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RESEARCH ARTICLE

EQUILIBRIUM AND ISOTHERM STUDIES ON THE ADSORPTION OF RHODAMINE B ONTO ACTIVATED CARBON PREPARED FROM BARK OF *ERYTHRINA INDICA*

V.ROOPA[1], K. RAMESH [2], A.RAJAPPA[3] AND V. NANDHAKUMAR[4*]

[1,4]Department of Chemistry, A.V.V.M Sri Pushpam College, Poondi,Tamil Nadu, India
[2]Department of Chemistry, Arasu Engineering College, Kumbakonam, Tamil Nadu, India
[3]Department of Chemistry, Sri Manakula Vinayagar Engineering College, Pondicherry, India

Corresponding Author: vnchem13@gmail.com

Abstract

In this study activated carbon was prepared from bark of *Erythrina Indica,* and used for the adsorption of Rhodamine B dye from aqueous solution. Batch mode adsorption experiments were carried out. The influence of various parameters such as effect of initial concentration, adsorption dose, agitation time and temperature were studied. The equilibrium adsorption data were analyzed with four isotherm models. Order of best fitting isotherm models were found to be Freundlich > Langmuir > Tempkin > Dubinin Raduskevich.

Keywords: Adsorption; activated carbon; Isotherms; Rhodamine B
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Introduction

The textile industry is one of the largest polluters in the world. The World Bank estimates that almost 20% of global industrial water pollution comes from the treatment and dyeing of textiles. Many treatment methods have been used to remove the dyes from wastewater. Among the various methods, adsorption is an effective separation process which is now recognized as an effective and economical method for the removal of both organic and inorganic pollutants from wastewater. The most widely used adsorbents are activated carbon because of their high surface area due to the presence of micro and meso pores. A number of studies have also been performed using activated carbon prepared from agricultural wastes for the removal of dyes from aqueous solution (Moreno-Castilla, 2004; Abechi, et al., 2011). Rhodamine dyes are generally toxic, and are soluble in water, Methanol, and Ethanol (Lyon 1978). It belongs to the class of Basic dyes. On dissolution in water, it splits into coloured cation and colourless anion (http://www.brown.edu/Departments/Visual_Art/documents/ NavalJelly.pdf,).

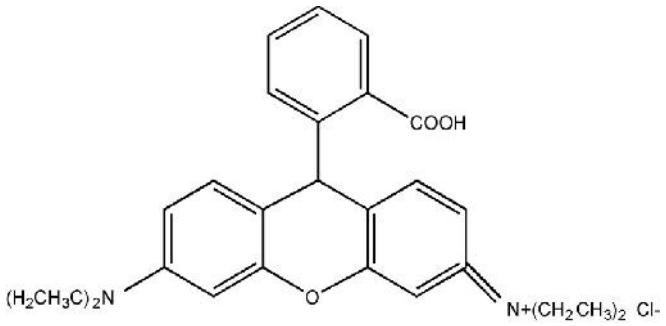


Figure 1. Structure of Rhodamine B

The aim of present study is to establish the mechanism of adsorption of Rhodamine-B onto the prepared activated carbon.

Nomenclature			
C_i , C_t and C_e	Initial Concentration, at the time 't' and at equilibrium respectively	b_T	Tempkin constant related to heat of sorption (J/mg)
Q_t and q_e	Quantity adsorbed at the time 't' and at equilibrium respectively	ε	Polanyi potential
V	Volume of the dye solution in liter (L)	E	Activation energy
W	Mass of the adsorbent in gram (g)	R	Gas Constant
Q_e	Amount of solute adsorbed per unit weight of adsorbent (mg/g)	T	Temperature (K)
Q_0	Adsorption efficiency	h	Initial adsorption rate (mg/g min)
b	Adsorption energy	a_T	Equilibrium binding constant
R_L	Separation factor	q_D	Theoretical saturation capacity (mg/g)
K_f and n	The constants incorporating all factors affecting the adsorption capacity and intensity of adsorption respectively	B	Constant related to the mean free energy

Materials and Methods

Preparation of adsorbent

The bark of *Erythrina Indica* were cut into smaller pieces and soaked in concentrated H_2SO_4 at 1:1 ratio (W/V) for 48 hour and activated at 160°C for 6 h. The activated carbon was repeatedly washed with distilled water until the pH of the wash water became neutral. The carbon obtained was dried at 110 ± 1°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 desicator.

Preparation of stock Solution

Analar grade Rhodamine - B dye was used without further purification. The dye stock solution was prepared by dissolving appropriate amount of accurately weighed dye in double distilled water to a concentration of 1000 mg/L. The experimental solutions were prepared from the stock solution by proper dilution (Venkatraman et al., 2011; Arivoli et al., 2009).

Adsorption experiments

Adsorptions of Rhodamine - B dye on EIBC carried by a batch method at 305K temperature. The effect of contact time and initial concentration of Rhodamine - B were investigated. The adsorption process was carried out with three different initial concentrations at 25 mg/L, 50 mg/L and 75 mg/L of the dye. 40 mg of adsorbent was taken in 100 mL iodine flask. 50 mL of the dye 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 dye concentration of the centrifugate was measured using Systronics Double Beam UV-visible Spectrophotometer: 2202 at 555 nm to determine the percentage removal of the dye from the solution (Venkatraman et al., 2011; Arivoli, 2009; Hema and Arivoli, 2009).

Data Processing Tools

Data processing tool was represented in Table.1

Results and discussion

Effect of contact time and initial concentration

The percentage of removal of Rhodamine - B from aqueous solution with respect to contact times and with different initial concentrations was shown in Figure 2.It reveals that the dye uptake increases with the increase of time and attained equilibrium around 80 minutes for all the studied initial concentrations. Further it is noticed that the rate adsorption was high at initial stages and rate gradually decreased till the attainment of equilibrium.

Table 1. Data Processing Tools

S.No.	Parameters		Formulae
1.	**Mass balance relationships**	% of Removal	$(C_i - C_t) \times V/C_i$
		Quantity adsorbed at equilibrium, q_e	$(C_i - C_e) \times V/W$
		Quantity adsorbed at the time t, q_t	$(C_i - C_t) \times V/W$
2.	**Isotherms**	Langmuir	$C_e/Q_e = 1/Q_0 b + C_e/Q_0$
		Separation factor	$R_L = 1 / (1+ bC_0)$
		Freundlich	$\log Q_e = \log K_f + 1/n \log C_e$
		Tempkin	$q_e = RT/b_T \ln a_T + RT/b_T \ln C_e$
		Dubinin – Raduskevich,	$\ln q_e = \ln q_D - B\varepsilon^2$
		Polanyi potential	$\varepsilon = RT \ln (1+1/C_e)$
		Mean free energy of adsorption	$E = 1/ (2B)^{1/2}$

Figure 2. Effect of Contact times and with different initial concentrations

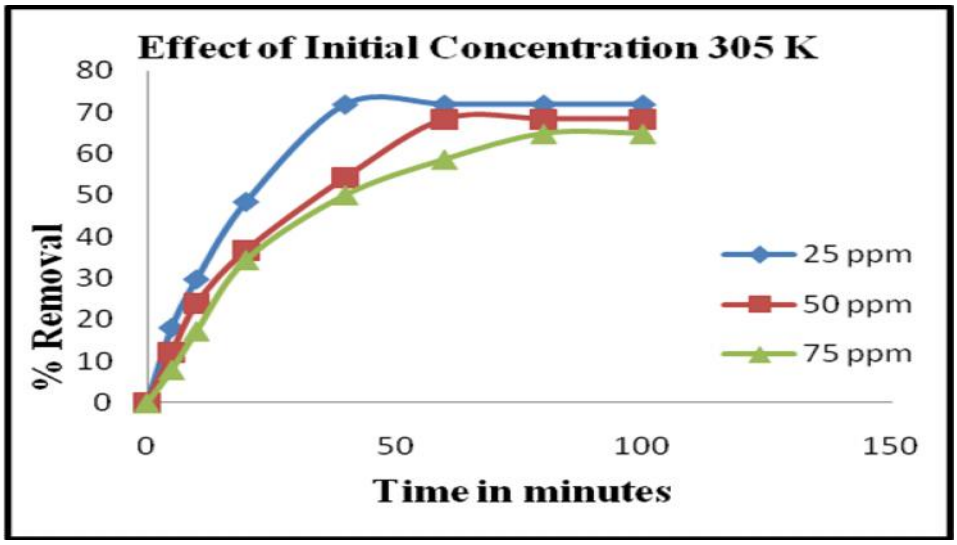


Table 2. Amount of dye adsorbed with respect to initial concentrations of dye

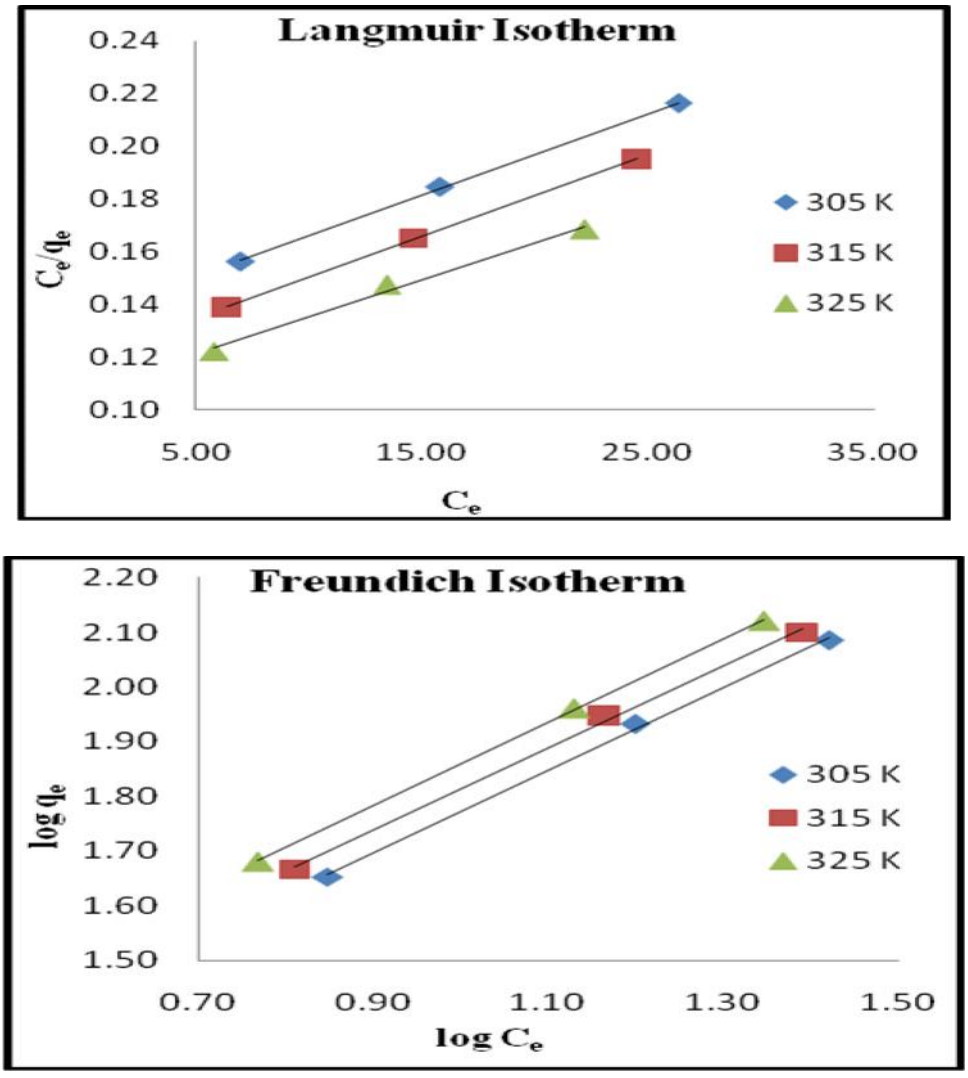
S.No.	Initial concentrations of dye (mg/L)	Time to attain equilibrium (min)	Amount of dye adsorbed (mg/g)
1	25	40	22.4875
2	50	50	42.7625
3	75	80	60.8500

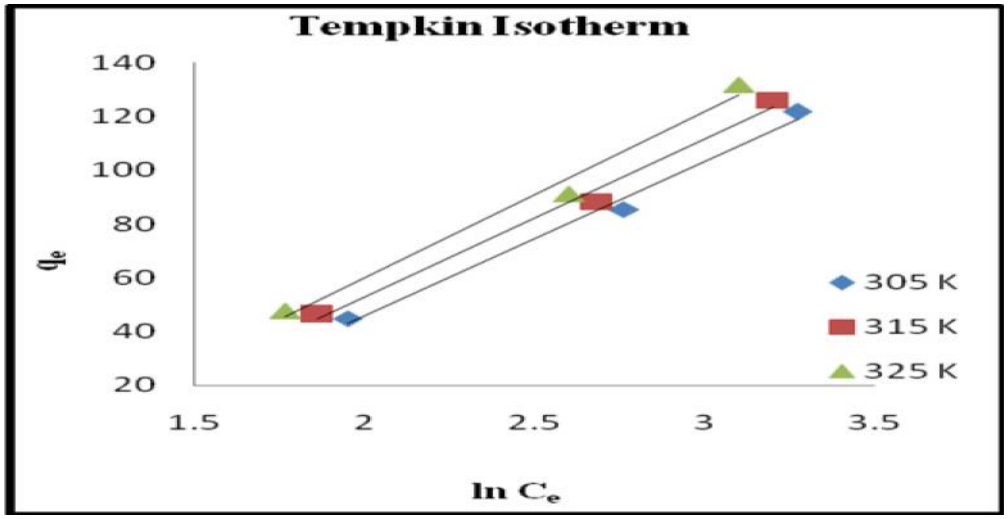
The table -2 infers that the time to attain equilibrium found to increase with the increase of initial concentration as expected, because of the extra time required to access into the interior pores. The percentage of removal of the dye at equilibrium decreased with an increase of initial concentration of the adsorbate. This is due to the decrease in the ratio between number of available adsorption sites and the concentration of solute in the solution with the increase of initial concentration (Venkatraman et al., 2011; Arivoli, S 2009; Hema and Arivoli, 2009). It is observed that the amount of solute adsorbed by the adsorbent, increased with the increase of initial concentrations of the dye which is depicted in the Table - 2. Similar trend has been reported in literatures (Hema and Arivoli, 2009; Namasivayam et al., 2001).

Isotherm studies

The existence of equilibrium between the liquid and solid phase is well described by adsorption isotherms. Equilibrium data collected at different temperatures were fitted in Langmuir, Freundlich, Tempkin and Dubinin-Raduskevich adsorption isotherm models (Foo, and Hameed, 2010; Basar, 2006). These isotherms are depicted in Figure 3.

Figure 3 Isotherm Models





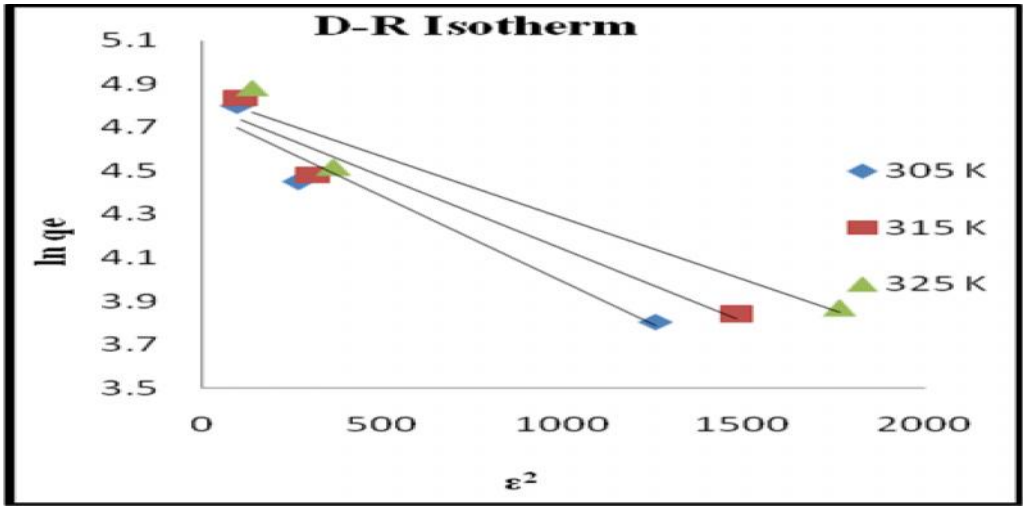


Table 3. Isotherm parameters for removal of Rhodamine by EIBC

Langmuir Isotherm							Freundlich Isotherm		
Temperature (K)	Q_0 (mg/g)	b (L/mg)	R_L			R^2	n	k_f ($mg^{1-1/n}.L^{1/n}.g^{-1}$)	R^2
			10 ppm	15 ppm	20 ppm				
305	333.33	0.020	0.64	0.44	0.41	0.999	1.320	10.35	0.998
315	400.00	0.025				0.999	1.335	11.59	0.998
325	500.00	0.019				0.992	1.314	12.53	0.999

Dubinin Raduskevich					Temkin Isotherm		
Temperature (K)	q_D (mg/g)	$B \times 10^{-4}$ (mol^2/J^2)	E (kJ/mol)	R^2	b_T (J/mol)	a_T (L/g)	R^2
305	118.64	7.9	0.025	0.951	44.24	3.296	0.990
315	122.50	6.7	0.027	0.950	44.61	3.006	0.990
325	127.50	5.7	0.029	0.944	43.67	2.790	0.985

Analysis of isotherm results

R^2 values of these isotherm plots reveal that Freundich isotherm well describes the present system, which describes the adsorption at heterogeneous surface but within a restricted range only. The 'n' values should be in between 1 and 10 for favourable adsorption. In the present study 'n' value ranges from 1.32 – 1.31, which indicates the favourable adsorption. The Langmuir model was originally developed to describe the adsorption of gas on to solid surface. It suggests the formation of monolayer adsorption and also the surface is energetically homogeneous (Venkatraman et al., 2011; Arivoli, 2009) where, Q_0 is a constant related to adsorption capacity (mg/g) and b is Langmuir constant related to energy of adsorption. The essential characteristics of Langmuir isotherm can be expressed by dimensionless separation factor, R_L (Satish Manocha et al., 2002). The R_L values of this adsorption process were in between 0 and 1, indicates the favourable adsorption. R^2 value of Dubinin-Raduskevich isotherm is very low. It is a most popular model for a single solute system, based on the distribution of solute between the solid phase and aqueous phase at equilibrium (Singh et al., 1999). The very low values of the Dubinin Raduskevich parameter 'B' related to the mean free energy of adsorption per mole of the adsorbate and the Activation energy (E) inferred that the adsorption is physical in nature. If the values of Temkin Isotherm parameter b_T is less than 20 and a_T is in between from 0 to 8, then the adsorption is physical nature, otherwise it is chemical nature (Tempkin et al., 1940). In our present study the values of b_T and a_T confirm the adsorption is physical nature.

Conclusion

Activated carbon (EIBC) was prepared from bark of *Erythrina Indica* found to have good capacity of adsorption. Experimental data indicated that EIBC was effective in removing Rhodamine B from aqueous solution. Equilibrium adsorption was achieved in about 80 minutes for the dosage of 40 mg/50 mL of solution at room temperature of 305 K for the initial concentration of Rhodamine B solutions ranging from 25 to 75 mg/L. The separation factor R_L values and intensity of adsorption 'n' values from Langmuir isotherms and Freundlich isotherms respectively indicated that the adsorption is more favourable. Dubinin Raduskevich and Temkin isotherm parameter values infer the physisorption nature.

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