The Adsorption Kinetics of Cr (Vi) Metal by Using Granulated Particles of Tamarindus Indica Seed

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Abstract

The objective of this study was to investigate the possibility of using granulated particle of Tamarindus Indica seed as an alternative adsorbent for the removal of Chromium (VI) ions from aqueous solutions. The effect of pH, solution temperature, contact time, initial metal ion concentration and adsorbent dose on the adsorption of Chromium (VI) by granulated particle of Tamarindus Indica seed was investigated using batch methods. Adsorption for Chromium (VI) was found to be highly pH dependent compared to the other parameters investigated. Obtained results gave an adsorption capacity of 77.56 % for Chromium (VI) at pH 2, exposure time of 3hr at 25 ºC. The data obtained from the batch processes have used to fit in Freundlich and Langmuir isotherm equations. The results suggest that granulated particle of Tamarindus Indica seed could be used as effective adsorbents for the removal of Cr (VI) ions.

Keywords: Adsorption, Granulated particle of *Tamarindus Indica* seed, Chromium (VI), Batch adsorption process, Adsorption kinetics, Thermodynamics adsorption isotherm.

Introduction

Chromium (Cr) is found naturally in rocks, soil, plants, animals, volcanic dust and gases. It is present in aqueous solution mainly in Cr (III) and Cr (VI) oxidation states. Cr (VI) salts show higher mobility than Cr (III) and hence is considered to be more toxic to humans (ATSDR, 1998). Chromium enters water bodies from industries such as electroplating, leather tanning, cement, steel, paint, ink, dyes, aluminium and textiles. Heavy metal, due to their high toxicity poses a serious threat to biota and the environment[1]. It can also percolate into the soil by leaching and has the potential to contaminate groundwater, which can be a major source of drinking water (IARC, 1987; ATSDR, 1998). In view of the health problems caused by Cr (VI)[2], the present study was performed to evaluate granulated particle of *Tamarindus Indica* seed as adsorbents for the removal of Cr (VI) from polluted water by systematic evaluation of the parameters involved such as pH, Chromium concentration, time, adsorbent dose and temperature[3-6]. Furthermore, the

Freundlich and Langmuir adsorption isotherms were applied to study the kinetics of adsorption and to calculate isotherm parameters.

Materials and Methods

Preparation of Adsorbent

Tamarindus Indica seed was collected from a Pandhari forest. It was cut in to small particle and dried in sunlight until almost all the moisture evaporated. Then it was ground to get desired particle size of 100 to 200 micron. It was then soaked 2 hours in 0.1M NaOH solution to remove the lignin content. Excess alkalinity was then removed by neutralizing with 0.1 N HCl. The granulated particle of *Tamarindus Indica* seed was then washed several times with distilled water till the washings are free from colour and turbidity. The washed granulated particle of *Tamarindus Indica* seed was oven dried at 200^0 C for 24 hrs and stored in Desicator for the further study.

Preparation of solutions

All the reagents used were of AR grade.

Cr (VI) solution

Stock Chromium ions solution (1000 mg/L) was prepared by dissolving 29.4 gm of A.R. grade $K_2Cr_2O_7$ in 1000 ml distilled water. The solutions of lower concentrations were prepared by dilution of appropriate volume of stock solution. 3 Molar aqueous solution of H_2SO_4 was prepared by dissolving 42ml H_2SO_4 in 250 ml volumetric flask.

Diphenyl Carbazide

0.25% solution was prepared by dissolving Diphenyl Carbazide in 50% Acetone.

Results and Discussion

Equilibrium adsorption isotherms for Ce Vs qe plotted for granulated particle of *Tamarindus Indica* seed are shown in fig.-I. The adsorption capacity in mg/L was calculated from the equation.

$$q_e = (C_0 - Ce)V/M$$

Where,

C_0 = is the initial concentration of Cr (VI) in mg/L

Ce = is the concentration of Cr (VI) at equilibrium in mg/L

V = Volume of solution in litre and

M = Mass of Adsorbent in gram

Adsorption Isotherms

Langmuir and Freundlich isotherm were studied, and results are shown in Table No.1 Which illustrates the plot of Langmuir and Freundlich isotherm of granulated particle of *Tamarindus Indica* seed. The saturated mololayer can be represented by:

$$q_e = Q^0.b.Ce / 1+b.Ce$$

Equilibrium adsorption isotherm equations are used to describe the experimental adsorption data. The parameters obtained from the different models provide important information on the sorption mechanisms and the surface properties and affinities of the adsorbent. The most widely accepted surface adsorption models for single-solute systems are the Langmuir and Freundlich models. Linear regression is frequently used to determine the best-fitting isotherm, and the applicability of isotherm equations is compared by judging the Correlation coefficients.

Freundlich Adsorption Isotherm

The sorption data of Chromium ions onto granulated particle of *Tamarindus Indica* seed was also fitted to Freundlich isotherm, in the following linear form

$$log\ qe = b\ log\ Ce + log\ K \qquad (1)$$

Where, *qe* is the amount of metal ion adsorbed per gram of adsorbent (mg/g). Ce is the equilibrium concentration of metal ion in solution (mg/L). *K* and *b* are Freundlich constants, indicating the Adsorption Capacity and Adsorption Intensity respectively. Straight lines were obtained by plotting *log qe* against *log Ce*, which show that sorption of Chromium ions obeys Freundlich isotherm well. The *K* and *b* values were calculated from intercept and slop of the plot respectively and presented in Table 1. The Correlation coefficient R^2> 0.978 and the values of n were higher than 1.0, indicating that adsorption of Cr (VI) ions on Granulated particle of *Tamarindus Indica* seed follows the Freundlich isotherm.

Langmuir Adsorption isotherm

The Langmuir isotherm is valid for sorption of a solute from a liquid solution as monolayer adsorption on a surface containing a finite number of identical sites. Langmuir isotherm model assumes uniform energies of adsorption onto the surface without transmigration of adsorbate in the plane of the surface. The Linear form of Langmuir equation is

$$1 / qe = 1/ b\ Q_0 \text{ X } 1/Ce + 1/Q_0$$

Q_0 and *b is* Langmuir Constants related to the capacity and energy of sorption respectively. A plot of *qe* versus *C*e should indicate a straight line of slope 1/ b Q_0 and an intercept of 1/ Q_0. The values of *Qo* and b and Correlation coefficient obtained from the Langmuir model are shown in Table 1. The Correlation coefficient R^2 > 0.995 suggests that adsorption of Cr(VI) ions onto Granulated particle of *Tamarindus*

Indica seed follows the Langmuir isotherm. The maximum monolayer capacity Q_0 obtained from the Langmuir is 4.917 mg/g.

Table 1 Isotherm Constants

Cr(VI) Concentration	Freundlich Constants			Langmuir Constants		
Conc.	K	B	R^2	Q_0 mg/g	B L/mg	R^2
20mg/L	3.458	1.627	0.978	4.917	0.325	0.995

Effect of pH on the retrieval of Cr (VI)

The effect of pH on the retrieval of Cr (VI) is shown in Table number 2. Experiments were conducted at the constant initial Cr (VI) concentration, adsorbent dose of Granulated particle of *Tamarindus Indica* seed of 0.5 gms /100 ml and the contact time of 3 Hr. Result indicate that at pH 2.0 the Granulated particle of *Tamarindus Indica* seed shows maximum adsorption capacity for the retrieval of Cr (VI) ions shown in graph- I.

Effect of adsorbent Dosage: Batch adsorption studies were performed to determine the effect of sorbent dosage on Chromium (VI) removal. The percent removal increase rapidly and reaches about 95%. For 100% removal of the Chromium (VI), the dosage required is 300mg/50ml for the initial concentration of 50 mg/L at pH = 2

Sorption Kinetics: The rate of adsorption of Chromium (VI) on Granulated particle of *Tamarindus Indica* seed was studied by using the first order kinetic model, Pseudo second order kinetic and Elovich models are used to test the experimental data.

First order kinetics: The rate of adsorption of Chromium (VI) on Granulated particle of *Tamarindus Indica* seed was studied by using the first order rate equation proposed by Lagergren. It is found that as initial Chromium (VI) concentration increases, Lagergren rate constant decrease. This indicates that, adsorption does not follow the 1st order kinetics.

Pseudo Second order models: The time data of metal ion fitted to Pseudo second order kinetics. Pseudo second order model showed that, Rate constant K_2 is almost constant at different initial concentration which is shown in Table 2. This indicates that adsorption of Chromium (VI), On Granulated particle of *Tamarindus Indica* seed obey the 2nd order kinetics. Also the concentration of Chromium (VI) increasing from 20mg/L to 60 mg/L, equilibrium sorption capacity qe increases.

Elovich Model: Adsorption of Chromium (VI) on Granulated particle of *Tamarindus Indica* seed is shown. A linear relationship is obtained between the amount of Chromium (VI) adsorbed q_t and lnt. From the Table 2, Shows that the value varied as a function of Chromium (VI) concentration. As the concentration of Chromium (VI) increases from 20mg/L. to 60mg/L. value of α increase and β decreases. This favoured the adsorption phenomenon.

Table-2 Kinetic model value for adsorption of Chromium (VI) on Granulated particle of *Tamarindus Indica* seed

Concentration	1st order			Pseudo second order			Elovich model		
	K_L	q_e	r^2	q_e	k_2	r^2	α	β	r^2
20mg/L	0.1332	7.31	0.998	5.287	0.0432	0.978	0.3752	0.2301	0.9921
40mg/L	0.1058	12.84	0.973	8.467	0.0318	0.9852	0.7380	0.0867	0.9754
60mg/L	0.0897	17.37	0.992	15.152	0.0275	0.9878	1.8752	0.0438	0.9812

Conclusions

i) It is found that, at pH 2.0, Cr (VI) uptake capacity is maximum.

ii) The low cost adsorbent of Granular particle of *Tamarandus indica* seed act as a good adsorbent for the removal of Cr (VI)

iii) It is concluding that, as the dose of adsorbent of Granular particle of *Tamarandus indica* seed increases, the adsorption efficiency increases.

iv) Adsorption process is in a good agreement with Langmuir and Freundlich adsorption isotherm indicating monolayer adsorption process.

v) Adsorption of Chromium (VI) on Granular particle of *Tamarandus indica* seed followed the pseudo second order model and Elovich model.

vi) It is concluded that the adsorbent prepared from Granular particle of *Tamarandus indica* seed could be exploited for commercial applications. Regeneration studies are not necessary with the view that the cost of adsorbent is very low and available in large quantity.

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