



Adsorption of Fe(III) from aqueous solution by acanthaceae activated carbon

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ABSTRACT

In this study, a series of batch laboratory experiments were conducted in order to investigate the feasibility of Acantheace activated carbon for the removal of iron from aqueous solution by adsorption process. Batch experiments were performed as function of process parameters like contact time, initial concentration of iron, temperature, carbon dose and effect of pH. All batch experiments were carried out at a constant temperature of 30°C using wrist action shaker that operated with a speed of 120 rpm. The single component equilibrium data was analyzed using Langmuir, Freundlich isotherms. The kinetic process of iron adsorption on Acantheace activated carbon was described by AAC applying pseudo second order rate equations, Elovich and intra-particle diffusion models. The AAC investigated in this study exhibited a high potential for the removal of iron from aqueous solution.

Keywords: Fe(III), Adsorbent, Batch Adsorption, Adsorption Isotherms, Kinetics.

INTRODUCTION

The removal of heavy metals such as Pb, Fe, Cr, Cd, Co, etc., from ground and industrial water is a matter of great interest in the poor countries that have limited water resources. Of these, iron ions are attracting wide attention of researchers as one of the heavy metals and they are found in many manufacturing industries such as the metal finishing and galvanized pipe[1]. The presence of iron ions in ground and industrial water becomes toxic at high level and then causes environmental and human health problems[2,3]. In general, there are various technological methods that exist for removing heavy metal ions from water and wastewater including supercritical fluid extraction[4], bioremediation[5] and oxidation with oxidizing agent[6]. However, most of these technologies are either extremely expensive or too inefficient in reducing metal ion levels in effluent to concentrations that are required by the governmental legislation. Among all methods, the adsorption is a cost-effective technique and simple to operate[7-10]. The adsorption process usually uses natural organic or inorganic materials that are particularly abundant and inexpensive. Among these materials are modified cellulose material[11], sawdust[12], residual lignin[13,14], polymerized orange skin and banana husk[15], wool[16], AAC residues[17], pine bark[18], palm kernel husk[19], corn cobs[20], peanut hull[21-24].

The main objective of this research is to develop inexpensive and effective metal ion adsorbents from plentiful sources of natural wastes, such as acanthaceae to offer these adsorbents as replacements for existing commercial materials. In the present paper, acanthaceae was examined for their sorption properties towards Fe(III). The influence

of experimental parameters such as initial solution pH, contact time, adsorbent dose and initial iron concentration were investigated at 30-60°C. The adsorption process is studied from isotherm and kinetic standpoints.

EXPERIMENTAL SECTION

ADSORBENT MATERIALS

The dried acanthaceae was carbonized with concentrated sulphuric acid in the weight ratio of 1: 1 (w/v). The resulting carbon was washed with distilled water until a constant pH of the slurry was reached. Then the carbon was dried for four hours at 100°C in a hot air oven. Heating for twelve hours in a furnace at 600°C has completed the activation. The dried material was ground well to a fine powder and sieved.

ADSORBATE

All the chemicals used were of analytical reagent grade. Stock solution of iron (1000 mg/L) was prepared by dissolving Fe₂(SO₄)₃.9H₂O in double distilled water. The concentration range of iron prepared from stock solution varied between 50 and 100 mg/L.

ADSORPTION EXPERIMENT

Batch adsorption experiments were performed by contacting 50 mg of the selected AAC with 50 ml of the aqueous solution of different initial concentrations (50 to 250 mg/L) at different solution pH. The experiments were performed in wrist action shaker for a period of 1 hour at 120 rpm using 250 ml Erlenmeyer flasks containing 100 ml of different iron concentrations at (30° to 60°C). Continuous mixing was provided during the experimental period with a constant agitation speed of 120 rpm for better mass transfer with high interfacial area of contact. The remaining concentration of iron in each sample after adsorption at different time intervals was determined by AAS after filtering the adsorbent with Whatman GF/A filter paper to make it adsorbent free. The iron concentration retained in the adsorbent phase was calculated according to

$$q_e = (C_i - C_e) V / W \dots\dots\dots (1)$$

where C_i and C_e are the initial and equilibrium concentrations (mg/L) of iron solution respectively; V is the volume(L); and W is the weight (g) of the adsorbent. The ions removal percentage can be calculated as follows :

$$\%R = (C_0 - C_t) \times 100 / C_0 \dots\dots\dots (2)$$

Batch kinetic studies

The batch kinetic [25] experiments were basically identical to those of adsorption equilibrium methods. The aqueous samples were taken at present time intervals and the concentrations of Fe(III) ions were similarly measured. All the kinetic experiments were carried out at 30, 40, 50 and 60°C at an initial concentration of 50, 100, 150, 200, and 250 mg/L. The amount of adsorption at time t, q_t (mg/g) was calculated by

$$q_t = (C_0 - C_t) V / W \dots\dots\dots (3)$$

Where C_t (mg/L) is the liquid phase concentration of Fe(III) ions at any time.

EFFECTS OF VARIABLE PARAMETERS

Dosage of adsorbent

The various doses of the adsorbents were mixed with the Fe(II) ions solutions and the mixture was agitated in a mechanical shaker. The adsorption capacities for different doses were determined at definite time intervals by keeping all other factors constant.

Initial concentration of Fe(III) ions

In order to determine the rate of adsorption experiments were conducted with different initial concentrations of Fe(III) ions ranging from 50 to 250 mg/L. All other factors were kept constant.

Contact time

The effect of period of contact on the removal of the Fe(II) ions on adsorbent in a single cycle was determined by keeping particle size, initial concentration, dosage, pH and concentration of other ions constant.

pH

Adsorption experiments were carried out at pH 2,3,4,5,6,7,8,9 and 10. The acidic and alkaline pH of the media was maintained by adding the required amounts of dilute hydrochloric acid and sodium hydroxide solutions. The parameters like particle size of the adsorbents, Fe(III) ions concentration, dosage of the adsorbent and concentration of other ions were kept constant while carrying out the experiments. The pH of the samples was determined using a portable pH meter Systronics make. The pH meter was calibrated with 4.0 and 9.2 buffers.

Chloride

The experiments were done in the presence of varying chloride environments using various sodium chloride solutions. While doing the experiments, the absence of other anions was ensured.

Temperature

The adsorption experiments were performed at four different temperatures viz., 30,40,50 and 60°C in a thermostat attached with a shaker, Remi make. The constancy of the temperature was maintained with an accuracy of ± 0.5 °C.

Zero point charge

The pH at the potential of zero charge of the carbon (pH) was measured using the pH drift method. The pH of the solution was adjusted by using 0.01 M sodium hydroxide or hydrochloric acid. Nitrogen was bubbled through the solution at 25°C to remove the dissolved carbon dioxide. 50 mg of the activated carbon was added to 50 ml of the solution. After stabilization, the final pH was recorded. The graphs of final pH versus initial pH were used to determine the zero point charge of the activated carbon.

Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the Fe(III) ions. The effect of various reagents used for desorption were studied.

RESULTS AND DISCUSSION**Effect of contact time and initial Fe(III) ions concentration**

The experimental results for the adsorption at various concentrations (50 to 250 mg L⁻¹) with contact time are shown in Figure 1. The respective data are presented in Table-1, revealing that, percent adsorption decreased with increase in initial Fe(III) ions concentration, but the actual amount of Fe(III) ions adsorbed per unit mass of AAC increased with increase in Fe(III) ions concentration. It means that the adsorption is highly dependent on initial concentration of Fe(III) ions. It is because of the reason that at lower concentration, the ratio of the initial number of Fe(III) ions molecules to the available surface area is low. Subsequently the fractional adsorption becomes independent of initial concentration. However, at higher concentrations, the available sites of adsorption becomes fewer and hence the percentage removal of Fe(III) ions is dependent upon initial concentration [26,27].

TABLE .1. EQUILIBRIUM PARAMETERS FOR ADSORPTION OF Fe(III) ON AAC

M ₀	C _e (Mg / L)				Q _e (Mg / g)				Removed (%)			
	30° C	40° C	50° C	60° C	30° C	40° C	50° C	60° C	30° C	40° C	50° C	60° C
25	1.881	1.8302	1.7817	1.7425	46.237	46.3396	46.4366	46.515	92.474	92.6792	92.8732	93.03
50	2.902	2.6715	2.5172	2.3095	94.195	94.657	94.9656	95.3810	94.195	94.657	94.9656	95.381
75	4.705	4.4441	4.2027	3.9390	140.58	141.111	141.594	142.122	93.7264	94.0745	94.3964	94.748
100	8.237	7.7395	7.2862	6.7654	183.52	184.521	185.427	186.469	91.7625	92.2605	92.7138	93.2346
125	12.69	11.604	10.727	9.7612	224.61	226.790	228.545	230.477	89.8451	90.7160	91.418	92.1910

TABLE 2. LANGMUIR AND FREUNDLICH ISOTHERM PARAMETER FOR Fe(III) ON AAC

TEMP. (C°)	LANGMUIR PARAMETER		FREUNDLICH PARAMETER	
	Q _m	b	K _f	n
30°	503.31952	0.06807	4.6844	1.27914
40°	549.1162	0.06466	4.74666	1.25294
50°	601.9030	0.06075	4.79491	1.22571
60°	684.4758	0.05525	4.86488	1.19706

Equilibrium has been established at 40 minutes for all concentrations. Figure-2 reveals that the curve is single, smooth and continuous leading to saturation, suggesting the possibility of monolayer coverage of the Fe(III) ions on the AAC adsorbent surface.

TABLE .3. DIMENSIONLESS SEPERATION FACTOR (R_L) FOR Fe(III) ON AAC

(C _i)	TEMPERATURE °C			
	30°C	40°C	50°C	60°C
25	0.37012	0.38216	0.39701	0.41992
50	0.22708	0.23621	0.24767	0.26576
75	0.16378	0.17093	0.17997	0.19439
100	0.12808	0.13392	0.141338	0.15324
125	0.105162	0.11009	0.11636	0.12647

TABLE .4. THERMODYNAMIC PARAMETER FOR THE ADSORPTION FOR Fe(III) ON AAC

C ₀	ΔG°				ΔH°	ΔS°
	30° C	40° C	50° C	60° C		
25	-6319.43	-6605.7	-6894.48	-7174.19	2.32689	28.5388
50	-7019.96	-7480.19	-7887.68	-8382.38	6.58773	44.90653
75	-6811.83	-7194.86	-7583.88	-8008.38	5.23593	39.7347
100	-6072.41	-6449.18	-6830.47	-7276.76	5.89281	39.4544
125	-5492.06	-5931.77	-6353.11	-6834.45	7.9771	44.43383

TABLE 5. THE KINETIC PARAMETERS FOR ADSORPTION OF Fe(III) ON AAC

C ₀	Temp °C	PSEUDO SECOND ORDER				ELOVICH MODEL			INTRAPARTICLE DIFFUSION		
		q _e	K ₂	γ	h	α	β	γ	K _{id}	γ	C
25	30	47.242	0.0147	0.9941	32.901	2.2400	0.4885	0.9925	1.8850	0.9913	0.0457
	40	46.974	0.0207	0.9945	45.696	1.4401	0.7895	0.9926	1.9158	0.9916	0.0279
	50	47.080	0.0203	0.9948	45.193	1.5201	0.7892	0.9971	1.9167	0.9962	0.0278
	60	47.623	0.1369	0.9952	31.070	1.3684	0.4443	0.9975	1.8804	0.9951	0.5014
50	30	95.852	0.0085	0.9935	78.952	7.4635	0.2966	0.9966	1.9082	0.9981	0.0367
	40	95.958	0.0102	0.9957	94.288	2.9728	0.3865	0.9968	1.9251	0.9982	0.0279
	50	96.253	0.1028	0.9946	95.264	4.8119	0.3905	0.9969	1.9271	0.9985	0.0275
	60	96.627	0.0105	0.9959	98.702	1.3940	0.4002	0.9930	1.9305	0.9943	0.0267
75	30	142.53	0.0068	0.9960	139.60	4.7301	0.2607	0.9919	1.9209	0.9946	0.0278
	40	143.01	0.0069	0.9973	142.44	6.3901	0.2619	0.9918	1.9229	0.9928	0.0276
	50	143.54	0.0068	0.9981	140.65	4.1901	0.2579	0.9914	1.9238	0.9930	0.0279
	60	144.02	0.0069	0.9984	144.77	1.3601	0.2655	0.9916	1.9270	0.9931	0.0270
100	30	186.10	0.0051	0.9990	178.16	3.5289	0.1966	0.9941	1.9108	0.9941	0.0283
	40	187.10	0.0051	0.9983	180.23	2.8278	0.1942	0.9946	1.9129	0.9922	0.0284
	50	187.96	0.0052	0.9988	184.27	5.8795	0.1973	0.9932	1.9161	0.9929	0.0278
	60	189.00	0.0051	0.9989	185.07	7.6309	0.1977	0.9933	1.9188	0.9945	0.0276
125	30	228.22	0.0036	0.9928	190.58	9.9455	0.1541	0.9936	1.8987	0.9963	0.0295
	40	229.64	0.0045	0.9930	241.15	6.7308	0.1715	0.9938	1.9096	0.9973	0.0262
	50	231.68	0.0042	0.9940	226.25	6.0663	0.1593	0.9961	1.9097	0.9911	0.0280
	60	233.66	0.0041	0.9950	226.67	5.6521	0.1576	0.9964	1.9132	0.9910	0.0281

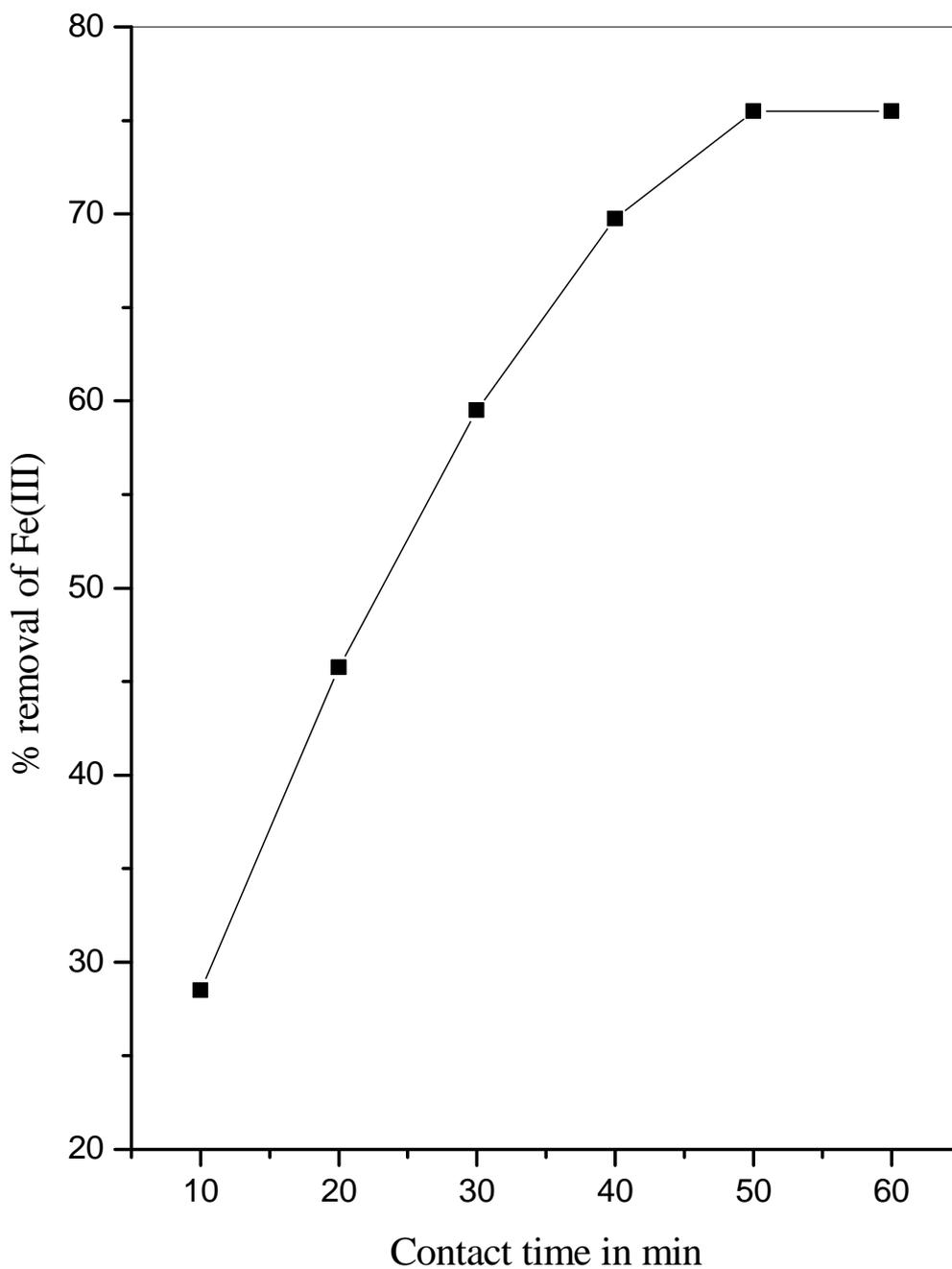


Fig.1-Effect of contact time on the removal of Fe(III) ion
[Fe(III)]=50 mg/L:adsorbent dose=25mg/50ml: pH=6.5:emp=30⁰C

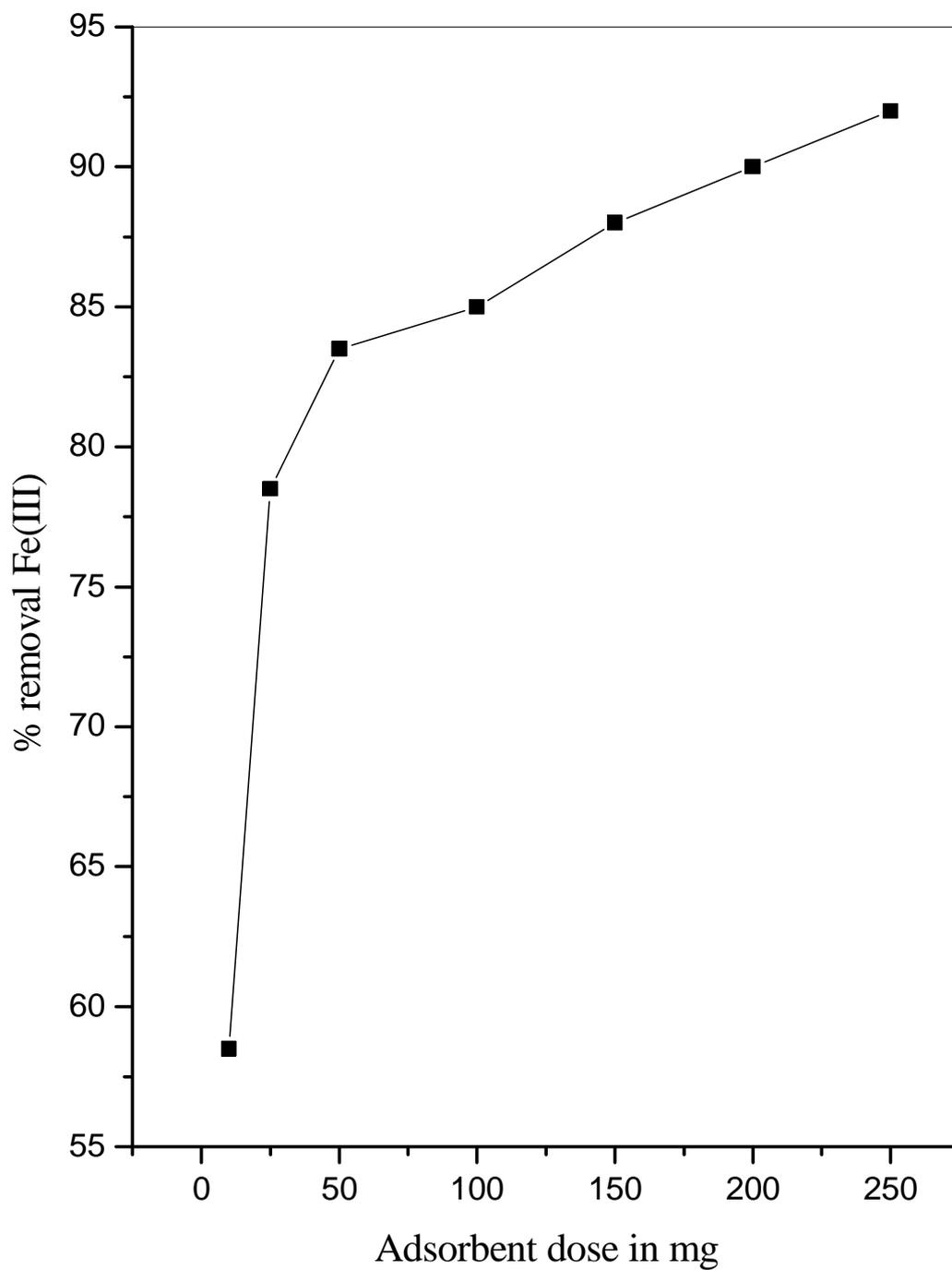


Fig.2-Effect of adsorbent dose on the removal of Fe(III)
[Fe(III)]=50 mg/L:Contact time=60 min:pH=6.5:Temp=30⁰C

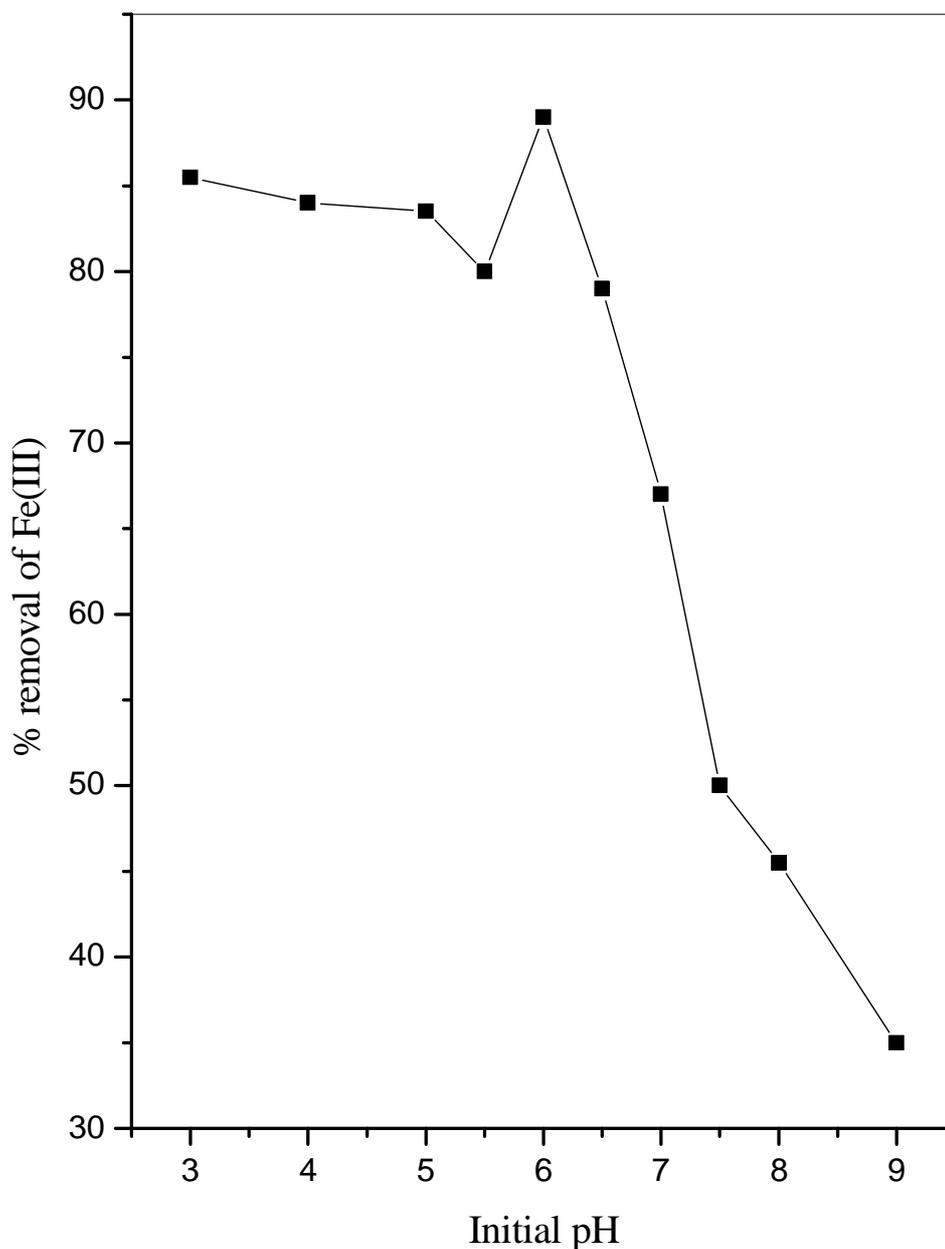


Fig.3-Effect initial pH on the removal of Fe(III)
[Fe(III)]=50 mg/L:Contact time=60 min:Adsorbent dose=25 mg/50 ml

Effect of Dosage

The adsorption of Fe(III) ions on AAC was studied by varying the dosage of adsorbent (10 - 250 mg / 50ml) for 30 mg L⁻¹ of Fe(III) ions concentration. The percent of adsorption increased with increase in the AAC dose (Figure 2). This may be due to the increased AAC surface area and availability of more adsorption sites. Hence the remaining parts of the experiments were carried out with an optimum dose of the adsorbent (25 mg/50 ml).

Theory of Adsorption isotherm

To quantify the sorption capacity of the adsorbent for the removal of Fe(III) ions, the most commonly used isotherm, namely Freundlich and Langmuir has been adopted.

Freundlich isotherm

The linear form of Freundlich isotherm [28] is represented by the equation

$$\text{Log } q_e = \log K_f + (1/n) \log C_e \dots\dots\dots(4)$$

Where q_e is the amount of Fe(III) ions adsorbed per unit weight of the sorbent (mg/L), K_f is (mg/g(L/mg)) measure of adsorption capacity and $1/n$ is the adsorption Intensity. The value of K_f and n are calculated from the intercept and slope of the plot of $\log q_e$ vs $\log C_e$ respectively. The constant K_f and n values are given in table 2. In general K_f value increases the adsorption capacity for a given adsorbate increases. The magnitude of the exponent $1/n$ gives an indication of the favorableness of adsorption. The value of $n > 1$ represents favorable adsorption condition [29] (or) the value of $1/n$ lying in the range of 1 to 10 confirms the favorable condition for adsorption. This is further supported by Langmuir isotherm.

Langmuir isotherm

The Langmuir isotherm model [30] is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface. The linear form of the Langmuir isotherm equation can be described by the equation

$$C_e/q_e = (1/Q_m b) + (C_e/Q_m) \dots\dots\dots(5)$$

Where C_e (mg/L) is the equilibrium concentration of the adsorbate, q_e (mg/g) is the amount of adsorbate per unit mass of adsorbent, Q_m and b are Langmuir constants related to adsorption capacity and rate of adsorption respectively. Q_m is the amount of adsorbate at complete monolayer coverage (mg/g) which gives the maximum adsorption capacity of the adsorbent and b (L/mg) is the Langmuir isotherm constant that relates to the energy of adsorption (or rate of adsorption) The linear plot of specific adsorption capacity C_e/q_e against the equilibrium concentration (C_e) shows that the adsorption obeys the Langmuir model. The Langmuir constants Q_m and b were determined from the slope and intercept of the plot respectively and are presented in table (2) In order to find out the feasibility of the isotherm, the essential characteristics of the Langmuir isotherm can be expressed in terms of dimensionless constant separation factor R_L [31,32] by the equation

$$R_L = 1/(1+bC_o) \dots\dots\dots(6)$$

Where C_o (mg/L) is the highest initial concentration of adsorbent and b (L/mg) is Langmuir isotherm constant. The parameter R_L indicates the nature of shape of the isotherm accordingly.

- $R_L > 1$ Unfavorable adsorption
- $0 < R_L < 1$ Favorable adsorption
- $R_L = 0$ Irreversible adsorption
- $R_L = 1$ Linear adsorption

The R_L values between 0 and 1 indicate favorable adsorption for all initial concentrations (C_o) and temperatures studied. The calculated R_L values are given in Table. 3

Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change (ΔG^0), standard enthalpy change (ΔH^0) and standard entropy change (ΔS^0) were calculated as follows. The free energy of adsorption process considering the adsorption equilibrium constant K_0 is given by the equation

$$\Delta G^0 = -RT \ln K_0 \dots\dots\dots (7)$$

Where ΔG^0 is the free energy of adsorption (kJ/mol), T is the temperature in kelvin and R is the universal gas constant (8.314 J mol⁻¹K⁻¹).The adsorption distribution coefficient K_0 for the sorption reaction was determined from

the slope of the plot of $\ln (q_e/C_e)$ against C_e at different temperatures and extrapolating to zero C_e according to the method suggested by Khan and Singh [33]. The adsorption distribution coefficient may be expressed in terms of enthalpy change (ΔH°) and entropy change (ΔS°) as a function of temperature,

$$\ln K_0 = (\Delta H^\circ/RT) + (\Delta S^\circ/R) \dots\dots\dots(8)$$

Where ΔH° is the standard heat change of sorption (kJ/mol) and ΔS° is standard entropy change (kJ/mol). The value of ΔH° and ΔS° can be obtained from the slope and intercept of plot $\ln K_0$ against $1/T$. The value of thermodynamic parameter calculated from equation 7 and 8 are shown in table 4. The thermodynamic treatment of the sorption data indicates that ΔG° values were negative at all temperatures.

From the results it could be made out that physisorption is much more favorable for the adsorption of Fe(III) ions. The positive values of ΔH° show the endothermic nature of adsorption and it governs the possibility of physical adsorption. Because in the case of physical adsorption, while increasing the temperature of the system, the extent of Fe(III) ions adsorption increases, this rules out the possibility of chemisorptions. The low ΔH° value that depicts Fe(III) ions is physisorbed onto adsorbent AAC.

The negative values of ΔG° (Table-5) show the adsorption is highly favorable and spontaneous. The positive values of ΔS° (Table-4) show the increased disorder and randomness at the solid solution interface of Fe(III) ions with AAC adsorbent. While in the adsorption there are some structural changes in the Fe(III) ions and the adsorbent occur. The adsorbed water molecules, which have been displaced by the adsorbate species, gain more translational entropy than is lost by the adsorbate molecules, thus allowing the prevalence of randomness in the system. The enhancement of adsorption capacity of the AAC at higher temperatures was attributed to the enlargement of pore size and activation of the adsorbent surface [34,35,36,37].

Adsorption kinetics

The study of adsorption dynamics describes the solute uptake rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface. The kinetics of Fe(III) ions adsorption on the AAC were analyzed using pseudo second-order [38] Elovich [39,40] and intra-particle diffusion [41] kinetic models.

The conformity between experimental data and the model predicted values was expressed by the correlation coefficient (γ), (γ , values close or equal to 1). A relatively high correlation coefficient (γ) value indicates that the model successfully describes the kinetics of Fe(III) ions adsorption on AAC adsorbent.

The pseudo-second- order equation

The pseudo-second-order adsorption kinetic rate equation is expressed as

$$dq_t/dt = k_2(q_e - q_t)^2 \dots\dots\dots(9)$$

Where, k_2 is the rate constant of pseudo- second- order adsorption ($\text{g mg}^{-1}\text{min}^{-1}$). For the boundary conditions $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$ the integrated form of Eq. (9) becomes

$$1/(q_e - q_t) = 1/q_e + k_2t \dots\dots\dots (10)$$

This is the integrated rate law for a pseudo-second-order reaction. Equation (10) can be rearranged to obtain

Eq.(11), which has a linear form:

$$t/q_t = (1/k_2q_e^2) + ((1/q_e)t) \dots\dots\dots(11)$$

If the initial adsorption rate (h) ($\text{mg g}^{-1}\text{min}^{-1}$) is :

$$h = k_2q_e^2 \dots\dots\dots(12)$$

equation (11) and (12) becomes ,

$$t / q_t = 1 / h + 1 / q_e t \dots\dots\dots (13)$$

The plot of (t/q_t) and t of Eq.(13) should give a linear relationship from which q_e and k_2 can be determined from the slope and intercept of the plot, respectively. The pseudo-second-order rate constants k_2 , the calculated h values, and the correlation coefficients (γ) are summarized in Table 5.

The Elovich equation

The Elovich model equation is generally expressed as

$$dq_t / dt = \alpha \exp (-\beta q_t) \dots\dots\dots(14)$$

Where, α is the initial adsorption rate ($\text{mg g}^{-1} \text{min}^{-1}$) and β is the desorption constant (g mg^{-1}) during any one experiment. To simplify the Elovich equation. Chien and Clayton (1980) assumed $\alpha\beta t \gg 1$ and by AAC applying boundary conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$ Eq.(14) becomes:

$$q_t = 1/\beta \ln (\alpha\beta) + 1/\beta \ln (t) \dots\dots\dots (15)$$

If Fe(III) ions adsorption fits the Elovich model, a plot of q_t vs. $\ln(t)$ should yield a linear relationship with a slope of $(1/\beta)$ and an intercept of $(1/\beta) \ln (\alpha\beta)$. The Elovich model parameters α , β , and correlation coefficient (γ) are summarized in table 5.

The intra particle diffusion model

The intra -particle diffusion model used here refers to the theory proposed by Weber and Morris [41] based on the following equation for the rate constant:

$$q_t = k_{id} t^{(1/2)} + C \dots\dots\dots(15)$$

Where k_{id} is the intra -particle diffusion rate constant ($\text{mg g}^{-1} \text{min}^{-1/2}$) and C is the constant. If the rate limiting step is intra -particle diffusion, the graphical representation of (q_t) adsorbent Fe(III) ions (mg g^{-1}) depending on the square root of the contact time ($t^{1/2}$) should yield a straight line passing through the origin [41].The slope of the plot of q_t Vs $t^{1/2}$ will give the value of the intra -particle diffusion coefficient (k_{id}) and correlation coefficient (γ) indicates the fitness of this model. The intercept value indicates that the curve is not passing through the origin, so the intra-particle diffusion is not only a rate controlling step .The intra-particle parameters are summarized in table 5.

Effect of pH

One of the most important parameters controlling the adsorption process is pH. The effect of pH of the solution on the adsorption of Fe(III) Ions on AAC was determined. The result is shown in Figure. 3. The pH of the solution was controlled by the addition of HCl or NaOH. The uptake of Fe(III) ions at pH 7.5 was the minimum and a maximum uptake was obtained at pH 3.0 – 6.0. However, when the pH of the solution was increased (more than 7.5), the uptake was increased. If AAC bears that a change in pH of the solution results in the formation of different ionic species, different AAC surface changes. At pH values lower than 6, the Fe(III) ions can enter the pore structure. At a pH value higher than 6, the zwitterions form in water may increase the aggregation of Fe(III) ions to form a bigger molecular form (dimer) and become unable to enter the pore structure of the AAC surface.

Effect of the Ionic strength on the Adsorption of Fe(III) ions on AAC

The effect of sodium chloride on the adsorption of Fe(III) ions on AAC is shown in Figure-4 In a low solution concentration. NaCl had little influence on the adsorption capacity. At higher ionic strength the adsorption of Fe(III) ions will be increased due to the partial neutralization of the positive charge on the AAC surface and a consequent compression of the electrical double layer by the chloride ion . The chloride ion can also enhance adsorption of Fe(III) ions onto AAC by the pairing of their charges and hence reducing the repulsion between the Fe(III) ions molecules adsorbed on the surface. This initiates AAC to adsorb more of positive Fe(III) ions .

Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the Fe(III) ions. If the adsorbed Fe(III) ions can be desorbed using neutral pH water, then the attachment of the Fe(III) ions of

the adsorbent is by weak bonds. If sulphuric acid or alkaline water desorbs the Fe(III) ions, then the adsorption is by ion exchange. If organic acids, like acetic acid can desorb the Fe(III) ions, then the Fe(III) ions has been held by the adsorbent through chemisorptions. The effect of various reagents used for desorption studies indicate that hydrochloric acid is a better reagent for desorption, because of more than 68% removal of adsorbed Fe(III) ions. The reversibility of adsorbed Fe(III) ions in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of Fe(III) ions by mineral acids and alkaline medium indicates that the Fe(III) ions were adsorbed ACC through physisorption.

CONCLUSION

The present study proves that Acantheace activated carbon is a good sorbent of Fe(III) ions from aqueous solution. The kinetic study was performed by pseudo second order, Elovich and intra- particle diffusion model. The data indicate intra-particle diffusion is the plays the major role in the adsorption process. The adsorption follows both Freundlich and Langmuir models. Thermodynamics parameters indicate that the sorption is physisorption process

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