Research Article

ISOTHERMAL ANALYSES ON THE REMOVAL OF RHODAMINE B USING ACTIVATED CARBON

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ABSTRACT

This paper presents the removal of cationic dye Rhodamine-B from aqueous solutions by using a low cost natural adsorbent *Solanum trilobatum*. The effects of various experimental parameters on adsorption such as contact time, temperature, initial pH, initial dye concentration, adsorbent dosage, ionic strength were examined and the optimal experimental conditions were evaluated. Adsorption isothermal data could be interpreted by the Langmuir, Freundlich, Temkin, Dubinin-Radushkevich, Hurkins-Jura, Halsey, Redlich-Peterson, Jovanovich and BET isotherm models equations. The values of free energy change (ΔG^0), enthalpy change (ΔH^0), and entropy change (ΔS^0) indicated the process to be spontaneous. Kinetic data have been studied using Elovich and Pseudo-second order equations for understanding the reaction mechanism.

Keywords: Activated *Solanum trilobatum* Nano Carbon, Adsorption, Rhodamine B, Isotherm Models, Thermodynamic and Kinetic studies.

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INTRODUCTION

Dyeing and finishing are some of the important industrial processes in textile, paper making and leather manufacturing industries. Pollution of the water environment of dyes can cause health risks to humans and their environment. Many of the organic dyes are hazardous and may affect aquatic life and even the food chain. Release of these dyes in water stream is aesthetically undesirable and has serious environmental impact. Rhodamine B, which is a dark pink basic dye of the xanthene class and it is highly water soluble was exclusively used for many patterns of Krajood products. It has been widely used as a colorant in textiles and food stuffs. It is also a well-known watertracer fluorescent and biological stains. In this research, the Rhodamine B was selected for the adsorption experiment due to its presence in the wastewater of several industries (such as textile, leather, jute and food industries). Many dyes may cause allergic dermatitis, skin irritation, dysfunction of kidney, liver, brain, reproductive and central nervous system. Besides, some are suspected carcinogens and mutagens. It is carcinogenic, and may cause irritation, redness and pain in eyes and skin. When inhaled, it causes irritation in respiratory tract with symptoms of coughing, sore throat, labored breathing and chest pain [1-5]. Today there are more than 10,000 dyes available commercially. Most of which are not easy to biodegrade because of their stability toward light and oxidation; also these dyes are resistant to aerobic digestion due to their complex aromatic molecular structure and synthetic origin. Highly colored wastewater containing hazardous dyes is another serious environmental problem. The high organic concentration, toxicity, complex composition and poor degradability of dye-containing wastewater have impeded the development of efficient purification and treatment methods. Various techniques like precipitation,

ion exchange, chemical oxidation and adsorption have been used for the removal of toxic pollutant from, wastewater. Adsorption has been found to be the suitable method for the removal of the dye from the industrial waste water [6, 7]. Activated carbon has high adsorptive capacity. This is due to the extensive internal porous structure formed in activation process. In this study, the quality and quantity of adsorption of Rhodamine B using in (Solanum trilobatum) activated carbon from water were analysed [8-15].

MATERIALS AND METHODS
Preparation of the Adsorbate
The stock solution was prepared by dissolving 1 g of Rhodamine B in 1000 ml of double distilled water. The test solutions were prepared by diluting stock solution to the desired concentrations. The concentration of the Rhodamine B dye was determined at 554 nm. The pH measurements were done using Digital pH meter (Equip-Tronics EQ 614A, India) and adsorption studies were carried out on UV-Vis Double Beam spectrophotometer (Systronics 2203, India). The Rhodamine B dye structure is given below [16].

Preparing the Adsorbent
At first, *Solanum trilobatum* was collected from local area of Tiruvarur district and washed several times by de-ionized water in order to remove the primary impurities. Next, the material was placed in Con.H_2SO_4 (w/v) for 24 hours for carbonization and increasing the adsorbent's porosity. Finally, this was activated around 1100°C in muffle furnace for 12 hours; the fine micro-porous size of activated nano carbon was utilized as the adsorbent [17].

Batch Equilibrium Method
The adsorption experiments were carried out in a batch process at 30, 40, 50, and 60°C. A known weight of *Solanum trilobatum* was added to 50 ml of the dye solutions with an initial concentration of 25 mg/L to 125 mg/L, which is prepared from 1000 mg/L of Rhodamine B stock solution. The contents were shaken thoroughly using a mechanical shaker with a speed of 150 rpm. The solution was then filtered at present time intervals and the residual dye concentration was measured [18-23].

RESULTS AND DISCUSSION
Effect of Contact Time
The adsorption experiments are carried out for different contact times with a fixed adsorbent dose (0.025g) at room temperatures. It is observed that the uptake of the dye increases with time. The extent of adsorption was rapid in the initial stage and becomes slow in later stage till saturation was attained around50 min. This shows that equilibrium can be assumed to be achieved by 50 min of contact time. It is basically due to

saturation of the active site which does not allow further adsorption. The adsorption rates are found to decrease with increase in time.

Effect of Adsorbent Dose
The removal of Rhodamine B dye on *Solanum trilobatum* was studied by different adsorbent doses (25-125 mg/50ml) for 50 mg/L of dye concentration. The percentage of adsorption increases with increase in adsorbent concentration; this is due to the increase in surface area and availability of more adsorption site. All studies were carried out with 0.025g of adsorbent /50 ml of the varying adsorbate solutions, 25, 50, 75, 100 and 125mg. This reveals that the direct and equilibrium capacities of Rhodamine B are functions of the activated adsorbent dosage.

Effect of pH
The pH of the dye solution plays an important role in the whole adsorption process. There is an increase in adsorption capacity of the nano composite is noticed as the pH increases from 2 -10, whereas above 6 the adsorption amount was only slightly affected by pH. As pH of the system decreases, the number of negatively charged adsorbent sites decreases and the number of positively charged surface sites increases. This favours the adsorption of positively charged dye cations due to electrostatic repulsion. In addition, lower adsorption of Rhodamine B at acidic pH might be due to the presence of excess H+ ions competing with dye cations for the available adsorption sites. The maximum removal percentages of Rhodamine B onto ASTNC were 92 to 94% respectively.

Adsorption Isotherm Models
Adsorption isotherm describes the relation between the amount or concentration of adsorbate that accumulates on the adsorbent and the equilibrium concentration of the dissolved adsorbate. Equilibrium studies were carried out by agitating a series of beakers containing 50 ml of Rhodamine B solutions of initial concentration 20 mg/L with 0.025 g of activated nano carbon at 30°C with a constant agitation. Agitation was provided for 1.0 h, which is more than sufficient time to reach equilibrium.

The Freundlich Isotherm
The Freundlich adsorption isotherm is based on the equilibrium sorption on heterogeneous surfaces. This isotherm is derived from the assumption that the adsorption sites are distributed exponentially with respect to heat of adsorption. The adsorption isotherm is expressed by the following equation.

$$q_e = K_F C_e^{1/nF} \ldots\ldots\ldots(1)$$
This can be linearized as
$$\ln q_e = \ln K_F + 1/nF \ln C_e \ldots\ldots(2)$$

Where q_e is the amount of Rhodamine B dye adsorbed (mg/g), C_e is the equilibrium concentration of dye in solution (ppm). K_F(L/g) and $1/nF$ are the Freundlich constants related to adsorption capacity and sorption intensity, respectively.

The Freundlich constants K_F and $1/nF$ were calculated from the slope and intercept of the $lnq_e VslnC_e$ plot, as shown in Fig.4, and the model parameters are shown in table 2. The magnitude of K_F showed that adsorbent had a high capacity for Rhodamine B dye adsorption from the aqueous solutions studied. The Freundlich exponent, n_F, should have values in the range of 1 and 10 (i.e., $1/n_F < 1$) to be considered as favorable adsorption. A $1/n_F$ value of less than 1 indicated that Rhodamine B dye is favorably adsorbed by adsorbent. The Freundlich isotherm did not show a good fit to the experimental data as indicated by SSE and Chi-square statistics.

Langmuir Isotherm

The theoretical Langmuir isotherm is used for adsorption of a solute from a liquid solution as monolayer adsorption on a surface containing a finite number of identical sites. Therefore, the Langmuir isotherm model was chosen for estimation of the maximum adsorption capacity corresponding to complete monolayer coverage on the adsorbent surface. The Langmuir non-linear equation is commonly expressed as follows:

$$C_{eq}/Q_{eq}= 1/Q_m b + C_{eq}/Q_m \dots\dots\dots (3)$$

Where C_{eq} is the equilibrium concentration of adsorbate in the solution (mg/L), Q_{eq} is the amount adsorbed at equilibrium (mg/g),Q_m and b are Langmuir constants related to adsorption efficiency and energy of adsorption, respectively. The linear plots of C_{eq}/Q_{eq} vs. C_{eq} shown in Fig.5 suggest the applicability of the Langmuir isotherms. The values of Q_m and b were calculated from slope and intercepts of the plots are given in Table 2. From the results, it is obvious that the value of adsorption efficiency Q_m and adsorption energy b of the ASTNC increases on increasing the temperature. The values can conclude that the maximum adsorption corresponds to a saturated monolayer of adsorbate molecules on adsorbent surface with endothermic nature of adsorption. To confirm the favorability of the adsorption process, the separation factor (R_L) was determined and given in Table 3. The values were established to be between 0 and 1 and confirm that the ongoing adsorption process is favorable.

Temkin Adsorption Isotherm

The Temkin adsorption isotherm assumes that the heat of adsorption decreases linearly with the sorption coverage due to adsorbent-adsorbate interactions. The Temkin isotherm equation is given as:

$$q_e = \frac{RT}{bT} \ln(K_T C_e) \dots\dots\dots(4)$$

Which, can be represented in the following linear form

$$q_e = \frac{RT}{b} \ln K_T + \frac{RT}{b} \ln C_e \dots\dots\dots(5)$$

Where, K_T (L/g) is the Temkin isotherm constant, b_T (j/mol) is a constant related to heat of sorption, R is the ideal gas constant (8.314 J/mol K), and T is absolute temperature (k). a plot of q_e versus $\ln C_e$ enables the determination of isotherm constants K_T and b_T from the slope and intercept, as shown in Fig. 6. The model parameters are listed in Table 2. The Temkin isotherm appears to provide a good fit to the adsorbent adsorption data.

The adsorption energy in the model, b_T, is positive for Rhodamine B adsorption from the aqueous solution, which indicates that the favorable adsorptions. The experimental equilibrium curve is close to that predicted by Temkin model. Consequently, the adsorption isotherm of Rhodamine B on ASTNC can be described reasonably well by the Temkin isotherm.

Hurkins-Jura Adsorption Isotherm

The Hurkins-Jura adsorption isotherm can be expressed as

$$q_e = \sqrt{\frac{A_H}{B_H + \log C_e}} \dots\dots\dots(6)$$

This can rearranged as follows:

$$\frac{1}{qe^2} = \frac{B_H}{A_H} - \frac{1}{A_H} \log Ce \dots\dots\dots (7)$$

Where, A_H (g^2/L) and B_H (mg^2/L) are two parameters characterizing the sorption equilibrium.

The isotherm equation accounts for multilayer adsorption and can be explained by the existence of a heterogeneous pore distribution. The Harkins-Jura isotherm parameters are obtained from the plots of $1/q_e^2$ versus log C_e enables the determination of model parameters A_H and B_H from the slope and intercept in Fig.7.

Halsay Adsorption Isotherm

The Halsay adsorption isotherm can be given as

$$q_e = \exp\left(\frac{\ln K_{Ha} - \ln C_e}{n_{Ha}}\right) \dots\dots\dots(8)$$

And, a linear form of the isotherm can be expressed as follows:

$$\ln q_e = \frac{\ln K_{Ha}}{n_{Ha}} - \frac{\ln C_e}{n_{Ha}} \dots\dots\dots(9)$$

Where, K_{Ha} (mg/L) and n_{Ha} are the Halsay isotherm constants.

A plot of lnqeVslnCe, shown in Fig.8, enables the determination of nH_a and K_{Ha} from the slope and intercept. This equation is suitable for multilayer adsorption and the fitting of the experimental data to this equation attest to the heteroporous nature of adsorbent. Fig. 8 also shows that the experimental data and the model predictions based on the non-linear form of the Halsay models. The model parameters are listed in Table 2. This result also shows that the adsorption of Rhodamine B on ASTNC was not based on significant multilayer adsorption. The Halsay model is also not suitable to describe the adsorption of Rhodamine B on ASTNC, because this model also assumes a multilayer behavior for the adsorption of adsorbate onto adsorbent.

Radlich-Peterson Adsorption Isotherm

The Radlich-Peterson adsorption isotherm contains three parameters and incorporates the features of Langmuir and Freundlich isotherms into a single equation. The general isotherm equation can be described as follows

$$q_e = \frac{K_R C_e}{1 + a_R C_e^g} \quad \text{.................(10)}$$

The linear form of the isotherm can be expressed as follows:

$$\ln \frac{C_e}{q_e} = g \ln C_e - \ln K_R \quad \text{..............(11)}$$

Where, K_R (L/g) and a_R (L/mg) are the Radlich-Peterson isotherm constants and 'g' is the exponent between 0 and 1. There are two limiting cases: Langmuir form for g=1 and Henry's law for g=0.

A plot of $\ln C_e/q_e$ versus $\ln C_e$ shown in Fig.9 enables the determination of isotherm constants g and K_R from the slope and intercept. The values of K_R, presented in table 2, indicate that the adsorption capacity of the ASTNC decreased with an increase temperature. Furthermore, the value of g lies between 0 and 1, indicating favorable adsorption.

Dubinin-Radushkevich Adsorption Isotherm

The Dubinin-Radushkevich adsorption isotherm is another isotherm equation. It is assumed that the characteristic of the sorption curve is related to the porosity of the adsorbent. The linear from of the isotherm can be expressed as follows:

$$\ln q_e = \ln Q_D - B_D \left[RT \ln \left(1 + \frac{1}{C_e}\right) \right]^2 \quad \text{..............(12)}$$

Where, Q_D is the maximum sorption capacity (mol/g), and B_D is the Dubinin-Radushkevich constant (mol^2/kJ^2). A plot of $\ln q_e Vs R_T \ln(1+1/C_e)$ enables the determination of isotherm constants B_D and Q_D from the slope and intercept, as shown in Fig. 10. The Q_D values obtained (table 2) from the graph shows the adequate tendency of ASTNC adsorbent to adsorb Rhodamine B.

Jovanovic Adsorption Isotherm

The model of an adsorption surface considered by Jovanovic is essentially the same as that considered by Langmuir. The Jovanovic model leads to the following relationship:

$$q_e = q_{max} \left(1 - e^{K_J C_e}\right) \quad \text{..........(13)}$$

The linear form of the isotherm can be expressed as follows:

$$\ln q_e = \ln q_{max} - K_J C_e \quad \text{...........(14)}$$

Where, K_J (L/g) is a parameter. Q_{max} (mg/g) is the maximum Rhodamine B uptake.

The q_{max} is obtained from a plot of $\ln q_e$ and C_e, as shown in Fig.11. Their related parameters are listed in table 2. By comparing the values of the error functions, it was found the Langmuir and Jovanovic models are best to fit the Rhodamine Badsorption on the adsorbent. Both models show a high degree of correlation. This is clearly shown in Fig. 11, confirming the good fitness of Langmuir and Jovanovic with the experimental data for removal of Rhodamine B from the solution.

The Brunauer-Emmett-Teller (BET) Isotherm Model

Brunauer-Emmett-Teller (BET) isotherm is a theoretical equation, most widely applied in the gas-solid equilibrium systems. It was developed to derive multilayer adsorption systems with relative concentration ranges from 10 to 50 mg/L corresponding to a monolayer coverage lying between 0.1439 and 0.0528. Its extinction model related to liquid-solid interface is exhibited as:

$$q_e = \frac{q_s C_{BET} C_e}{(C_S - C_e)[1 + (C_{BET} - 1)(C_e/C_S)]} \quad \text{..............(15)}$$

Where, C_{BET}, Cs, qs and qe are the BET adsorption isotherm relating to the energy of surface interaction (L/mg), adsorbate monolayer saturation concentration (mg/L), theoretical isotherm saturation capacity (mg/g) and equilibrium adsorption capacity (mg/g), respectively. As C_{BET} and C_{BET} (C_e/C_s) is much greater than 1, In the linear form as used is represented as

$$\frac{C_e}{q(C_S - C_e)} = \frac{1}{q_s C_{BET}} + \left(\frac{C_{BET} - 1}{q_s C_{BET}}\right)\left(\frac{C_e}{C_S}\right) \quad \text{..............(16)}$$

In the BET isotherm model for slope and intercept of the $C_e/q_e(C_s-C_e)$ VsC_e/C_s plot were used to calculate C_{BET} and $q_s$the arrived C_{BET} and q_s values are listed in table 2, the BET model graph shown in Fig.12 indicates the physical nature of adsorption of Rhodamine B onto ASTNC.

Kinetic Parameters

The rate and mechanism of the adsorption process can be elucidated based on kinetic studies. Rhodamine B adsorption on solid surface may be

explained by two distinct mechanisms: (1) an initial rapid binding of Rhodamine B molecules on the adsorbent surface; (2) relatively slow intra-particle diffusion. To analyze the adsorption kinetics of the Rhodamine B, the pseudo-first-order, the pseudo-second-order, and intra-particle diffusion models were applied. Each of these models and their linear modes of them equations presented in below.

Kinetic models and their linear forms

Model	Nonlinear Form	Linear Form	Number of Equation
Pseudo-first-order	$dq_t/d_t=K_1(q_e-q_t)$	$\ln(q_e-q_t)=\ln q_e-K_1t$	(17)
Pseudo-second-order	$dq_t/d_t=K_2(q_e-q_t)^2$	$t/q_t=1/K^2q_e^2+(1/q_e)t$	(18)

Where, q_e and q_t refer to the amount of Rhodamine B adsorbed (mg/g) at equilibrium and at any time, t (min), respectively and k_1 (1/min), k_2 (g/mg.min) are the equilibrium rate constants of pseudo-first order and pseudo-second order models, respectively.

Pseudo-first order is a simple kinetic model, which was proposed by Lagergren during 1898 and is used for estimation of the surface adsorption reaction rate. The values of ln (q_e-q_t) were linearly correlated with t. The plot of ln (q_e-q_t) Vs t should give a linear relationship from which the values of k_1 were determined from the slope of the plot. In many cases, the first-order equation of Lagergren does not fit well with the entire range of contact time and is generally applicable over the initial stage of the adsorption processes.

In the pseudo-second order model, the slope and intercept of the t/qtVs t plot were used to calculate the second-order rate constant, k_2. The values of equilibrium rate constant (k_2) are presented in Table 5. According to Table 5, the values of R^2 (0.999) related to the pseudo-second order model revealed that Rhodamine B adsorption followed this model, which is in agreement with the results obtained by Karagoz et al. Hameed et al., nevertheless, pseudo-first order and pseudo-second order kinetic models cannot identify the mechanism of diffusion of Rhodamine B into the adsorbent pores.

Simple Elovich Model
The simple Elovich model is expressed in the form,
$$Q_t=\alpha + \beta \ln t \ldots\ldots\ldots(19)$$
Where, q_t is the amount adsorbed at time t, α and β are the constants obtained from the experiment. A plot of q_tVslnt should give a linear relationship for the applicability of the simple Elovich kinetics. The Elovich kinetics of Rhodamine B on to ASTNC for various initial concentrations (10, 20, 30, 40 and 50 mg/L) of volume 50 mL (each), adsorbent dose 0.025g, temperature 30ºC and pH 6.5.

The Elovich Equation
The Elovich model equation is generally expressed as
$$Dq_t/d_t=\alpha \exp(-\beta q_t)\ldots\ldots\ldots\ldots.(20)$$
Where α is the initial adsorption rate (mg g^{-1} min^{-1}) and β is the desorption constant (g/mg) during any one experiment. To simplify the Elovichequation. Chien and Clayton (1980) assumed $\alpha\beta t>>t$ and by applying boundary conditions $q_t=0$ and q_t at t=t Eq.(20) becomes:
$$Q_t = 1/\beta \ln (\alpha\beta) + 1/\beta \ln t \ldots\ldots.(21)$$
If Rhodamine B adsorption fits with the Elovich model, a plot of $q_t$vs. ln(t) yields a linear relationship with a slope of $(1/\beta)$ and an intercept of $(1/\beta)\ln(\alpha\beta)$. The Elovich model parameters α,β, and correlation coefficient (γ) are summarized in table 5. The experimental data such as the initial adsorption rate (α) adsorption constant (β) and the correlation co-efficient (γ) calculated from this model indicates that the initial adsorption (α) increases with temperature similar to that of initial adsorption rate (h) in pseudo-second-order kinetics models. This may be due to increase the pore or active site on the adsorbent.

Intra-Particle Diffusion Model
The kinetic results were analyzed by the Intraparticle diffusion model to elucidate the diffusion mechanism. The model is expressed as:
$$Q_t = K_{id}t^{1/2} + I \ldots\ldots\ldots\ldots..(22)$$
Where I is the intercept and K_{id} is the intra-particle diffusion rate constant. The intercept of the plot reflects the boundary layer effect. Larger the intercept, greater is the contribution of the surface sorption in the rate controlling step. The calculated diffusion coefficient K_{id} values are listed in table5. The K_{id} value was higher at the higher concentrations. Intra-particle diffusion is the sole rate-limiting step if the regression of q_t versus $t^{1/2}$ is linear and passes through the origin. In fact, the linear plots at each concentration did not pass through the origin. This deviation from the origin is due to the difference in the rate of mass transfer in the initial and final stages of the sorption. This indicated the existence of some boundary layer effect and further showed that Intra-particle diffusion was not the only rate-limiting step.

It is clear from the Table 5 that the pseudo-second-order kinetic model showed excellent linearity with high correlation coefficient ($R^2>0.99$) at all the studied concentrations in comparison to the other kinetic models. In addition, the calculated q_e values also agree with the experimental data in the case of pseudo-second-order kinetic model. It is also evident from Table 6 that the values of the rate constant k_2 decrease with increasing initial Rhodamine B concentrations. This is due to the

lower competition for the surface-active sites at lower concentration but at higher concentration the competition for the surface active sites will be high and consequently lower sorption rates are obtained.

Desorption Studies

Desorption studies assist to illuminate the nature of adsorption and recycling of the spent adsorbent. The effect of various reagents used for desorption studies indicate that hydrochloric acid is a better reagent for desorption. Desorption of Rhodamine B dye by dilute mineral acid indicates that the dyes were adsorbed onto the activated carbon through physisorption.

Table 1. Equilibrium Parameters for the Adsorption of Rhodamine B Dye onto ASTNC

C_0	C_e (Mg / L)				Q_e (Mg / L)				Removal %			
	30ºC	40ºC	50ºC	60ºC	30ºC	40ºC	50ºC	60ºC	30ºC	40ºC	50ºC	60ºC
25	1.4250	0.8550	0.5707	0.5416	47.150	48.290	48.859	48.917	94.300	96.580	97.717	97.834
50	3.1350	2.8513	2.5770	1.9957	93.730	94.30	94.846	96.009	93.730	94.297	94.846	96.009
75	6.8635	6.2142	5.4151	5.0172	136.27	137.57	139.17	139.97	90.849	91.714	92.780	93.310
100	9.9989	9.1441	8.6737	8.1361	180.00	181.71	182.65	183.73	90.001	90.856	91.326	91.864
125	14.820	14.306	13.990	13.159	220.36	221.39	222.02	223.68	88.144	88.555	88.808	89.472

TABLE 2. Isotherm Parameters for the Adsorption Of Rhodamine B Dye Onto ASTNC

Model	Constant	Temperature (º C)			
		30	40	50	60
Freundlich	K_f(mg/g) (L/mg)$^{1/n}$	40.200	52.720	62.690	66.620
	n	1.5518	1.8402	2.0850	2.1039
Langmuir	Q_m(mg/g)	352.18	298.98	277.04	272.08
	b (L/mg)	0.1060	0.1734	0.2389	0.2837
Temkin	b_T (J/mol)	71.932	60.353	53.283	53.596
	K_T (L/mg)	1.5060	2.8410	3.5790	3.8950
Hurkins-Jura	A_H (g^2/L)	-2523.2	-3000.9	-3418.9	-3542.5
	B_H (mg^2/L)	-1.0691	-1.0464	-1.0291	-0.9970
Halsay	K_{Ha}(mg/L)	308.70	1474.5	5586.4	6865.3
	n_{Ha}	1.5518	1.8402	2.0850	2.1039
Radlich-Peterson	g	0.3556	0.4566	0.5204	0.5247
	K_R (L/g)	0.0249	0.0190	0.0160	0.0150
Dubinin-Radushkevich	q_s (mg/g)	174.30	164.02	160.94	165.50
	$K_D \times 10^{-4}$ mol^2 kJ^{-2}	1.6410	1.6204	1.6109	1.6158
Jovanovic	K_J (L/g)	0.1046	0.1049	0.1036	0.1077
	q_{max} (mg/g)	55.751	59.745	63.470	65.514
BET	C_{BET} (L/mg)	15.499	27.826	42.690	50.206
	qs (mg/g)	0.0645	0.0359	0.0234	0.0199

Table 3. Dimensionless Separation Factor (R_L) for the adsorption of rhodamine b onto ASTNC

(C_i)	Temperature °C			
	30ºC	40ºC	50ºC	60ºC
25	0.2740	0.1874	0.1434	0.1236
50	0.1587	0.1034	0.0773	0.0659
75	0.1117	0.0714	0.0529	0.0449
100	0.0862	0.0545	0.0402	0.0341
125	0.0702	0.0441	0.0324	0.0274

**Table 4. Thermodynamic Parameter For The Adsorption Of Rhodamine B Onto ASTNC**

C_0	ΔGº				ΔH°	ΔS°	E_a	S*
	30ºC	40ºC	50ºC	60ºC				
25	-7068.8	-8693.5	-10088.3	-10549.0	28.999	119.81	27.963	8×10^{-7}
50	-6813.4	-7300.8	-7821.3	-8804.9	12.773	64.333	12.123	5×10^{-4}
75	-5782.2	-6256.3	-6856.9	-7296.2	9.8179	51.465	9.0466	3×10^{-3}

| 100 | -5535.4 | -5975.3 | -6321.9 | -6711.0 | 6.2023 | 38.799 | 5.6418 | 1×10^{-3} |
| 125 | -5053.7 | -5324.5 | -5562.2 | -5924.5 | 3.5613 | 28.388 | 3.1626 | 3×10^{-2} |

Table 5. The kinetic parameters for the adsorption of rhodamine b onto ASTNC

| C_0 | Temp °C | Pseudo second order | | | | Elovich model | | | Intraparticle diffusion | | |
		q_e	k_2	γ	h	α	β	γ	K_{id}	γ	C
25	30	49.389	0.0057	0.9919	14.019	8.4×10^3	0.2519	0.9806	0.0901	0.9971	1.8098
	40	49.531	0.0105	0.9911	25.702	2.2×10^7	0.4199	0.9826	0.0513	0.9898	1.8910
	50	49.657	0.0163	0.9939	40.298	5.2×10^{11}	0.6291	0.9866	0.0334	0.9917	1.9288
	60	49.672	0.0173	0.9950	42.661	2.7×10^{12}	0.6629	0.9836	0.0316	0.9907	1.9326
50	30	96.744	0.0040	0.9972	37.078	1.1×10^6	0.1757	0.9870	0.0638	0.9955	1.8528
	40	97.153	0.0043	0.9939	40.598	2.6×10^6	0.1840	0.9816	0.0604	0.9907	1.8626
	50	97.664	0.0048	0.9965	45.678	6.9×10^6	0.1930	0.9836	0.0570	0.9897	1.8733
	60	98.384	0.0052	0.9982	50.408	5.0×10^7	0.2129	0.9806	0.0509	0.9917	1.8883
75	30	139.18	0.0039	0.9922	76.025	1.7×10^9	0.1751	0.9816	0.0434	0.9957	1.8763
	40	141.11	0.0043	0.9913	85.318	4.3×10^8	0.1611	0.9877	0.0465	0.9897	1.8793
	50	143.23	0.0037	0.9905	76.180	2.7×10^8	0.1382	0.9862	0.0539	0.9917	1.8714
	60	143.10	0.0051	0.9907	105.02	8.7×10^8	0.1628	0.9878	0.0452	0.9897	1.8909
100	30	184.38	0.0039	0.9926	132.19	3.4×10^8	0.1194	0.9852	0.0480	0.9938	1.8713
	40	186.06	0.0036	0.9935	126.20	2.7×10^8	0.1172	0.9811	0.0486	0.9907	1.8734
	50	186.87	0.0039	0.9956	134.75	5.1×10^8	0.1201	0.9841	0.0471	0.9963	1.8787
	60	187.98	0.0038	0.9967	135.87	5.8×10^8	0.1201	0.9872	0.0467	0.9918	1.8818
125	30	225.00	0.0023	0.9954	118.00	7.1×10^8	0.1020	0.9819	0.0462	0.9921	1.8576
	40	226.17	0.0023	0.9975	117.16	5.7×10^8	0.1004	0.9879	0.0467	0.9907	1.8588
	50	226.50	0.0024	0.9922	124.37	2.1×10^9	0.1063	0.9866	0.0439	0.9917	1.8652
	60	228.39	0.0022	0.994	117.03	5.7×10^8	0.0994	0.9836	0.0468	0.9949	1.8628

Fig 1. Structure of Rhodamine B
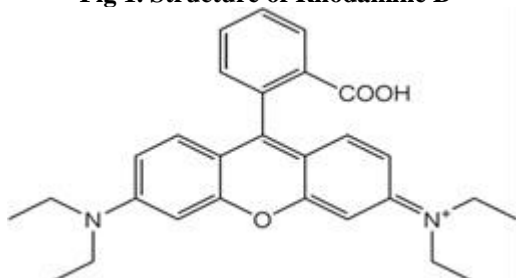
Fig 2. Solanum Trilobatum

Fig 1. Contact time in Min
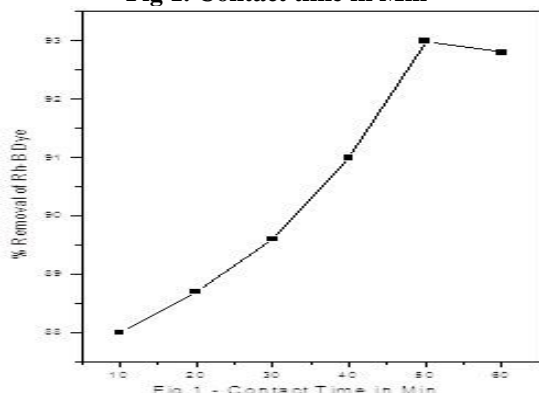
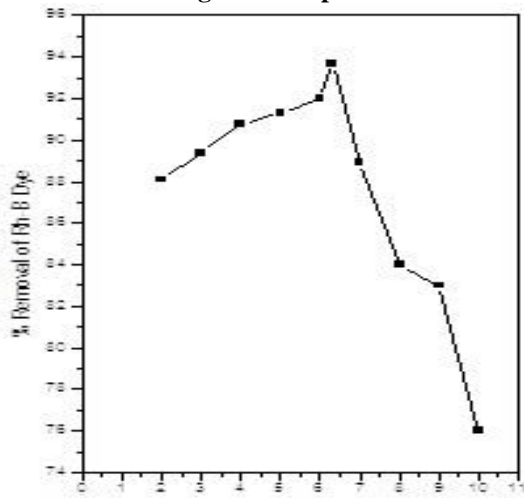**Fig 2. Adsorbent dose in mg**
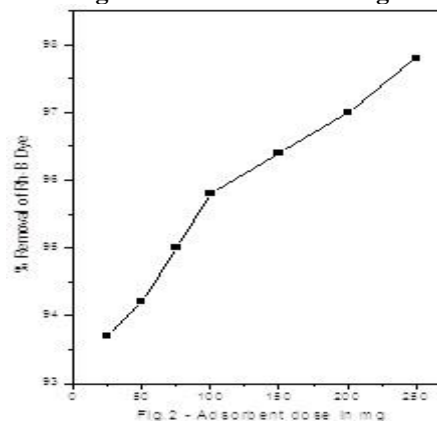
Fig 3. Initial pH

Fig.3 - Initial pH
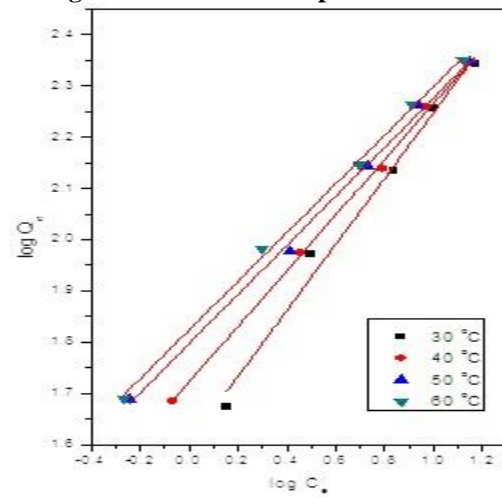
Fig 4. Freund lich absorption isotherm

Fig.4 - Freundlich adsorption isotherm
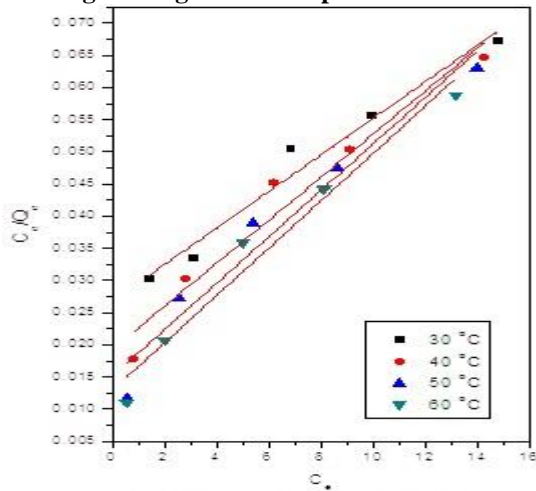
Fig 5. Lang muir adsorption isotherm

Fig.5 - Langmuir adsorption isotherm

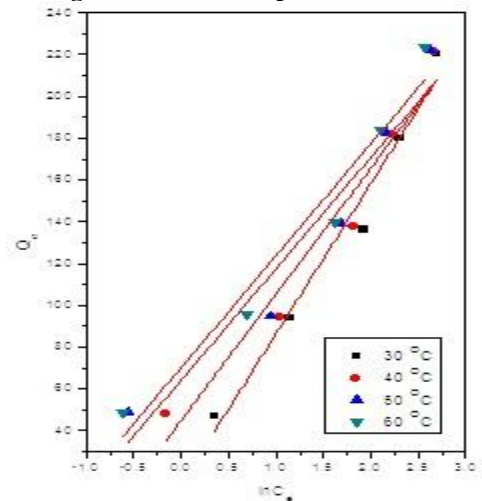**Fig 6. Temkin adsorption isotherm**

Fig.6 - Temkin adsorption isotherm
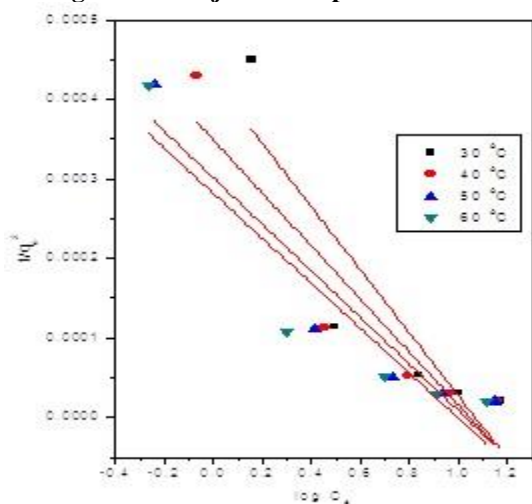
Fig 7. Hurkinsjura adsorption isotherm

Fig.7 - Hurkins jura adsorption isotherm
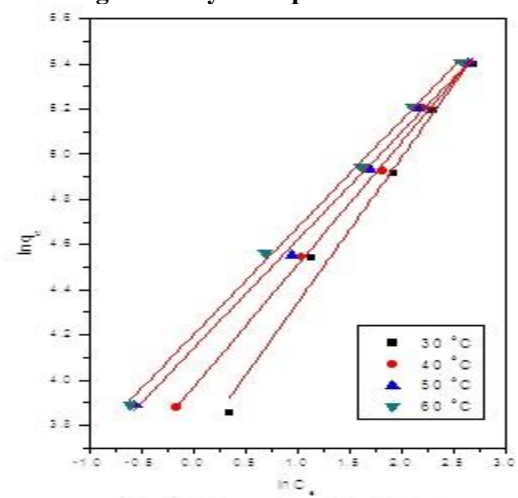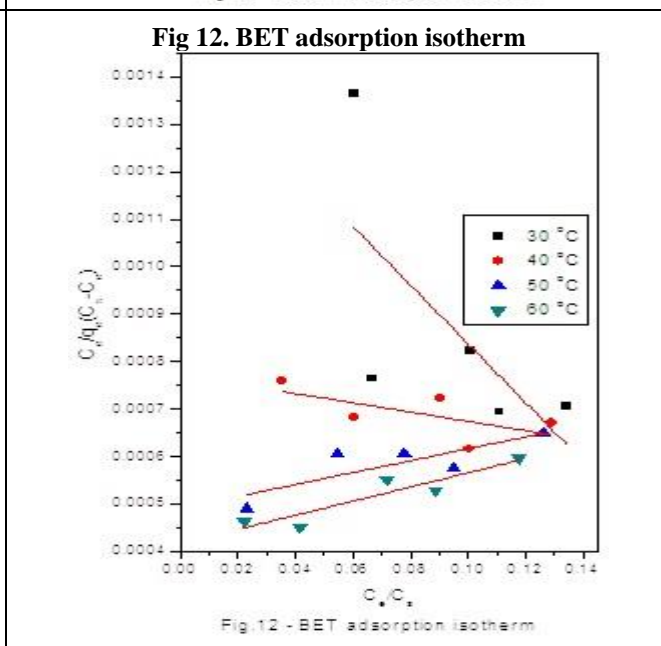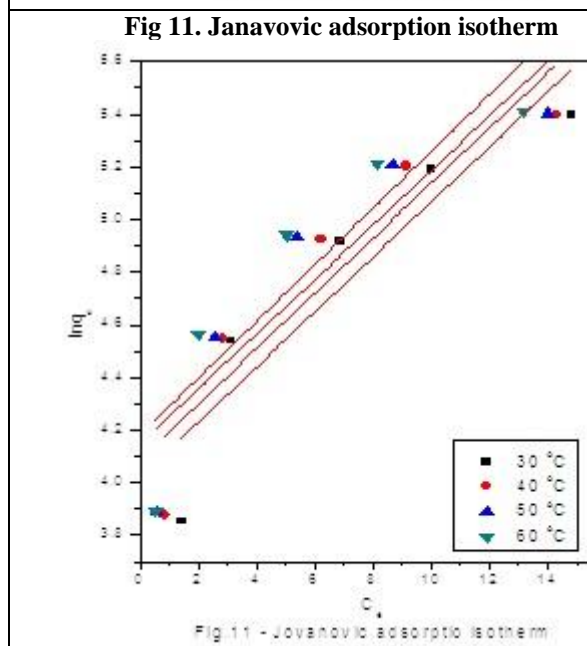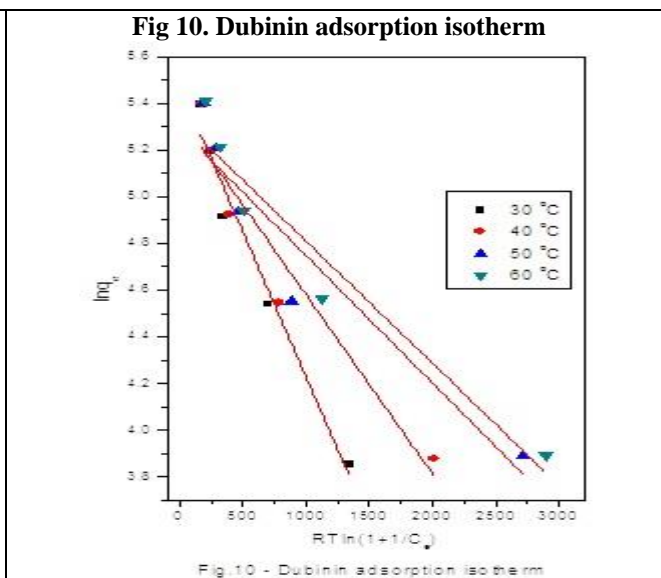
Fig 8. Halsay adsorption isotherm

Fig.8 - Halsay adsorption isotherm

Fig 9. Radlich adsorption isotherm

Fig.9 - Radlich adsorption isotherm

Fig 10. Dubinin adsorption isotherm

Fig.10 - Dubinin adsorption isotherm

Fig 11. Janavovic adsorption isotherm

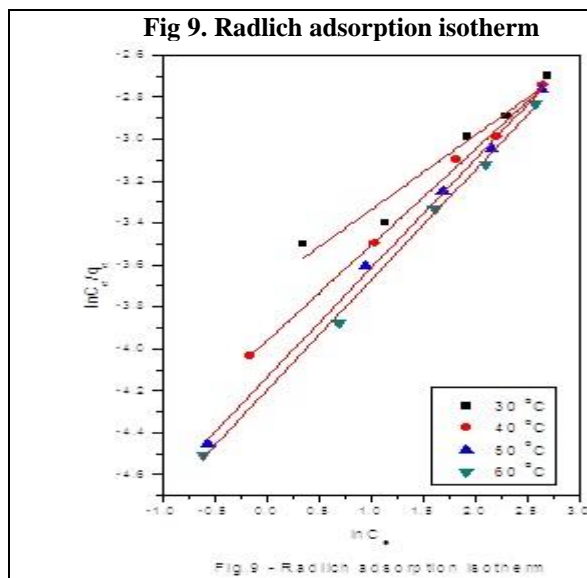Fig.11 - Jovanovic adsorptio isotherm

Fig 12. BET adsorption isotherm

Fig.12 - BET adsorption isotherm

CONCLUSION

The adsorption of Rhodamine B on to Activated *Solanum trilobatum* nanocarbon was investigated in this research work. The adsorption equilibrium well correlated with both Langmuir and BET isotherm models. The adsorption kinetic process was found pseudo-second-order model. Isotherm and kinetic study indicates that the activated carbon can be effectively employed for the adsorption of Rhodamine B.

CONFLICT OF INTEREST
None

REFERENCES

1. Vijayakumar G, Tamilaras R and Dharmendirakumar M. Adsorption, Kinetic, Equilibrium and Thermodynamic studies on the removal of basic dye Rhodamine-B from aqueous solution by the use of natural adsorbent perlite. *J. Mater. Environ. Sci.,* 3(1), 2002, 157-170.

2. Sumanjit R, *et al*. Removal of Rhodamine-B by Adsorption on Walnut Shell Charcoal. *J. Surface Sci. Technol.,* 24(3-4), 2008, 179-193.
3. Tabrez A, *et al.* Adsorption of Rhodamine B dye from aqueous solution onto acid activated mango (Magniferaindica) leaf powder: Equilibrium, kinetic and thermodynamic studies. *Journal of Toxicology and Environmental Health Sciences,* 3(10), 2011, 286-297.
4. Li L, Shuangx L and Tan Z. Application of activated carbon derived from scrap tires for adsorption of Rhodamine B. *Journal of Environmental Sciences*, 22(8), 2010, 1273-1280.
5. Karthikeyan S, Shanthi P, Saravanan A and Saranya K. Sorption of Basic Dye (Rhodamine B) by Nano Porous Activated Carbon from Sterculia Quadrifida Shell Waste. *J. Environ. Nanotechnol.,* 3(1), 2012, 88-100.
6. Kavitha K, Senthamilselvi MM and Arivoli S. Adsorption of Rhodamine B from an aqueous solution: Kinetic and Thermodynamic Studies. *Int.J.Curr.Res.Chem.Pharma.Sci.,*1(7), 2010, 147-154.
7. Harouna M, BaiboussaG, Abia D, Tcheka C, Loura BB, Ketcha JM and Ileana Denisa Nistor. Adsorption of Rhodamine B in Aqueous Solution by Activated Carbon from the Seed Husks of *Moringa oleifera. International journal of engineering research and science& science,* 4(1), 2015, 52.
8. Venkatraman BR, Gayathri U, Elavarasi S and Arivoli S. Removal of Rhodamine B dye from aqueous solution using the acid activated Cynodondactyl on carbon. *Pelagia Research Library*, 3(1), 2012, 99-113.
9. Sarangerel D, Altangerel A, Munkhzaya TS, Sukhbaatar B and Amarzaya B. Equilibrium and Kinetic Studies for Removal of Reactive Blue 50 from Aqueous Media Using Zero Valent Iron. *International Journal of Civil & Environmental Engineering*, 14(6), 2014, 74.
10. Shakti D and Sanghamitra B. Studies On Removal Of Safranine-T And Methyl Orange dyes from aqueous solution using Nax Zeolite Synthesized from Fly Ash. *International Journal of Science, Environment and Technology,* 2(4), 2013, 735 -747.
11. Geetha KS and Belagali SL. Adsorption Studies of Some Dyes on Acacia Concinna Powder. *International Journal of Research in Engineering and Technology,* 4(2) 2015.
12. Acemioglu B. Batch kinetic study of sorption of methylene blue by perlite. *Chemical Engineering Journal,* 106, 2005, 73-81.
13. Ahmad AA and Hameed BH. Fixed-bed adsorption of reactive azo dye onto granular activated carbon prepared from waste. *Journal of Hazardous Materials*, 175, 2012, 298-303.
14. Ahmad A, Rafatullah M, Sulaiman O, Ibrahim MH and Hashim R. Scavenging behaviour of meranti sawdust in the removal of methylene blue from aqueous solution. *Journal of Hazardous Materials*, 170, 2009, 357–365.
15. AksuZ and Karabayir G. Comparison of biosorption properties of different kinds of fungi for the removal of Gryfalan Black RL metal-complex dye.*Bioresource Technology,* 99, 2009, 7730-41.
16. Aksu Z, Tatlı AI and Tunc OA. Comparative adsorption/biosorption study of Acid Blue 161: Effect of temperature on equilibrium and kinetic parameters. *Chemical Engineering Journal,* 142, 2008, 23-39.
17. Aksu Z. Application of biosorption for the removal of organic pollutants. a review, *Process Biochemistry,* 40, 2005, 997-1026.
18. Aksu Z and Gonen F. Biosorption of phenol by immobilized activated sludge in a continuous packed bed: prediction of breakthrough curves. *Process Biochemistry*, 39, 2004, 599–613.
19. Altenor S, Carene B, Emmanuel E, Lambert J, Ehrhardt JJ and Gaspard S. Adsorption studies of methylene blue and phenol onto vetiver roots activated carbon prepared by chemical activation. *Journal of Hazardous Materials,* 165, 2009, 1029-1039.
20. Annadurai G, Juang RS and Lee DJ. Use of cellulose-based wastes for adsorption of dyes from aqueous solutions. *Journal of Hazardous Materials B*, 92, 2002, 263-274.
21. Argun ME, Dursun S, Ozdemir C and Karatas M. Heavy metal adsorption by modified oak sawdust: Thermodynamics and kinetics. *Journal of Hazardous Materials,* 141, 2007, 77-85.
22. Arica MY and Bayramoglu G. Biosorption of Reactive Red-120 dye from aqueous solution by native and modified fungus biomass preparations of Lentinussajor-caju. *Journal of Hazardous Materials,* 149, 2007, 499-507.
23. Chien SH and Clayton WR. Application of Elovich Equation to the kinetics of Phosphate release and sorption on soil.*Soil sci. Sco, am. J*, 44, 1980, 265 – 268.