



Sorption dynamics of acid and basic dyes onto activated carbon derived from ipomoea carnea stem waste

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ABSTRACT

Activated carbon materials were prepared from abundantly available *Ipomoea Carnea* stem waste. A series of carbon samples were prepared by subjecting the carbon material to various chemical processes. These materials accumulate superior properties and good adsorption behaviours. The adsorption capacity of selected derived carbon sample using *Ipomoea Carnea* stem waste prepared by Dolomite process was much greater than the capacities of the other carbons prepared by various processes. The adsorption of Acid Red 2 (Acid dye) and Basic Violet 10 (Basic dye) on this dolomite treated activated carbon was investigated to assess the possible use of this adsorbent for the processing of dyeing industry wastewater. The influence of various factors such as initial dye concentration, agitation time and Particle size on the adsorption capacity has been studied. The percentage removal of dye is observed to decrease with the increase in initial dye concentration. The adsorption of dye also decreases with increase in Particle size. Kinetic data have been studied using Pseudo-first order and Pseudo-second order equations for understanding the reaction mechanism.

Keywords: Activated Carbon, Acid Red 2, Basic Violet 10, Adsorption

INTRODUCTION

Many reports have appeared on the development of low cost activated carbon adsorbents developed from cheaper and readily available materials [1]. Nanoporous carbon material with large surface area, micro porous character and chemical nature of their surface have made them potential adsorbents for removal of heavy dyes from industrial wastewater. The adsorptive properties of activated carbon for removal of pollutants are well documented [2]. Adsorption of hazardous soluble chemicals from wastewater in to surface of a solid adsorbent has provided a new dimension to wastewater technology [3]. One of the major challenges associated with adsorption by activated carbon is its cost effectiveness. This has led many workers to search for cheaper substitutes. Crab shell [4], peanut hull pellets [5], Petiolar felt-seath of palm [6], corn starch [7], soyabean hull and sugar beat fibre [8], rice husk [9], spent grain [10], de-oiled soya [11], *Ipomoea carnea* stem [12], *Leuceana leucocephala* shell waste [13], turmeric waste [14] and sawdust [15] are some new adsorbents, which have been tried with varying success. Moreover, the affinity of carbon surface towards solute molecules must be enhanced in order to increase the extent of solute adsorption. Comparison of size information available for commercial activated carbon pores and solute molecules in natural waters suggest that some fractions of solute will be able to access finer carbon pores [16]. In the present work, we have prepared activated carbon from *Ipomoea carnea* stem waste which is used as an adsorbent for Acid Red 2 and Basic Violet 10 removal and the adsorption capacity of chosen adsorbent was regulated by many influencing factors such as Particle size, pH and initial dye concentrations. The kinetic adsorption data obtained were correlated to characterize the prepared carbon sample for the adsorption of Acid Red 2 and Basic Violet 10.

MATERIALS AND METHODS

Preparation of Adsorbent

The raw stems of Ipomoea Carnea were cut into small pieces and dried in sunlight until the moisture was evaporated. The dried materials were used for the preparation of activated carbons using physical and chemical activation methods. The stem waste material was treated with dolomite for a period of 24 hours. Then the material was placed in the muffle furnace carbonized at 400°C. The dried materials were powdered and activated in a muffle furnace kept at 800°C for a period of 60 minutes. After activation, the carbon obtained was washed with plenty of water, dried and sieved to desired particle size .

Preparation of Adsorbate

The textile dyes Acid Red 2 and Basic Violet 10 were obtained as research grade chemicals and were used without purification. The stock solutions of respective dyes were prepared by dissolving 1 g of dye in 1000 mL of double distilled water and used for further studies by diluting as concentrations required.

Batch adsorption studies

All reagents used were of AR –grade (E-merk). Different concentrations of dye solution of Acid Red 2 and Basic Violet 10 were prepared with distilled water. 50 ml of each of this dye solution of known initial concentration (C_0) and initial pH was taken in a 100 ml screw-cap conical flask with a required amount of adsorbent and was agitated at a speed of 200 rpm in a temperature controlled thermostatic shaker bath at 30⁰ C for a specified period of time. Then the solution was filtered and the concentrations of dye in solutions were determined before and after adsorption using Elico UV-visible spectrophotometer. The amount of dye adsorbed and adsorption efficiency were calculated .

Determination of Acid Red 2 and Basic Violet 10

These dyes were estimated spectrophotometrically. The amount of dye adsorbed in mg/L at time ,t was computed by using the following equation.

$$q_t = \frac{C_0 - C_t}{m_s} \times V \quad (1)$$

where, C_0 and C_t are the dye concentration in mg/L initially and at given time t, respectively, V is the volume of the dye solution in ml and m_s is the weight of the activated carbon. The percentage of removed dyes in solution was calculated using equation. (2)

$$\% \text{ Removal} = \frac{C_0 - C_t}{C_0} \times 100 \quad (2)$$

Adsorption dynamics

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 adsorption on the activated carbon was analyzed using pseudo first order Lagergren, pseudo second order kinetic models .The conformity between experimental data and the model predicted values was expressed by the correlation coefficients. A relatively high R^2 value indicates that the model successfully describes the kinetics of dye adsorption.

The pseudo first – order equation

The pseudo first – order Lagergren equation [17] is generally expressed as follows.

$$\frac{dq_t}{dt} = k_1(q_e - q_t) \quad (3)$$

where, q_e and q_t are the adsorption capacity at equilibrium and at time t, respectively (mg g^{-1}), k_1 is the rate constant of pseudo first –order adsorption (lmin^{-1}). After integration and applying boundary conditions $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$, the integration form of equation (3) becomes.

$$\log(q_e - q_t) = \frac{\log(q_e) - k_1}{2.303} \times t \quad (4)$$

The value of $\log (q_e - q_t)$ were linearly correlated with t . The plot of $\log (q_e - q_t)$ Vs t should give a linear relationship from which k_1 and q_e can be determined from the slope and intercept of the plot, respectively.

The pseudo second – order equation.

The pseudo second – order adsorption kinetic rate equation [18] is expressed as

$$\frac{dq_t}{dt} = k_2(q_e - q_t)^2 \quad (5)$$

where, k_2 is the rate constant of pseudo second order adsorption ($\text{g} \cdot \text{mg}^{-1} \cdot \text{min}^{-1}$). For the boundary conditions $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$, the integrated form of equation (5) becomes.

$$\frac{1}{q_e - q_t} = \frac{1}{q_e} + k_2 t \quad (6)$$

Which is the integrated rate law for pseudo second – order reaction. Equation (6) can be rearranged to obtain equation(7), which has a linear form.

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (7)$$

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

$$h = k_2 q_e^2 \quad (8)$$

Then, Equations. (7) And (8) become:

$$\left(\frac{t}{q_t} \right) = \frac{1}{h} + \frac{1}{q_e} t \quad (9)$$

The plot of (t/q_t) and t of equation (7) should give a linear relationship from which q_e and k_2 can be determined from the slope and intercept of the plot, respectively.

RESULTS AND DISCUSSION

Surface characters of activated carbon

The morphology of the surface of the prepared activated carbon sample was examined using Scanning Electron Micrographs. Ipomoea Carnea Activated Carbon (ICAC) has many pores, small cavities and rough areas with micro pores which were clearly found on the surface. This shows that dolomite treatment created welldeveloped pores with uniform distribution on the surface of the precursor, therefore leading to the activated carbon with large surface area and porous structure. The morphological study by SEM of the above adsorbent shown in the Fig. 1 revealed that it is highly porous in nature (Yoshida et al. 1993).

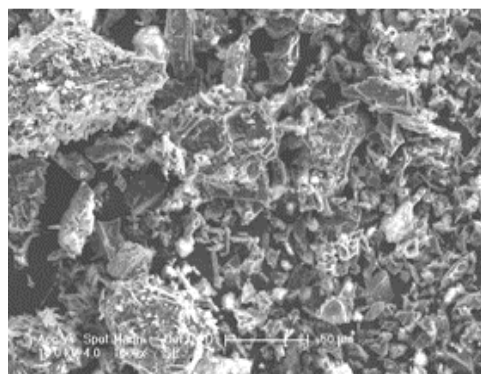


Figure. 1 SEM image of ipomea Carnea stem waste

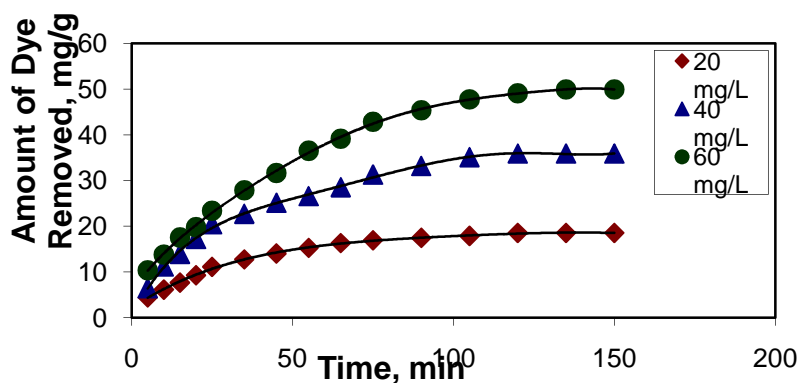


Figure. 2 Effect of Agitation time and initial dye concentration On Acid Red 2 Adsorption

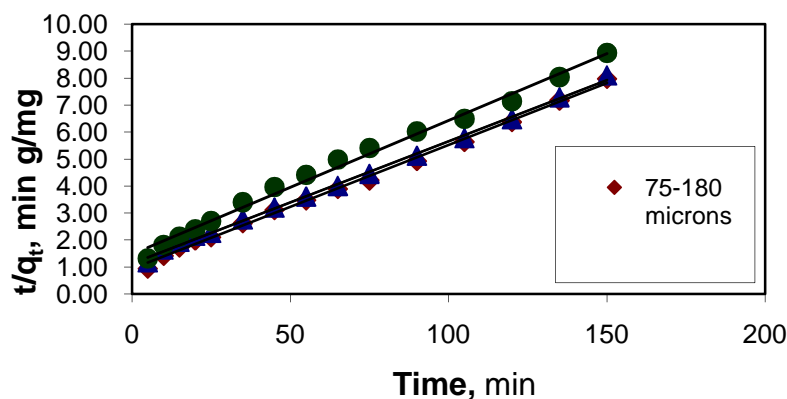


Figure 3 Effect of particle size Variation on Pseudo Second Order Plot for Acid Red 2 Adsorption

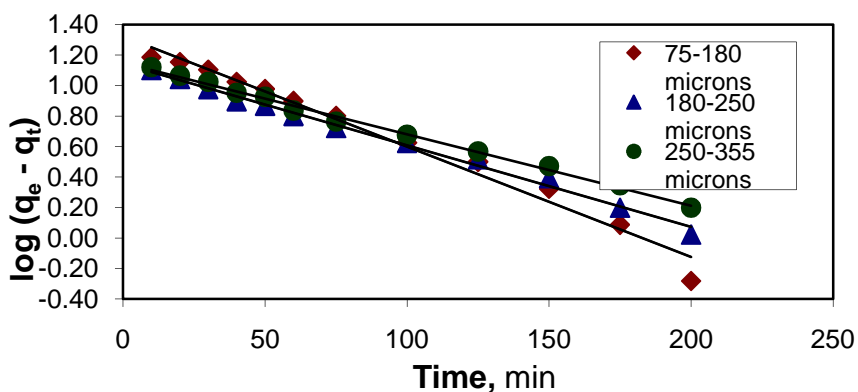


Figure 4 Effect of particle size Variation on Pseudo First Order Plot for Basic Violet 10 Adsorption

Effect of pH

The pH value of the solution being an important controlling parameter in adsorption is mainly influenced by two factors: (i) Distribution of the dye ionized species in the solution phase and (ii) Overall charge of the adsorbent. Therefore the interaction between dye molecule and the adsorbent is basically a combined result of charges on the dye molecules and the surface of the adsorbent. The adsorption behaviour of the dye on the adsorbent was studied over a wide pH range of 2 -10. It is Observed that the pH significantly affects the extent of adsorption of dye over the adsorbent and a reduction in the amount adsorbed dye with increasing pH was observed. The maximum uptake of the Acid Red 2 and Basic Violet 10 was observed at pH 5.0 and pH 4.0 as well as a large decrease in adsorption capacity was observed as the pH was increased above the pKa value of Acid dye and the reverse pattern was observed for Basic dye.

Effect of Agitation time and Initial dye Concentration

The uptake of Acid dye from water by activated carbon increases when the agitation time was varied from 10 to 160 minutes and attains equilibrium at 160 minutes and when the temperature was 30°C, pH 6.5, initial concentration of the dye solutions used was 20 mg/L and the adsorbent dosage of 50mg and 240 minutes for Basic dye. As the initial dye concentration increases from 20 mg/L to 60 mg/L, the amount of dye removal also increases. The increase in adsorption of dye with increase in agitation time may be attributed to the increased intra particle diffusion occurring at long shaking time (Fig. 2). A similar result was observed by Rao & Bhole [20] in the removal of chromium using fly ash and bagasse.

Effect of particle size on kinetic rate constant and rate parameters

For this adsorption process, adsorption experiments were carried out with fixed initial dye concentration (20mg/L) and pH 6.5 with different particle size viz. 75-180, 180-250 and 250-355 μm . The analysis of the data in Table 1 and 2 reveals that the influence of particle size on the adsorption of both the dyes have comparatively little effect on the pseudo first order rate constants. The table 1 and 2 also reveals that the influence of the particle size on pseudo second order (Fig.3) rate constant is appreciable. It is obvious that the adsorption of dye onto the adsorbent is best described by pseudo second order rate equation with regression coefficient value which is greater than 0.98.

Table 1. The adsorption kinetic model rate constants for Activated Carbon ICAC with different particle size

Dye	Particle size	Pseudo first order		Pseudo Second order		
		k_1 lmin^{-1}	R^2	k_2 $\text{g mg}^{-1} \text{min}^{-1}$	h $\text{mg g}^{-1} \text{min}^{-1}$	R^2
AR 2	75-180 μm	0.0191	0.9722	0.0024	1.1284	0.9983
	180-250 μm	0.0184	0.9751	0.0010	2.123	0.9896
	250-355 μm	0.0209	0.9511	0.0013	1.9827	0.9873

Table 2. The adsorption kinetic model rate constants for Activated Carbon ICAC with different particle size

Dye	Particle size	Pseudo first order		Pseudo Second order		
		k_1 lmin^{-1}	R^2	k_2 $\text{g mg}^{-1} \text{min}^{-1}$	h $\text{mg g}^{-1} \text{min}^{-1}$	R^2
BV 10	75-180 μm	0.0110	0.9823	5.6195	2.7626	0.9929
	180-250 μm	0.0122	0.9653	0.0012	1.7989	0.9948
	250-355 μm	0.0170	0.9752	9.5300	2.2968	0.9917

CONCLUSION

In the present study, adsorption of Acid Red 2 and Basic Violet 10 on activated Ipomoea carnea carbon has been investigated. The data obtained through this work support that the Ipomoea carnea carbon is an effective low cost adsorbent for the removal of these dyes from aqueous solution. The dye adsorption is dependent on the initial concentration and agitation time. Equilibrium of Acid Red 2 and Basic Violet 10 adsorption reaches at 160 minutes and 240 minutes respectively.

The pseudo-second order equation provided a best fit description for the sorption of Acid Red 2 and Basic Violet 10 onto Ipomoea carnea stem waste carbon, as it had better correlation coefficient values than pseudo first order equation. Therefore, pseudo-second order was considered the most appropriate due to high correlation coefficient when compared to pseudo first order equation. The adsorption of Acid Red 2 and Basic Violet 10 onto Ipomoea carnea stem waste carbon gave better results.

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