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Batch Adsorption of Rhodamine-B Dyes onto Chemically Activated Nano Sized Carbon from Chloroxylon Swietenia

C. Kamatchi*[1], S. Arivoli[2] and R. Prabakaran[3]

[1,2*]PG and Research Department of Chemistry, Poompuhar College (AU) - Affiliated to Bharathidasan University, Melaiyur 609107, Ngapattinam,Tamilnadu, India
[3]Department of Chemistry, Periyar Maniammai Institute of Science & Technology (Deemed to be University), Vallam, Thanjavur-613403, Tamilnadu, India

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ABSTRACT

The work was investigated for the removal of Rhodamine B dye from an aqueous solution by the application of Chloroxylon Swietenia Activated Carbon (CSAC), which is obtained from Chloroxylon Swietenia tree barks because it's harder and widely used for agricultural tools, timber, construction, and boat building. For the experimental methods, batch mode adsorption was used. The following operational parameters were followed: initial dye concentration, pH, and temperature for the adsorption of Rhodamine B dye. The adsorption equilibrium was attained after 75 minutes. The removal percentage of Rhodamine B dye was mainly dependent on the initial concentration of the dye solution. Three different adsorption isotherm models were used to calculate the equilibrium adsorption data. The diffusion of Rh-B dye inside the new formation of active sites occurred at maximum temperature, which predicted that the adsorption would be an endothermic reaction. The characteristics of CSAC were evaluated by SEM and FTIR spectroscopy.

Key words: Chloroxylon Swietenia *Activated Carbon (CSAC), Rhodamine B dye (Rh-B), Redlich Peterson Adsorption isotherm and pH parameter.*

Introduction

Due to the widespread use of harmful coloured dyes in industrial waste water, global environmental issues like water pollution have been challenged in now days. In the textile, leather, culinary, and other industries, harmful organic dyes are frequently utilised. Many colours are included in the industrial effluents released from the chemical industrial units as pollutants, and they are mostly to blame for the water pollution.

The textile and dyeing industries utilise around 75% of all dyes, while the remaining 25% is produced as dye pollution that contaminate neighbouring waterways Inyinbor *et al.* (2016) ; Rohan *et al*. (2021). Living things, especially humans and other living organisms are seriously harmed by the dye pollution. One of the cationic dyes used in the dying industry to enhance the colouring effect is rhodamine B dye (Shukla *et al*., 2017; Mashaallah *et al*., 2017). We have picked this kind of dye to reduce water pollution as a solution to this problem. For the treatment of waste water, a variety of chemical treatment technologies have recently been used.

Reverse osmosis, chemical precipitation, ion exchange, electrodialysis, and adsorption technology make up the key treatment technologies. Adsorption is one of these techniques that is frequently used since it is less expensive, more effective, and allows for the recovery of the adsorbent (Al-Jibouri *et al*., 2015).

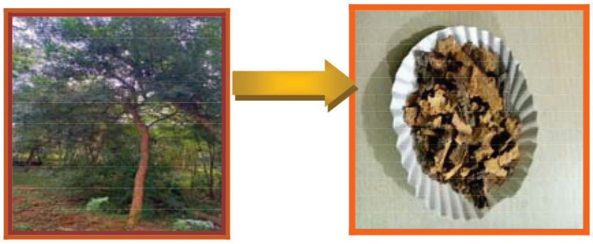

Fig. 1. Choloroxylon Swietenia tree and its Bark

Materials and Methods

Required Reagents

AR-grade reagents were employed in the experimental methods and preparation of the stock dye solution of Rhodamine B. Distilled water was used in the preparation of the stock solution.

Preparation of adsorbent

Chloroxylon Swietenia Activated Carbon was made from waste Chloroxylon Swietenia plant material that was obtained from the Timber Extraction Company in the Tamilnadu towns of Gandharvakkottai (TK) and Pudukkottai (DT). From the collected waste bark material,all dust and dirt particles were removed, then the waste bark materials were thoroughly cleaned with distilled water numerous times.

Thereafter the material was then dried at 160 °C in a hot air oven. After that, strong sulfuric acid was added during the carbonization process of the dried bark material to get primary activated carbon. The Chloroxylon Swietenia activated carbon was obtained by activating this carbon for six hours at 1100 °C Rajec *et al*. (2015); Muzaffar *et al*. (2022).

Characterization

The characteristics of *Chloroxylon Swietenia* Activated Carbon are listed in the Table 2.

Table 2. Characteristics of CSAC

Sl.No	Particulars	Value	
7.	1.	Moisture content (%)	0.102
8.	2.	Conductivity	41.01
9.	3.	Density of particle (g/cm^3)	0.263
10.	4.	pH slurry	4.5
11.	5.	Surface Area (m^2/g)	24.02

Experimental Methods and Results and Discussion

Batch Adsorption Experiments

The experiments were conducted to study the active parameters for contact time, carbon dose, effect of pH, and initial concentration of the Rhodamine B dye adsorption onto *Chloroxylon Swietenia* Activated Carbon. Dye solutions of different concentrations (25-125mg/l) and at different temperatures ranging from 30 ºC into 60 ºC with known amount of adsorbent and known pH were agitated at 120 rpm until they reached the equilibrium for adsorption isotherms.

The concentration of Rhodamine B dye was determined by the UV-VI S spectrophotometer at 554 nm. All experiments were done at normal pH for the removal of Rh-B dye. The effect of pH was computed over a pH range of 0 to 9. The initial pH of the

Table 1. Parameters symbols with explanation

Symbols	Explanation	Symbols	Explanation
Q	Amount of dyes adsorpbed	C_0	Initial dye concentration
Q_M	Langmuir adsorption capacity (in mg/g)	K_R	Redlich – Peterson isotherm constant
C_I & C_T	Initial and liquid phase concentration of dyes at time (t)	A_R	Redlich – Peterson isotherm constant
C_E	Concentration of dye in the aqueous phase at equilibrium	g	Exponent from 0 to 1
M	Mass of the adsorbent	K_L	Langmuir constants related to adsorption capacity and adsorption of energy
V	Volume of the dye solution	R_L	Dimensionless separation factor
Q_E	Amount of dye adsorbed at equilibrium (in mg/L)	KF and 1/nF	Freundlich constants related to adsorption capacity and intensity

solution was adjusted by the addition of acetate or phosphate buffer solution. The percentage of dye removal was calculated by using the following equation Chaiyaraksa *et al.* (2017).

$$Q = \frac{[C_I - C_T)}{M} \times V \qquad \text{... (1)}$$

$$\text{\% of Dye removal} = \frac{[C_I - C_T)}{C_I} \times 100 \qquad \text{.....[2]}$$

CSAC Doses for Rh-B dye adsorption

The effect of CSAC doses on Rh-B adsorption was studied from 0.025 to 0.125 g. As shown in Fig. 2, the percentage of Rh-B adsorption increased with increasing CSAC doses due to an increase in surface area and the availability of large active binding sites on the CSAC surface Muhammad *et al.* (2016).

Rh-B dye adsorption of contact time on CSAC

In order to establish the equilibrium time for maximum uptake and to know the kinetics of the adsorption process. The Rh-B dye adsorption on CSAC as an adsorbent was determined as a function of contact time, and the results are given in Fig. 3. The figure shows that the uptake rate was initially rapid, with 50 % of the adsorption completed in 30 minutes. The equilibrium was achieved in 50 minutes; therefore, an equilibrium period of one hour was selected for all further experiments.The time period of Rh-B uptake is a single smooth and continuous curve leading to saturation, suggesting the possible monolayer coverage of Rh-B on the surface of the adsorbent. The percentage removal of Rh-B dyes and the quantity level of dye taken up by CSAC

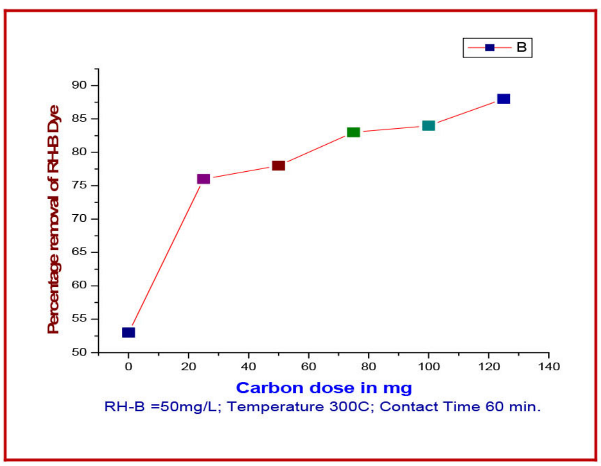

Fig. 2. Effect of Adsorbent Dose for the removal of Rh-B

were determined Ashokan *et al.* (2022).

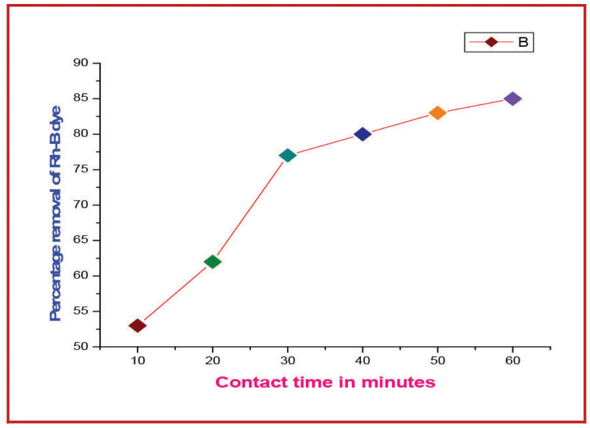

Fig. 3. Effect of contact time for the removal of Rh-B

Influence of Other Ion Concentration

In this study, other ions, such as calcium and chloride ions, on CSAC were determined at various concentrations due to other ions in the solution being added to the 20 ml of dye solution. Fig. 4 indicates that a little bit of chloride ion concentration does not affect the percentage removal of Rh-B dyes due to the interaction of chloride ions at the sites of adsorbent through competitive adsorption, whereas calcium ion concentration does not affect the percentage removal of Rh-B dye.

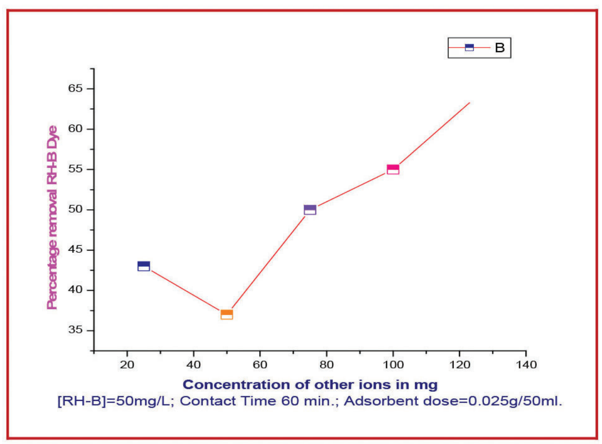

Fig. 4. Concentration of other ions for the removal of Rh-B

Influence of pH

The influence of pH on the adsorption of dyes onto CSAC was very well employed to conclude the optimised operational parameters for the adsorption process (Ling *et al.*, 2018). Adsorption of dyes onto CSAC was carried out in pH ranges between 2 to 9, as shown in Fig. 5. After dye adsorption on CSAC, the adsorption process slows down as the pH level rises. In particular, the pH ranges from 2 to 7, with the maximum possible adsorption of dyes using CSAC adsorbent ranging from 80 to 85, respectively (Ho. 2020).

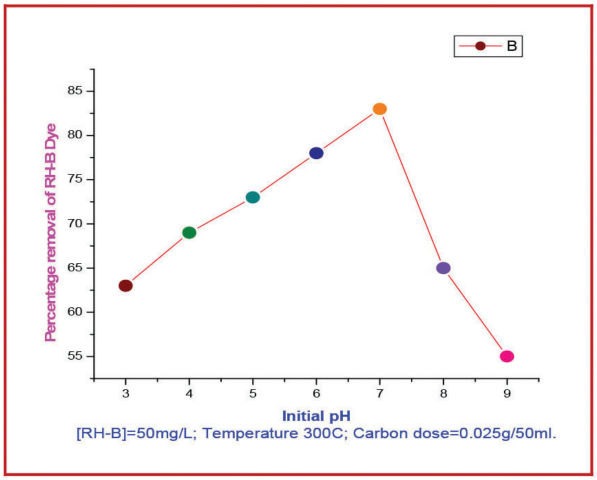

Fig. 5. Effect of pH for the removal of Rh-B

Results and Discussion

Evidences for Adsorption isotherms

The dispersal of adsorption dyes (adsorbate) and solids (adsorbent) was performed by adsorption isotherm models (Al-Ghouti *et al*., 2020). The equilibrium data have been determined by the following isotherms: Langmuir, Freundlich, Radlich Peterson (Abazli *et al*., 22022).

In the Langmuir model (Fig. 6), the q_m and K_L values were calculated from a linear plot of ($\frac{Ce}{qe}$ *vs Ce*) the experimental values are given in tables 1 and 4. From the experimental results, the high values of KL indicate a high adsorption affinity. The equilibrium data were calculated by using the following equations. Rh-B dyes were adsorbed as monolayers on the homogeneous surface of CSAC (Sabarish *et al*., 2020; Aminu *et al*., 2020).

$$\frac{C_E}{Q_E} = \frac{1}{Q_M K_L} + \frac{C_E}{Q_M} \quad .. (3)$$

$$R_L = \frac{1}{1 + K_L C_E} \quad .... (4)$$

The adsorption isotherm was favarouble if zero than R_L. The R_L values were computed from various concentrations as well as temperature. The values are given in the Table 1 & 5.

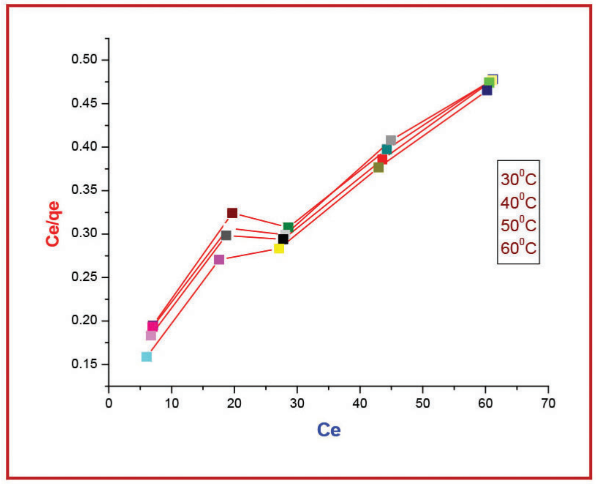

Fig. 6. Langmuir adsorption of Rh-B

In Freundlich adsorption isotherm, the following expressions were adopted for adsorption of dyes onto the surface of CSAC.

$$Q_E = K_F C_E \frac{1}{nf} \quad .... (5)$$

The equation [5] can be linearized by the following equation

$$\ln Q_E = \ln K_F + \frac{1}{nF} \ln C_E \quad .... (6)$$

The K_F and $\frac{1}{nF}$ values are Freundlich constants, which are obtained from slope and intercept ($\ln Q_E$ vs $\ln C_E$) plots as given in the Fig. 7. The values are listed in Table 3 and 4.

Redlich Peterson adsorption isotherm model (Fig. 8) is an empirical adsorption isotherm and it consists of three parameters of combined Langmuir and Freundlich isotherm (Al-Ghouti *et al*., 2020; Solis *et al*., 2021 and Khori *et al*., 2018). This isotherm is expressed by the following equation.

$$Q_E = \frac{K_R C_E}{1 + A_R C_E^g} \quad .. (7)$$

The g and K_R values (Table 1) were calculated from the slope and intercept (Fig. 8). The plot of $\ln C_E/Q_E$ vs $\ln C_E$. The values are shown in table 4. The linear form of the Redlich adsorption isotherm can be represented by the expression.

$$\ln \frac{Q_E}{C_E} = g \ln C_E - \ln K_R \quad ... (8)$$

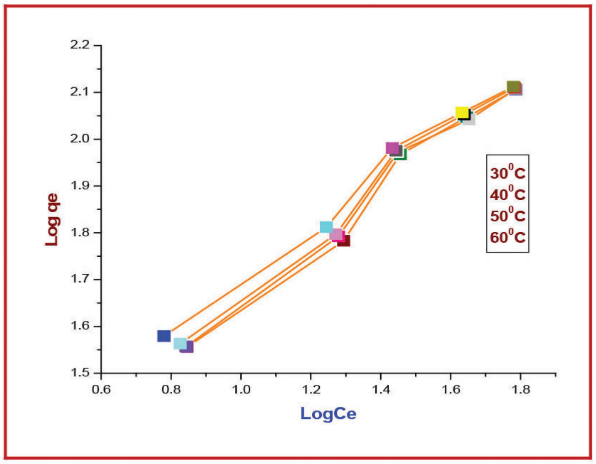

Fig. 7. Freunlich adsorption of Rh-B

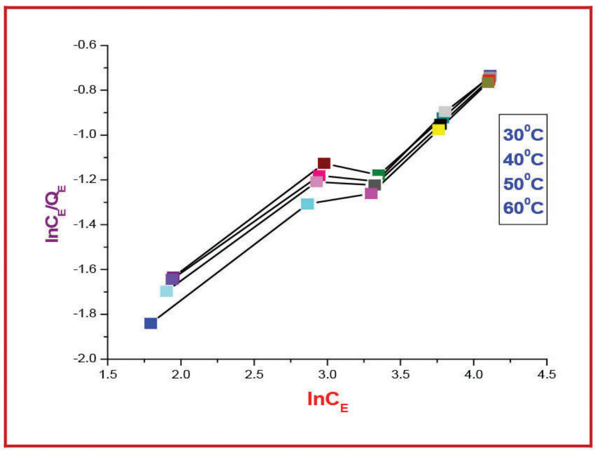

Fig. 8. Redlich Peterson adsorption isotherm of RhB

Evidences for Temperature

Temperature is an important parameter for the removal of Rh-B dye from an aqueous solution with the help of CSAC as an adsorbent. The adsorption speed of Rh-B dye increases quickly from 303 to 333K. Temperature had a greater impact on sorption, demonstrating that surface area increased with increasing temperature. It may be due to the diffusion of Rh-B dye inside the newly formed active sites at maximum temperature. Therefore, it was predicted that the adsorbed dyes onto CSAC would have an endothermic reaction (Sarma et al., 2019; Syieluing et al 2020).

Analytical Instruments for Adsorption Studies

SEM and FTIR Studies

A scanning electron microscope (SEM) is fundamentally a microscope generating on elctron beam scanning forth and back on a sample material. In morphological studies of before adsorption of CSAC adsorbent, the particle size was found 10 µm and randomness like structure (Smailov *et al*., 2022). But in the after adsorption of CSAC, the particle size was from 10 to 20 µm (Fig. 9). It shows a white ball like structure on the surface of the adsorbent. As a result, the rhodamine dye molecules were being loaded onto the pore cavity of the CSAC absorbent (Nirban Laskar and Upendra Kumar, 2017).

The FT-IR spectrum of after adsorption of Rhodamine B onto CSAC shown in the figure 10.

Table 3. Equilbrium parameters for the removal of Rh-B Dyes on the CSAC Adsorbent

Rh-B	Ce (mg / L)				Qe (mg / g)				(%) Removal of Rh-B			
	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	7.0161	6.9659	6.7040	6.0250	35.968	36.068	36.592	37.950	71.936	72.136	73.184	75.900
50	19.6681	19.0120	18.6840	17.5590	60.664	61.98	62.632	64.882	60.664	61.976	62.632	64.882
75	28.5746	28.0842	27.7760	27.1210	92.85	93.83	94.45	95.76	61.901	62.554	62.965	63.839
100	44.2762	44.9260	43.5590	42.9670	111.45	110.15	112.88	114.07	55.724	55.074	56.441	57.033
125	61.1643	61.0194	60.5940	60.2480	127.67	127.96	128.81	129.50	51.069	51.184	51.525	51.802

Table 4. Adsorption isotherm for the removal of Rh-B Dyes on the CSAC Adsorbent

Model	Constant	Temperature (°C)			
		30	40	50	60
Freundlich	K_f(mg/g) (L/mg)$^{1/n}$	10.89	11.33	11.86	14.15
	n	1.6446	1.6692	1.6870	1.8136
Langmuir	Q_m(mg/g)	206.01	199.63	199.69	186.47
	b (L/mg)	0.0263	0.0284	0.0297	0.0368
Radlich-Peterson	g	0.3919	0.4009	0.4072	0.4486
	K_R(L/g)	0.0918	0.0882	0.0843	0.0707

Table 5. Dimentionless Separation Factor (RL) for the removal of Rh-B Dyes on the CSAC

(C_i)	Temperature °C			
	30 °C	40 °C	50 °C	60 °C
25	0.6034	0.5849	0.5742	0.5210
50	0.4321	0.4134	0.4027	0.3522
75	0.3365	0.3196	0.3101	0.2661
100	0.2756	0.2605	0.2521	0.2138
125	0.2333	0.2199	0.2124	0.1787

The stretching vibration band was found at 3429 cm-1. It is clearly identify that the adsorption of Rh B dyes occur onto CSAC by vander waals forces of attraction. According to the FTIR study, there were substantial changes in the peak intensity, after the adsorption. Functional group like hydroxyl group have influenced the removal of RhB dye. (Wiwid *et al.,* 2014; Maria *et al*., 2022).

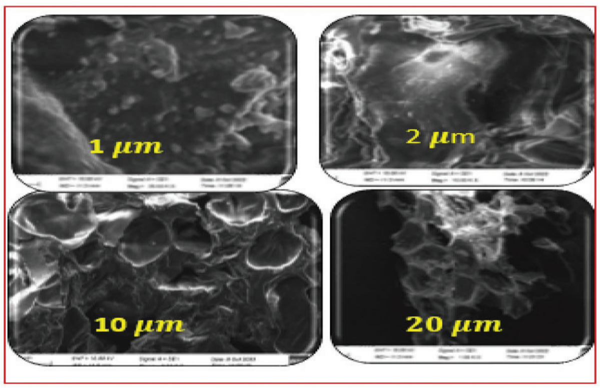

Fig. 9. SEM studies for adsorption of RhB

Conclusion

In this research, activated carbon made from the bark of Mammarai trees performed better than commercial activated carbon. The adsorption of dyes

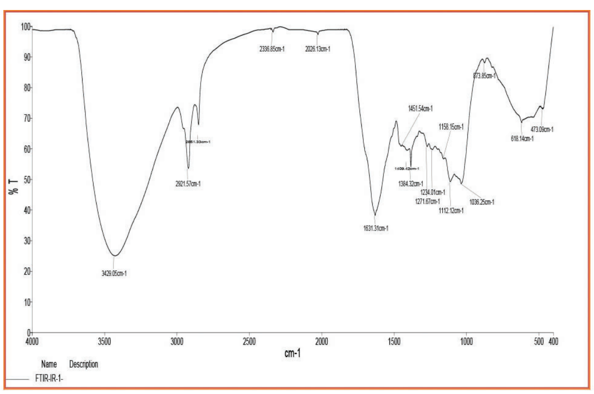

Fig. 10. FTIR studies for adsorption of RhB

onto CSAC was determined by carbon dosage, contact time, pH, and temperature parameters. The Langmuir, Freundlich, and Redlich Peterson isotherm models have all been used to demonstrate the effectiveness of adsorption. Temperature being used to compute the adsorption speed. Analytical tools provided proof that Rhadamine B had been removed. The goal of the adsorption study was primarily to reduce water pollution. Rh-B

Dye will eventually be eliminated from industrial waste water using CSAC adsorbent.

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Conflicts of interest

The authors declare that, they have no Conflict of interest.

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