Adsorption of Iron (II) from Aqueous Solution Using *Ricinus communis* Pericarp Carbon as an Adsorbent

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ABSTRACT

Activated carbon prepared from *Ricinus communis* pericarp (RCP) was used to remove Fe(II) ions from aqueous solutions by adsorption technique under varying conditions of agitation time, metal ion concentration, adsorbent dosage, pH and desorption. The effective pH was found to be 5 ± 0.2. Adsorption followed both Langmuir and Freundlich isotherm models.

INTRODUCTION

Heavy metals in the environment are of global concern due to their non-degradability and biomagnification. The main goal today is to adopt appropriate methods and to develop suitable techniques either to prevent metal pollution or to reduce it to very low levels (Edwin Vasu 2008). Iron has a broad industrial application. Anthropogenically, entry of iron into the environment is mainly through effluents of industries like ink, paint and pharmaceutical products, mining industries, ore processing, electroplating industries, zinc and steel processing plants. The presence of Fe (II) in water leads to growth of iron bacteria, which in turn leads to undesirable colour, taste and odour to water. Abundant growth of iron bacteria in water leads to a slimy condition. So the water becomes unfit for domestic and industrial purposes. The average iron content recommended in stream water is 0.3 mg/L. Presence of iron in water makes it turbid, besides causing staining of plumbing fixtures and laundry. Moreover, iron precipitates in the gills of fishes, which is deleterious to them (Mukhopadhyay & Konar 1982). Initial symptoms of iron toxicity on humans are vomiting, diarrhoea and damage to intestine (Venkatraman et al. 2007). Iron (II) is also toxic at higher concentrations. It is desirable, therefore, to undertake investigations on the removal of these metal ions from water. Among the various cleanup methods available for metal ions removal, namely, electrolytic reduction, precipitation, oxidation, ultra filtration, ion exchange, adsorption, etc., adsorption (especially, activated carbon adsorption) appears to have the least adverse effects. It includes a broad range of carbonaceous materials at a high degree of porosity and large surface area and finds use for the removal of toxic, biodegradable and non-biodegradable substances from wastewaters. It is attractive as it can treat wastewater to acceptable quality suitable for reuse. The removal efficiency of a *Ricinus communis* pericarp activated carbon iron (II) was attempted in the present study. The effects of contact time, adsorbate dose, pH and desorption were studied.

MATERIALS AND METHODS

Adsorbent: In the present study, pericarp of *Ricinus communis* was used for the preparation of activated carbon .The dried Pericarp was allowed to chemical activation by addition of 50% sulphuric acid with constant stirring (w/v). The charred material was kept in hot air oven at $100 \pm 5°C$ for 12h. This was washed with double distilled water, soaked in 10% sodium bicarbonate solution and allowed to stand overnight to remove the residual acid from pores of the carbon. The material was washed with distilled water, until the pH of the adsorbent reached 7 ± 0.2. It was dried in a hot air oven at $100 \pm 5°C$ for 12h. The dried material was ground and sieved to get the particle size of 125-250 μm. The sieved adsorbent was stored in an airtight container for further experiments. All the chemicals used were of analytical reagent grade obtained from B.D.H and E.Merck. Double distilled water was used for the whole experiment.

Batch mode adsorption studies: A stock solution of 1000 mg/L of Fe (II) was prepared by dissolving 4.9814g of $FeSO_4.7H_2O$ in double distilled water acidified with 2 mL of perchloric acid to prevent hydrolysis and diluted to 1000mL. Batch mode adsorption study was carried out by taking 50 mL of metal solution and 50mg of activated carbon in 100 mL conical flask. The working solution of 10, 20, 30, 40 mg/L of Fe(II) was prepared from stock solution. Batch mode adsorption studies were carried out with 50 mg of the adsorbent and 50 mL of Fe (II) solution of desired concentration at a pH of 5.0 ± 0.2, agitated at 120 rpm in a mechanical shaker at room temperature. The adsorbate solution was separated from the adsorbent by centrifugation at 500 rpm and estimated spectrophotometrically at 510 nm using 1,10 phenonthroline (APHA 1995). The effect of carbon dosage on percent removal of Fe (II) was studied with solutions of 30 mg/L for particle size 125- 250μm. Effect of pH on Fe(II) removal was studied for metal ion concentration of 20 and 30 mg/L using 50 mg of carbon dosage. Langmuir isotherm study was carried out with different initial concentrations of Fe (II) from 5 to 40 mg/L while maintaining the adsorbent dose at 50 mg/50mL. Desorption studies were carried out to confirm the adsorption mechanism proposed above and to recover the metal from the adsorbent using 0.025 to 0.300 M HCl solution.

RESULTS AND DISCUSSION

Adsorbent characterization: Characteristics of activated carbon prepared from *Ricinus communis* pericarp are presented in Table 1. The determined surface area of *Ricinus communis* pericarp activated carbon (RCP) was 495 m²/g and is comparable to various low cost adsorbents namely, peanut hull carbon (Periasamy & Namasivayam 1996) (208 m²/g), *Eichhornia* (Shekinah et al. 2002) (200 m²/g), cassava (Rajeshwari et al. 2001) (200 m²/g) and coconut tree saw dust carbon (Selvi et al. 2001) (325 m²/g). The moisture content of the carbon was 2.50%. The phenol adsorption capacity and decolourizing power were 21.00 mg/g which indicates that the carbon prepared by acid activation method has good adsorption capacity. The surface morphology of *Ricinus communis*

Table1: Characteristics of activated carbon.

Parameters	Value
pH, 1 % solution	6.90
Moisture content (%)	2.50
Ash content (%)	6.50
Decolorizing power (mg/g)	21.00
Ion-exchange capacity (equi g)	0.80
Determination of surface area (m²/g)	495
Bulk density (gm/L)	0.46
Porosity (%)	68.27
Specific gravity	1.46
Particle size (mm)	125-250
Iodine number (mg/g)	468
Yield (%)	70
Calcium (mg/g)	20.0
Sodium (mg/g)	28.8
Potassium (mg/g)	2.3
Water-soluble matter (%)	1.29
HCl soluble matter (0.25 N) (%)	2.45

pericarp carbon (RCPC) was visualized via scanning electron microscopy (SEM), the corresponding SEM micrographs being obtained using a JSM-840 JEOL microscope of JEOL Techniques LTD, Japan at 2000x magnification (Fig 1). Examination of SEM micrographs of the RCPC particles showed rough areas on surface of the carbon and the microspores were identifiable. The activation process of RCPC by adopting sulphuric acid treatment leads to corrode the surface of carbonaceous material and introduce micro, macro and mesopores.

Table 2: Lagergren rate constant for Fe(II) adsorption.

S.No.	Fe(II) concentration in mg/L	K_{ad} (1/min)
1	10	0.0962
2	20	0.0997
3	30	0.0725
4	40	0.0829

Effect of agitation time and initial metal ion concentration on Fe (II) removal: The effect of agitation on the percentage removal of Fe (II) from aqueous solution by activated carbon prepared from *Ricinus communis* pericarp is shown in Fig (2). The removal rate was rapid initially and then slowed down gradually until it attained equilibrium beyond which there was no significant increase in the rate of removal. The equilibrium was attained with in 40 min for all concentrations. The curves obtained were single, smooth and continuous till the saturation of Fe (II) onto activated carbon surface.

Adsorption kinetics: The rate constants of Fe (II) adsorption onto RCP carbon follows first order rate expression given by Lagergren.

$$\log_{10}(q_e - q) = \log_{10}q_e - \frac{k_{ad}t}{2.303}$$

Where q and q_e are the amount of metal ion adsorbed by the adsorbent at time 't' and at equilibrium time respectively. K_{ad} is the rate constant of adsorption in 1/min. The linear plots of $\log_{10}(q_e-q)$ versus t for different metal ion concentrations indicate applicability of the above equation for the adsorption of Fe(II) ion onto activated carbon (Fig. 4). The values of k_{ad} were calculated from the slope of the linear plots and are presented in Table 2.

Effect of carbon dosage on percent removal of Fe (II): The effect of carbon dosage on percent removal of Fe (II) is shown in Fig (3). When the carbon dosage increases, the percent removal also increases. It was found that 100% removal of 30 mg/L of Fe (II) requires 80 mg of carbon respectively.

Adsorption isotherm: The Langmuir isotherm can be applied for adsorption equilibrium of Fe (II) onto RCP carbon.

Table 3: Analysis of Langmuir isotherm for Fe(II) adsorption.

Sl. No.	Initial Fe (II) concentration (mg/L)	R_L	Q_0 (mg/g)	b (L/mg)
1	5	0.1278	32.15	1.3642
2	10	0.0682		
3	15	0.0465		
4	20	0.0353		
5	25	0.0284		
6	30	0.0238		
7	35	0.0205		
8	40	0.0179		

$$\frac{C_e}{q_e} = \frac{1}{Q_0 b} + \frac{C_e}{Q_0}$$

Where, C_e is the equilibrium concentration (mg/L). q_e is the amount of Fe (II) adsorbed (mg/g), Q_0 and b are Langmuir constants related to adsorption capacity and energy of adsorption, respectively. The linear plot of C_e/q_e Vs C_e shows that the adsorption follows Langmuir isotherm model (Fig. 5). The value of Q_0 and b calculated for 5-40mg/L concentrations were,

Q_0 = 32.15 mg/g

b = 1.3642 L/mg

Langmuir isotherm can be expressed in terms of dimensionless separation factor or equilibrium parameter (Mckay et al. 1980) and can be written as,

$$R_L = \left(\frac{1}{1 + bC_0} \right)$$

Where,

C_0 is the initial Fe (II) concentration in mg/L and b is the Langmuir constant (L/mg).

The type of isotherm can be revealed by R_L value.

R_L value   *Type of isotherm*

$R_L > 1$ Unfavourable
$R_L = 1$ Linear
$0 < R_L < 1$ Favourable
$R_L = 0$ Irreversible

R_L values (Table 3) between 0 and 1 for Fe (II) metal ion at different concentrations indicate favourable adsorption.
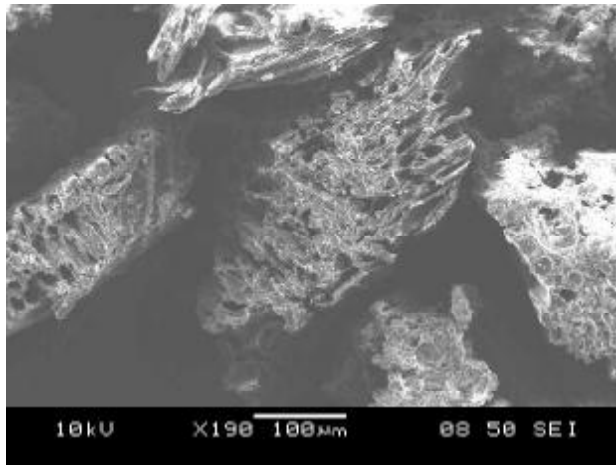

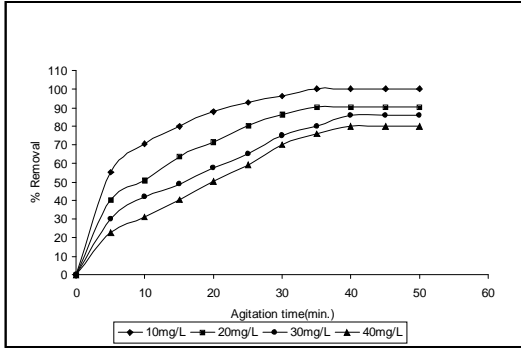Fig.1: SEM photograph of the RCP carbon.

Fig.2: Effect of agitation time and initial Fe(II) concentration on Fe(II) adsorption.
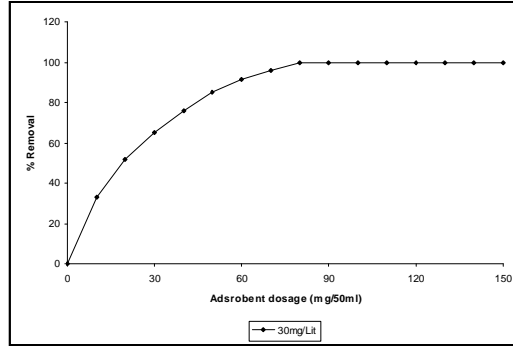

Fig.3: Effect of adsorbent dosage on Fe(II) adsorption.
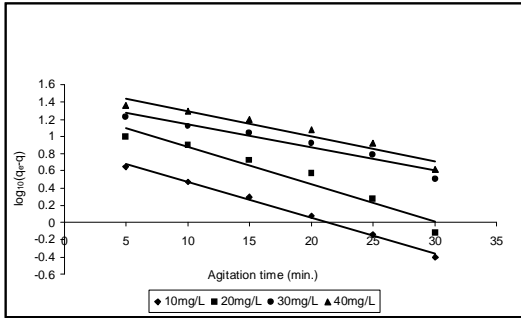

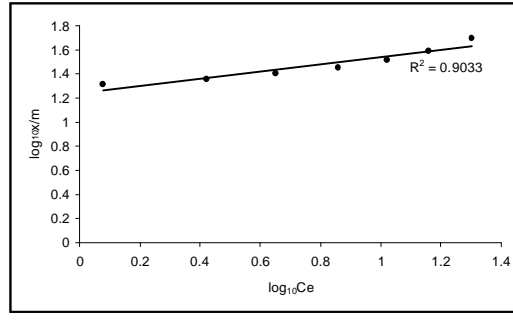Fig.4: Lagergren plots for Fe (II) adsorption.

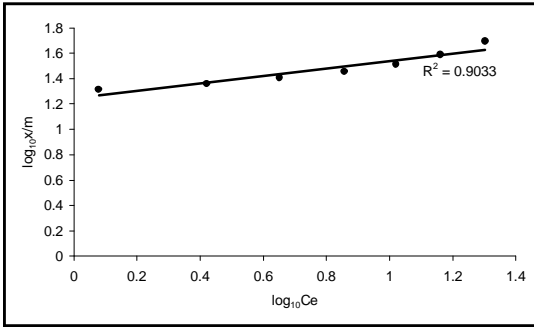Fig. 5: Langmuir plot for Fe(II) adsorption.
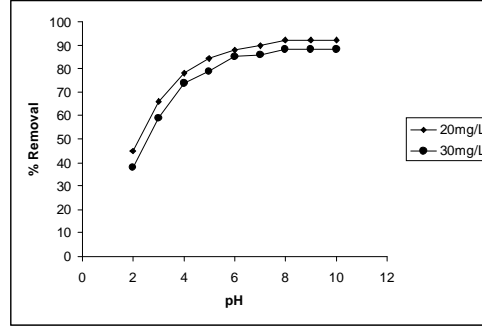

Fig.6: Freundlich plot for Fe(II) adsorption.

Fig. 7: Effect of pH on Fe(II) adsorption.

The linear form of Freundlich equation can be given by:

$$\log_{10}(x/m) = \log_{10}k_f + \frac{1}{n}\log_{10}C_e$$

Where, x is the amount of Fe (II) adsorbed at equilibrium (mg), m is the weight of adsorbent used (mg), C_e is the equilibrium concentration of Fe(II) in solution (mg/L). k_f and n are constants. Linear
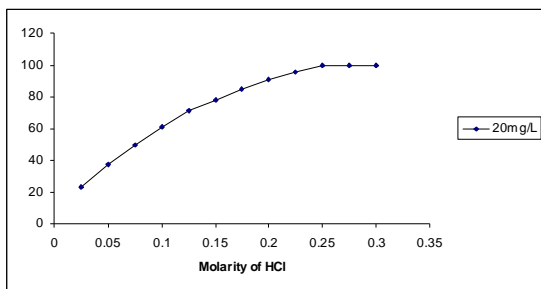
Fig.8: Effect of HCl concentrtion on desorption of Fe(II).

plot of log x/m Vs log C_e shows that the adsorption follows Freundlich isotherm (Fig. 6). The Freundlich constants k_f and n are found to be 17.534 and 3.388.

Effect of pH on Fe (II) removal: Effect of pH on Fe(II) removal is shown in Fig. 7. Adsorption increases with increase in pH from 2.0 to 10. The precipitation was observed from the results at pH 6.0 onwards and the intensity of precipitation increases with the increase in pH from 6.0 to 10.0. The removal of metal ions increases with increase in pH from 6 .0 to 10.0 even without adsorbent, this may be due to the formation of metal hydroxide precipitation.

Desorption studies: Attempts were made to regenerate metal ion from the laden carbon using various strengths of HCl from 0.025M to 0.300M (Fig. 8). Desorption data indicate that the mechanism of adsorption is the ion-exchange process and the complete regeneration of adsorbate and adsorbent is possible

CONCLUSION

The activated carbon prepared from *Ricinus communis* pericarp carbon can be used for removal of Fe (II) from aqueous solution effectively. The adsorption depends on solution pH, initial metal ion concentration and carbon dose. The adsorption followed both Langmuir and Freundlich isotherm models. Desorption data indicate that the mechanism of adsorption is the ion-exchange process and the complete regeneration of adsorbate and adsorbent is possible.

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