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Use of Beech Wood Sawdust for Adsorption of Textile Dyes

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Abstract: In this research a new efficient adsorbent of dyes is used. Thus, adsorption of some textile dyes from aqueous solution by using an industrial waste lignocellulosic product is studied. Between five dyes tested, three dyes were chosen for testing: Direct Orange 26, Acid Orange 7, Acid Green 20. Kinetics of adsorption and equilibrium isotherm of dyes was investigated using Longmuir and Freundlich models. This study showed that the beech wood sawdust could be employed as low-cost and effective sorbent for the removal of dyes from aqueous solution.

Key words: Beech, wood sawdust, adsorption, isotherms, adsorption kinetics, dye

INTRODUCTION

The release of effluent dyes into the ecosystem is a dramatic source of esthetic pollution and of perturbations in aquatic life. Some azo dyes and their degradation products such as aromatic amines are highly carcinogenic. Thus the proper treatment of the dye plant effluent must be concerned before discharge. This led to an intensive search for the best available technology, which can be used for the removal of dyes.

Many agricultural waste products and by products of the wood and forest industries of cellulosic origin have been successfully utilized, such as: bamboo pulp, sawdust, waste banana pith (Namasivayam and Kanchana, 1992), peat, moss, rice hulls (Poots *et al*., 1976), particles of palm fruit bunch, oak wood sawdust (Dulman *et al*., 2002) and rice husk (Abdelwahab *et al*., 2005).

The beech wood sawdust obtained from wood's industries is a lignocellulosic waste material, which may be used as a sorbent for discoulorating the aqueous solution of dyes: Direct Orange 26, Acid Orange 7 and Acid Green 20. The influence of some parameters such as: nature of the dye, dyes concentration and contact time has been studied. The characteristic parameters of adsorption were estimated by Longmuir and Freundlich isotherms.

MATERIALS AND METHODS

The present research was conducted at Natural Resources Faculty of Tehran University from October 2005 to September 2006.

Preparation of adsorbent: The beech wood sawdust obtained from the wood processing industry was sieved to 150-250 μm being used.

Preparation of dye solution: Dyes were obtained from ALVAN SABET dye production company and were used without further purification. Aqueous solutions of 1000 mg L^{-1} were prepared using bidistilled water. The experimental solution was prepared by diluting definite volume to get the desired concentration.

Adsorption procedure: 0.1 g adsorbent (based on dry weight) was placed in a 250 mL Erlenmeyer flasks and 50 mL of aqueous solution of dye was added. After the desired time the adsorbent was separated from the solution by filtering and the first 15 mL was chosen for examination.

The concentration of dye was determined with a UV-Vis spectro photometer at a maximum wavelength of each dye. The percentage of removal of dye is evaluated the relation

$$\text{Percentage of removal} = \frac{C_o - C}{C_o} \times 100 \quad (1)$$

where Co is the initial concentration of dye, C is the solution concentration after adsorption at any time.

Effect of contact time and concentration of dye on dye removal was studied. The experiments were performed using times 20-240 min and different dye concentration of 20, 40 and 80 mg L^{-1}.

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RESULTS

At first five dyes were tested. Dyes were used commercial without a preliminary purification. Structure and molecular formula of dyes is shown in Fig. 1. Fifty milliliter of aqueous solution of concentration 40 mg L^{-1} was added to 0.1 g sorbent. After 24 h, the absorbance of the solution was measured and the removal percentage of dyes was determined.

The results show the removal percentage 92.02 for Basic Blue 41, 87.32% for Acid Orange 7, 85.22% for Direct Orange 26, 76.04% for Acid Green 20 and 67.51% for Acid Blue 25. Among these dyes, three dyes Direct Orange 26, Acid Green 20 and Acid Orange 7 were selected for further experiments.

Effect of contact time and dye concentration: It has been observed from Fig. 2 that the removal of dyes decreased with time till equilibrium was attained. A high initial slope of the curves indicated the initial rapid removal of dye at beginning of contact. This may be due to the fact that at the beginning of the sorption process all the reaction sites are vacant and hence the extent of removal is high. After a rapid initial slope, there is a phase the rate of removal is slow with reaching almost a constant value. A 3 h contact time is efficient for carrying out adsorption and it was found to be independent of the nature of dyes.

The concentration of dye is effective on removal because a given mass of the adsorbent can adsorb only a fixed amount of dye. Therefore, the more concentrated solutions have smaller percentage removal of dye.

The data shows that as the concentration of the dye increased from 20 to 80 mg L^{-1} the percentage adsorption decreased from 27.07 to 15.03 for Direct Orange 26, from 24.38 to 11.27 for Acid Orange 7 and from 18.84 to 11.23 for Acid Green 20.

Kinetics of adsorption: The kinetics of adsorption of dyes was studied by applying the Lagergren equation (Trivedi *et al*., 1973). This equation is:

$$\log(q_e - q) = \log q_e - \frac{k'}{2.303}t \qquad (2)$$

where q (mg g^{-1}) is the amount of dye adsorbed at time t, q_e (mg g^{-1}) is the amount of dye adsorbed at equilibrium and k is the rate constant of sorption. The k values are calculated from the slopes of the linear plots obtained by the graphical representation of log (q_e-q) versus t (Fig. 3). The values of rate constant are presented in Table 1. The straight line plots of log (q_e-q) versus t indicated the validity of Eq. (2) and the process follows first order kinetics.

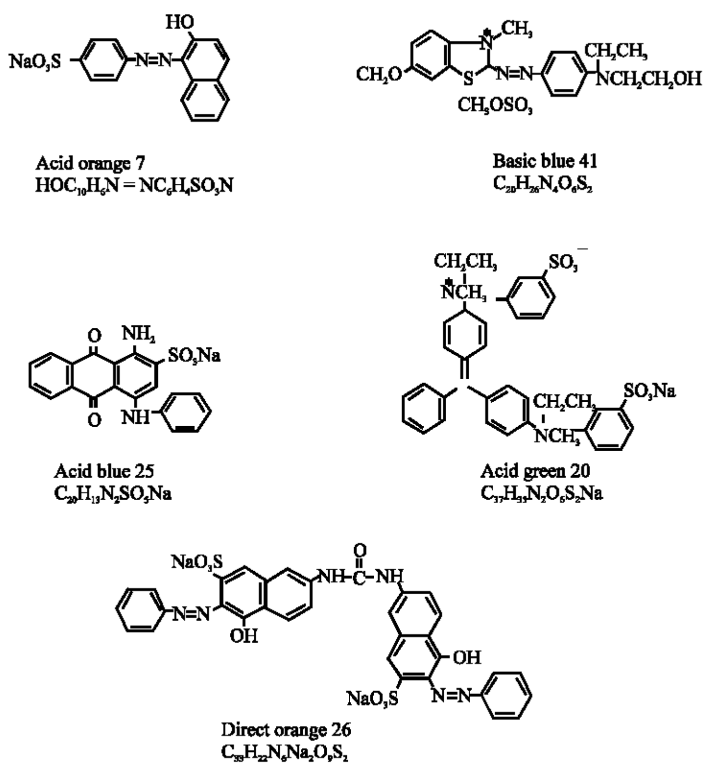

Fig. 1: Structural and molecular formula of dyes

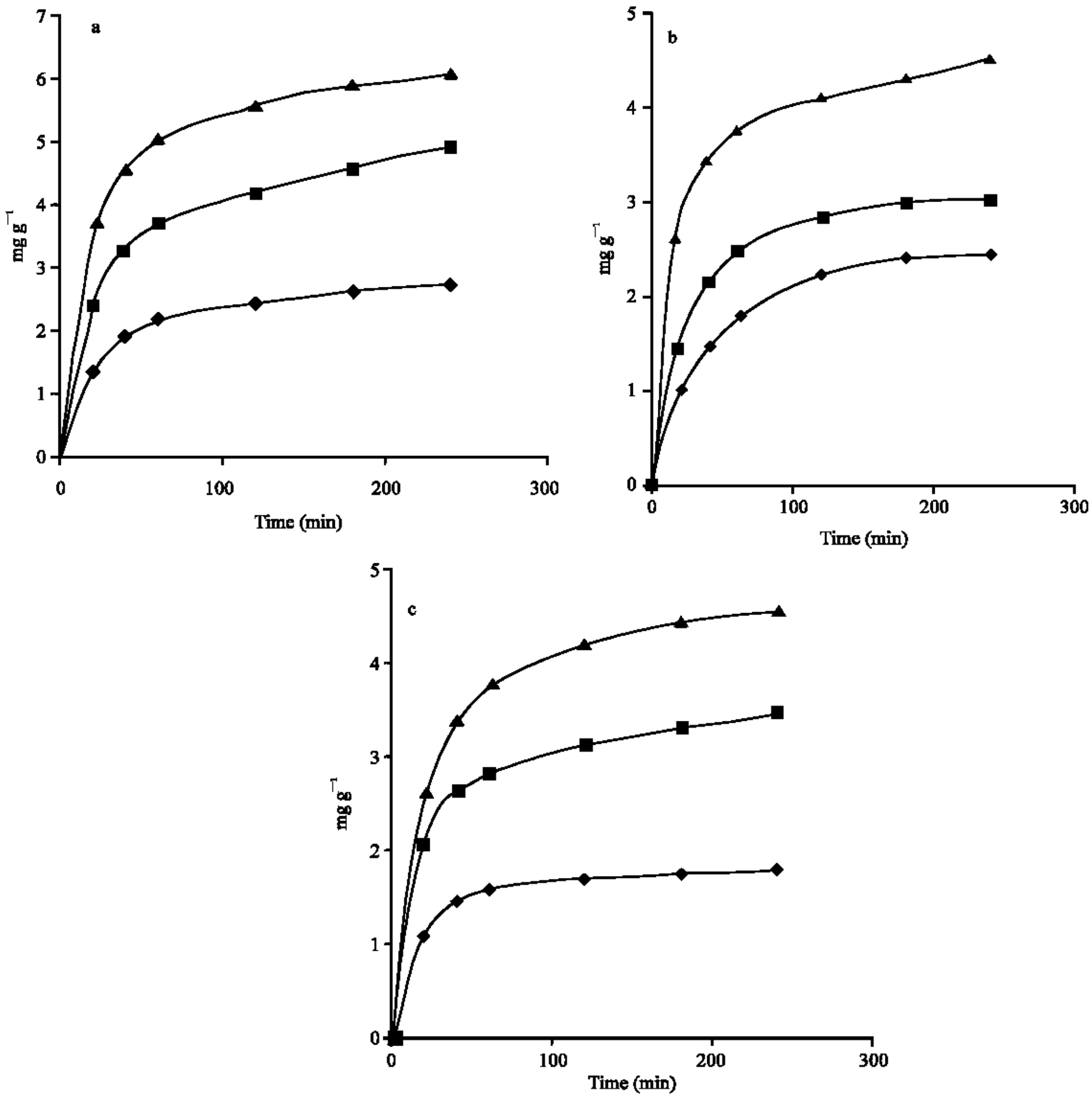

Fig. 2: Effect of contact time and dye concentration on the removal of dye. a) Direct Orange 26-b) Acid Orange 7 -C) Acid Green 20 (◆) 20 mg L^{-1}, (■) 40 mg L^{-1} and (▲) 80 mg L^{-1}

Equilibrium isotherms: When the system is in the state of equilibrium distribution of dye between the adsorbent and the dye solution is important to establish the capacity of the adsorbent for the dyestuff. The adsorption isotherms that can be used for describing dye adsorption are the Langmuir and the Freundlich type. The linear form of the Langmuir isotherm (Waranusantigul *et al*., 2003) can be represented by the following equation

$$\frac{C_e}{qe} = \frac{1}{Q^{\circ}b} + \frac{C_e}{Q^{\circ}} \qquad (3)$$

which Q^{O} and b are Langmuir constant related to adsorption capacity and energy of adsorption, respectively. C_e is the equilibrium concentration of the dye in solution (mg L^{-1}) and q_e is the amount of adsorbed dye (mg L^{-1}). The values of Q° and b, calculated from the slope and intercept of the straight-line plots of C_e/q_e versus C_e (Fig. 4). The values are represented in Table 2.

The essential characteristics of Langmuir isotherms may be expressed by a dimensionless constant, named parameter of equilibrium, R_L (4) and by Langmuir constant, k_L(5)

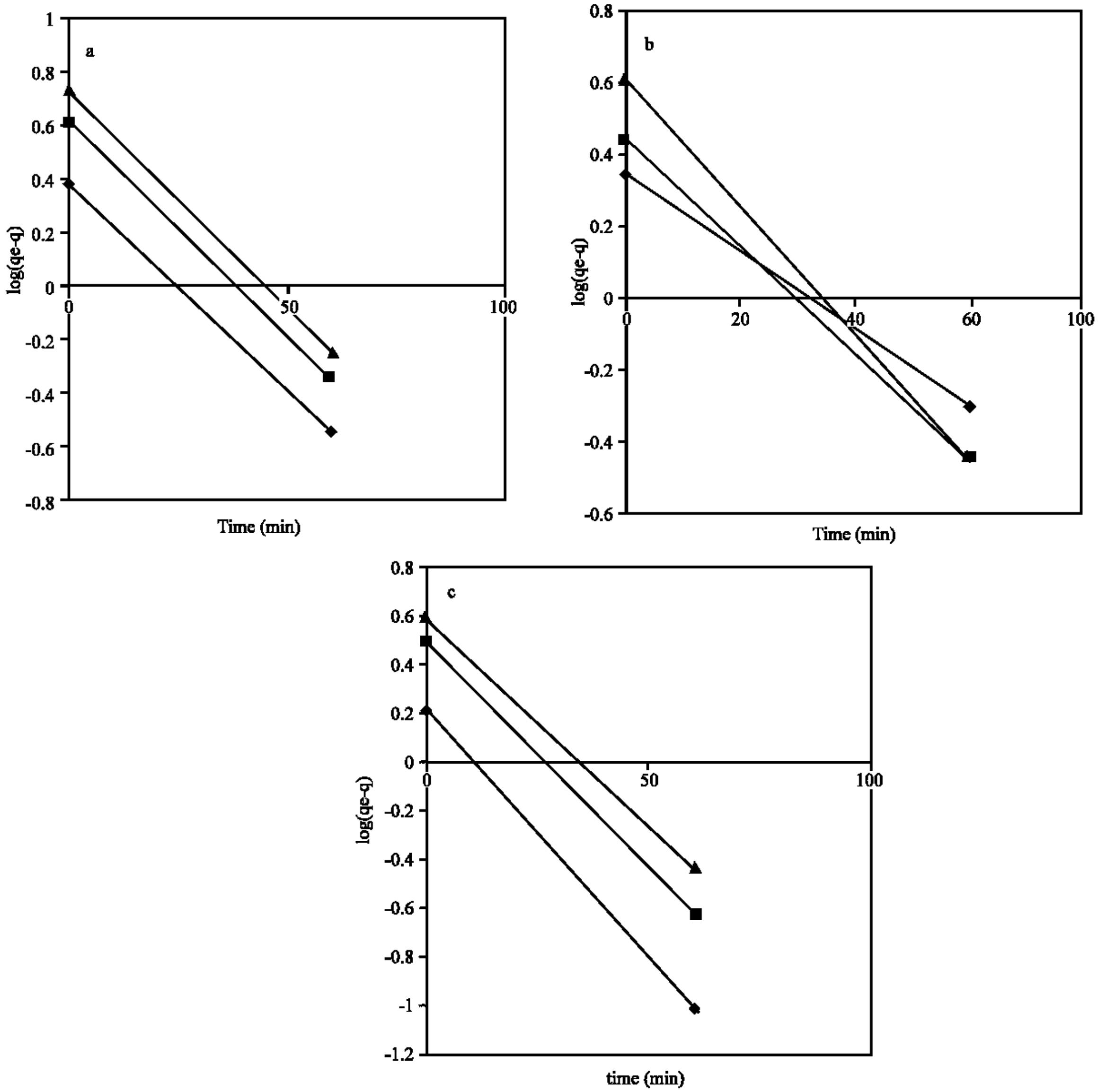

Fig. 3: Lagergren plots of adsorpation a) Direct Orange 26 -b) Acid Orange 7-C) Acid Green 20 (◆) 20 mg L^{-1}, (■) 40 mg L^{-1} and (▲) 80 mg L^{-1}

Table 1: Rate constants for adsorption

	K (min^{-1})		
Concentration (mg L^{-1})	Direct orange 26	Acid orange 7	Acid green 20
20	0.0134	0.0082	0.0112
40	0.0103	0.0132	0.0130
80	0.0080	0.0110	0.0119

$$R_L = \frac{1}{1 + bc_o} \quad (4)$$

$$K_L = Q^o b \quad (5)$$

The values of R_L between 0 and 1 show a favourable adsorption for dyes. The high fitness of the Langmuir model indicates monolayer coverage of dye on the outer surface of sorbent, in which the adsorption of dye ions occurs uniformly on the active part of the surface.

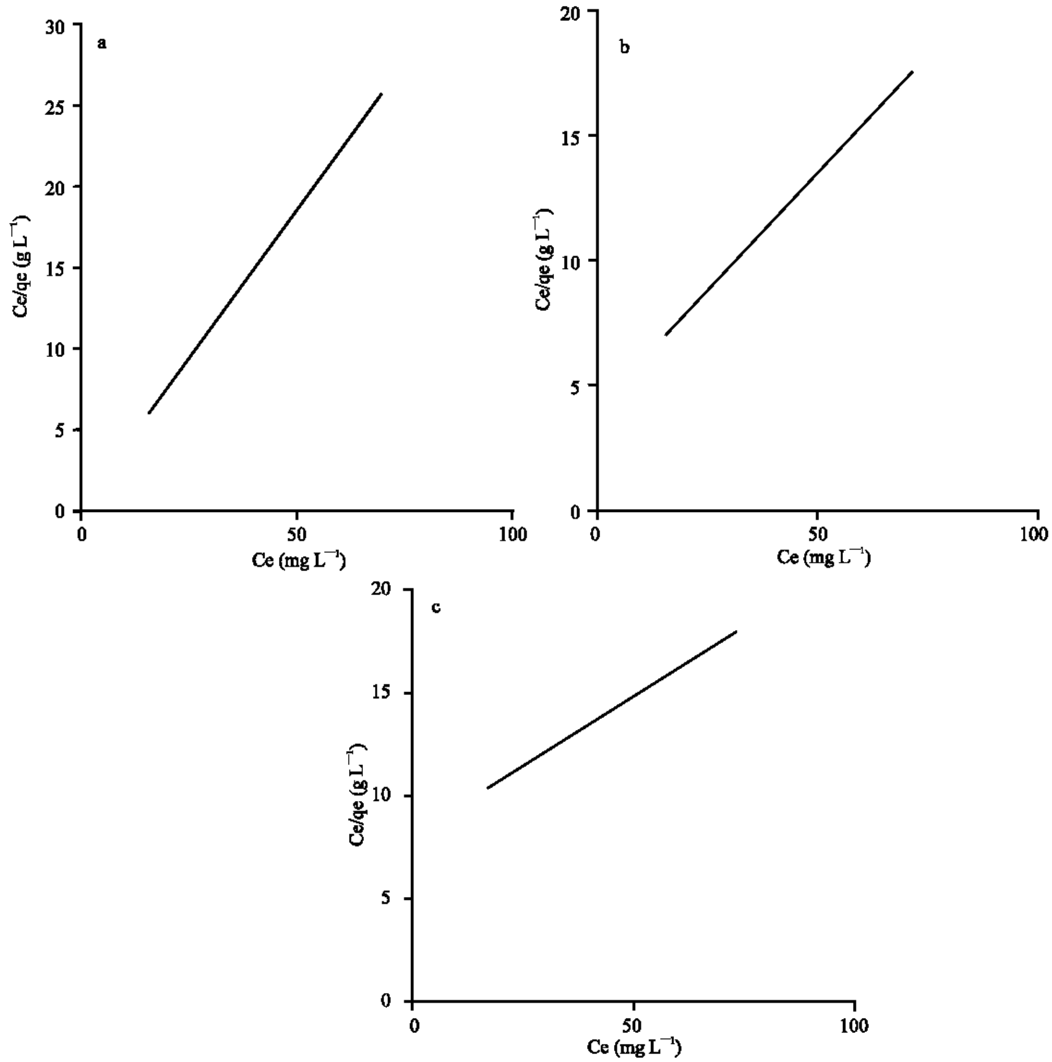

Fig. 4: Langmuir plots for the adsorpation of dyes a) Direct Orange 26 -b) Acid Orange 7 and C) Acid Green 20

Table 2: Constants of Longmuir isotherms

Initial dye concentration	Direct orange 26			Acid orange 7			Acid green 20		
(mg L^{-1})	Q^o (mg g^{-1})	b (L (mg)$^{-1}$)	R_L	Q^o (mg g^{-1})	b (L (mg)$^{-1}$)	R_L	Q^o (mg g^{-1})	b (L (mg)$^{-1}$)	R_L
20	2.78	0.239	0.173	5.06	0.044	0.532	7.84	0.017	0.746
40			0.095			0.362		0.595	
80			0.049			0.221		0.424	
	K_L = 0.664			K_L = 0.222			K_L = 0.133		

The Freundlich equation for a linear plot is described by the following equation:

$$\log\frac{x}{m} = \log k + \frac{1}{n}\log C_e \qquad (6)$$

where x is the amount of retained dye (mg L^{-1}), m is the amount of adsorbent (g L^{-1}), C_e is the concentration at equilibrium of the dye in solution (mg L^{-1}). K and n are Freundlich constants which include all parameters influencing the adsorption process, such as adsorption capacity and intensity. K and n values, calculated from the intercept, with the ordinate and the slope of the linear plots of log x/m versus log C_e (Fig. 5), are presented in Table 3. The values of n between 1 and 10 show a preference of the adsorbent for the studied dyes.

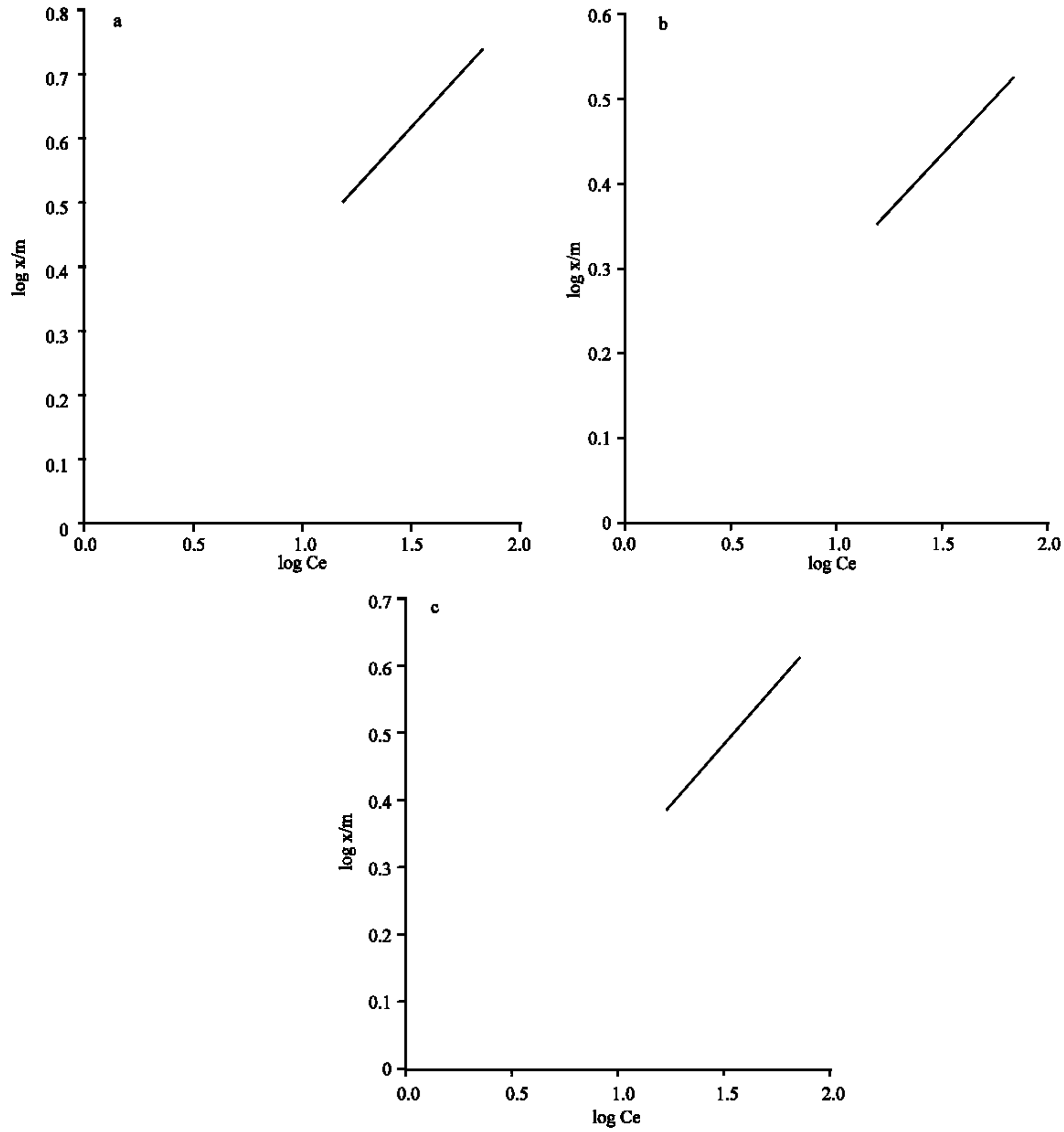

Fig. 5: Freundlich plots for the adsorpation of dyes a) Direct Orange 26 -b) Acid Orange 7 and -C) Acid Green 20

Table 3: Constants of Freundlich isotherms

Dye	K	N
Direct orange 26	1.122	1.020
Acid orange 7	1.529	1.153
Acid green 20	1.184	1.191

DISCUSSION

The results obtained from the present investigation revealed the ability of beech wood sawdust in treating dye effluents, e.g., Direct Orange 26, Acid Orange 7 and Acid Green 20. Since the beech sawdust is readily available in industry, it is more economical and higher sorption capacity than other sorbents. Also regeneration is not necessary and it can be burnt with the sorbed dyes as a source of energy. Since this study was performed using synthetic wastewater and at laboratory conditions, results obtained may vary if apply to real wastewater. Parameter such as equilibrium time and concentrations may not stand as indicated. Further study focused on the real wastewater from textile or paint sources is needed.

The removal versus time curves were single and continuous leading to saturation, suggesting the possibility of monolayer coverage of dye on the outer surface of the sorbent (Waranusantigul *et al*., 2003).

Adsorption is highly dependent on the contact time and dye concentration.

Kinetics of adsorption follows Lagergren first order kinetic model with film diffusion being the constitutive rate- controlling step.

In this study the value of R_L were found to be less than 1 and greater than 0 indicating the favourable adsorption of these dyes on beech sawdust. This was consistent with the observation of Abdelwahab *et al*. (2005).

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