

## Kinetics of Removal of Dyes from Aqueous Solution by Wood Charcoal of *Bombax Cieba* Activated at 1000 °C

F. K. BANGASH AND A. MANAF

*Institute of Chemical Sciences,  
University of Peshawar, Peshawar 25120*

(Received 24<sup>th</sup> January, 2006, revised 3<sup>rd</sup> May, 2006)

**Summary:** The Kinetics of sorption of basic dyes, (methylene blue and basic blue 3) from aqueous solution by charcoal activated at 1000°C, prepared from the wood of *Bombax cieba* was investigated. It was found that the adsorption process follow first order kinetics. The rate constants (*k*) increased with the rise in temperature showing endothermic nature of the adsorption process. Activation energies for methylene blue and basic blue 3. were found to be 2.33 and 8.74 kJ/mol respectively.

### Introduction

Color removal from textile effluents has been the subject of great attention in the last few years, not only because of its toxicity but also mainly due to its visibility [1]. Through hundreds of years, the scale of production and the nature of dyes have changed widely, and consequently the negative impact of dyes on the environment has increased.

Synthetic dyes are used extensively in textile dyeing, printing industries, color photography and as additives in petroleum products. It is estimated that 10 to 15% of the dye is lost in the effluent during the dyeing process [2, 3]. Effluents discharged from dyeing industries are highly colored and they can be toxic to aquatic life in receiving waters [4, 5]. The discharge of dyes in to watercourses causes serious pollution problem threatening the water supply and quality due to their non-degradability, toxicity, accumulation and magnification through out the food chain.

The economical de-colorization of effluents by removal of dyes remains an important problem. A number of adsorbents such as chitin [6], silica gel [7], wood [8], natural clay [9], baggass pith fibers [10] and polymeric adsorbents [11] have been used recently, but activated carbon technology and its potential for waste water treatment has been appreciated. This method is widely used due to its simplicity, effectiveness and low space requirements. Activated carbon can be produced from a variety of materials such as wood, coal, peat and lignin etc. Although the raw materials are cheap but its activation at high temperatures make it rather expensive and skillful. Adsorption is a unit operation in which surface active materials in true solution are

removed from the solvent by inter-phase transfer to the surfaces of an adsorbent particle.

Activated charcoal with large internal surfaces and pores has potential for dyes adsorption. Moderate amount of activated carbon can effect the removal of significant amounts of pollutants from wastewater [12, 13], soil and waste gas [14]. Due to their great adsorption capability, activated charcoal is also used for the removal of undesirable substances from edible oil, fats, sugar, alcoholic beverages, chemicals and pharmaceuticals as well as solvents. Activated carbon is also a recommended and a strategic adsorbent for removal of organic volatile compounds [15], which are used in perfumes, paints, solvents, varnishes and chemical cleaners.

The objective of this work was to study the effectiveness of activated charcoal prepared from the low cost wood of *Bombax cieba* for use in the management of wastewaters, using basic dyes such as basic blue 3 (BB3) and methylene blue (MB) as adsorbates.

### Results and Discussion

The effect of temperature on the kinetics of methylene blue and basic blue 3 adsorption on activated charcoal in aqueous solution are shown in figures 1 and 4. The initial rates of dyes up take was high which after slowing down, gradually attains equilibrium. This behavior is because of the fact that activated carbon has micro and macro porous structures, initially having all bare surface sites which gets reduces as the dye adsorb on and diffuse [16] in to the porous structures with the laps of time. The

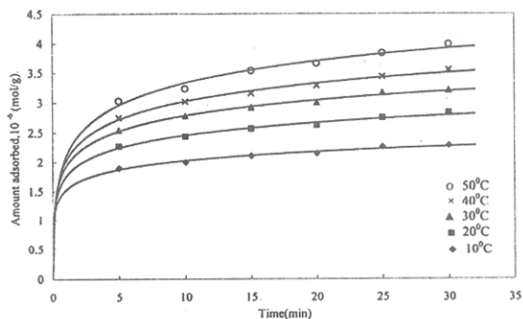


Fig. 1: Adsorption of methylene blue on activated charcoal at different temperatures.

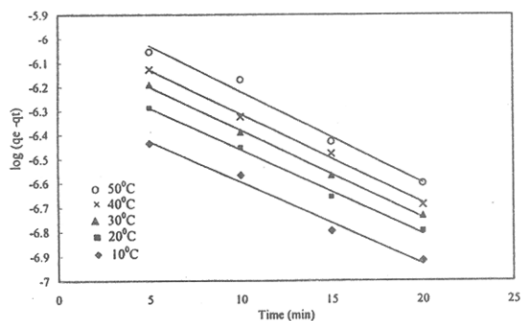


Fig.-2: Lagergren plots of methylene blue adsorption on activated charcoal.

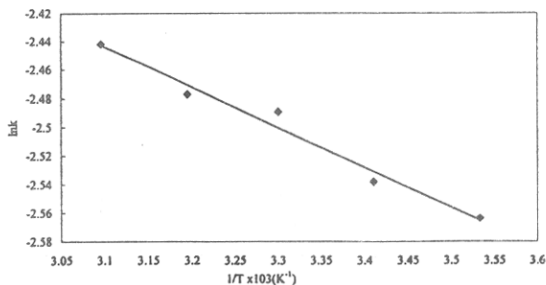


Fig. 3: Plot of  $\ln k$  vs  $1/T$  of methylene blue adsorption on activated charcoal.

initial rapid uptakes of dyes may likely be due to the extra cellular binding and the slower sorption phase likely resulted from intracellular binding [17]. The equilibrium time was taken as 30 minutes in this study. It is also clear from these figures that uptake of the dyes from aqueous solution increases with rise in temperature. The following Lagergren equation [18], was found to apply to the data.

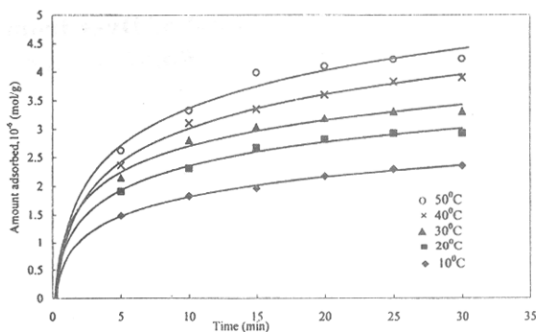


Fig. 4: Adsorption of basic blue 3 on activated charcoal at different temperatures.

$$\log(q_e - q_t) = -\frac{kt}{2.303} + \log q_e \quad (1)$$

Where  $q_e$  and  $q_t$  are the amount of dyes ( $\text{mol g}^{-1}$ ) adsorbed at equilibrium time and at time  $t$  respectively.  $k$  is the overall rate constant. Linear plots were obtained by plotting  $\log(q_e - q_t)$  against  $t$ , (Fig. 2 and 5), showing that the adsorption process follow first order kinetics. The values of the rate constant  $k$  (Table-1 and 2) increase with the rise in temperature, which shows endothermic nature of the adsorption process.

Table-1: Rate constants and activation energy of methylene blue adsorption on activated charcoal sample.

Shaking Temp. ( $^{\circ}\text{C}$ )	$k$ ( $\text{min}^{-1}$ )	$\ln k$	$1/T \times 10^{-3}$ ( $\text{K}^{-1}$ )	$E_a$ ( $\text{kJ/mol}$ )
10	0.077	-2.564	3.533	2.33
20	0.079	-2.538	3.410	
30	0.083	-2.489	3.300	
40	0.084	-2.477	3.195	
50	0.087	-2.442	3.096	

Table-2: Rate constants and activation energy of basic blue 3 adsorption on activated charcoal sample.

Shaking Temp. ( $^{\circ}\text{C}$ )	$k$ ( $\text{min}^{-1}$ )	$\ln k$	$1/T \times 10^{-3}$ ( $\text{K}^{-1}$ )	$E_a$ ( $\text{kJ/mol}$ )
10	0.109	-2.22	3.53	8.74
20	0.151	-1.89	3.41	
30	0.149	-1.90	3.30	
40	0.112	-2.19	3.195	
50	0.180	-1.71	3.096	

The activation energies of adsorption were determined by using the Arrhenius equation [19].

$$\ln k = -\frac{E_a}{RT} + \text{Constant} \quad (2)$$

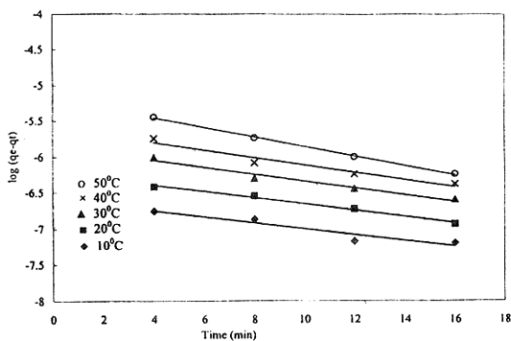


Fig. 5: Lagergren plots of basic blue 3 adsorption on activated charcoal.

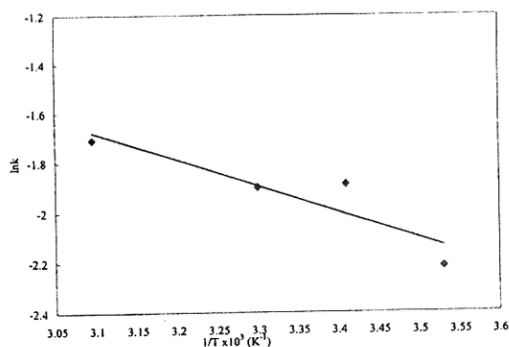


Fig. 6: Plot  $\ln k$  vs  $1/T$  basic blue3 adsorption on activated charcoal.

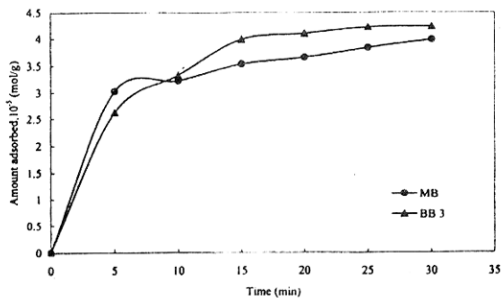


Fig. 7: Comparative adsorption of methylene blue (MB) and basic blue 3 (BB 3) on activated charcoal.

Where  $E_a$  is the energy of activation,  $R$  is the gas constant and  $T$  is the absolute temperature. The values of activation energies of adsorption determined from the slopes of the plots  $\ln k$  vs.  $T^{-1}$  (Fig. 3

and 5) were found to be 2.33 and 8.74  $\text{kJ mol}^{-1}$  for methylene blue and basic blue 3 respectively (Table 1 and 2). The results of the dyes removal from aqueous solutions are indicative that the activated charcoal produced from the wood of *Bombax cieba* could be utilized as an alternative low cost adsorbent material for industrial waste water treatment.

### Experimental

Powdered activated charcoal was obtained from debarked wood of *Bombax Cieba* by subjecting the wood pieces for carbonization at  $450^\circ\text{C}$ - $600^\circ\text{C}$ . The charcoal prepared was ground in to fine powder and leached with molar solutions of  $\text{HCl}$  and  $\text{HNO}_3$  in 1: 1 ratio for the removal of inorganic substances. It was then extracted with *n*-hexane and dried at  $90^\circ\text{C}$  in a vacuum oven for 50 minutes. The samples having mesh size 180-212 $\mu$  were activated under vacuum in a tube furnace at temperature of  $1000^\circ\text{C}$ .

Surface area was found by Snow's iodine adsorption method [20] by using the formula;  $12.5(24-V) \text{ m}^2/\text{gm}$ , where  $V$  is the volume of sodium-thiosulphate used. Concentration of the dyes was determined at 653nm ( $\lambda_{\text{max}}$ ) and 660nm ( $\lambda_{\text{max}}$ ) for BB3 and MB respectively, using spectrophotometer (Spectronic 20D). Standard solutions of  $1 \times 10^{-5}$  to  $6 \times 10^{-5} \text{ M}$  of the BB 3 (Analytical grade, Aldrich No. 37801-1) and MB (Analytical grade, Aldrich No. 31, 911-2) were respectively prepared in doubly distilled water. Duplicate samples containing 20ml portions of  $1 \times 10^{-5}$  to  $6 \times 10^{-5} \text{ M}$  dyes were taken in reagent bottles that contained 0.200g of activated charcoal. The reagent bottles were shaken at a constant speed in a water bath at different fixed experimental temperatures, for different time intervals. After each interval of time the solutions were filtered laboratory filter paper sheets by discarding first 4-5ml portion of the filtrate. The amount adsorbed (mol/g) was then calculated using the formula,

$$\text{Amount adsorbed} = \frac{(C_i - C_e)V}{W} \quad (3)$$

Where  $C_i$  is the initial concentration of dye (mol/L),  $C_e$  is the equilibrium concentration (mol/L),  $V$  is the volume of solution in liters and  $W$  is the amount of activated charcoal in grams.

### Acknowledgements

Authors acknowledge the financial support provided by the University of Peshawar for carrying out this work.

## References

1. V. Meyer, F. H. H. Carlsson and R. A. Oellermann, *Wat. Sci. Tech.* **26** (5), 1205 (1992).
2. A. Pala1, E. Tokat and H. Erkaya, *Proceedings of the First Int. Conf. on Envir. Res. and Assessment*, Bucharest, Romania, March 23-27 (2003).
3. U. Dani, A. Gurses and N. Canpolat, *1st International Workshop on Environmental quality and Environmental Engineering in the Middle East Region*, Konya, Turkey (1998).
4. C. K. Lee, K. S. Low and P. Y. Gan, *Environ. Technol.* **20** (6), 99 (1999).
5. K. Kadirvelu, M. Kavipriya, C. Karthika, M. Radhika, N. Vennilamani and S. Pattabhi, *Bioresource Technol.* **87**, 129 (2003).
6. G. McKay, H. S. Blair and J. R. Gardner, *J. Appl. Polym. Sci.* **27**(8), 3043 (1982).
7. G. McKay, M. S. Otterburn and A. G. Sweeney, *Wat. Res.* **14**, 15 (1980).
8. V. J. P. Poots, G. McKay and J. J. Healy, *Wat. Res.* **10**(12), 1067 (1976).
9. M. S. El-Geundi, *Adsor. Sci. Technol.* **9**(2), 109 (1993).
10. G. McKay, *Adsorption*, **4**, 361 (1998).
11. M. C. Hwang and K. M. Chen, *J. Appl. Polym. Sci.* **49**(6), 975 (1993).
12. V. K. Gupta, D. Mohan, S. Sharma, and M. Sharma, *Sep. Sci. Technol.*, **35**(13), 2097 (2000).
13. F. K. Bangash, S. Alam and M. Iqbal, *Jour. Chem. Soc. Pak.* **23**, 215 (2001).
14. S. H. Lin and A. L. Chen, *Water Research* **31**, 868 (1997).
15. M. M. Naim and Y. M. Elabd, *Separation and Purification Methods*, **31**, 171 (2002).
16. S. Venkata, and Kartikyan, *J. Clean Technol. Environ Policy*, **6**, 196 (2004).
17. F. K. Bangash and A. Manaf, *J. Chin. Chem. Soc.* **52** (3), 489 (2005).
18. H. S. Altandogan, S. Altandogan, F. Tumen and M. Bildik, *Waste Management* **22**, 357 (2002).
19. K. J. Laidler *Chemical kinetics*; 3<sup>rd</sup> ed. Harper and Row, Inc; New York, pp. 39 (1987).
20. M. L. Studebaker, *Rubber Chem. Tech.*, **30**, 1400 (1957).