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Kinetics of removal of hexavalent chromium from aqueous solution using an eco-friendly activated carbon adsorbent

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ABSTRACT

One of the heavy metals that have been a major focus in water and waste water treatment- has been studied by adsorption technique. The pods of Delonix regia were used for preparing low cost activated carbon/ adsorbent and used in the removal of hexavalent chromium from aqueous solution. The optimum time required for the adsorption process has been evaluated. The kinetic of the process has been calculated using Lagergren's first order equation. The results demonstrate that the carbon derived from the Delonix regia pods can be used as an efficient adsorbent for the removal of toxic Cr(VI) from aqueous solution. The adsorption of Cr(VI) was found to be time and concentration dependent. Maximum Cr(VI) removal (≈ 66%) was achieved with just 100mg of the adsorbent with an optimum contact time of 180 minutes at pH~4 when the initial concentration of Cr(VI) solution was 0.06 mg/l. Confirmation of data to the Lagergren's rate equation indicates first order kinetics.

Keywords: activated carbon, adsorption, hexavalent chromium, first order kinetics , Lagergren equation.

INTRODUCTION

Heavy metals like lead, nickel, copper, cobalt, aluminium, phenolic compounds and DDT etc. are usually not present in the environment. These either do not degrade or degrade very slowly and thereby pollute the environment (Tripath et al.,2001). One of the heavy metals that has been a major focus in water and waste water treatment is chromium and the hexavalent form of it has been considered to be more hazardous due to its carcinogenic properties (Karthikeyan et al.,2005). One of the methods of chromium removal from the environment is by adsorption using economic adsorbents.The advantage of this technique is that adsorbed substance can be recovered in the same form in which they present(Kudesia,1998; 2000).

In the present work pods of *Delonix regia* were used for preparing low cost activated carbon/ adsorbent and used in the removal of hexavalent chromium from aqueous solution. The optimum time required for the adsorption process has been evaluated. The kinetic of the process has been calculated using Lagergren's first order equation.

MATERIALS AND METHODS

Plant profile

COMMON NAME	**:**	GULMOHUR
KINGDOM	**:**	PLANTAE
DIVISION	**:**	PHANEROGAMS
CLASS	**:**	DICOTYLEDONEAE
SUBCLASS	**:**	POLYPETALAE
SERIES	**:**	CALYCIFLORAE
ORDER	**:**	ROSALES
FAMILY	**:**	LEGUMINOSAE
SUB-FAMILY	**:**	CAESALPINEACEAE
GENUS	**:**	DELONIX
SPECIES	**:**	REGIA

Batch studies were conducted with the activated carbon prepared form *Delonix regia* pods. The adsorption technique was used owing to its simplicity in evaluating some basic parameters which influence the adsorption process.

Preparation of activated carbon

Pods of *Delonix regia* were collected from Avinashilingam Deemed university campus, Coimbatore. The pods were cut into small pieces, dried in sunlight for 5 days and further dried in a hot air oven at 60^0C for 24 hours. The completely dried material was powdered well, chemically activated by treating with concentrated sulphuric acid with constant stirring and kept for 24 hours. The carbonized material obtained washed well with water several times to remove excess acid and dried at 105-110^{o}C in a hot air oven for 24 hours. The adsorbent thus obtained was ground well and sieved through a 250 mesh and kept in an airtight container for further use.

Reagents

Preparation of Cr(VI) metal ion solution

All chemicals used were of analytical grade. In order to assess the performance of the low-cost adsorbent prepared and to avoid interference by other contaminants in waste water, the experiments were conducted with aqueous solution of Cr(VI) prepared by dissolving 283mg of potassium dichromate in one liter of double distilled water.

Preparation of complexing reagent

The complexing reagent was prepared by dissolving 250mg of diphenyl carbazide in 50ml of acetone. The reagent (0.5% in acetone) was kept in an amber bottle and used for the study.

Equipments

- Elico pH meter was used to measure pH.
- Elico CL157 colorimeter was used for spectrophotometric work.
- Genuine Equipment Manufacturers mechanical shaker was used for the shaking of solution containing adsorbent and adsorbate.

Variation of time of adsorption of chromium (VI) onto activated carbon from *Delonix regia*

100ml of Cr(VI) standard solution containing 0.06 µg/100ml of Cr(VI) was added to 100mg of the adsorbent taken in Pyrex bottles and shaken in an electrical horizontal bench shaker for various time intervals (10 to 180 minutes) at room temperature and at constant pH4$\pm$0.02.The solutions were filtered and Cr(VI)concentrations in the filtrate were estimated colorimetrically

by diphenyl carbazide method. Similarly the study was carried out at concentrations , 0.08, 0.1 and 0.12 µg/100ml.

RESULTS AND DISCUSSION

Effect of variation of contact time on adsorption of Cr(VI) from aqueous solution

Effect of agitation time on adsorption is one of the factors affecting the adsorption potential. The time of contact of the adsorbate and adsorbent was varied from 10 to 180minutes to arrive at the optimum time of contact for adsorption. The adsorbate concentrations were varied from 0.06 to 0.12 mg/l and batch studies were performed to optimize the time at different initial concentrations of the adsorbate. The percentage removal of Cr(VI) with variation in time at different concentration of Cr(VI) solution is given in table - 1. The data shows that with increase in time the percentage of adsorption of chromium increases steadily. At low concentrations there was an increase from ~26% to ~66%. This may be probably due to the fact that with time the adsorbate has more time for covering the adsorption sites.

Table – 1: Adsorption potential of Cr(VI) with variation of time of adsorption of Cr(VI) onto the adsorbent

Adsorbent dosage : *100mg*
pH : *~4.00*
Temperature : *32^{o}C*
Contact time : *10-180 minutes*

Time in minutes	Removal of Cr(VI) in percentage			
	0.06 mg/l	**0.08mg/l**	**0.1mg/l**	**0.12mg/l**
10	25.72	15.25	15	11.75
20	28.5	21.75	17.5	13.25
30	31.43	28.25	22.81	14.67
40	34.33	30.38	24.6	16.17
50	37.17	32.35	26.3	22.08
60	42.83	34.75	28.1	23.5
90	51.5	39.13	31.6	26.5
120	57.17	43.5	35.1	30.92
150	60	45.6	38.6	32.33
180	65.67	52.13	43.9	36.75

Lagergren Kinetic Modelling for Cr(VI) adsorption

The rate constant of adsorption was calculated (table - 2) using the Lagergren first order kinetic equation.

$$\log(q_e - q) = \log q_e - K_a/2.303\ t$$

where, q and q_e are the amount of Cr(VI) adsorbed at time‘t’ and at equilibrium time. K_a is the rate constant for Cr(VI) adsorption.

The linear plot obtained by plotting log (q_e – q) Vs time‘t’ shows the validity of Lagergren first order kinetic equation for the adsorption of Cr(VI). The rate constant K_a evaluated from the slope of Lagergren plots are given below.

Concentration of Cr(VI) solution in mg /l	**K_a in minutes^{-1}**
0.06	1.51 X 10^{-2}
0.08	1.42 X 10^{-2}
0.1	1.13 X 10^{-2}
0.12	2.57 X 10^{-2}

Table – 2 Kinectic modelling for Cr(VI) adsorption using lagergren equation (variation of initial concentration Cr(VI) solution)

Time in minutes	log (q_e-q)			
	0.06 mg/l	**0.08mg/l**	**0.1mg/l**	**0.12mg/l**
10	-1.562	-1.530	-1.551	-0.3979
20	-1.651	-1.614	-1.578	-0.4814
30	-1.688	-1.718	-1.676	-0.5228
40	-1.725	-1.759	-1.714	-0.6197
50	-1.767	-1.806	-1.755	-0.6575
60	-1.863	-1.856	-1.801	-0.7212
90	-2.070	-1.983	-1.910	-1.0000
120	-2.292	-2.161	-2.056	-1.5228
150	-2.468	-2.284	-2.276	-2.0000
180	-	-	-	-
Intercept $\log q_e$	-1.4838	-1.4056	-1.5022	-0.1726
Slope $-K_a/2.303$	-0.0065	-0.0062	-0.0050	-0.0111
K_a in minutes	1.51×10^{-2}	1.42×10^{-2}	1.13×10^{-2}	2.57×10^{-2}

CONCLUSION

The carbon derived from the *Delonix regia* pods can be used as an efficient adsorbent for the removal of toxic Cr(VI) from aqueous solution. The adsorption of Cr(VI) was found to be time and concentration dependent. Maximum Cr(VI) removal (≈ 66%) can be achieved with just 100mg of the adsorbent with an optimum contact time of 180 minutes at pH~4 when the initial concentration of Cr(VI) solution was 0.06 mg/l. Confirmation of data to the Lagergren's rate equation indicates first order kinetics for Cr(VI) removal by adsorption using activated carbon prepared from the *Delonix regia* pods.

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