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Research Article

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Kinetics of Adsorption of Copper (II) Ion on to Activated Carbon Prepared from bark of *Erythrina Indica*

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ABSTRACT

A basic investigation on the kinetics of adsorption of Copper (II) ion from aqueous solution by activated carbon prepared from bark of *Erythrina Indica* has been carried out under batch mode. The influence of various parameters such as effect of initial concentration, adsorption dose and agitation time were studied. Experimental data were fitted into linearised form of Lagergren and Ho kinetic equations for pseudo first order and pseudo second order models respectively. The kinetic parameters have been calculated and discussed in detail. The results revealed that the adsorption of Copper (II) ion onto chosen adsorbent followed the pseudo first order kinetics. Intra particle diffusion was confirmed as one of the rate determining steps using Webber Morris plot parameters.

Keywords: Adsorption, Kinetics, Copper (II) Ion, Activated Carbon

ARTICLE INFO

CONTENTS

1. Introduction	1673
2. Materials and Methods	1674
3. Results and Discussion	1674
4. Conclusion.	1676
5. References	1676

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1. Introduction

Heavy metals have been used by humans for thousands of years. Although several adverse health effects of heavy

metals have been known for a long time, exposure to heavy metals continues in less developed countries. The heavy

metals are of special concern because they are non-degradable and therefore persistent. Commonly encountered heavy metals are Pb^{2+} , Cu^{2+} , Zn^{2+} , Co^{2+} , Ni^{2+} etc. These metals are toxic both in their chemically combined forms and in the elemental form [1].

Environmental contamination due to copper is caused by mining and metal plating industry and agricultural sources such as fertilizers, fungicidal sprays, and animal wastes [2]. The presence of copper (II) in wastewater is also a problem. When Cu (II) ion is ingested at high concentrations it can become toxic to humans, causing cancer and promoting oxidation [3]. Conventional methods such as precipitation, coagulation/flocculation, ion exchange, cementation, complexation/ sequestration, electrochemical operation and biological treatment have been used for the removal of Cu (II) from aqueous solution. Removal of Copper by activated carbon has gained industrial importance recently. Many reports have appeared on the development of activated carbon from cheaper and readily available materials [4]. The objective of this work was to evaluate the potential of activated carbon prepared from bark of *Erythrina Indica* for the removal of Copper (II) ions from water.

2. Materials and Methods

2.1 Preparation of Adsorbent

The bark of *Erythrina Indica* were cut into smaller pieces and soaked in concentrated H_2SO_4 in at 1:1 ratio (W/V) for 48 hour and activated at $160^\circ C$ for 6 h. The activated carbon was repeatedly washed with distilled water until the pH of the wash water become neutral. The carbon obtained was dried at $110^\circ C$ for nearly 2 h to remove the moisture. The above prepared carbon was designated as *Erythrina Indica* Bark Carbon (EIBC) and kept in a desiccator.

2.2 Adsorption Studies

Adsorption of Copper (II) ions onto EIBC was carried by a batch method. The effect of contact time and initial concentration of copper (II) ions were investigated at three temperatures were 305, 315 and 325 K. The adsorption process was carried out with three different initial concentrations at 25 mg/L, 50 mg/L and 75 mg/L of Copper (II) ion. 50 mg of adsorbent was taken in 100 mL iodine flask. 50 mL of the adsorbate solution was added to the flask. This aliquot was shaken in rotary shaker at 150 rpm for predetermined time. Then the solution was centrifuged and the adsorbate concentration of the centrifugate was measured using Systronics Double Beam UV-visible Spectrophotometer: 2202 at 555 nm to determine the percentage removal of the adsorbate from the solution. The kinetic experiments were performed with the working pH 7 and for contact times 5, 10, 20, 40, 60, 80, 100, 120, 140, 160 and 180 minutes [5, 6].

2.3 Kinetics Studies

2.3.1 Pseudo First order kinetics

Lagergren equation is

$$\log (q_e - q_t) = \log q_e - k_1 / 2.303 \times t$$

Where q_e and q_t are the amounts of adsorbate adsorbed (mg/g) at equilibrium and at time t (min), respectively and

k_1 is the pseudo first rate constant of adsorption (l/min) [7].

2.3.2 Pseudo Second order kinetics

Ho equation is

$$t/q_t = 1/k_2 q_e^2 + 1/q_e t$$

The equilibrium adsorption capacity (q_e) and the pseudo second order constants k_2 (g/ (mg.min)) can be determined experimentally from the slope and intercept of plot of t/q_t versus t [8].

The initial adsorption rate, h (mg/(g min)), as $t \rightarrow 0$ can be defined as

$$h = k_2 q_e^2$$

The initial adsorption rate (h).

2.3.3 Intra particle diffusion

Weber–Morris equation is

$$q_t = k_p t^{1/2} + C$$

Where k_p is the intra-particle diffusion rate constant, a plot of q_t versus $t^{1/2}$ should be a straight line with a slope k_p which is the rate constant for intra particle diffusion and intercept C is the thickness of the boundary film [9].

2.3.4 Test for kinetics models

The percentage sum of error squares is given below

$$SSE (\%) = [(q_e)_{exp} - (q_e)_{cal}]^2 / N$$

Where N is the number of data points, $(q_e)_{exp}$ is the experimental q_e , $(q_e)_{cal}$ is the calculated q_e [7].

3. Results and Discussion

3.1 Effect of Dose

The adsorption of Copper (II) ion onto EIBC was studied. by varying the dose of the adsorbent from 10 mg/ 50 mL to 70 mg/ 50 mL by taking 50 mg/ L of the adsorbate concentration which were shown in the Figure 1. The percentage of removal of Copper (II) ions from aqueous solution increased with increase of carbon dose. This is due to the increased carbon surface area and availability of more adsorption sites [1]. 50 mg of adsorbent per 50 mL of adsorbate solution was chosen for further studies.

3.2 Effect of contact time for different initial concentrations

The experimental results for adsorption of Copper (II) ion onto activated carbon at various concentrations (25, 50 and 75 mg/L) and contact times at 305 K temperature as representative graph are shown in Figure 2. The equilibrium data reveal that percentage of removal decreased with increase in initial Copper ion concentration but the actual amount of Copper ion adsorbed per unit mass of carbon increased with increase in metal ion concentration. This means that the adsorption is highly dependent on the initial concentration of Copper ion. This is because the ratio between the surface available on the adsorbent and the concentration of metal ion in the solution phase decrease with the increase of initial concentration of the solute [5 & 10].

3.3 Effect of temperature

The percentage of removal increased with an increase of temperature of the solution for all studied initial concentrations of the metal ion. The results are given in Table 1. Plots of percentage removal versus temperature were given in Figures 3. The reason may be as follows, at higher temperature, pores may widen up due to increased

vibration. So that more number of solute may enter into the pore and get adsorbed in the inner part of the pore surfaces.

3.4 Kinetic models

The results obtained from pseudo first order and second order kinetic models for Copper (II) ions were presented in Table 2. Representative graphs at 305 K were shown in Figures 4, 5 and 6. The pseudo first order rate constant k_1 (min^{-1}) ranged from 0.027 to 0.461 and pseudo second order rate constant k_2 ($\text{g/mg}\cdot\text{min}$) ranged from 1×10^{-3} to 4.5×10^{-3} . The initial sorption rate 'h' increases directly with an increase of initial Copper (II) ion concentration at each temperature. Experimental q_e (exp), calculated q_e (cal) and SSE % for the pseudo first order and pseudo second order kinetics were given in Table 2. It shows that q_e (exp) is close to q_e (cal) for first order kinetics. It can be seen that SSE (%) value is lower for the first order kinetic model than that of pseudo second order kinetic model. This confirms the applicability of the pseudo first order kinetic model. The determination coefficient (R^2) for pseudo second order model ranged between 0.968 and 0.997 whereas these values for the first order model were close to 1. It indicates that the experimental data best fitted into pseudo first order. Intra particle diffusion rate constant K_p values were found to increase with an increase of Copper (II) ion concentration that reveals the rate of adsorption is governed by the diffusion of adsorbed Copper (II) ions within the pores of the adsorbent. Present results show the pore diffusion limits the overall rate of the Copper (II) ion adsorption [6, 11 & 12].

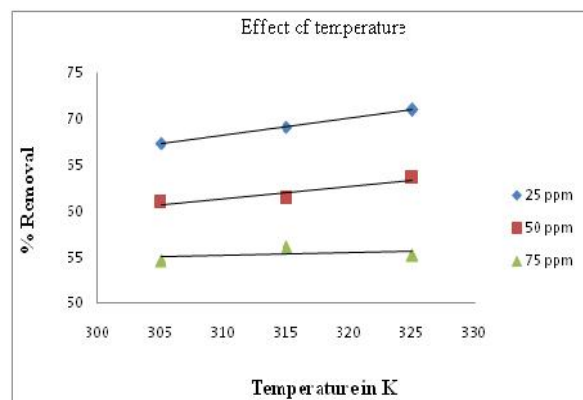


Figure 3

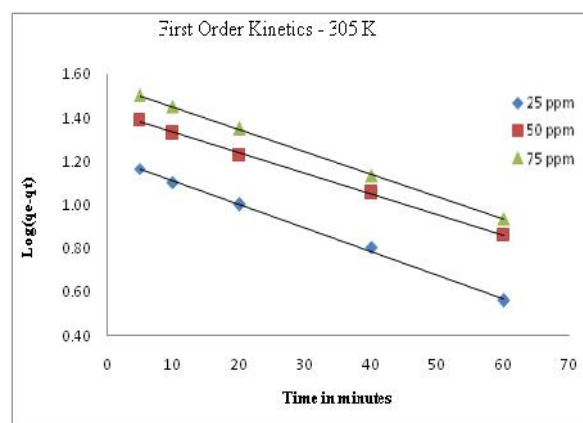


Figure 4

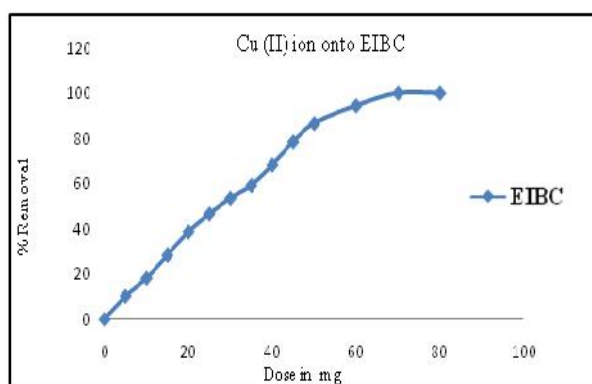


Figure 1

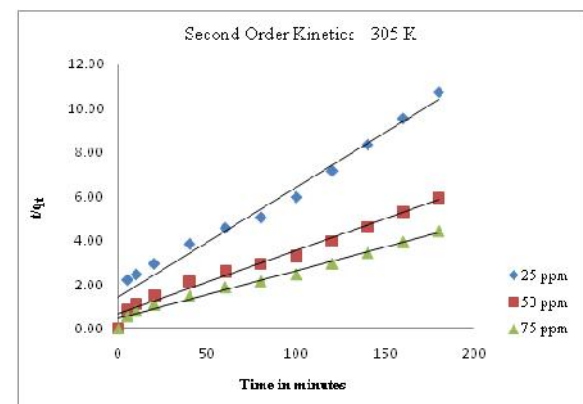


Figure 5

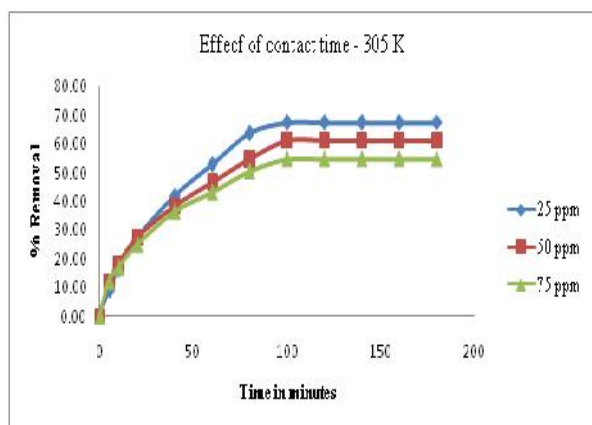


Figure 2

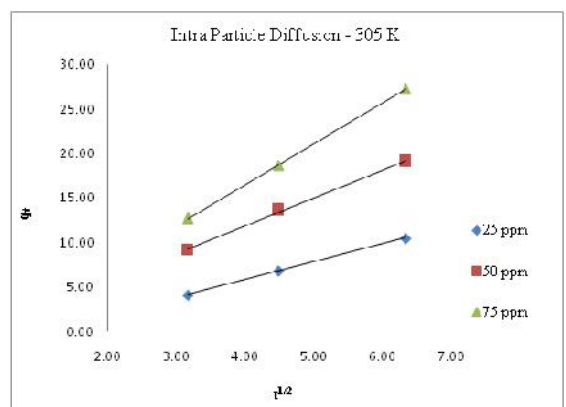


Figure 6

Table 1: Effect of temperature on Cu (II) ion adsorption

Initial Concentration (mg/L)	Temperature (K)	% Removal
25	305	67.27
	315	69.09
	325	70.91
50	305	60.91
	315	61.36
	325	63.64
75	305	54.55
	315	56.06
	325	55.15

[pH = 7; Dose = 50 mg/ 50 mL; Contact time = 180 min]

Table 2: Kinetic parameters for the removal of Copper (II) ion by EIBC

C (ppm)	T (K)	First Order Kinetics					Second Order Kinetics					Intra Particle Diffusion	
		k_1 (min^{-1})	$q_{e(\text{cal})}$ (mg/g)	$q_{e(\text{exp})}$ (mg/g)	R^2	SSE %	$k_2 \times 10^{-3}$ (g/mg·min)	$q_{e(\text{cal})}$ (mg/g)	h	R^2	SSE %	k_p (mg/g·min)	R^2
25	305	0.0207	16.48	16.82	0.998	0.499	1.7	20.41	0.71	0.968	2.389	2.01	0.999
	315	0.0276	15.99	17.27	0.995		3.6	19.23	1.32	0.989		2.01	0.999
	325	0.0415	17.78	17.73	0.998		4.5	19.23	1.66	0.991		2.58	0.998
50	305	0.0217	26.73	30.45	0.998		1.2	35.71	1.55	0.98		3.42	0.997
	315	0.0299	22.08	34.55	0.998		3.8	37.04	5.15	0.997		2.88	0.999
	325	0.0438	29.30	31.82	0.995		2.7	34.48	3.24	0.992		4.03	0.999
75	305	0.0230	35.72	40.91	0.999		1.0	47.62	2.34	0.984		4.60	0.999
	315	0.0345	44.66	48.64	0.997		2.6	52.63	7.09	0.996		3.58	0.999
	325	0.0461	39.81	41.36	0.997		2.4	45.45	4.93	0.995		5.26	0.987

*C – Concentration in ppm,

T – Temperature in K

4. Conclusion

The adsorption dynamics of Copper (II) ion onto *Erythrina Indica* bark Carbon was studied. Adsorption experiments were carried out as a function of contact time, initial concentration in a batch mode process. Experimental data indicated that EIBC adsorbent was effective in removing Copper (II) ion from aqueous solution. The percentage of removal increased with an increase in contact time and achieved equilibrium around 100 minutes when 50 mg EIBC was used as adsorbents for 50 mL solution. Adsorption capacity of EIBC was found to be higher at higher initial concentrations. In the kinetics studies, R^2 value and SSE (%) revealed that the process of adsorption followed pseudo first order kinetics.

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