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Kinetic Modeling of Adsorption of Remazol Black 5 Dye Using a Low Cost Activated Carbon Obtained from Bauhenia Racemosa Seed Pod Carbon

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Abstract:
Adsorption process has been found to be one of the best treatment methods for the removal of dyes from aqueous solution. This study was carried out to examine the adsorption capacity of the low cost adsorbent prepared from ripened Bauhenia racemosa seed pods(BRSP) for the removal of Remazol black 5(RB5) dye from aqueous solution. The influence of contact time, pH, adsorbent dose on the adsorption process was studied. The experimental results indicated that the rate of adsorption increased rapidly with time and equilibrium was attained within about eighty minutes. The adsorption kinetics of Remazol black 5 onto the low cost adsorbent used in this study followed first order Lagergren kinetic rate equation. The intra particle diffusion study shows that the rate constants for intra particle diffusion (Kp)increased with increase in initial concentration of Remazol black 5 solution.

Keywords: *Bauhenia Racemosa, Remazol black 5, Kinetic modeling, Intra particle diffusion*

1. Introduction

Improper disposal methods and inadequate control of toxic effluents from various industries have lead to the wide spread contamination of surface as well as ground water resources. The conventional methods for the treatment of coloured waste water are physical, chemical and biological treatments. However these techniques are not applicable on large scale because of its high cost and sludge disposal problems[1]. The adsorption process is an effective and efficient method for the removal of dyes from effluents due to its low cost, simplicity of design, ease of operation and insensitivity to toxic pollutants. Most of the commercial systems currently use commercial activated carbon as adsorbent for waste water treatment. But because of its high cost and regeneration problem there has been a constant search for potential low cost adsorbents.[2]. Some low cost naturally occurring adsorbents such as Chitosan, Zeolites, Fly ash, Coal, Agricultural wastes, Rice straw, Papaya seeds, Orange peel, Neem leaves, and Moringa olifera barkhave been identified to be good sources of activated carbon which make them useful to a host of applications[4-6].

Remazol black 5 is a vinyl sulphone fiber reactive dye that is often used to dye Cotton, Silk and Wool. The vinyl sulphone group present in the dye is covalently bonded with the fiber during the dyeing process[7]. Under anaerobic conditions azo group can be reduced to form aromatic amines which are colourless but are toxic and carcinogenic.[8]

Thus the objective of the present study is to investigate the adsorptive removal of Remazol black 5 dye from aqueous solution by using a low cost adsorbent prepared from ripened *Bauhenia racemosa* seed pod carbon.

2. Materials and Methods

The activated carbon was prepared from the ripened seed pods of *Bauhenia Racemosa* by treatment with conc.sulphuric acid. The *Bauhenia Racemosa* belonging to the family ***Caesalpiniaceae*** and is abundantly found in Tamil Nadu, Kerala and Karnataka.

2.1. Preparation of the Adsorbent

The adsorbent was prepared by following the literature given in our previous paper[9]. The ripened *Bauhenia Racemosa* seed pods were collected and cut into small pieces, dried in sunlight for 10 days and further dried in hot air oven at 60^0C for 24 hours. The completely dried material was powdered well and chemically activated by treating it with concentrated sulphuric acid with constant stirring and kept for 24 hours. It is then activated at 110^0C in the hot air oven for 12 hours. The carbonized material thus obtained was washed well with plenty of distilled water several times to remove the excess acid present and then dried at 100^0C to 120^0C in a hot air oven for 24 hours. The adsorbent thus obtained was ground well and sieved through a 125-250 mesh and kept in air tight containers for further use.

2.2. Preparation of Adsorbate
Stock solution (1000 mg/L) of Remazol black 5 dye was prepared by dissolving 1g dye in 1000 ml of double distilled water. All the test solutions were prepared by diluting the stock solution with double distilled water.

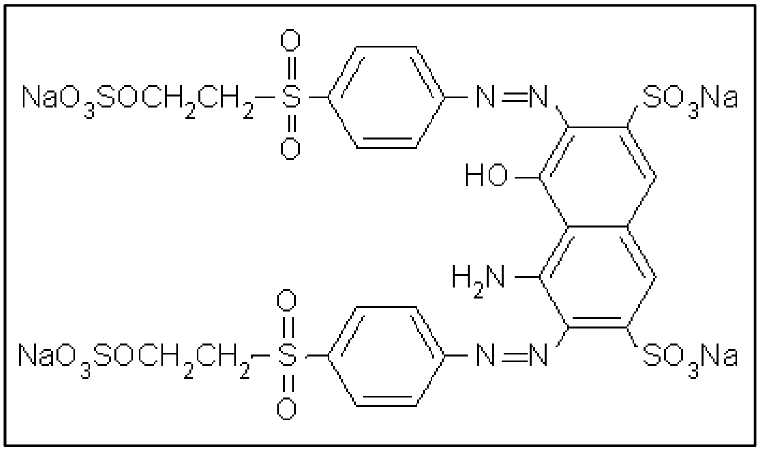

Figure 1: Chemical structure of Remazol black 5

2.3. Equipments
- Elico pH meter was used to measure pH
- Digital Systronic model 104 Spectrophotometer was used for measuring the concentration of the dye solution.
- Lab line mechanical shaker with temperature control was used for shaking the solution containing adsorbent and adsorbate.

2.4. Adsorption Studies
Batch mode experiments were performed to study the effect of contact time, concentration of the adsorbate, pH, and adsorbent dose which influence the removal of RB5 dye by adsorption. In the batch adsorption experiments 50 ml of the dye solutions of the desired concentration and pH were taken in Pyrex bottles containing pre-determined weighed amounts of adsorbents. The pyrex bottles containing adsorbent and adsorbate were equilibrated by shaking the contents at room temperature using thermo stated rotary shaker (200 rpm) for different time intervals (10,20,40,60,80,100 and 120 minutes). Then the solutions were filtered using Whatmann 40 filter paper and the filtrates were analysed for the RB5 dye concentration spectrophotometrically at a wavelength of 597 nm against a reagent blank.

$$\text{Removal of RB5 dye in \%} = \frac{C_o - C_e}{C_0} \times 100 \quad (1)$$

Where C_o and C_e (mg/L) are the initial and equilibrium concentration of RB5dye respectively.
The amount of dye adsorbed at equilibrium (q_e) was calculated from the equation.

$$q_e = \frac{(C_0 - C_e)}{M} V \quad (2)$$

Where q_e is the amount of dye adsorbed at equilibrium (mg/g). C_0 andC_e(mg/L) are the initial and equilibrium concentration of RB5respectively. V is the volume of the solution (L) and M is the mass of the adsorbent used (g).

3. Result and Discussion

3.1. Effect of Initial Dye Concentration
The initial concentration of RB5 dye solution was varied (20,30,40, and 50 mg/L) and batch experiments were carried out by taking 50 mL of the RB5 dye solution with fixed adsorbent dosage of 100 mg of the adsorbent. The system was equilibrated by shaking the contents of the flask at 32^0C. The results (Fig .2) reveal that the percentage removal of RB5 dye decreases with increase in initial dye concentration and this may be due to the saturation of adsorption sites on the adsorbent surface ((Jayarajan et al.,2011, Mane and vijaybabu, (2011) The amount of dye adsorption q_e (mg/g) increases with increase in contact time at all initial dye concentrations used in this study is on par with the results by various researchers (Marius Sebastian Secula et al.,2011, Mittal et al 2010) This is because, the initial dye concentration provides the driving force to overcome the resistance to the mass transfer of dye between the aqueous and the solid phase.

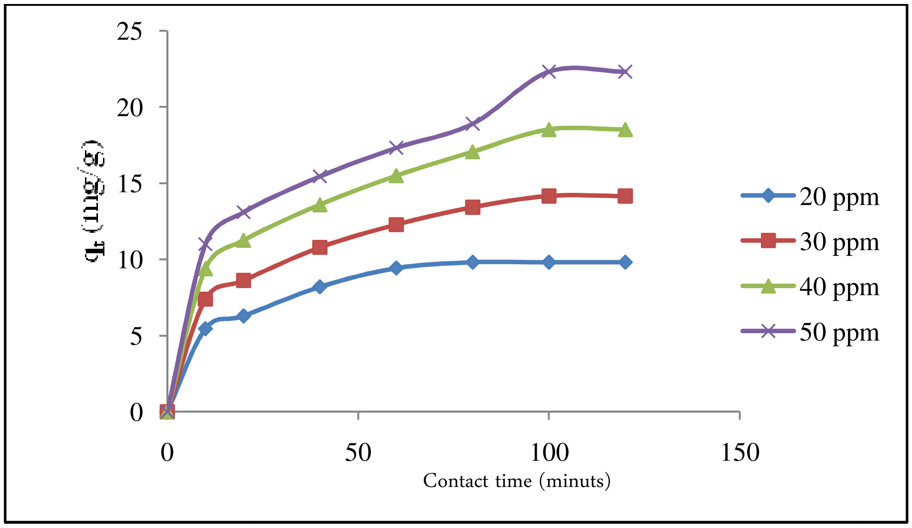

Figure 2: Effect of initial dye concentration on Remazol black 5 dye removal

3.2. Adsorption Kinetics

Lagergren pseudo first order and intra particle diffusion models were applied to the experimental data obtained in this study.Lagergren's first order rate equation is given as follows.

$\log(q_e\text{-}q_t) = \log q_e - k_1 t /2.303$ (3)

Where q_e and q_t (mg/g) are the amount of dye adsorbed at equilibrium and at time t and k_1 (1/min) is the rate constant of the pseudo first order adsorption. The plot of values of log (q_e-q_t) Vs. t (Table 1) gives a linear relationship (Figure 3). The values of k_1 and q_e were calculated from the slope and intercept of the plots respectively. In the pseudo first order kinetic plots, for all initial concentrations the regression coefficient r^2 are more than 0.97. This high regression coefficient confirms that the adsorption kinetics of RB 5 onto BRSP carbon follows pseudo first order kinetic rate equation.

contact time (mins) (t)	**log(q_e-q)**			
	20 ppm	**30 ppm**	**40 ppm**	**50 ppm**
10	0.6404	0.8308	0.9608	1.0538
20	0.5465	0.7442	0.8617	0.9647
40	0.2095	0.5282	0.6931	0.8369
60	-0.4089	0.275	0.482	0.6989
80	0	-0.1343	0.1655	0.534
slope	-0.0209	-0.0135	-0.0110	-0.0072
intercept	0.9280	1.0143	1.0952	1.1217
r^2	0.9789	0.9876	0.9915	0.9989

Table 1: Kinetic modeling for RB 5 adsorption using pseudo first order equation

Conditions: Adsorbent dose: 100 mg, pH:3.5 ± 0.02, Temperature: 35^0C

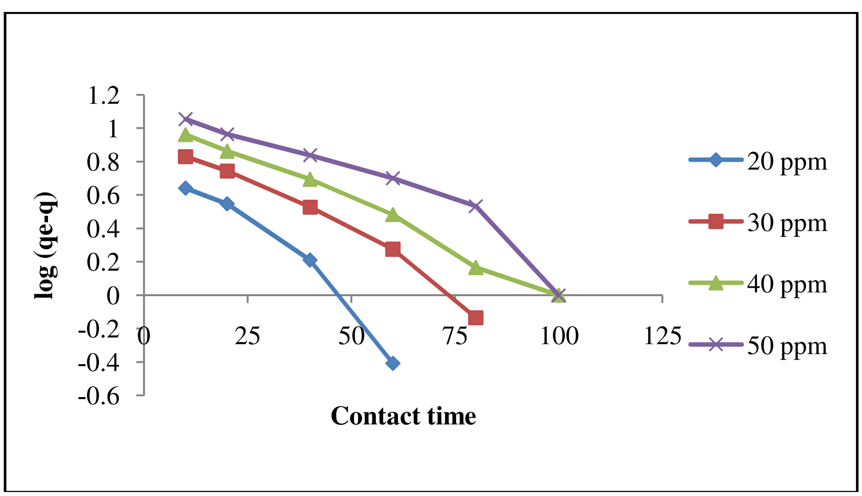

Figure3: Lagergren's plots for Remazol black 5adsorption

3.3. IntraparticleDiffusion

The intraparticle diffusion rate equation is expressed as

$q_t = Kp\ t^{0.5} + C$ (4)

Where C is the intercept and K_p is the intraparticle diffusion rate constant (mg g^{-1} $min^{0.5}$) which can be calculated from the slope of the linear plot of q_t Vs. $t^{1/2}$ given in table 2. Figure 4 shows the plot of intraparticle diffusion of RB5 onto BRSP carbon. The experimental data showed a multi linear plot which indicates that two or more steps influence the adsorption process. The first linear portion is due to the diffusion of adsorbate through the solution to the external surface or boundary layer diffusion of solute molecules.The second linear portion showed the gradual reach of equilibrium stage and the third linear portion is due to low adsorbate concentration left in the solution. (Mane and Vijay babu, 2011). The slope of the first linear plot gives the intraparticle rate constant (k_p) and intercept of this portion is proportional to the thickness of the boundary layer. The lines obtained by plotting q Vs $t^{1/2}$ are not passing through the origin and therefore the intra particle diffusion alone is not the rate determining step and boundary layer control may also be involved in the process. (Weng et al,2009).

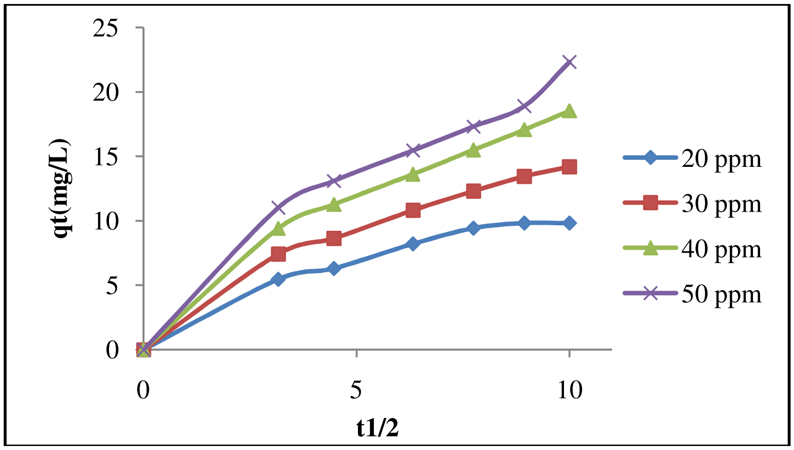

Figure 4: Intra particle diffusion plots for Remazol black 5 dye adsorption

$t^{1/2}$	q_t(mg/L)			
	20 mg/L	30 mg/L	40 mg/L	50 mg/L
3.16	5.45	7.40	9.40	11.00
4.47	6.30	8.62	11.26	13.10
6.32	8.20	10.80	13.6	15.45
7.74	9.43	12.29	15.5	17.32
8.94	9.82	13.44	17.07	18.90
10.01	9.82	14.17	18.53	22.32
10.95	9.82	14.17	18.53	22.32
slope	0.6082	0.9336	1.2359	1.4994
Intercept	3.9224	4.6764	5.7321	6.1487
r^2	0.9513	0.9883	0.9909	0.9983

Table 2: Intra particle diffusion rate equation for adsorption of Remazol black 5 dye

4. Conclusion

The kinetic study of RB5 dye adsorption onto Bauhenia racemosa seed pod carbon has revealed that the adsorption process fitted very well to Pseudo first order kinetics. The intra particle diffusion study showed that the rate constants for intra particle diffusion (Kp) increased with increase in initial concentration ofRB5 dye solution and this is due to concentration diffusion. The experimental data shows that the uptake of dye gradually decreases with increase of pH and increases with increase of temperature. Therefore, it may be concluded from the experimental data that Bauhenia racemosa seed pod carbon is a potential biosorbent for the removal of Remazol black 5 dye from aqueous solution.

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