

**Pelagia Research Library** 

Der Chemica Sinica, 2012, 3(1):99-113



# Removal of Rhodamine B dye from aqueous solution using the acid activated *Cynodon dactylon* carbon

# B.R. Venkatraman\*<sup>1</sup>U. Gayathri<sup>2</sup>, S. Elavarasi<sup>1</sup> and S. Arivoli<sup>3</sup>

 <sup>1</sup>P.G. & Research Department of Chemistry, Periyar E.V.R.College (Autonomous), Tiruchirapppalli, Tamilnadu, India
<sup>2</sup>Department of Chemistry, Sengamala Thayaar Educational Trust Women's College, Mannargudi, Tamilnadu, India
<sup>3</sup>Department of Chemistry Thiru.Vi.Ka. Government Arts College, Thiruvarur, Tamilnadu, India

# ABSTRACT

Rhodamine B adsorption from an aqueous solution onto acid activated Cynodon dactylon carbon has been studied experimentally using batch adsorption method. Adsorption Kinetics and equilibrium were investigated as a function of initial dye concentration, pH, contact time, and adsorbent dosage. Kinetic studies indicated that the adsorption followed reversible First order reaction. Equilibrium data was analyzed using Langmuir and Freundlich isotherm models. The adsorption capacity of Cynodon dactylon was found to be 94 % on the basis of experimental results and the model parameters, it can be inferred that the carbonaceous Cynodon dactylon is effective for the removal of Rhodamine B from aqueous solution.

**Key words:** Acid activated carbon (CDC), Rhodamine B, Adsorption isotherm, Equilibrium, Kinetic and Thermodynamic parameters, Intra particle diffusion, Regenaration pattern.

# INTRODUCTION

Among the different pollutants of aquatic ecosystem, dyes are a large and important group of industrial chemicals for which world production in 1978 was estimated at 640,000 tons [1]. Most of this quantity was used in the textile industry and the dyes in use include many different compounds and their environmental behavior is largely unknown [2]. Most of the dyes and pigments are considered inert or non – toxic, although some are not totally innocuous [3]. Interest in the environmental behavior of dyes is prompted primarily by concern over their possible toxicity and carcinogenicity, heightened by the fact that many dyes formerly were made of known carcinogens such as benzidine, which may be reformed as a result of metabolism [1, 2] Disperse dyes have been shown to have high partition coefficients and solubility, suggesting significant potential for bioconcentration [4]. Dye toxicity is not well defined implant effluents and their long term effects on animal and human health are not documented, with an exception of a study by Sturm and co – workers [5].

Most dyestuffs are designed to be resistant to environmental conditions like light, effects of pH and microbial attack [6]. Hence, their presence in waste water is unwarranted, and it is desirable to remove coloring material from effluents, before their discharge in the environment, not only for aesthetic reasons. This is important to regions where water resources might be scarce or sensitive.

The removal of such compounds at such levels consist a difficult problem. Among the methods employed are the adsorption onto sludge of waste water treatment plant, as well as other physico chemical techniques as coagulation,

flocculation, ozonation, reverse osmosis and adsorption on activated carbon, manganese dioxide, silica gel and clays [7-12]. The biological processes typically accomplish very little towards color removal [7].

The present study undertaken to evaluate the efficiency of a carbon adsorbent prepared from acid activated *Cynodon dactylon* carbon for removal of dye Rhodamine B in aqueous solution. In order to design adsorption treatment systems, knowledge of kinetic and mass transfer processes is essential. As the dye once adsorbed on adsorbents can be readily stripped by acid treatment and hence the adsorbent life can be increased.

# MATERIALS AND METHODS

## Materials

## **Adsorbent Preparation**

*Cynodon dactylon* was used in this work for the removal of Rhodamine B dye from aqueous solution. The dried material was carbonized with concentrated sulphuric acid in the weight ratio of 1:1 (W/V). The resulting mixture was kept in a furnace maintained at  $600^{\circ}$ C and 12 hours heating needed for completion of carbonization and activation. The activated carbon was washed with distilled water and then it was dried at  $125^{\circ}$ C for 4 hours. The carbon material was powdered, sieved for the range between 0.022 to 0.025 mm sieves were separated, stored and used for the entire adsorption studies.

#### Chemical and reagents

Chemicals used for all the experiments are of analytical and lab reagents grades and distilled water was used in throughout the experiments.

#### **Rhodamine B stock solution**

Stock solution of Rhodamine B dye ranging from 15 mg to 75 mg was dissolved in one litre of distilled water.

## **Buffer preparation**

Different pH buffers had been used a range of 3 - 9 to study the effect of pH on the removal efficiency of the adsorbent. For maximum range of pH solution of dilute hydrochloric acid and sodium hydroxide are used for maintaining the pH of the solution.

## Experiment

#### **Equilibrium studies**

Batch equilibrium experiments had been carried out to find the optimum pH, contact time and equilibrium isotherms. A series of 250 ml Erylenmeyer flasks were used. The procedure involved filling each flask with 50 ml of dye solutions with an initial concentration of 15 mg/l to 75 mg/l. The contents were shaken thoroughly using a mechanical shaker rotating with a speed of 125 rpm to achieve equilibrium. The solution was then filtered at preset time intervals and the residual dye concentration was measured. The effect of pH of dye removal using *Cynodon dactylon* was studied in a pH range of 3 - 9. The amount of *Cynodon dactylon* varied from (10 – 100 mg/50 ml).

#### **Batch kinetic studies**

Batch kinetic experiments were carried out to find kinetics of the adsorption process. The procedure involved filling flask with 15 mg to 75 mg/l dye solution. The solution is adjusted to optimum pH 7.2 and 25 mg *Cynodon dactylon* was added. During the experiment small amount of samples are taken for analysis at predetermined intervals.

#### Analysis

The removal of Rhodamine B was analyzed by using FT - IR, SEM images and XRD patterns were recorded at the CECRI, Karaikudi, South India.

# **RESULTS AND DISCUSSION**

#### **Properties of the Adsorbent**

The chemical nature and pure structure usually determines the sorption activity. The physical and chemical properties of the *Cynodon dactylon* were listed in Table 1.

### Effect of Cynodon dactylon adsorbent

The adsorption of the dyes on carbon was studied by varying the carbon concentration (10 - 100 mg/50 ml) for 45 mg/l of dye concentration. The percent adsorption increased with increased in the *Cynodon dactylon* concentration (Figure 1). This was attributed to increase the carbon surface area and availability of more adsorption sites [13, 14].

# Effect of contact time

The effect of contact time and different initial concentration was also studied. It was observed that percentage removal of dye decreases with increase in Rhodamine B initial concentration. Equilibrium had established at 60 minutes for all concentrations. From this, it means that the adsorption was highly dependent on initial concentration of dye. Figure 2 reveals that the curves are single, smooth and continuous, leading to saturation, suggesting the possible monolayer coverage of the dyes on the carbon surface.

Properties	CDC
Particle size (mm)	0.025
Density (g/cc)	0.1528
Moisture content (%)	0.98
Loss on ignition (%)	82
Acid insoluble matter (%)	3.2
Water soluble matter (%)	0.39
pH of aqueous solution	6.3
pH <sub>zpc</sub>	5.4
Surface groups (m equiv/g)	
(i) Carboxylic acid	0.325
(ii) Lactone, lactol	0.074
(iii) Phenolic	0.067
(iv) Basic (pyrones and chromenes)	0.026

#### Table 1 chemical composition of the CDC adsorbent

#### **Adsorption Isotherms**

The adsorption isotherms were studied using initial concentration of dye between 15 mg to 75 mg/l at an adsorbent dose 25mg/l. The data obtained is fitted into the Langmuir isotherm which is the most popular and is a two parameters equation described as [15].

$$C_e/Q_e = 1/Q_m b + C_e/Q_m$$
 ------[1]

Where constants b and  $Q_m$  related to the energy of adsorption and adsorption capacity and their values are obtained from the slope and intercept of the plot of  $C_e/Q_e$  versus  $C_e$  as shown in figure 3, and Table 3. The observed values shows that the adsorbent prefers to bind acidic ions and that speciation predominates on sorbent characteristics, when ion exchange is the predominant mechanism takes place in the adsorption of Rhodamine B, it confirms the endothermic nature of the process involved in the system [16-18]. The value of b, which is a measure of heat of adsorption is utilized to calculate dimensionless separation parameter  $R_L$  [19]. The values found to be in between 0 to 1 and confirm that the ongoing adsorption process is favorable [20] shown in Table 4. The adsorption data obtained are also fitted to the Freundlich isotherm which is the earliest known relationship known as described by the following equation [21].

$$\text{Log } Q_e = \log K_f + 1/n \log C_e$$
 -----[2]

Where,  $K_f$  and n were Freundlich constants, which corresponds to adsorption capacity and adsorption capacity and adsorption intensity respectively. The slope (1/n) and intercept ( $K_f$ ) of a log – log plot of  $Q_e$  vs  $C_e$  are determined. The results of both regressed isotherms are tabulated in Table 5 and figure 4. The intensity of adsorption is an indicative of the bond energies between dye and adsorbent and the possibility of slight chemisorptions rather than physisorption [17, 18]. However, the multilayer of adsorption of Rhodamine B through the percolation process may be possible. The values of n are greater than one indicating the adsorption is much more favourable[20].

#### **Effect of Temperature**

Effect of temperature on adsorption of Rhodamine B was studied by conducting various sets of experiments at initial concentration of 45 mg/l at different temperature i.e, 35, 45, 55 and  $65^{\circ}$ C. It is observed that adsorption of Rhodamine B increases with increase in the temperature.

# Thermodynamic parameters

The thermodynamic equilibrium constant  $K_0$  is obtained by calculating the difference between solid phase concentration and liquid phase concentration and extrapolating to zero [22].

 $K_0 = C_{solid} / C_{liquid}$  -----[3]

 $C_{solid}$  is the solid phase concentration at equilibrium (mg/l),  $C_{liquid}$  is the liquid phase concentration at equilibrium (mg/l), T is the temperature in Kelvin and R is the gas constant. The thermodynamic constants, Gibbs's free energy ( $\Delta G^0$ ), enthalpy change ( $\Delta H^0$ ), and entropy change ( $\Delta S^0$ ), are calculated to evaluate the thermodynamic feasibility of the process and to confirm the nature of the adsorption process. The Gibb's free energy change of the process is related to equilibrium constant ( $K_0$ ) by equation

 $\Delta G^{0} = - RT ln K_{0} - -----[4]$ 

The Gibb's free energy change is related to the enthalpy change ( $\Delta H^0$ ) and entropy change ( $\Delta S^0$ ) as

The  $\Delta H^{\circ}$  and  $\Delta S^{\circ}$  values obtained from the slope and intercept of Van't Hoff plots (representative Fig.5) have presented in Table 6. The values  $\Delta H^{\circ}$  is within the range of 1 to 93 KJ/mol indicates the physisorption. From the results we could make out that physisorption is much more favorable for the adsorption of Rhodamine B. The positive value of  $\Delta H^{\circ}$  show the endothermic nature of adsorption and it governs the possibility of physical adsorption [18, 23]. Because in the case of physical adsorption, while increasing the temperature of the system, the extent of dye adsorption increases, this rules out the possibility of chemisorptions [23]. The low  $\Delta H^{\circ}$  value depicts dye is physisorbed onto adsorbent CDC. The negative values of  $\Delta G^{\circ}$  (Table 6) shows the adsorption is highly favorable and spontaneous. The positive values of  $\Delta S^{\circ}$  (Table 6) show the increased disorder and randomness at the solid solution interface of Rhodamine B with CDC adsorbent, while the adsorption there are some structural changes in the dye and the adsorbent occur. The adsorbed water molecules, which have displaced by the adsorbate species, gain more translational entropy than is lost by the adsorbate molecules, thus allowing the prevalence of randomness in the system. The enhancement of adsorption capacity of the activated carbon at higher temperatures was attributed to the enlargement of pore size and activation of the adsorbent surface [20, 23, 24].

#### **Kinetics of adsorption**

The kinetics of sorption describes the solute uptake rate, which in turn governs residence time or sorption reaction. It is one of the important characteristics in defining the efficiency or sorption. In the present study, the kinetics of the dye removal was carried out to understand the behavior of these low cost carbon adsorbents. The adsorption of dye from an aqueous follows reversible first order kinetics, when a single species are considered on a heterogeneous surface. The heterogeneous equilibrium between the dye solutions and the activated carbon are expressed as

A 
$$\underset{k_2}{\overset{k_1}{\longleftarrow}}$$
 B

Where  $k_1$  is the forward rate constant and  $k_2$  is the backward rate constant. A represents dyes remaining in the aqueous solution and B represent dye adsorbed the surface of activated carbon. The equilibrium constant (K<sub>0</sub>) is the ratio of the concentration adsorbate in adsorbent and in aqueous solution (K<sub>0</sub>=  $k_1/k_2$ ). In order to study the kinetics of the adsorption process under consideration the following kinetic equation proposed by Natarajan and Khalaf as cited in literature has been employed [25].

 $\log C_0/C_t = (K_{ad}/2.303)t$  -----[6]

Where  $C_0$  and  $C_t$  are the concentration of the dye in (in mg/l) at time zero and at time t, respectively. The rate constants ( $K_{ad}$ ) for the adsorption processes have been calculated from the slope of the linear plots of log  $C_0/C_t$  versus t for different concentrations and temperatures (representative Fig.6). The determination of rate constants as described in literature given by  $C_0/C_t$  versus t for different concentrations and temperatures (representative Fig.6). The determination of rate constants as described in literature given by  $C_0/C_t$  versus t for different concentrations and temperatures (representative Fig.6). The determination of rate constants as described in literature given by

$$K_{ad} = k_1 + k_2 = k_1 + (k_1/K_0) = k_1 [1 + 1/K_0]$$
 ------[7]

The overall rate constant  $K_{ad}$  for the adsorption of dye at different temperatures are calculated from the slopes of the linear Natarajan-Khalaf plots. The rate constant values are collected in Table 7 shows that the rate constant ( $K_{ad}$ ) increases with increases in temperature suggesting that the adsorption process in endothermic in nature. Further,  $K_{ad}$  values decrease with increase in initial concentration of the dye. In cases of strict surface adsorption a variation of rate should be proportional to the first power of concentration. However, when pore diffusion limits the adsorption process, the relationship between initial dye concentration and rate of reaction will not be linear. Thus, in the present study pore diffusion limits the overall rate of dye adsorption. The overall rate of adsorption is separated into the rate

of forward and reverse reactions using the above equation. The rate constants for the forward and reverse processes are also collected in Table 7a and 7b indicated that, at all initial concentrations and temperatures, the forward rate constant is much higher than the reverse rate constant suggesting that the rate of adsorption is clearly dominant [18,23,25].

# Intraparticle diffusion

The most commonly used technique for identifying the mechanism involved in the sorption process is by fitting the experimental data in an intraparticle diffusion plot. Previous studies by various researchers showed that the plot of Qt versus  $t^{0.5}$  represents multi linearity, which characterizes the two or more steps involved in the sorption process. According to Weber and Morris, an intraparticle diffusion coefficient  $K_p$  is defined by the equation: coefficient  $K_p$  is defined by the equation

 $K_p = Q/t^{0.5} + C$  ------[8]

Thus the  $K_p$  (mg/g min<sup>0.5</sup>) value can be obtained from the slope of the plot of Qt (mg/g) versus t<sup>0.5</sup> for Rhodamine B. From figure 7, it was noted that the sorption process tends to be followed by two phases. The two phases in the intraparticle diffusion plot suggest that the sorption process proceeds by surface sorption and intraparticle diffusion [26, 27]. The initial curved portion of the plot indicates a boundary layer effect while the second linear portion is due to intraparticle or pore diffusion. The slope of the second linear portion of the plot reflects the boundary layer effect. The larger the intercept the greater would be the contribution of the surface sorption in the rate limiting step. The calculated intraparticle diffusion coefficient  $K_p$  value was given by 0.096, 0.144, 0.192, 0.247 and 0.292 mg/g min<sup>0.5</sup> for initial dye concentration of 15, 30, 45, 60 and 75 mg/L at 35<sup>o</sup>C.

# Effect of pH

pH is one of the most important parameters controlling the adsorption process. The effect of pH of the solution on the adsorption of Rhodamine B ions on CDC was determined. The result is shown in Figure. 8. The pH of the solution was controlled by the addition of HCl or NaOH. The uptake of Rhodamine B ions at pH 7.2 was the minimum and a maximum in uptake was obtained at pH 3.0 - 5.5. However, when the pH of the solution was increased (more than pH 7.2), the uptake of Rhodamine B ions was increased. It appears that a change in pH of the solution results in the formation of different ionic species, and different carbon surface charge. At pH values lower than 5.5, the Rhodamine B ions can enter into the pore structure. At a pH value higher than 5.5, the zwitterions form of Rhodamine B in water may increase the aggregation of Rhodamine B to form a bigger molecular form (dimer) and become unable to enter into the pore structure of the carbon surface. The greater aggregation of the zwitter-ionic form is due to the attractive electrostatic interaction between the carboxyl and xanthane groups of the monomer. At a pH value higher than 7.2, the existence of OH-creates a competition between -N+ and COO-and it will decrease the aggregation of Rhodamine B, which causes an increase in the adsorption of Rhodamine B ions on the carbon surface. The effect of the charge on the carbon surface and the electrostatic force of attraction and repulsion between the carbon surface and the Rhodamine B ions on the carbon surface and the result [20.28].

# Effect of the ionic strength on the adsorption of Rhodamine B on CDC

The effect of sodium chloride on the adsorption of Rhodamine B on CDC is shown in Figure. 9. In a low solution concentration NaCl had little influence on the adsorption capacity. At higher ionic strength the adsorption Rhodamine B will be increased due to the partial neutralization of the positive charge on the carbon surface and a consequent compression of the electrical double layer by the Cl anion. The chloride ion can also enhances adsorption of Rhodamine B ion onto CDC by pairing of their charges and hence reducing the repulsion between the Rhodamine B molecules adsorbed on the surface. This initiates carbon to adsorb more of positive Rhodamine B ions [25, 28]<sup>-</sup>

# **Desorption studies**

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the dye. If the adsorbed dyes can be desorbed using neutral pH water, then the attachment of the dye of the adsorbent is by weak bonds. If sulphuric acid or alkaline water desorp the dye then the adsorption is by ion exchange. If organic acids, like acetic acid can desorp the dye, then the dye has held by the adsorbent through chemisorption. The effect of various reagents used for desorption studies indicate that hydrochloric acid is a better reagent for desorption, because we could get more than 74% removal of adsorbed dye. The reversibility of adsorbed dye in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of dye by mineral acids and alkaline medium indicates that the dyes were adsorbed onto the activated carbon through by physisorption mechanisms [20, 29].

# **Evidences for adsorption**

The IR spectra of the raw activated carbon and after adsorption of Rhodamine B have shown in figures 10a and 10b. It could be seen that the slight reduction of stretching vibration adsorption bands. This clearly indicates the adsorption of dye on the adsorbent by physical forces [23, 25]. The XRD diagrams of activated carbon and Rhodamine B adsorbed carbon have shown in figures 11a and 11b. The intense main peak shows the presence of highly organized crystalline structure of raw activated carbon [23,25] after the adsorption of dye, the intensity of the highly organized peaks are slightly diminished. This has attributed to the adsorption of Rhodamine B on the upper layer of the crystalline structure of the carbon surface by means of physisorption. The SEM diagrams of raw activated carbon and Rhodamine B dye-adsorbed activated carbon have shown in figures 12a and 12b. The bright spots, shows the presence of tiny holes on the crystalline structure of raw activated carbon have shown in figures 12a and 12b. The bright spots became black shows the adsorption of the Rhodamine B dye on the surface of the carbon by means of physisorption [23,25].

Table 2 – Equilibrium	parameters	for the ads	orption of <b>F</b>	Rhodamine B	by	CDC
-----------------------	------------	-------------	---------------------	-------------	----	-----

Rhodamine B	$C_e (mg/L)$					Qe (mg/g)				Dye removed (%)		
concentration		Temperature <sup>o</sup> C										
(mg/ L)	35	45	55	65	35	45	55	65	35	45	55	65
15	1.9254	1.7829	1.5448	1.3112	26.1492	26.4342	26.9104	27.3776	87.16	88.14	89.70	91.25
30	4.9847	4.5594	4.1212	3.6775	50.0306	50.8812	51.7576	52.6450	83.38	84.80	86.26	87.74
45	8.0194	7.5428	7.0175	6.5812	73.9612	74.9144	75.9650	76.8376	82.17	83.23	84.40	85.37
60	15.2947	14.7442	14.2349	13.7884	89.4106	90.5116	91.5302	92.4232	74.50	75.52	76.27	77.00
75	25.5442	25.0124	24.5915	20.0172	98.9116	99.9752	100.8170	109.9656	65.94	66.65	67.21	73.31

Table 3 -	Lanomuir	isotherm	results f	or the	adsorption	of Rhor	lamine R	hv	CDC
Table 3 -	Langmun	150ther m	1 courto re	or the	ausoi puon	OI MIDU	Jannie D	Dy	UDU

Temperature	Statistical	Statistical parameters/constants								
٥C	$\mathbf{r}^2$	Qm	В							
35	0.9964	128.36	0.1410							
45	0.9972	126.74	0.1597							
55	0.9952	123.30	0.1923							
65	0.9959	137.17	0.1798							

# Table 4 - Dimensionless Separation factor $\left(R_L\right)$ for the adsorption of Rhodamine B by CDC

Rhodamine B	Temperature <sup>0</sup> C							
concentration (mg/ L)	35	45	55	65				
15	0.321	0.294	0.263	0.270				
30	0.191	0.172	0.147	0.156				
45	0.136	0.122	0.103	0.109				
60	0.106	0.094	0.079	0.084				
75	0.086	0.076	0.064	0.068				

#### Table 5 – Freundlich isotherm results for the adsorption of Rhodamine B by CDC

Temperature	Statistical parameters/constants								
٥C	$\mathbf{r}^2$	Kf	n						
35	0.9714	1.6904	1.9047						
45	0.9676	1.6622	1.9677						
55	0.9684	1.6227	2.0656						
65	0.9856	1.6520	1.9920						

#### Table 6 Equilibrium constant and thermodynamic parameters for the adsorption of Rhodamine B

Dhadamina D		I	K <sub>0</sub>		$\Delta \mathbf{G^0}$					
Knodamine B				Tempe	rature <sup>0</sup>	ture <sup>o</sup> C				
concentration (mg/ L)	35	45	55	65	35	45	55	65	$\Delta \mathbf{H^0}$	$\Delta S^0$
15	6.79	7.41	8.71	10.43	-4.90	-5.29	-5.90	-6.59	10.35	49.46
30	5.01	5.57	6.28	7.16	-4.12	-4.54	-5.01	-5.53	9.86	46.63
45	4.61	4.96	5.41	5.83	-3.91	-4.23	-4.61	-4.96	8.81	42.53
60	2.92	6.07	3.21	3.35	-2.74	-2.96	-3.18	-3.39	7.59	37.34
75	1.93	1.99	2.04	2.74	-1.69	-1.83	-1.96	-2.83	6.55	32.52

Rhodamine B	K <sub>ad</sub> Temperature ⁰C						
concentration (mg/ L)	35	45	55	65			
15	3.36	3.61	3.94	4.27			
30	2.58	2.85	3.04	3.23			
45	2.53	2.61	2.72	2.84			
60	1.54	1.68	4.85	1.99			
75	1.23	1.36	1.52	1.65			

Table 7a – Rate constants for the adsorption of Rhodamine B  $(10^3 k_{ad}, min^{-1})$ 

 $\label{eq:table 7b-Rate constants for the adsorption of Rhodamine B~(10^3\,k_{ad},\,min^{-1}) \ and \ the \ constants \ for \ forward (10^3\,k_1,\,min^{-1}) \ and \ reverse~(10^3\,k_2,\,min^{-1}) \ process~(CDC)$ 

Rhodamine B concentration (mg/ L)	Temperature <sup>0</sup> C								
	35		45		55		65		
	k <sub>1</sub>	<b>k</b> <sub>2</sub>	<b>k</b> 1	<b>k</b> <sub>2</sub>	<b>k</b> 1	<b>k</b> <sub>2</sub>	<b>k</b> 1	<b>k</b> <sub>2</sub>	
15	2.93	0.43	3.19	0.42	3.53	0.41	3.87	0.40	
30	2.16	0.42	2.42	0.43	2.56	0.48	2.84	0.39	
45	2.08	0.45	2.17	0.44	2.30	0.42	2.43	0.41	
60	1.15	0.39	1.27	0.41	1.42	0.43	1.54	0.45	
75	0.81	0.42	0.91	0.45	1.02	0.50	1.21	0.44	



Fig.1 – Effect of adsorbent dose on the adsorption of rhodamine B by CDC [RDB] = 30 mg/L; Temp = 35°C; Contact time = 60 min



Fig.2 – Effect of contact time on the adsorption of ferrous ion by CDC [RDB] = 45 mg/L; Adsorbent dose = 25 mg/50 ml; Temp = 35°C



Fig,3-Linear Langmuir isotherm for the adsorption of rhodamine B



Fig.4 – Linear Freundlich isotherm for the Adsorption of rhodamine B by CDC



Fig.5-Vant-Hoffs plot for the adsorption of rhodamine B [RDB]=45 mg/L;Adsorbent dose=25 mg/50 ml;Contact time=60 min



Fig.6-Natarajan-Khalaf plot for the adsorption of rhodamine B [RDB]=45 mg/L;Adsorbent dose=25 mg/50 ml;Temp=35<sup>o</sup>C



Fig.7-Intra-particle diffusion effect for the adsorption of rhodamine B [RDB]=45 mg/L;Adsorbent dose=25 mg/50 ml;Temp=35<sup>0</sup>c





Pelagia Research Library



Figure 10a FT-IR spectra for raw cynodon dactylon carbon

Figure 10b FT-IR spectra for the adsorption of Rhodamine B by CDC



Pelagia Research Library



Figure 11a XRD Spectra for Raw Cynodon dactylon carbon







Figure 12a SEM Images for raw Cynodon dactylon carbon

Figure 12b SEM Images for the adsorption of Rhodamine B by CDC



#### CONCLUSION

The experimental data correlated reasonably well by the Langmuir and Freundlich adsorption isotherms and the isotherm parameters were calculated. The low as well high pH value pays the way to the optimum amount of adsorption of the dye. The amount of Rhodamine B adsorbed increased with increasing ionic strength and increased with increase in temperature. The dimensionless separation factor ( $R_L$ ) showed that the activated carbon could be used for the removal of Rhodamine B from aqueous solution. The values of  $\Delta H^\circ$ ,  $\Delta S^\circ$  and  $\Delta G^\circ$  results shows that the carbon employed has a considerable potential as an adsorbent for the removal of Rhodamine B.

#### Acknowledgement

The author acknowledge sincere thanks to Dr. B.R. Venkatraman, Periyar E.V.R. College, Trichy, Dr. S. Arivoli, Thiru.Vi.Ka. College, Thiruvarur and the Correspondent, the Principal, S.T.E.T. Women's College, Mannargudi for carrying out this research work successfully.

#### REFERENCES

- [1] E.A. Clarke, R. Anliker, Organic dyes and pigments., in the Handbook of Environmental Chemistry Vol. 3,
- Part A. Anthropogenic compounds. Hutzinger. O.(Ed). Springer Verlag, Heidelberg, 1980, 181 215.
- [2] G. Baughman, T.A. Perenich, Environ. Toxicol. Chem., 1988, 7, 183 199.
- [3] I.G. Laing, Rev prog. Coloration., 1991, 21, 56 71.
- [4] R. Anliker, E.A. Clarke, P. Moser, *Chemosphere*, **1981**, 10, 263 274.
- [5] K. Strum, E. Williams, K.J. Macek, *Water Resources.*, **1975**, 9, 211 219.
- [6] U.M. Pagga, K. Taeger, Water Resources., 1994, 28, 1051 1057.
- [7] L. Davis, C. Randal, Wastewater., J. WPCF, 1978, 50, 382 386.
- [8] M. Pollock, Americian Dyestuff Reporter., **1973**, 62, 21 23.
- [9] I. Arvanitoyannis, S.I. Eleftheriadis, E. Kavlentis, Chemosphere., 1987, 16, 2523 2529.
- [10] I. Arvanitoyannis, S.I. Eleftheriadis, E. Tsatsaroni, Chemosphere., 1989, 18, 1707 1711.
- [11] N. Nyhlom, B.N. Jacobsen, B.M. Pedersen, O. Poulsen, A. Damborg, B. Schultz, *Water Resources.*, **1992**, 26, 339 353.
- [12] P. Mavros, A.C. Daniilidou, N.K. Lazaridi, L. Stergiou, Flotation Environ. Technol., 1994, 15, 601 616.
- [13] C. Namasivayam, N. Muniasamy, K. Gayathri, M. Rani, K. Renganathan, Biores Technol., 1996, 57, 37.
- [14] C. Namasivayam, R.T. Environ. Pollut., 1995, 89, 1, 1-7.
- [15] I. Langmuir, J. Am. Chem. Soc., 40, 1918, 1361.
- [16] D.G. Krishna, G. Bhattacharya, Appl. Clay. Sci., 2002, 20, 295.
- [17] S. Arivoli, M. Viji Jain, T. Rajachandrasekar, Mat. Sci. Res. India., 2006, 3, 241-250.
- [18] S. Arivoli, M. Hema, Intern. J. Phy.Sci., 2007, 2, 1, 10-17.
- [19] T.W. Weber, R.K. Chakraborti, J. AIChE., 1974, 20, 228-238.
- [20] S. Arivoli, B.R. Venkatraman, T. Rajachandrasekar, M. Hema, Res.J.Chem. Environ., 2007, 17, 70-78.
- [21] H. Freundlich, Phys. Chemie., 1906, 57-384.
- [22] A.K. Bhattacharya, S.N. Mandal, S.K. Das, Chem. Eng. J., 2006, 123, 43-51.
- [23] S. Arivoli, K. Kalpana, R. Sudha, T. Rajachandrasekar, E.J. Chem., 2007, 4, 238-254.
- [24] Renmin Gong, Yingzhisun, Jian Chen, Huijum Liu, Chaoyang, Dyes and pigments., 2005, 67, 179.
- [25] S. Arivoli, Ph D., Thesis, Gandhigram Rural University, Gandhigram, 2007.

[26] W.J. Weber, Principle and application of water chemistry, edited by S.D. Faust, J.V. Hunter, Wiley, New York, **1967.** 

[27] V.V. Vadivelan, K. Vasanthakumar, J. Colloid, Interface. Sci., 2005, 286, 91.

[28] Yupeng Guo, Jingzhu zhao, Huizhang, Shaofeng Yang, Zichen Wang and Hongding, X.,U., Dyes and pigments., 2005, 66, 123-128.

[29] M.K. Sreedhar, T.S. Anirudhan, Indian J Environ Protect., 1999, 19, 8.