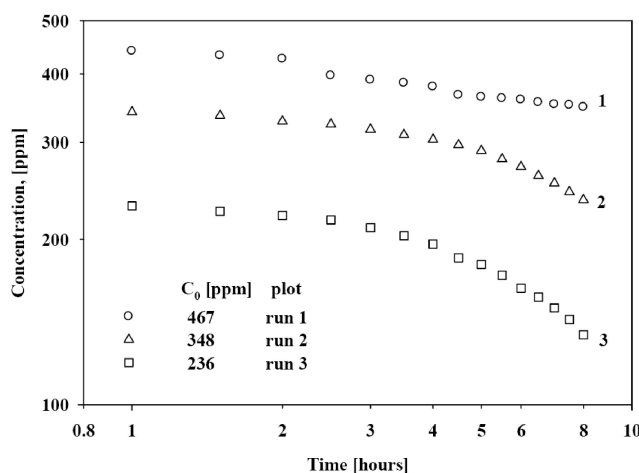


Figure 4 : Comparison of adsorption capacities with different initial concentrations at constant particle size of adsorbent = 0.353 mm.

**FOR 2<sup>nd</sup> run**

- Bed height of adsorbent = 40 cms
- Adsorbent size (average) used = 0.353 mm



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Flow rate of solution through the bed = 1 litre/min  
Initial Cr+6 solution concentration = 348ppm  
(9.84gms of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in 10 litres of RO distilled water)

Calculations:

Metal Uptake Capacity = 348ppm - 236ppm = 112ppm

Adsorption Capacity =  $(112/348) \times 100 = 32.18\%$

### Study of effect of size on adsorption capacity

Bed height of adsorbent = 40 cms

Initial Cr+6 solution concentration = 500ppm  
(14.14 gms of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in 10 litres of RO distilled water), Flow rate of solution through the bed = 1 litre/min

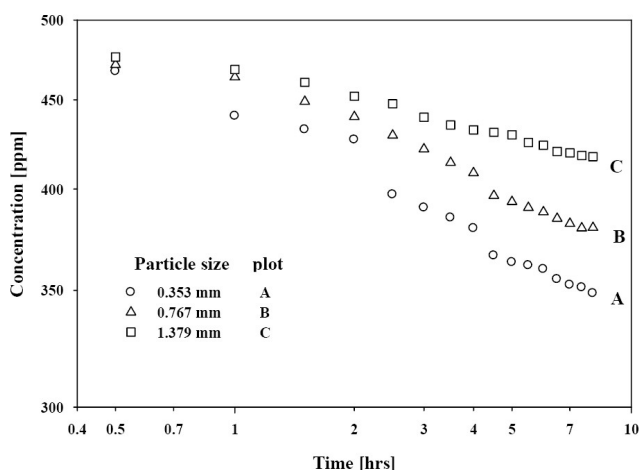


Figure 5 : Comparison of Concentration of solution at different time interval at varying particle sizes of adsorbent

### SUMMARY AND CONCLUSIONS

The continuous fixed bed column studies were performed for removal of Chromium (VI) ion from the effluent using different sizes of saw dust. The study indicated the suitability of the adsorbent for removal of Chromium (VI) from solution. The selected adsorbent was more economical. The results were obtained and summarized as follows:

#### Conclusions

1. The metal uptake capacity decreases with decrease in the initial concentration of Cr+6. However, the percentage of removal or the adsorption capacity increases with decreasing the concentration of chromium.
2. The saw dust size of 0.353mm required 3 fixed

bed columns of fresh saw dust to reduce the chromium ion from 500 ppm to 134 ppm with 24 hours durations.

3. The observed order of metal uptake capacity as well as adsorption capacity of Cr+6 for different sizes of saw dust was as follows : 0.353 > 0.767 > 1.379 mm. These experimental studies on the specified adsorbent would be quite useful in developing an appropriate technology for the removal of Cr+6 ions from contaminated industrial effluents.

### Future scope of work

1. Similar continuous column studies can be performed for locally available saw dust of different trees to compare the metal uptake capacity and adsorption capacities.
2. The metal uptake capacity and adsorption capacity can also be studied at different flow rates of the solution through the column bed and by also varying the bed height.

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