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Full Length Research Paper

Equilibrium uptake and sorption dynamics for the removal of a basic dye using bamboo

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The bisorption of basic dye from aqueous solution on bamboo based activated carbon was studied in a batch system. The effect of various experimental parameters, such as pH, adsorbent dosage, temperature and initial dye concentration was investigated. The results showed that these parameters influenced the adsorption capacity. Higher solution pH favoured the adsorption of basic dye. Dye removal increased with increase in the initial concentration of basic dye. The adsorption of dye increased with increasing temperature of the solution from 25 to 45℃, indicating the process to be endothermic. Dye removal increased with increase in the initial concentration of the dye. As adsorbent concentration increased, the amount adsorbed per unit mass of adsorbent decreased. The equilibrium data fitted very well to Langmuir and Freundlich models.

Key words: Activated carbon, bamboo, basic dye, isotherm, sorption.

INTRODUCTION

Dyes are used in many industries such as food, paper, carpets, rubbers, plastics, cosmetics, and textiles in order to colour their products (Bulut and Aydin, 2005). Effluents of these industries are highly coloured and the disposal of these wastes into receiving water causes damage to the environment as they may significantly affect photosynthetic activity in aquatic life due to reduced light penetration and may also be toxic to some aquatic life due to the presence of metals, chlorides, etc; in them (Aksu and Tezer, 2000). One of the major problems concerning textile wastewaters is coloured effluent (Hameed et al., 2006). The wastewater contains a variety of organic compounds and toxic substances, which are harmful to fish and other aquatic organisms (Ramakrishna and Viraraghavan, 1997; Lee et al., 1999; Kadirvelu et al., 2003; Kannan and Sundaram, 2001). Colour removal had been the target of significant attention in the last few years, not only because of its toxicity, but mainly due to its visibility problems (Aksu and Tezer, 2000; Yeh and Thomas, 1995; Morais et al., 1999; Correia et al., 1994). Equally, disposal of dying industrial effluents pose a major environmental problem because they contain pollutants that are especially resistant to removal by the typical microbial population and may be toxic to the micro-organisms present in treatment plants (Otero et al., 2003).

Various physicochemical and biological techniques can be employed to remove dyes from wastewaters (Suteu and Bilba, 2005; Bulut and Aydin, 2005). However, these processes are effective and economic only in cases where solute concentration are relatively high. Activated carbon is the most widely used adsorbent for the removal of colour and treatment of textile effluents but due to its high price it is not used on a great scale (Clarke and Anliker, 1980; El-Geundi, 1991; Lakshmi et al., 1994). This has led many researchers to search for the use of cheap and efficient alternative mate-rials such as coal, fly ash, palm-fruit bunch, rice husk, peat, activated clay, bagasse pits, cassava peel, palm tree cobs, date pits, fruit stones and nutshells (Mohan et al., 2002a; Mohan et al., 2002b; Wu et al., 2001; Nassar, 1997; Mckay, 1998; Girgis and El-Hendawy, 2002; Aygun et al., 2003).

The use of agricultural by-products as raw material for manufacturing activated carbon is advantageous as these raw materials are renewable and potentially less expensive to manufacture (Hameed et al., 2006). Solid waste from bamboo is highly abundant in Nigeria. The objective of this work is to study the utilization of bamboo as adsorbent to remove basic dye from an aqueous solution. Equilibrium and kinetic analysis were conducted to

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understand sorption process.

MATERIALS AND METHODS

Adsorbate

The basic dye used is 2, 4 – dinitrophenylhydrazine. The stock solution of 1000 mg/l was prepared by diluting the stock solution with distilled water.

Adsorbent preparation

Bamboo used for this study was obtained from Nnamdi Azikiwe University, Awka. The bamboo was washed with distilled water, dried and grounded into powder. 100 g of bamboo powder was mixed with 100 ml of 0.1 M phosphoric acid. The mixture was oven dried at 110°C for 24 h. The oven dried mixture was carbonized in a muffle furnace (United Nations database 073050) at 450°C for 3 h. The carbonized sample was washed with distilled water until pH of 6.0 was obtained. The sample was thereafter dried in an electric oven for 4 h at 95°C and then kept in desiccators for use after crushing and sieving with 1.18 mm sieve.

Characterization of adsorbent

The surface area of the adsorbent was determined by iodine adsorption method (ASTM D 4607-86). Moisture content was determined using ASTM D 2867 – 91. Bulk density was determined using method of Okieimen et al. (2007). pH of the carbon was determined by immersing 1 g sample in 100 ml of distilled water and stirring for 1 h.

Batch adsorption experiment

The adsorption experiments were performed by batch method where samples of 1 g of bamboo based activated carbon were equilibrated with 250 ml of solution containing various amount of basic dye with intermittent stirring. The initial pH of solution was adjusted to 3, 5, 7 and 9 using 0.1 M NaOH or HCl. Effect of carbon dosage was studied by varying the amount of each adsorbent (1, 3, 5 and 7 g) per 20 ml of a concentration of 100 mg/l stock solution of basic dye. The effect of contact time was investigated for 30, 60, 90 and 120 min. at pH 6 and 1 g/100 ml sample dosage. The temperature of solutions (25, 30, 35 and 40°C) was controlled with a thermostatic bath. At the end of adsorption period, the various samples were filtered using filter paper and the supernatant liquid was analysed for the remaining dye using a UV spectrophotometer by monitoring the absorbance changes at a wavelength of maximum absorbance of 550 nm. The amount of dye adsorbed was calculated using the equation

$$q_e = V(C_o - C_e) / m \quad (1)$$

Where, q_e is the amount adsorbed per gram of adsorbent, C_e is the equilibrium concentration of dye (mg/l), V is volume of solution (l) and m is mass of adsorbent used (g).

RESULTS AND DISCUSSION

Effect of carbon dosage on adsorption process

Adsorbent dosage is an important parameter because this factor determines the capacity of an adsorbent for a given initial concentration of the adsorbate. The effect of adsorbent dosage was studied on basic dye removal by keeping all other experimental conditions constant. The result showed that as the adsorbent concentration increased, the amount adsorbed per unit mass of the adsorbent decreased considerably (Figure 1). The decrease in unit adsorption with increasing dose of adsorbent is basically due to adsorption sites remaining unsaturated during the adsorption (Bulut and Aydin, 2006).

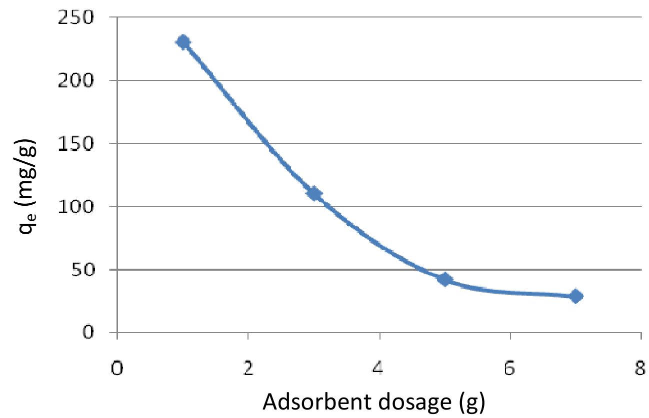

Figure 1. Effect adsorbent (bamboo) dosage on the sorption of basic dye at 30°C.

Effect of pH

The pH is one of the most important factors controlling the adsorption of dye onto adsorbent. The effect of pH in the adsorption of basic dye by bamboo is shown in Figure 2. The dye uptake was found to increase with increasing pH. The highest dye uptake was recorded at pH of 9.

Effect of temperature

Temperature has important effects on the adsorption process. As the temperature increases, rate of diffusion of adsorbate molecules across the external boundary layer and interval pores of the adsorbent particle increases (Waranusantigul et al., 2003). Figure 3 shows effects of different temperatures for basic dye removal on bamboo. The amount of basic dye adsorbed increased with increasing temperature of the solution from 25 to 45°C, indicating the process to be endothermic.

Effect of Initial dye concentration

The sorption capacity of powdered activated carbon for basic dye was determined at different initial dye concentrations. Figure 4 shows that percentage removal

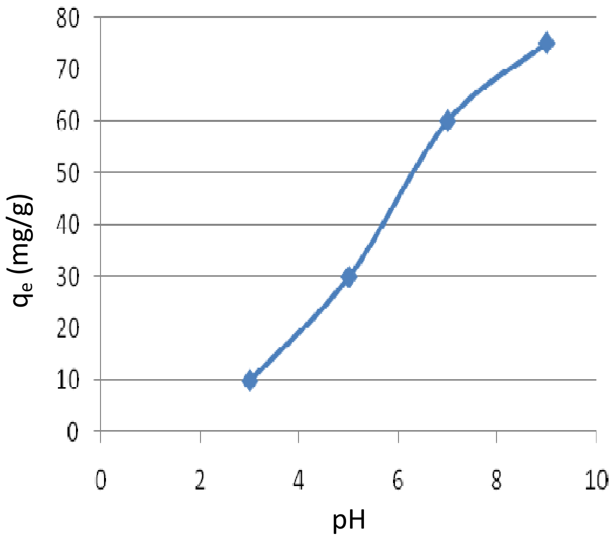

Figure 2. Effect of pH on the sorption of basic dye at 30°C using bamboo as absorbent.

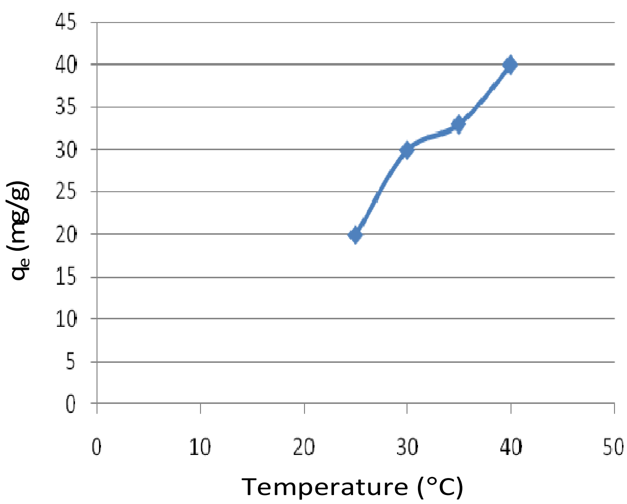

Figure 3. Effect of temperature on the sorption of basic dye at30°C using bamboo as absorbent.

rate increased with an increase in dye concentration. Dye removal is highly concentration dependent. The increase in loading capacity of the adsorbent with relation to dye ions is probably due to a high driving force for mass transfer. In fact, the more concentrated the solution, the better the adsorption.

Characteristics of Bamboo based activated carbon

The characteristics of activated carbon synthesized from bamboo were determined and reported in Table 1.

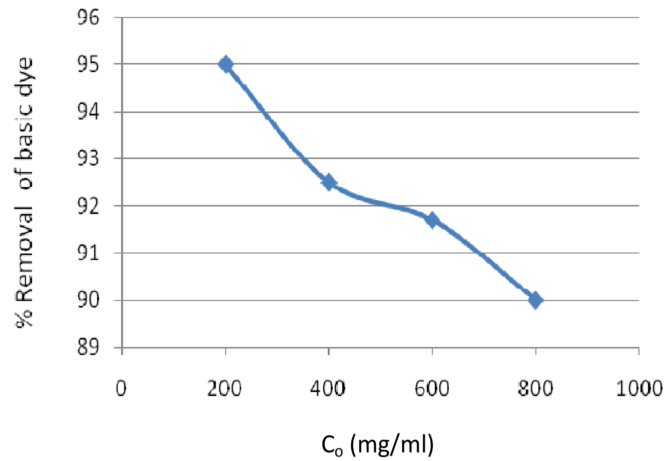

Figure 4. Effect of initial dye concentration on its removal using bamboo as absorbent.

Table 1. Characteristics of bamboo based activated carbon.

Characteristic	Value
Surface area (m^2/g)	364.24
Density (g/cm^3)	0.65
pH	6.0
Moisture Content	0.038

Adsorption isotherm

The relationship between the amount of a substance adsorbed at constant temperature and its concentration in the equilibrium solution is called the adsorption isotherm. Several models have been published in the literature to describe experimental data of adsorption isotherms. The Langmuir and Freundlich are the most frequently used models. In this study, both models were employed to analyse the relationship between the amount of dye adsorbed and its equilibrium concentration.

Langmuir isotherm

The Langmuir adsorption isotherm assumes that adsorption takes place at specific homogeneous sites within the adsorbent, and it has been used successfully for many adsorption processes of monolayer adsorption. The linearized Langmuir equation is represented as follows:

$$C_e/q_e = 1/Qb + (1/Q)C_e \quad (2)$$

where, C_e is the equilibrium concentration of the adsorbate (mg/l), q_e is the amount of adsorbate adsorbed per unit mass of adsorbate (mgg^{-1}), and Q and b are Langmuir

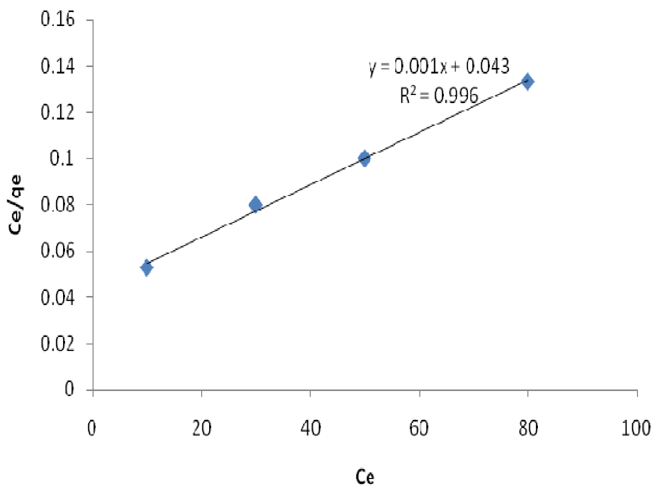

Figure 5. Langmuir isotherm for the sorption of basic dye at 30°C using bamboo as absorbent.

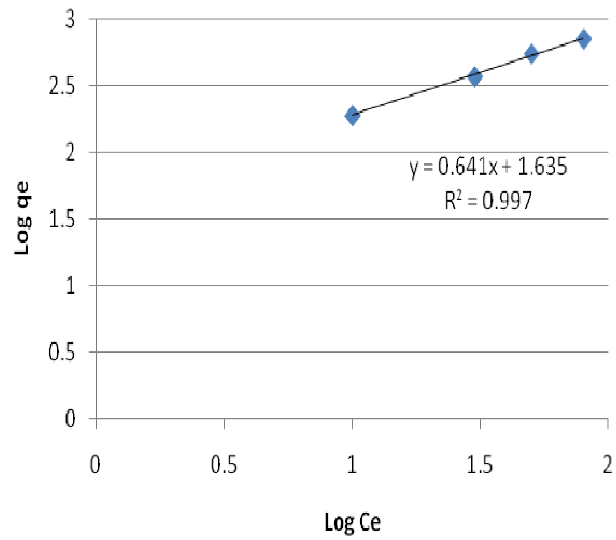

Figure 6. Freundlich isotherm for the sorption of basic dye 30°C using bamboo as absorbent.

Table 2. Langmuir and Freundlich isotherm constants at 30°C using bamboo as absorbent.

Parameter	Value
Langmuir isotherm	
Q (mgg^{-1})	884.96
b (lmg^{-1})	0.026
R_L	0.133
R^2	0.996
Freundlich isotherm	
1/n	0.641
K_F (mgg^{-1}) (Lmg^{-1})$^{1/n}$	43.15
R^2	0.997

constants related to adsorption capacity and rate of adsorption, respectively. Plotting C_e/q_e against C_e gave straight line with slope, 1/Q (Figure 5), indicating that the adsorption of basic dye on activated carbon follows the Langmuir isotherm. The Langmuir constants 'b' and Q were evaluated from this isotherm and their values are recorded in Table 2. The fact that the Langmuir isotherm fits the experimental data very well may be due to the homogeneous distribution of active sites onto the bamboo surface, since the Langmuir equation assumes that the surface is homogeneous.

The essential characteristics of the Langmuir isotherm can be expressed in terms of a dimensionless equilibrium parameter, R_L (McKay et al., 1984) which is defined by:

$$R_L = 1/(1 + bC_o) \quad (3)$$

Where, C_o is the highest initial solute concentration, b the Langmuir's adsorption constant (l/mg). The value of R_L indicated the type of the isotherm to be either unfavourable ($R_L > 1$), linear ($R_L = 1$), favourable ($0 < R_L < 1$) or irreversible (R_L = O). The value of R_L was obtained as 0.026. This confirmed that the activated carbon from bamboo is favourable for adsorption of basic dye under the conditions used in this work.

Freundlich isotherm

The Freundlich isotherm is an empirical equation used to describe heterogeneous systems. The well-known logarithmic form of Freundlich model is given by the following equation:

$$\text{Log } q_e = \log K_F + (1/n)\log C_e \quad (4)$$

Where, K_F and 1/n are Freundlich constants related to adsorption capacity and adsorption intensity of the sorbent, respectively. q_e is the amount adsorbed at equilibrium (mgg^{-1}), C_e is the equilibrium concentration of the adsorbate. The values of K_F and 1/n are calculated from the intercept and slope respectively, and are recorded in Table 2. The plot of log q_e versus log C_e gave straight line (Figure 6) with correlation coefficient of 0.997, which shows that the adsorption of basic dye follows the Freundlich isotherm.

Conclusion

The present investigation showed that bamboo is a promising adsorbent for the removal of basic dye from aqueous solution over a wide range of concentration. The amount of dye adsorbed was found to vary with adsorbent dosage, initial dye concentration, pH, and temperature. Basic dye was found to adsorb strongly on the surface of activated carbon. Adsorption behaviour is well described by a monolayer Langmuir type isotherm and Freundlich type isotherm.

REFERENCES

Aksu Z, Tezer S (2000). Equilibrium and Kinetic modelling of bisorption of Removal Black B by Rhizopus arrhizus in a batch system: effect of temperature. Process Biochem. 36: 431-439.

American Society for Testing and Materials (ASTM) (1986). Standard test method for determination of iodine number of activated carbon. Philadelphia, PA: ASTM Committee on Standards.

American Society for Testing and Materials (1991). Standard test methods for moisture in activated carbon. Philadelphia, PA: ASTM Committee on Standards.

Aygun A, Yenisoy-Karakas S, Duman I (2003). Production of granular activated carbon from fruit stones and nutshells and Evaluation of their physical, chemical and adsorption properties, micropor. Mater. 66: 189-195.

Bulut Y, Aydin H (2005). A kinetics and thermodynamics study of methylene blue adsorption on wheat shells, Desalination, 194: 259-267.

Clarke EA, Anliker R (1980). Organic dyes and pigments. In: Handbook of Environmental Chemistry. Anthropogenic Compounds, Part A, vol. 3. NY. Springer, pp. 181-215.

Correia VM, Stephenson T, Judd SJ (1994). Characterization of textile wastewaters: a review, Environ. Technol. 15: 917-919.

El-Geundi MS (1991). Colour removal form textile effluents by adsorption techniques. Water Res. 25: 271-273.

Girgis BS, El-Hendawy AA (2002). Porosity development in activated carbons obtained from date pits under chemical activation with phosphoric acid, Micropor. Mesopor. Mater. 52: 105-117.

Hameed BH, Din ATM, Ahmed AL (2006). Adsorption of methylene blue onto bamboo- based activated carbon: kinetics and equilibrium studies, J. Hazard Mat., 7: pp. 049.

Kadirvelu K, kavipriya M, Karthika C, Radhika M, Vennilamani N, Pattabhi S (2003). Utilization of various agriculture wastes for activated carbon preparation and application for aqueous solutions, Bioresour. Technol. 87: 129-132.

Kannan N, Sundaram MM (2001). Kinetics and mechanism of removal of methylene blue by adsorption on various carbons, a comparative study, Dyes and Pigments, 51: 25-40.

Lakshmi KC, Narayan R, Krishnaiah AK (1994). Colour removal from a dye stuff industry effluent using activated carbon. Indian J. Chem. Tech. 1: 13-19.

Lee CK, Low KS, Gan PY (1999). Removal of some organic dyes by acid treat spent bleaching earth, Environ. Technol. 20: 99-104.

Mckay G (1998). Application of surface diffusion model to the adsorption of dyes on bagasse pith, Adsorption, 4: 361-372.

Mckay G, Blair HS, Gardner JR (1984). The adsorption of dyes onto chitin in fixed bed columns and batch adsorbers, J. Appl. Polym. Sci. 29: 1499-1514.

Mohan D, Sing KP, Sing G, Kumar K (2002b). Removal of dyes from wastewater using fly ash, a low-cost adsorbent, Ind. Eng. Chem. Res. 41: 3688-3695.

Mohan SV, Rao NC, Karthikeyan J (2002a). Adsorption removal of direct azo dye from aqueous phase onto coal based sorbents: a kinetic and mechanistic study, J. Hazard. Mater. 90: 189-204.

Morais LC, Freitas OM, Gancolves EP, Vaskancelos LT, Beca CG (1999). Reactive dyes removal from wastewaters by adsorption on eucalyptus bark: variables that define the process, Water Res. 33: 979-988.

Nassar MM (1997). The Kinetics of basic dye removal using palm-fruit bunch, Adsorp. Sci. Technol. 15: 609-617.

Okieimen FE, Okieimen CO, Wuana RA (2007). Preparation and characterization of activated carbon from rice husks. J. Chem. Soc. Nigeria, 32(1): 126-136.

Otero M, Rozada F, Calvo LF, Garcia AI, Moran A (2003). Kinetic and equilibrium modelling of the methylene blue removal from solution by adsorbent materials produced from sewage sludges, Biochem. Eng. J. 15: 59-68.

Ramakrishna KR, Viraraghavan T (1997). Dye removal using low cost adsorbents, Water Sci. Technol. 36(2-3): 189-196.

Suteu D, Bilba D (2005). Equilibrium and Kinetic study of Reactive Dye Brilliant Red HE-3B Adsorption by Activated Charcoal. Acta Chim. Slov. 52: 73-79.

Waranusantigul P, Pokethitiyook P, Kruatrachue M, Upatham ES (2003). Kinetics of basic dye (methylene blue) bisorption by giant duckweed (spirodela polyrrhiza), Environ. Pollution, 125: 385-392.

Wu FC, Tseng RL, Juang RS (2001). Kinetics of colour removal by adsorption from water using activated clay. Environ. Technol. 22: 721-729.

Yeh RYL, Thomas A (1995). Colour difference measurement and colour removal from dye wastewaters using different adsorbents, J. Chem. Technol. Biotechnol. 63: 55-59.