RJC
http://www.rasayanjournal.com

RASĀYAN *J. Chem.*
Vol.4, No.3 (2011), 519-532
ISSN: 0974-1496
CODEN: RJCABP

SORPTION DYNAMICS AND EQUILIBRIUM UPTAKE OF BASIC DYE (BASIC BROWN 4) USING *JATROPHA CURCAS* STEM ACTIVATED CARBON

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ABSTARCT

The feasibility of activated carbon prepared from *Jatropha Curcas* stem waste to remove Basic brown 4 from aqueous solutions was investigated through batch mode contact time studies. Batch experiments were carried out to study the adsorption isotherm and kinetics at 30°C, with the initial concentration of 20-60mg/L. The influence of various factors such as initial concentration, agitation time and temperature on the adsorption capacity has been studied. The percentage removal of dye is observed to decrease, with the increase in initial concentration of dye. With increase in temperature the adsorption of dye also increases, indicating endothermic nature of the reaction. Adsorption isothermal data could be interpreted by the Langmuir and Freundlich equations. Kinetic data has been studied, using Elovich and Pseudo-second order equations for understanding the reaction mechanism.

Keywords: activated *Jatropha curcas* stem *waste* carbon, basic brown 4 (Basic dye), adsorption.

INTRODUCTION

Textile effluents are known toxicants, which inflict acute disorders in aquatic organisms. Uptake of textile effluents through food chain in aquatic organisms may cause various physiological disorders like hyper tension, sporadic fever, renal damage, cramps etc[1]. Basic brown 4 is one such effluent which causes various disorders when present in aqueous solution. Hence the treatment of waste water containing Basic brown 4 is a challenging problem. Adsorption using activated carbon is one of the efficient procedures for treatment of waste water[2]. Cellulosic and Lignocellulose wastes have long been recognized as starting materials for the preparation of activated carbon[3, 4]. Commercial activated carbons are expensive and their use requires elaborate regeneration and reactivation procedure[5]. Several low cost carbon and non conventional adsorbents have been used. Adsorbents used include fly-ash [6,7], Wollastonite [8,9,10], Saw dust and rice husk with coir pith carbon[11], Pomegranate Peel[12]etc. Now-a-days the interest has turned towards the preparation of activated carbon from Biodiesel Industrial waste.

The energy demand is expected to grow at an annual rate of 4.8% over the next couple of decades. Most of the energy requirements are currently satisfied by fossil fuels such as coal, petroleum based products and nature gas. Domestic production of crude oil can only fulfill 25-30% of national consumption. Hence it becomes very important for the search of alternative fuel. Biodiesel blended with regular petroleum diesel fuel for diesel engines, is currently attracting the attention of Indian Scientists. It is produced both from edible as well as non-edible vegetable oil.

Jatropha is found in large quantity and is generally grown as a live fence for the protection of agricultural fields against damage by livestock as it is unpalatable to cattle and goats. Reports suggest a sequential development of the clinical signs and lesions in the organs of desert sheep and Anglo Nubian goats with *Jatropha Curcas* seeds at 0.05, 0.5 and 1g/Kg/day. Diarrhea, reduced water consumption, dehydration, Sunken eye, in appetence and loss in condition were the important signs of poisoning in the sheep and goats.

The above observations have, therefore, restricted its use as a food or feed source. The toxic or irritant compound isolated from Jatropha Curcas includes curin, lectin, flavoride, vitexine[13, 14] and isovitexine[15] and 12-deoxyl-16hydroxy-phorbol[16]. The high concentrations of phorbolesters present in *Jatropha Curcas* have been identified as the main toxic agent responsible for *Jatropha Curcas* toxicity[17, 18]. It is not possible to destroy phorbolesters by heat treatment because they are heat stable and can withstand roasting temperature above 180°C.

The availability of this material in large quantity around our country also attracted us to utilize it as potential adsorbent for the removal of toxic substances. In the present investigation, we have demonstrated the use of Activated carbon prepared from *Jatropha curas* stem waste as an adsorbent for Basic brown 4 removals and the adsorption capacity of chosen adsorbent is regulated by many influencing factors, such as temperature, pH and initial dye concentrations.

EXPERIMENTAL

Adsorbent

Jatropha curcas stem waste is collected from local area of Erode district, Tamilnadu, India. It was dried, charred with excess quantity of concentrated sulphuric acid keeping at 120°C for 10 hours. Then the resultant carbon is washed with excess quantity of distilled water and dried at 110°C for 1hour[19] and the material obtained was soaked in 5% sodium bicarbonate solution and allowed to stand overnight to remove any residual acid. The material was thoroughly washed with hot distilled water until washings were nearly of neutral effect. To eliminate surface groups and thermal activation, the carbonized material was treated at 800° C for 60 min in a furnace under N_2 flow ($100 cm^3 min^{-1}$). The resulting carbons were ground in a mill, washed with pure distilled water, and finally dried at 120° C. The dried powders were sieved in the size range from 125-250µm.

Adsorbate

The textile dye, Basic brown 4, was purchased from Sigma-Aldrich (Germany), molecular structure of the dye is figured in Fig. 3 and characterization of the dye is summarized in table 2. All the chemicals used were obtained as research grade chemicals and were used without purification

Methods

The batch adsorption studies were performed at 30°C. 100mg of adsorbent is mixed with known initial concentration (20, 40 & 60 mg/L respectively) of Basic brown 4 solution and agitated, the adsorbent and the adsorbate were separated by filtration and the filtrate was analyzed for residual Basic brown 4 concentration spectrophotometrically (Using Elico make Bio-UV Spectrophotometer, Model BL-192).

Characterization of adsorbent

The N_2 adsorption-desorption isotherms of activated carbons were measured at 77k using a gas sorption analyzer (Nova 1000, Quanta Chrome Corporation) in order to determine the surface areas and total pore volumes. The surface areas were calculated using the BET equation. In addition, the t-plot method was applied to calculate the micropore volumes and external surface areas (Mesoporous Surface area). The total pore volumes were estimated to be the liquid volume of adsorbate (N_2) at a relative pressure of 0.99. All the surface area was calculated from the nitrogen adsorption isotherms by assuming the area of a nitrogen molecule to be $0.162 nm^2$. The selected properties of adsorbent are presented in the table 1.

The electronic structure of carbon samples were examined using FT-IR 1725x (Perkin-Elmer) spectrometer. The measurements were carried out over the range $4000-400 cm^{-1}$.Carbon samples (0.33wt %) were stirred with dry KBr (Merk, spectroscopy grade) and then pressed to form appropriate tablets. The surface morphologies of carbon samples were observed with SEM (HITACHI S3000N).

A stock solution of 100 mg/L of Basic brown 4 was prepared by dissolving 1 g of dye in 100mL of double distilled water and used for further studies by diluting to the concentrations required. The properties of dye Basic brown 4 are presented in table 2.

Kinetic models

In order to investigate the mechanism of sorption and potential controlling steps such as mass transport, several kinetic models were tested including the Elovich model and the pseudo second order kinetic model for a batch contact time process, where the rate of sorption of dye on to the given adsorbent is proportional to the amount of dye sorbed from the solution phase.

Elovich Model

The Elovich or Roginsky – Zeldovich equation is generally expressed as follows[20,]

$$dq_t/dt = \alpha \exp(-\beta q_t) \quad (1)$$

Where,

q_t = The amount of dye adsorbed in mg/g, at time t
α = The initial dye sorption rate, mg/g. min.
β = The desorption constant, g/mg during the experiment.

To simplify the Elovich equation, Chien and Clayton [21] assumed $\alpha\beta >> 1$, and on applying the boundary conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$, the above equation becomes,

$$q_t = \frac{1}{\beta} \ln(\alpha\beta) + \frac{1}{\beta} \ln t \quad (2)$$

Thus the constants α and β can be obtained from the slope and intercept of linear plot of q_t versus ln t. The above equation will be used to test the applicability of the Elovich equation to the kinetics of chosen adsorbent adsorbate system.

Pseudo second Order Kinetic Model

To describe dye adsorption, the modified pseudo second order kinetic equation is expressed as[22]

$$\frac{dq_t}{dt} = k_2 (q_e - q_t)^2 \quad (3)$$

Where

q_e = The amount of dye adsorbed at equilibrium, mg/g
q_t = The amount of dye adsorbed at time t, mg/g
k_2 = The rate constant for pseudo first order adsorption, g/mg.min

This has a linear from and is as given as :

$$t / q_t = \frac{t}{k_2 q_e^2} + \frac{1}{q_e} \quad t \quad (4)$$

In the limit $(q_t / t) \rightarrow 0$, the initial sorption rate, h, is given by $k_2q_e^2$, mg/g min. Thus, a pot t/q_t versus t of the above equation should give a linear relationship with a slope of

$1/q_e$ and an intercept of $\frac{1}{k_2 q_e^2}$

Isotherm Studies

Langmuir Isotherm

The Langmuir model was developed based on the assumption of the formation of a monolayer of the adsorbate species onto the surface of the adsorbent. It has also been assumed that the surface sites are completely energetically homogeneous but in the true sense, the adsorbent surface is energetically heterogeneous[23]. The study of the Langmuir isotherm is essential in assessing the adsorption efficiency of the adsorbent. This study is also useful in optimizing the operating conditions for effective adsorption. In this respect, the Langmuir isotherm is important though the restrictions and the limitations of this model have been well recognized. The Langmuir and the rearranged Langmuir equations are given below.

$$\frac{1}{qe} = \frac{1}{Q_o b} \cdot \frac{1}{Ce} + \frac{1}{Q_o} \qquad (5)$$

$$\frac{C_e}{q_e} = \frac{Ce}{Q_o} + \frac{1}{Q_o b} \qquad (6)$$

Where,

q_e = The amount of dye removed at equilibrium, mg/g
C_e = The equilibrium concentration of dye, mg/L
q_o = The Langmuir constant, related to the adsorption capacity, mg/g and
b = The Langmuir constant, related to energy of adsorption, L/,mg

The essential characteristics of Langmuir isotherm can be expressed in terms of dimension less constant, separate ion factor or equilibrium parameter. R_L[24], which is defined by

$$R_L = \frac{1}{1+bC_0} \qquad (7)$$

Where C_o is the initial dye concentration (mg/L) and b is the Langmuir constant (L/mg). The parameter indicates the shape of isotherm as follows-

R_L	Type of isotherm
$R_L > 1$	Unfavorable
RL = 1	Linear
0 < RL < 1	Favorable
RL = 0	Irreversible

Freundlich Isotherm

At Equilibrium conditions, the adsorbed amount, q_e can also predicted by using the Freundlich Equation[25].

$$q_e = K_f C_e^{1/n} \qquad (8)$$

Where,

q_e = Dye concentration in solid equilibrium, mg/g
C_e = Dye concentration in solution at equilibrium, mg/L
K_f = Measure of adsorption capacity
n = Adsorption intensity

A logarithmic form of the above equation is

$$\log q_e = \log K_f + (1/n) \log C_e \qquad (9)$$

The values of n and k_f were determined from the plot log q_e v_s log C_e. k_f is the indication of the adsorbent capacity and 1/n is a measure of surface heterogeneity, ranging between 0 and 1, becoming more heterogeneous as its value gets closer to zero.

Adsorption thermodynamics

Any chemical system tends to attain a state of equlibrium from one that of non-equilibrium. The thermodynamic parameters, which characterize the equilibrium of the system are the Gibbs free energy change ΔG, the enthalpy change ΔH and the entropy change ΔS. These parameters were determined using the following relations[26, 27]

$K_c = C_{Ae}/ C_e$
$\Delta G^{\circ} = -RT \ In\ K_c$
$\log K_c = \Delta S/2.303R - \Delta H/2.303RT \qquad (10)$

Where K_c is the equilibrium constant, C_{Ae} is the solid phase concentration at equilibrium, C_e is the residual concentration at equilibrium. R is the gas constant in J/mole and T is the temperature in Kelvin.

RESULTS AND DISCUSSION

Surface characters of activated carbon

The morphological study by SEM of the above adsorbent shown in the figure 1 revealed that it is highly porous in nature[28]. From the SEM results, it was found that there are holes and care type openings on the surface of the specimen that would definitely have increased the surface that are available for the adsorption. The FT-IR spectrum of the activated *Jatropha curcas* stem waste carbon shown in the figure 2 revealed that the carbon contains four classes of surface oxides: carboxyl, lactones, phenols and carbonyls.

The assignment of the specific wave number to a given functional group was not possible because the adsorption bands of various functional groups overlap and shift, depending on their molecular structure and environment.

Shift in absorption position may be caused by factors such as intra molecular and intermolecular hydrogen bonding, steric effect and degree of conjugation. For instance, within its given range, the position of C=O stretching band (Common to carbonyls, carboxylic acids and lactones) is determined by many factors, such as:

1. The physical state
2. Electronic and mass effects of neighboring substituent's
3. Conjugation
4. Hydrogen bonding
5. Ring strain.

The FT-IR absorption bands of oxygen groups on the surface of activated Carbon prepared using *Jatropha curcas* stem waste activated carbon are likely to be affected by some or all of the factors listed above.

The carbon exhibit a very intense/sharp H-bonded –OH stretching of carboxyl, phenol chelated and alcohols vibration from 3600 – 3000 cm^{-1} and aliphatic "C-H" stretching absorption from 2750 to 3000 cm^{-1}. The group of bands appeared in the region 1420 to 1460 cm^{-1}. The broad band observed in the spectrum of "OH" derivatives between 900 to 1250 cm^{-1} was assigned due to a characteristic absorption of "-C-OH" group.

Effect of agitation time

The uptake of Basic brown 4 from water by activated *Jatropha curcas* stem waste carbon increases up to 93.4% when the agitation time was varied from 10 to 160 minutes and attains equilibrium in 180 minutes at 30ºC and at pH 7.0, when the initial concentration of the Basic brown 4 solution used was 20 mg/L and the adsorbent dosage was 100mg. The increase in adsorption of Basic brown 4 with increase in agitation time may be attributed to the increased intra particle diffusion occurring at long shaking time (Figure 3). A similar result was observed by[29] Rao and Bhole (2001) in the removal of chromium fly ash and bagasse

Effect of initial concentration of Basic brown 4 solutions

The initial concentration of Basic brown 4 solutions was varied (20, 40 and 60mg/L) and batch adsorption experiments were carried out with 100mg of the adsorbent at 30ºC and at pH 7.0. An increased percentage removal of Basic brown 4 from 75 to 93.4% was observed with 100 mg of the adsorbent in agitation time of 240 minutes when the initial concentration of the Basic brown 4 solution was varied from 20, 40, 60, mg/L .The higher uptake of Basic brown 4 at low concentration may be attributed to the availability of more active centers on the surface of the adsorbent for lesser number of adsorbate species. Basic brown 4 adsorption curves are single, smooth and continuous (Figure 3) suggesting the possible monolayer coverage of dye molecules on the surface of the adsorbent. Mise and Rajamanya also reported a similar result in the removal of Basic brown 4 using activated carbon[30].

Isothermal modeling

The Langmuir adsorption isotherm obtained in 240 minutes of agitation time is shown in the figure 4.The values of $R_L<1$, obtained in this study indicates the applicability of Langmuir adsorption isotherm.

Figure 5 shows that the values of adsorption intensity $1/n>1$ reveals that the applicability of Freundlich adsorption not good when compared to Langmuir adsorption isotherm. The values of k_f are given in the table 3 .The study of temperature effects on the Freundlich parameter reveals that decreasing trend in the adsorption capacity with increase in temperature . These data are useful for practical design purposes.

Kinetic modeling

Elovich model

The results of the sorption of Basic brown 4 on to *Jatropha curcas* stem waste carbon has been represented in the form of Elovich Equqtion in Figure 6 at various initial dye concentrations(viz.20, 40and 60 mg/L respectively). From the plot a linear relationship between the amount of Basic brown 4 adsorbed, q_t and ln(t) was established.

Table 4 shows the kinetic constants obtained form the Elovich equation. It will be seen from the data that the values of α and β varied as a function of initial Basic brown 4 concentration. Thus, on increasing the initial concentration of Basic brown 4 from 20 mg/L to 60 mg/L the value of α increased from 16.86 to 79.14 mg / (g.min) and the β value decreased from 0.319 to 0.105 g/mg. Although the Elovich equation does not provide any mechanistic evidence, it has been proved suitable for highly heterogeneous systems of the adsorption of Basic brown 4 on to *Jatropha curcas* stem waste carbon.

Pseudo second order model

The same data are shown as pseudo second order equations in figure 7 at various initial dye concentrations(viz.20, 40 and 60 mg/L respectively).These plots show the data fit had good correlation coefficients(>0.991) when pseudo second order equation was employed; it was possible to ascertain from them whether the rate determining process is a chemical reaction .The initial dye concentration increases from 20mg/L to 60 mg/L the equilibrium sorption capacity, q_e, increased from 13.53 mg/g to 49.48 mg/g. Basic brown 4 sorbed at any contact time increases.

The corresponding linear plots of the values of q_e, k_2 and h against C_0 were regressed to obtain the expressions for these values in terms of the initial Basic brown 4 concentration, C_0, with high correlation coefficients (>0.992). Hence, it further considered that q_e, k_2 and h could be expressed as functions of C_0 as follows:

$$q_e = \frac{C_0}{1.020C_0-19.95} \tag{11}$$

$$k_2 = \frac{C_0}{108.6C_0-1.726\times10^4} \tag{12}$$

$$h = \frac{C_0}{0.5113C_0 - 10.19} \tag{13}$$

Substituting the values of q_e, k_2 and h from equations (11) and (13) in to equations (4), the rate law for a pseudo-second order reaction and the relationship of q_t, C_0 and t can be represented as:

$$q_t = \frac{C_0 t}{(0.5113C_0 - 10.19) + (1.020C_0 - 19.95)t} \tag{14}$$

Equation (10) represents the generalized productive model for Basic brown 4 adsorption at any contact time and initial concentration with in the specified concentration range. It indicates that the amount of Basic brown 4 at any contact time increased with increasing the initial dye concentration. This is obvious for higher initial concentration values, as a more efficient utilization of the sportive capacities of the sorbent would be expected due to greater sorption driving force. This equation can then be used to derive the amount of Basic brown 4 sorbed at any given initial dye concentration and reaction time.

The mathematical treatment as suggested by Boyd et al. (1947) and Reichenberg (1953)[31, 32] were used to identify whether the ongoing process is particle diffusion or film diffusion. These mathematical models also helped in determining the mechanism of the undergoing process. An established fact is that when a solid chemical substance adsorbs over the porous adsorbent, three types of diffusion processes takes place in following three consecutive steps: [33]

1. Transport of the ingoing adsorbate ions to external surface of the adsorbent (film diffusion),
2. Transport of the adsorbate ions within the pores of the adsorbent except for a small amount of adsorption, which occurs on the external surface (particle diffusion) and
3. Adsorption of the ingoing adsorbate ions on the interior surface of the adsorbent.

The third step is very fast and can not be considered as a rate-determining step, while for the adsorption carrying out via remaining two steps, the following three possibilities exist.
Case 1: External transport > internal transport, where rate is governed by particle diffusion.
Case 2: External transport < internal transport, where the rate is governed by film diffusion.
Case 3: External transport ≈ internal transport, which accounts for the transport of the adsorbate ions to the boundary and may not be possible within a significant rate, which later on gives rise to the formation of a liquid film surrounded by the adsorbent particles with a proper concentration gradient.

To investigate the actual process involved in the present adsorption, the quantitative treatment of the sorption dynamics was found in accordance with the observation of Reichenberg (1953)[32], as described by the following equation:

$$F = 1 - \frac{6}{\pi^2} \sum_{N-1}^{\alpha} \frac{1}{n^2} \exp\left[\frac{-Dit\pi^2 n^2}{r^2}\right] \tag{15}$$

$$F = 1 - \frac{6}{\pi^2} \sum_{N-1}^{\alpha} \frac{1}{n^2} \exp\left[-n^2 \beta_t\right] \tag{16}$$

Where F is the fractional attainment of equilibrium at time t and is obtained by using following equation, and n. is the adsorption intensity of the adsorbate.

$$F = \frac{q_t}{q_e} \qquad (17)$$

Where q_t and q_e are the amounts adsorbed at time t and at equilibrium respectively.

On the basis of F values, corresponding values of B_t were obtained from Reichenberg's table[32] and the linearity test was carried out by plotting B_t with respect to time for both the solutions at different time intervals and at 30°C, 45°C and 60°C. The linearity test of B_t versus time plot drawn for different concentrations is employed to distinguish between film diffusion and particle diffusion. From the slope of the straight line obtained from time versus B_t graph, the B value (time constant) were calculated. The values of effective diffusion coefficient (D_i) were calculated at different temperatures using the following Equation-

$B = \pi^2 D_i / r^2$, here 'r' is the radius of the absorbent particle. The Di values are given in the table 5.

The plot of 1/T versus log D_i was found linear with negative slope indicating thereby the increase in the mobility of the ions, This is due to the fact that with the rise in temperature the mobility of ion increases, which consequently decreases the retarding force acting on the diffusing ions.

The Values of energy of activation E_a, entropy of activation $\Delta S^\#$ and pre-exponential constant D_o were calculated using following equations.

$$D_i = D_o \exp[-E_a / RT] \qquad (18)$$

$$D_o = (2.72\, d^2 kT/h) \,.\, \exp[\Delta S^\# / R] \qquad (19)$$

where d is the average distance between the successive exchange sites and is taken as 5 A°. R, h and k are the gas, Planck, and Bolzmann constants, respectively. The values of E_a, D_i, D_o, $\Delta S^\#$ and other parameters are given in table 6. The negative values of $\Delta S^\#$ reflect that no significant change occurs in the internal structure of chosen adsorbent during the adsorption process.

Thermodynamic parameters

ΔH and ΔS were obtained from the slope and intercept of Vant Hoff plot (1/T vs ln k_L) as given in the figure 8. A batch adsorption studies were carried out with Basic brown 4 solutions at pH $\approx$ 7.0 by varying the temperature (303 K, 318 K and 333 K). The initial concentration of Basic brown 4 solution used was maintained to be 20 ppm with 100 mg of the adsorbent. The free energy changes ΔG (Vary with temperature from -1918.88 to -4054.40 (KJ / mole) at 30 to 60 °C. The negative ΔG value suggests the adsorption of Basic brown 4 is spontaneous. Such negative values in all the temperature under study suggest that the adsorption is more spontaneous. The enthalpy change ΔH for adsorption of a standard adsorption process shows +ve values suggesting that the adsorption is an endothermic process[30]. Entropy change, ΔS, was found to be 3.2550 J/K/mole, which suggest the randomness in the adsorption of Basic brown 4[33] on the chosen adsorbent. Further investigations on a more detailed analysis of the presentation of carbons by different methods and their applications in the removal of heavy metals and pesticides are in progress.

CONCLUSION

In the present study adsorption of Basic brown 4 on activated *Jatropha curcas* stem waste carbon has been investigated. The data obtained through this work supports that the *chosen adsorbent* is an effective low cost adsorbent for the removal of Basic brown 4 from aqueous solution. The adsorption of Basic brown 4 is dependent on the initial concentration and agitation time. Equilibrium of Basic brown 4 adsorption reaches at 180 min. The values of $R_L<1$, obtained in this study indicates the applicability of Langmuir adsorption isotherm. The study of temperature effects on the Freundlich parameters reveals that decreasing trend in the adsorption capacity with increase in temperature. These data are useful for practical design purposes.

The Elovich and pseudo-second order equations provided a best filting description for the sorption of Basic brown 4 onto *Jatropha curcas* stem waste carbon, but the pseudo-second order equation had better correlation coefficient value than Elovich equation. Therefore pseudo-second order was considered the most appropriate due to high correlation coefficient when compared to Elovich equation.

The adsorption of Basic brown 4 onto activated *Jatropha curcas* stem waste carbon is an endothermic reaction based on enthalpy change values.

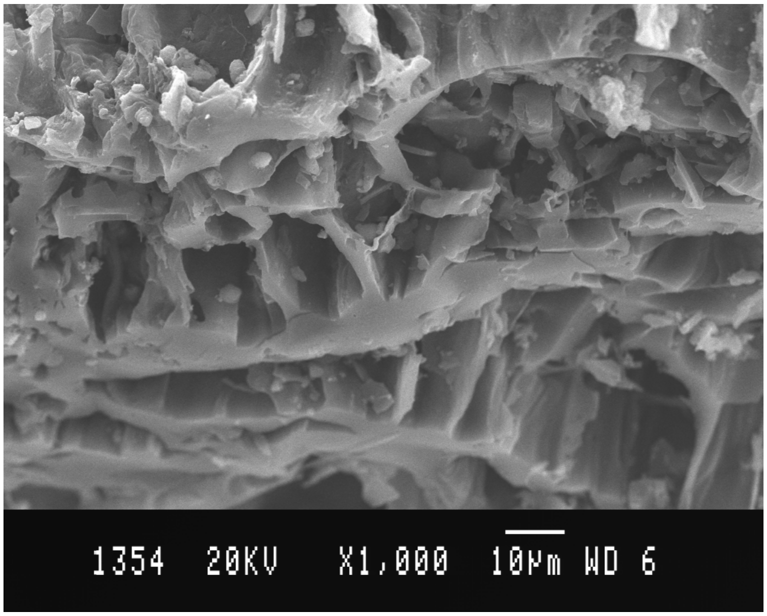

Fig.-1: SEM Image of activated *Jatropha curcas s*tem waste carbon

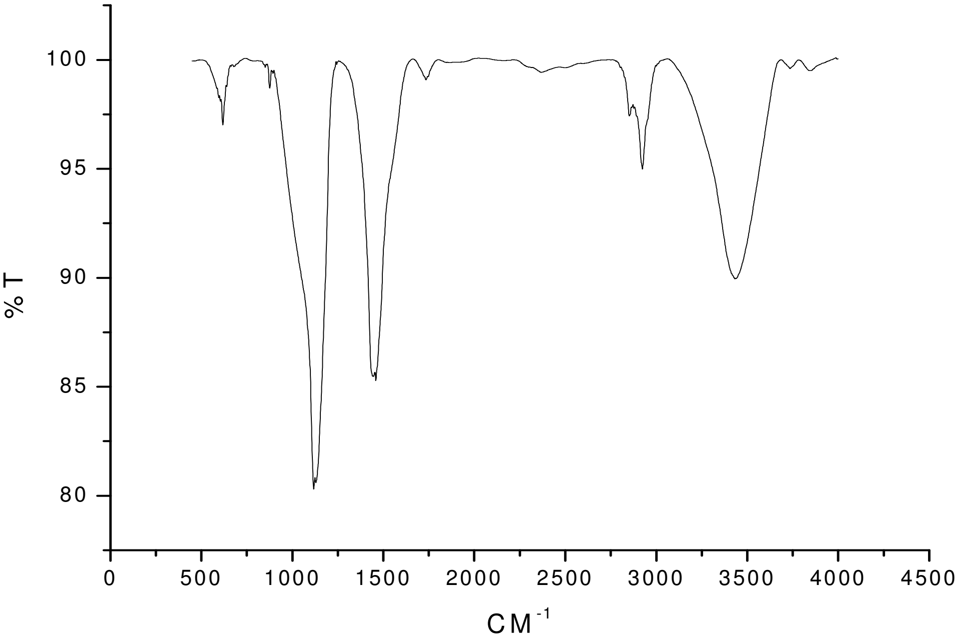

Fig.-2: FT-IR spectrum of *Jatropha curcas* stem waste activated carbon

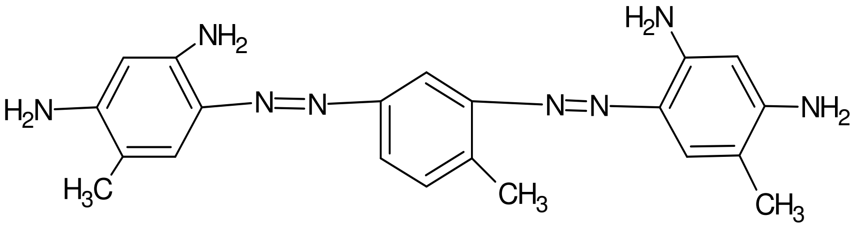

Fig.-3: Molecular Structure of Basic brown 4

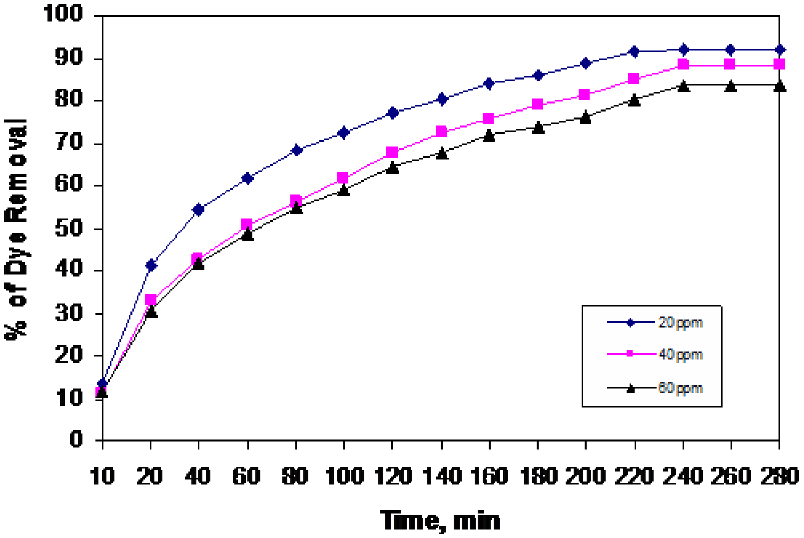

Fig.-4a: Effect of Agitation Time on Basic brown 4 Removal –Initial Dye Concentration Variation

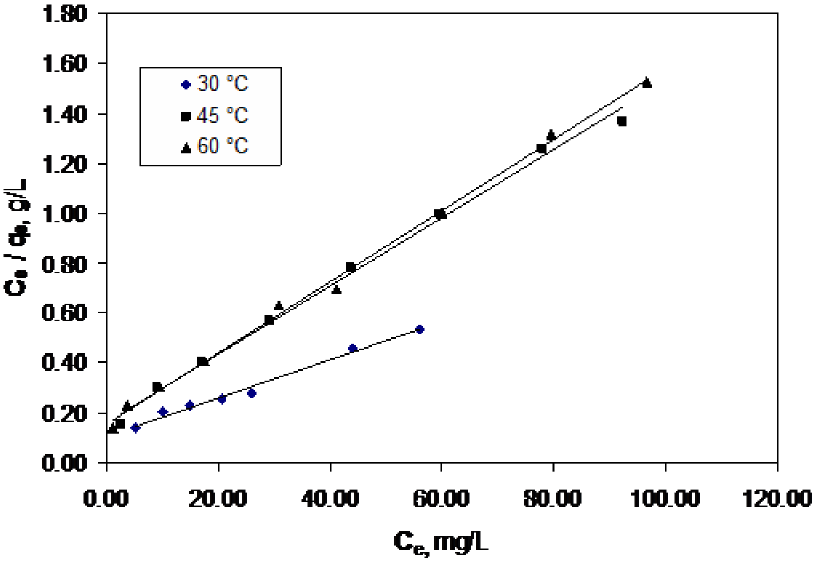

Fig.-4b : Langmuir plot – temperature variation

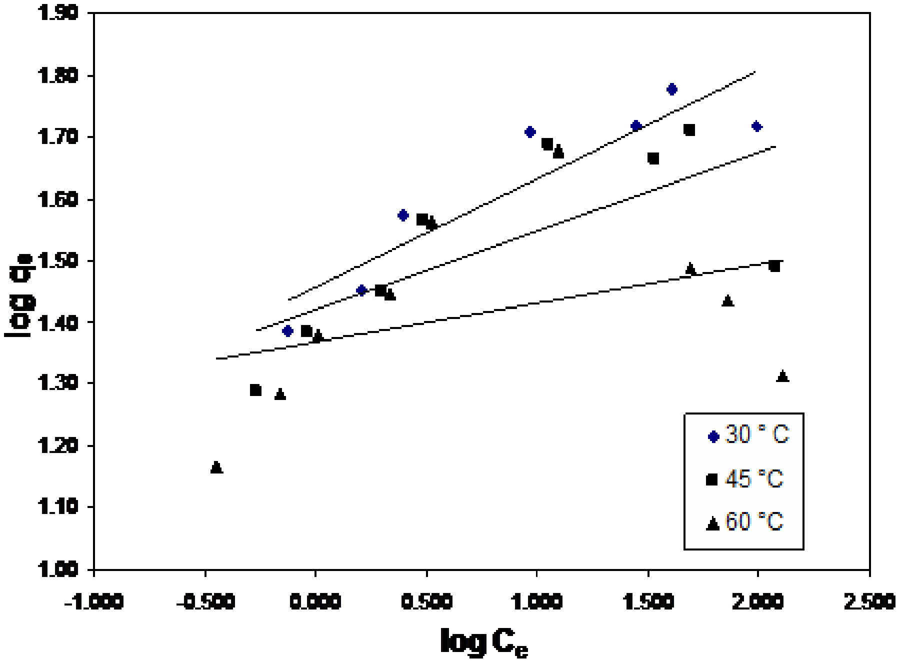

Fig.-5: Freundlich plot – temperature variation

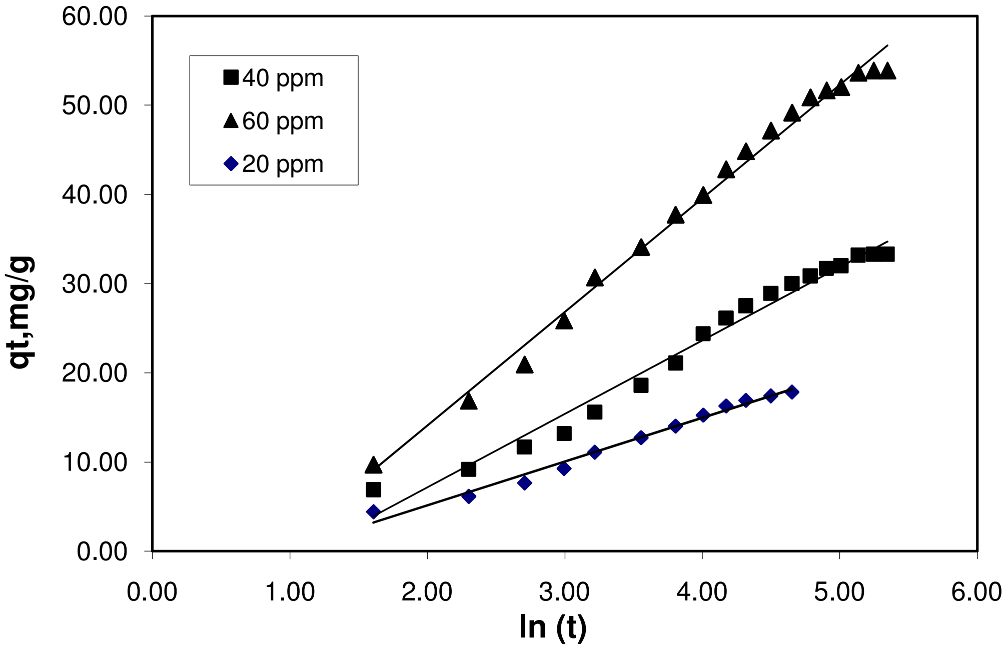

Fig.-6: Elovich Plot of Basic brown 4 Removal -Initial Dye Concentration Variation

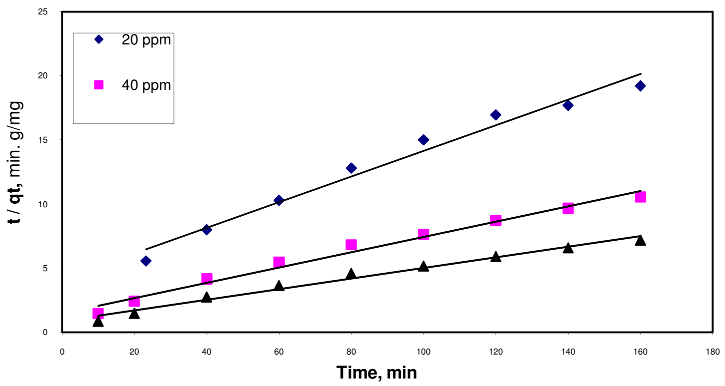

Fig.-7 : Pseudo Second Order Plot for Basic brown 4 Removal –Initial Dye Concentration Variation

Table-1: Some selected properties of activated *Jatropha curcas* stem waste Carbon.

S. No	Properties	Value
1	BET Surface area, m^2/gm	513.16
2	S_{EXt}, m^2/gm	334.21
3	V_{micro}, cm^3 / gm	139.66
4	S_{micro} m^2 /gm	0.06
5	V_{tot}, cm^3 / gm	97.56
6	Porosity, ζ p	47.08
7	Bulk density, g/cm^3	0.21
8	Moisture content, %	31.12
9	Iodine Number	311.33

Table-2: Properties of Basic brown 4

Parameters	Value
Suggested Name	Basic brown 4
C.I Number	45170
C.I. Name	Basic violet
Class	Rhodamine
Ionization	Basic
Empirical formula	$C_{21}H_{26}Cl_2N_8$
Formula weight	479.029

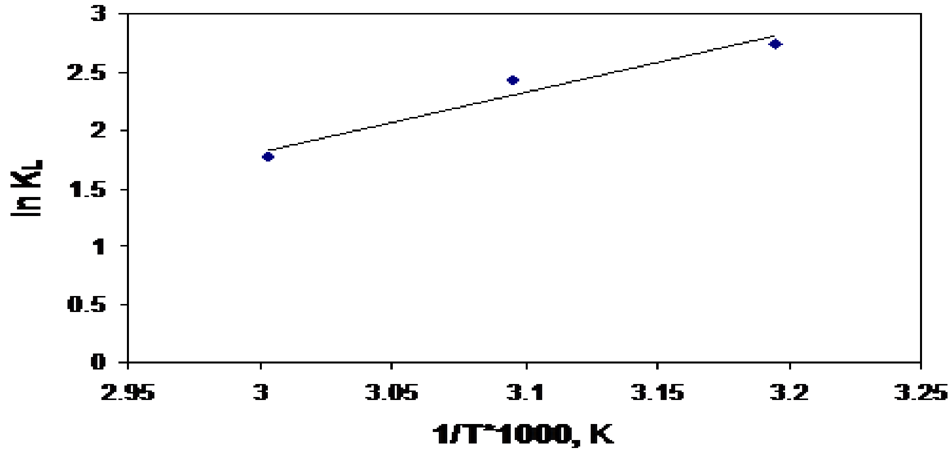

Fig.-8 : A Plot of Temperature Vs Ln K_L

Table-3: Parameters of Langmuir and Freundlich adsoption isotherms for Basic brown 4 adsoption calculated for 160 minutes of agitation time on to activated *Jatropha curcas* stem waste carbon.

Temperature, ° C	Langmuir Isotherm		Freundlich Isotherm		
	b, L/mg	Q_0, mg/g	1/n	n	k_f
30	0.2114	112.66	0.399	2.561	29.11
45	0.3161	126.71	0.381	3.121	36.19
60	.4519	129.47	0.321	3.421	46.53

Table-4: Kinetic model values for the adsoption of Basic brown 4 on to activated *Jatropha curcas* stem waste carbon.

Concentration, ppm	Elovich Values			Pseudo second order values			
	α	B	r^2	q_e	$K_2 \times 10^3$	h	R^2
30	17.77	0.349	0.928	14.53	0.1620	0.288	0.962
40	43.41	0.199	0.914	29.44	0.0058	0.405	0.902
60	78.64	0.181	0.864	48.43	0.0020	0.416	0.875

Table-5: Values of energy of activation E_a, entropy of activation $\Delta S^\#$ and sPre - exponential constant D_o for the present study

S.No.	Parameter	Value
1.	D_i, cm^2s^{-1}	
	30° C	1.397×10^{-11}
	45° C	1.3778×10^{-11}
	60° C	1.0661×10^{-11}
2.	E_a, $KJmol^{-1}$	-8.6735
3.	$\Delta S^\#$, $JK^{-1}mol^{-1}$	-167.66
4.	D_o, cm^2s^{-1}	9.6625×10^{-12}

ACKNOWLEDGEMENTS

The authors are expressing their humble gratitude to Principal and Head of the department of Chemistry, Chikkanna Government Arts College, Tirupur for their kind co-operation in respect of the present investigations.

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[RJC-797/2011]