Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2015, 7(12):78-83

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Removal of toxic metal chromium(VI) from industrial wastewater using activated carbon as adsorbent

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ABSTRACT

Removal of toxic metals from industrial waste water is essential for the standpoint of environmental pollution control. Among all toxic heavy metals mercury, lead, chromium and cadmium are in the limelight due to their major impact on environment. Chromium(VI) is one of them and permissible limit in drinking water is 0.05 mg/l and when present above this limit it causes various types of acute and chronic disorder. The toxicity of Cr(VI) is higher than Cr(III). Many physical-chemical wastewater treatment process viz, oxidation-reduction, precipitation, ion exchange and liquid membrane are being used. However, all these have the limitation of technical and /or economical constraints. Adsorption is a viable and attractive method for the removal of metal from the effluents due to its high efficiency, easy handling and less expensive. The adsorption process is being widely used by various researchers for the removal of heavy metals from waste streams and activated carbon is frequently used as an adsorbent. In recent years, the need for safe and economical methods for the elimination of heavy metals from contaminated waters has necessitated research interest towards the production of low cost alternatives to commercially available activated carbon. A carbonaceous adsorbent prepared from an indigenous waste by acid treatment was tested for its efficiency in removing chromium ion. The parameters studied include agitation time, initial chromium ion concentration, carbon dosage, pH and temperature.

Keywords: Chromium(VI), Adsorption, Activated carbon, Wastewater, Coconut coir.

INTRODUCTION

The chromium(VI) ions in wastewater is a typical heavy metal environment pollution. The potential source of chromium in wastewater is industrial wastes from textile, leather tanning, metal finishing, electroplating, ceramics, cooling tower effluents and animal glue manufacture. Maximum permissible limit if Cr(VI) by WHO, ICMR and others is 0.05 mg/l. Injection of Cr(VI) above its permissible limit causes pain, vomiting, nausea hemorrhage, acute diarrhea and abnormities related to genetic cycle causing mutation. The toxicity of Cr(VI) is greater than that of Cr(III) however this is probably due to its higher solubility[1-3].

Various waste water treatment process viz. oxidation-reduction, precipitation, ion exchange and liquid membrane are being used. Adsorption is viable and attractive method for the removal of metal from the effluents due to its high efficiency, easy handling and less expansive. For this many biosorbents viz. tea powder, wood sawdust, coconut coir, rice polish were studied but coconut coir appeared to be more efficient[4-6].

Many chemisorbents like activated carbon, carbon slurry etc. are also used for the removal of heavy metals, which have very high dynamics and rate of intra particle diffusion has been evaluated[7].

1.1 Physisorption

Physical adsorption, or Vander Waals adsorption, a readily reversible phenomenon is the result of intermolecular forces of attraction between molecules of the solid and the substance adsorbed[8].

1.2 Chemisorption

Chemisorption or activated adsorption is the result of chemical interaction between the solid and the adsorbed substance. The strength of the chemical bond may vary considerably, and identifiable chemical compounds in the usual sense may not actually form, but the adhesive force is generally much greater than that found in physical adsorption[9-10].

EXPERIMENTAL SECTION

2.1 Preparation of Adsorbent

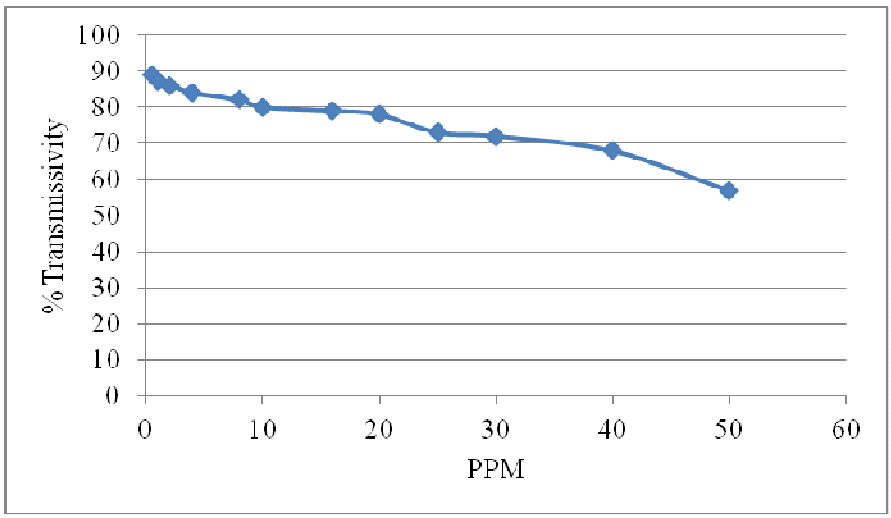
The adsorbent material is washed with distilled water to remove dirt particles and treated with 0.1 N NaOH solution for a period of 10 hours which cause delignification. The material is washed 2 to 3 times with distilled water at room temperature. Adsorbent material is treated again with 0.1 N H_2SO_4 solution for about 4 to 5 hours to remove alkalinity from the adsorbent material. Then the adsorbent material is washed with distilled water till the wash water became colorless. The treated adsorbent material is dried in sunlight and stored[11-13].

2.2 Calibration Curve

22.6 mg of $K_2Cr_2O_7$ is dissolved in 1000 ml of distilled water to get 8 ppm solution. 8 ppm solution is diluted to get 4, 2 and 1 ppm solutions. From the prepared 8, 4, 2, 1 ppm solutions 5 ml of each sample is pipette out and 1 ml of diphenylcarbazide and 1 ml of H_2SO_4 are added to the sample. Each sample is placed in calorimeter to find the absorbance.

Table-1. Calibration data

PPM	0.5	1	2	4	8	10	16	20	25	30	40	50
% T	89	87	86	84	82	80	79	78	73	72	68	57



Graph-1. Calibration curve

RESULTS AND DISCUSSION

3.1 Experimental Procedure

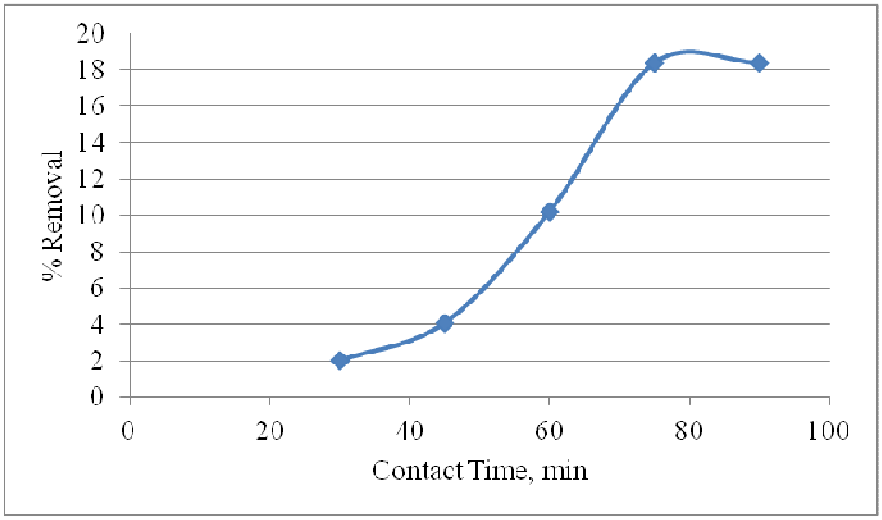
1000 ml of 8 ppm $K_2Cr_2O_7$ solution is prepared. From this 200 ml is taken and known amount of adsorbent, activated carbon is added. The above solution is vigorously shacked for about 1 hr. At regular intervals of time (15 min) 5 ml of the sample is taken and to that 1 ml of diphenylcarbazide and 1 ml of H_2SO_4 are added. Absorbance is found for the above samples and the corresponding concentrations are determined from the standard plot.

The above procedure is repeated by varying contact time, adsorbent dosage, RPM, temperature and pH.

3.1.1 Effect of contact time on % removal

Table-2. Contact time vs. % removal

Contact Time, min	30	45	60	75	90
% Removal	2.0	4.08	10.2	18.36	18.36



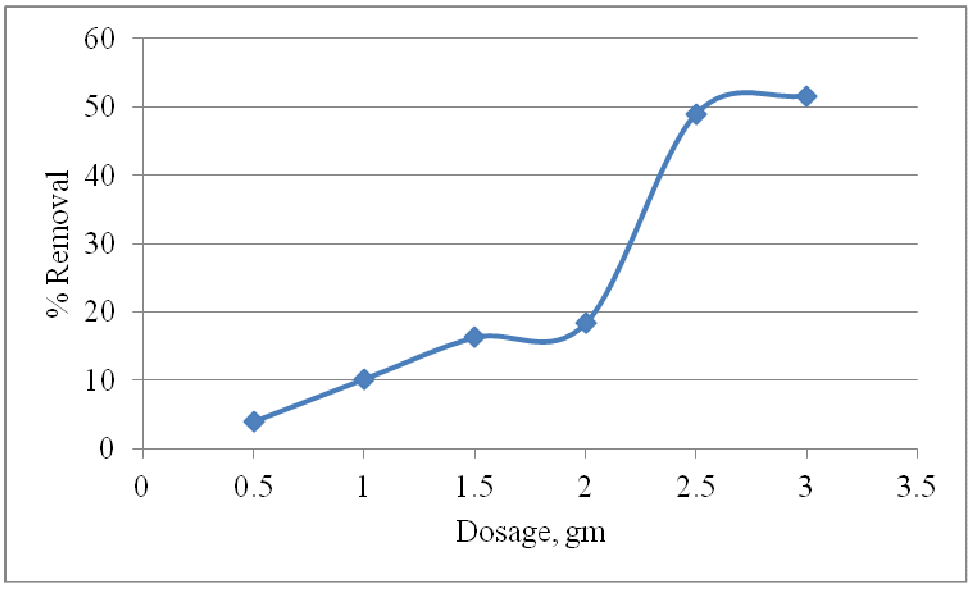
Graph-2. Contact time vs. % removal

The experimental runs measures the effect of contact time on the batch adsorption of Cr(VI) and at an initial pH of 4.5 and initial Cr(VI) concentration of 8 ppm and it is indicated that increase in contact time enhances the percentage removal of Cr(VI) significantly. The initial rapid adsorption gives away a very slow approach to equilibrium. The nature of adsorbent and its available sorption sites affected the time needed to reach the equilibrium.

3.1.2 Effect of adsorbent dosage on % removal

Table-3. Dosage vs. % removal

Dosage, gm	0.5	1	1.5	2	2.5	3
% Removal	4.08	10.26	16.3	18.36	48.9	51.6



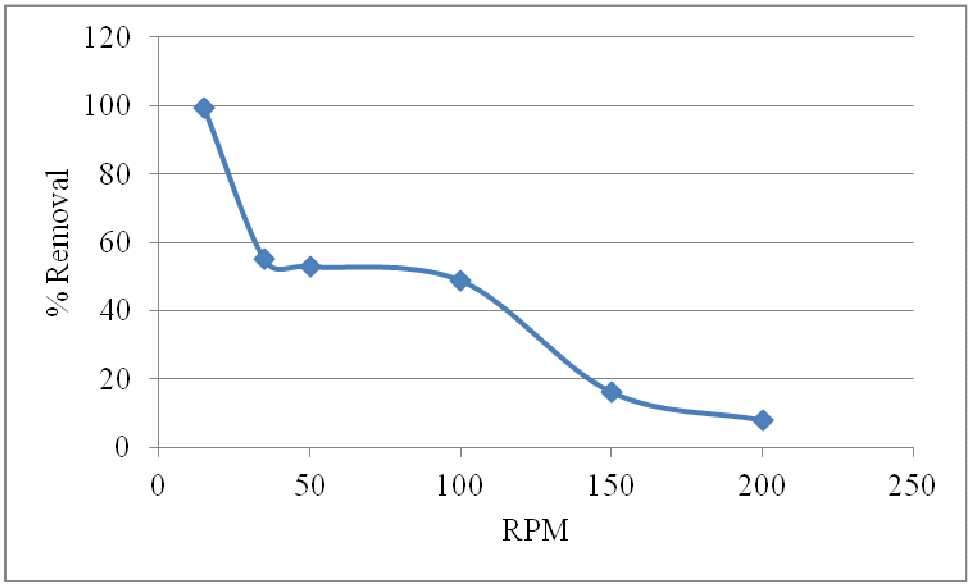
Graph-3. Dosage vs. % removal

It is indicated that increase in dosage enhances the percentage removal of Cr(VI) significantly.

3.1.3 Effect of RPM on % removal

Table-4. RPM vs. % removal

RPM	15	35	50	100	150	200
% Removal	99.38	55.1	53.06	48.9	16.3	8.16



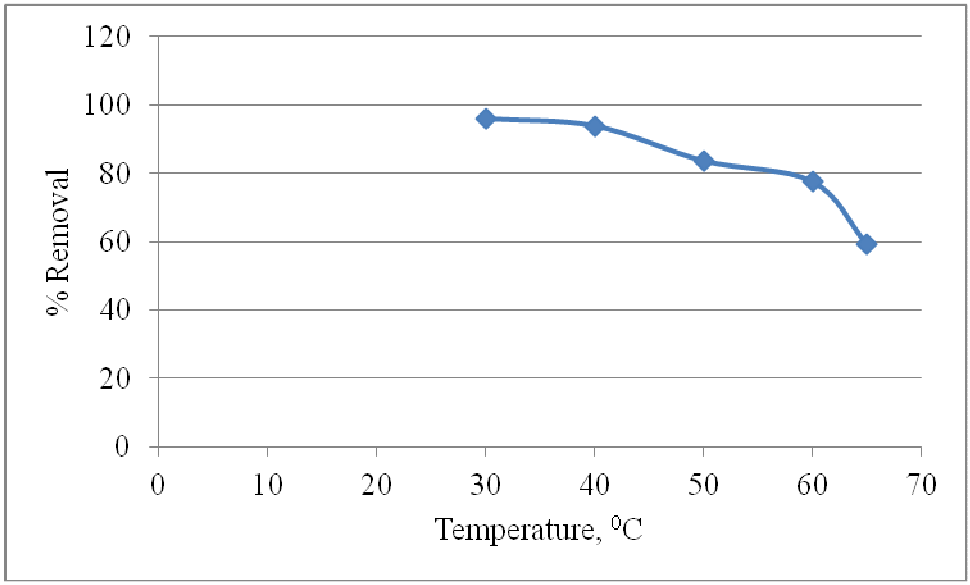
Graph-4. RPM vs. % removal

Effect of agitation speed on removal of Cr(VI) ions was studied using 50 ml of 8 ppm solution with shaking rate of 15-200 rpm. It is shown that the ion uptake was found to decrease with an increase in agitation rate from 15 to 200 rpm. It is known that at lower rpm the % removal is more than at higher rpm. So rpm 15 is preferable for the adsorption.

3.1.4 Effect of Temperature on % removal

Table-5. Temperature vs. % removal

Temperature, ^{0}C	30	40	50	60	65
% Removal	95.9	93.8	83.6	77.5	59.18



Graph-5. Temperature vs. % removal

Effect of Temperature on removal of Cr(VI) ions was studied using 50 ml of 8 ppm solution with shaking rate of 15

rpm at different temperatures between 30 and 65^{0}C. It is shown that the ion uptake was found to decrease with an increase in temperature from 30 to 65^{0}C. It is known that at lower temperature the % removal is more than at higher temperature. So temperature at 30^{0}C is preferable for the adsorption.

3.1.5 Effect of pH on % removal

Table 6. pH vs. % Removal

pH	4	5	6	7	8	9
% Removal	87.7	93.8	97.9	98.36	98.57	98.9

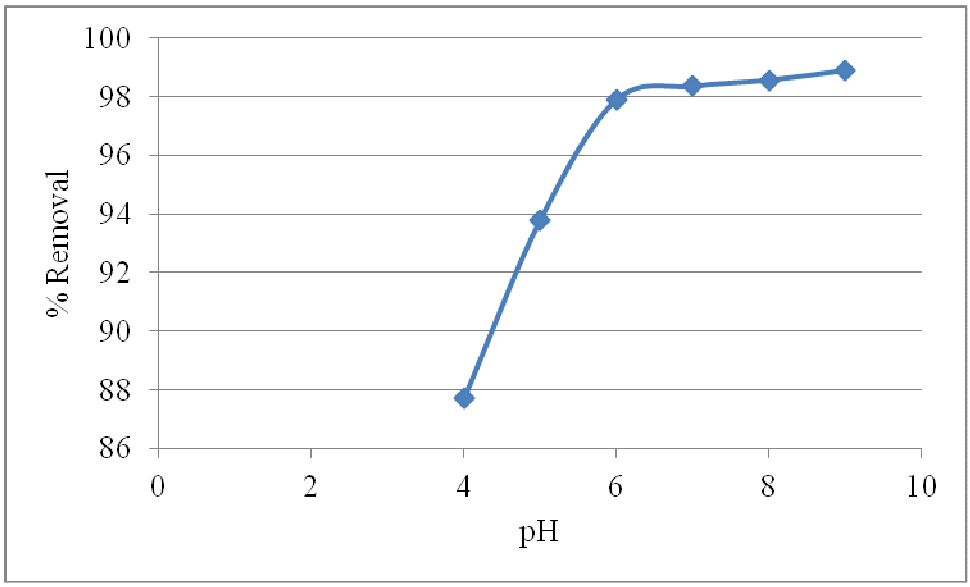


Figure 6. pH vs. % Removal

It was observed that the adsorption of Cr(VI) increases with pH. The maximum removal was occurred at a pH of 9. At lower pH the surface area of the adsorbent is not more protonated and competitive negative ions adsorption occurred between positive surface and free chromate ion. Adsorption of Cr(VI) at pH of 4 shows the bind of the negatively charged chromium species ($HCrO_4^-$) occurred through electrostatic attraction to the positively charged (due to more H^+ ions) surface functional groups of the adsorbent. But in highly basic medium (pH ≈9) the % removal is more predominant.

CONCLUSION

It is evident that adsorption using biomaterials is an effective method for the removal of chromium from industrial wastewater. From our experimental studies, it is concluded that

- As the contact time of adsorption increases the % removal also increases and the optimum time is 75 min.
- As the amount of adsorbent increases, the removal of Cr is also increases. The optimum amount of activated carbon for Cr removal is about 3 gm.
- The activity of carbon increases at a pH of 9 and maximum removal is observed at this pH.
- As the temperature increases the % removal gets decreases. So, the adsorption of Cr by activated carbon is exothermic in nature and a phenomenon of adsorption is physisorption.
- As the RPM increases the % removal gets decreases and observed that the maximum % removal is at lower RPM.

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