Sorption of Basic Dye from Aqueous Solution by Durian Peel *(Durio zibethinus Murray)*

¹Siew-Teng Ong, ²Pei-Sin Keng, ³Meng-Seap Voon,
⁴Siew-Ling Lee and ⁵Yung-Tse Hung

¹Department of Chemical Science, Faculty of Science, Universiti Tunku Abdul Rahman,
Jalan Universiti, Bandar Barat, 31900 Kampar, Perak, Malaysia
²Department of Pharmaceutical Chemistry, International Medical University,
No. 126, Jalan 19/155B, Bukit Jalil, 57000 Kuala Lumpur, Malaysia
³Department of Science, Faculty of Engineering and Science, Universiti Tunku Abdul Rahman,
Jln Genting Kelang, Setapak, 53300 Kuala Lumpur, Malaysia
⁴Ibnu Sina Institute for Fundamental Science Studies,
Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
⁵Department of Civil and Environmental Engineering, Cleveland State University,
2121 Euclid Avenue, Cleveland, Ohio 44115-2214, USA

Abstract: The present study explored the potential of durian peel to remove basic dye from aqueous solution. A series of column studies were performed under various experimental conditions. Increase in bed depth resulted in a longer service time and this could be explained by an increase in surface area and hence binding sites. The sorption process was flow rate dependent within the scope of this study. Surface morphology analysis was carried out also using scanning electron microscopy (SEM).

Key words: Sorption · Durian peel · Basic dye · Column study

INTRODUCTION

The demand for synthetic dyes has experienced phenomenal growth in the past several decades due to the various applications in a variety of industries. Many industries, particularly, textile, ceramic, paper, printing and plastic industries use dye to colour their products. As such, effluent contaminated with dye from these industries has become one of the main sources of environmental pollution.

A range of conventional treatment technologies for dye removal from industrial effluents has been investigated extensively, which include biological treatment, coagulation, ozonation, electrochemical processes, nanofiltration and activated carbon adsorption [1-3]. Although carbon adsorption has demonstrated high efficiency in handling liquid industrial wastewater, the high cost of activated carbon remains as the major drawback.

Agriculture wastes and industrial by-products have been identified as economical alternative because they can be obtained readily and are in great abundance. Numerous studies have been conducted to investigate the potential of using these materials as an adsorbent for hazardous pollutants [3-8]. Attention has also been focused on the utilization of these materials in modified form to enhance their sorption capacity [3, 9-11].

However, most of the investigations deal with the adsorption in batch equilibrium mode. Studies conducted under the continuous flow conditions is considered more useful as this is more closely related to the industrial application. In this paper, we report the testing of durian peel (*Durio zibethinus Murray*), which is a very important tropical fruit crop in Southeast Asia in sorbing dye from synthetic solution using column technique.

Corresponding Author: Siew-Teng Ong, Department of Chemical Science, Faculty of Science,
Universiti Tunku Abdul Rahman, Jalan Universiti, Bandar Barat, 31900 Kampar, Perak, Malaysia.
E-mail: ongst@utar.edu.my

MATERIALS AND METHODS

Sorbates: The basic dye, Methylene Blue (MB) was purchased from Sigma-Aldrich Chemical Company and used as received without further purification. Synthetic dye solution of MB with the concentration of 1000 mg L^{-1} was prepared as stock solution and subsequently diluted when necessary.

Sorbents: Durian peel (DH) used throughout the experiment was collected from a local supermarket in Kuala Lumpur, Malaysia. The DH collected was washed several times with tap water to remove any dirt or durian's flesh. The DH was cut into tiny pieces which are approximately 5-8 cm long and then sun dried. The dried DH was then ground to pass through a 1 mm sieve and used for the adsorption studies. The chemical composition of durian peel contains about 13.09% of hemi-cellulose and 15.45% of lignin [12].

Scanning Electron Microscopy: The surface morphology of DH was studied using SEM which is equipped with energy dispersive X-ray Spectrometer (SEM-EDX)-JEOL JSM-6400. The sample was ground and palletized using a pellet compressor before it was stuck on a stub using double-sided tape. Before the sample was analyzed, the prepared pellet was coated with a thin layer of gold to prevent the occurrence of charging effect.

Column Study: A glass column with internal diameter of 1.0 cm was used. The flow rate of the eluant was controlled by using a peristaltic pump. The effect of bed depth on the MB sorption was tested by packing the column to 2.5, 6.0 and 9.0 cm, corresponding to 0.5, 1.5 and 2.0 g of DH, respectively, while maintaining the influent concentration at 2.5 mg/L with the flow rate of 10 mL/ min. The effect of flow rate on the sorption capacity of MB was varied from 7, 10 and 15 mL/min while maintaining the bed depth at a height of about 6.0 cm using 1.5 g of DH. The concentrations of MB were analyzed using a Perkin Elmer Lambda 35 UV-vis spectrophotometer. All measurements were made at the wavelength corresponding to maximum absorption for MB, λ_{max} = 664 nm. Dilutions were carried out when measurement exceeded the linearity of the calibration curve.

RESULTS AND DISCUSSION

Scanning Electron Microscopy: Figure 1 shows the surface morphology of DH examined using scanning electron microscope. From the SEM micrographs, it is clear that the investigated sorbent is non-porous material, due to the absence of pores and cavities.

Effect of bed depth: The effect of bed depth on the sorption characteristics of MB was studied. Figure 2 shows the breakthrough curve shifted to the right as the
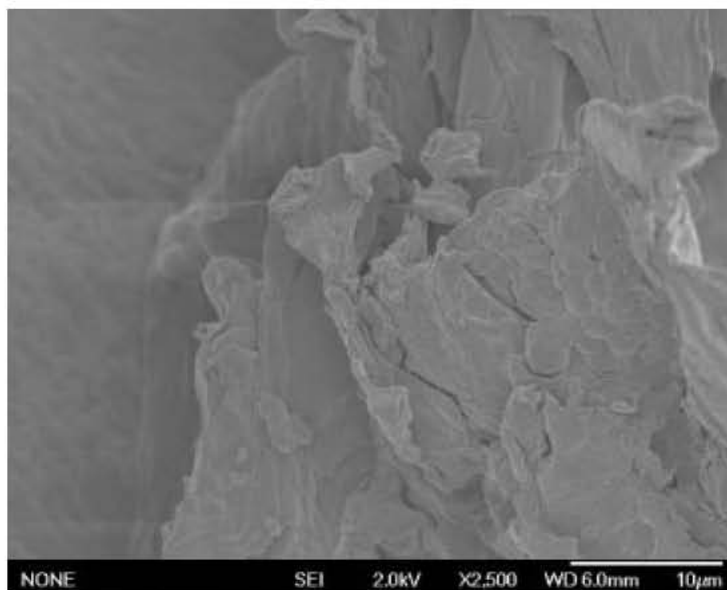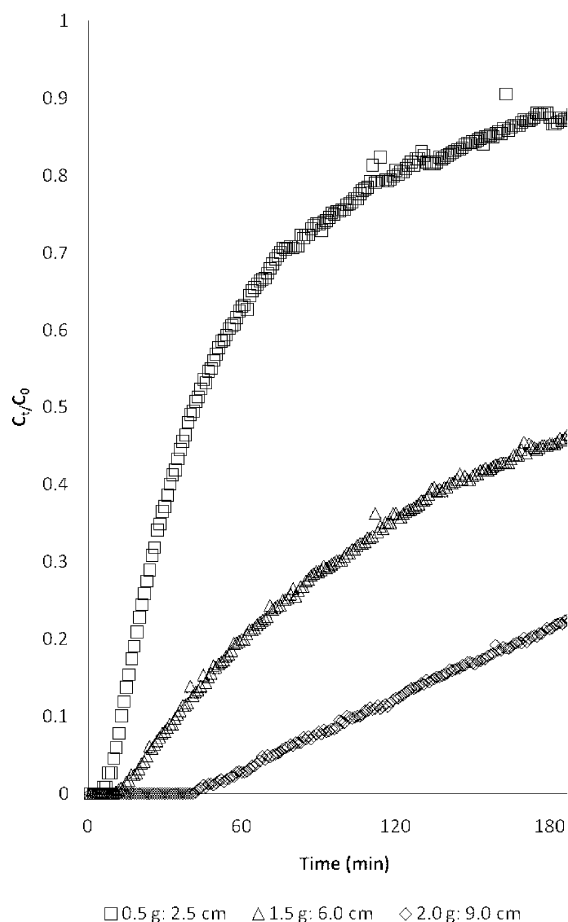

Fig. 1: SEM micrograph of DH

Fig. 2: Effect of bed depth on the breakthrough curve

Fig. 3: BDST plot for different bed depth and breakthrough point

bed depth increases from 2.5 to 9.0 cm. Breakthroughs at $C_t/C_o = 0.2$ occurred at 190, 610 and 1700 ml of dye solutions for bed depths of 2.5, 6.0 and 9.0 cm, respectively. The breakthrough time increases with increasing bed depth because a higher bed depth provides more binding sites for the adsorption [2,13]. Besides, a higher bed depth will also increase the contact time of MB with DH in the column and resulted in higher removal efficiency. Similar trend was also reported for the adsorption of Reactive Black 5 by polysulfone-immobilized *Corynebacterium glutamicum* [13] and the adsorption of Congo Red by EDA rice husk [10].

Several models have been proposed to correlate the service time of a fixed-sorption bed with the other operation variables. Amongst all, the most commonly quoted model for this correlation is the Bed-Depth-Service-Time (BDST) model [14] which states that the service time for a column is given by:
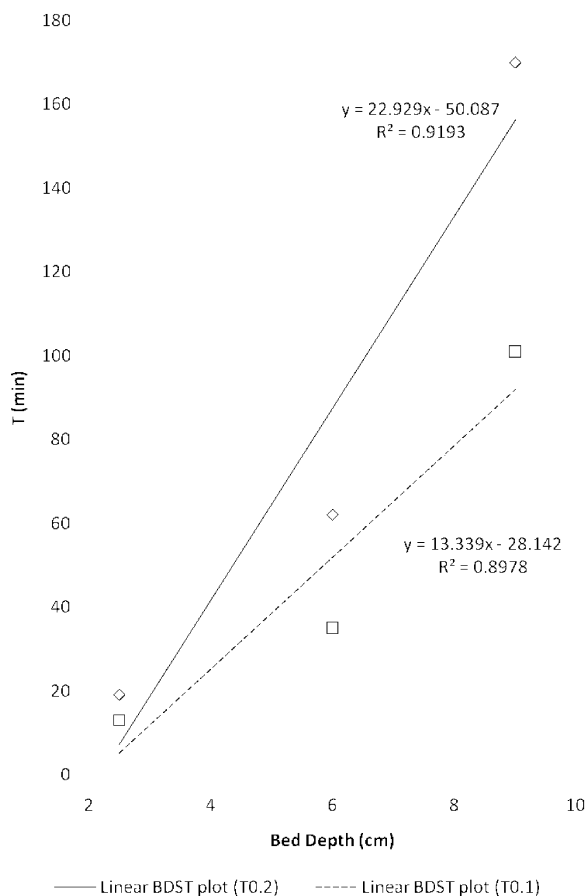
$$t = \frac{N_o}{C_o U} H - \frac{1}{kC_o} Ln\left(\frac{C_o}{C_t} - 1\right) \qquad (1)$$

where

t = service time to breakthrough (min)
N_o = sorption capacity (mg/g)
C_o = initial dye concentration (mg/l)
C_t = effluent concentration (mg/l)
U = linear flow rate (cm/min)
H = bed depth (cm)
k = rate constant of sorption (l/mg min)

The equation bears a linear relationship and can be reduced to:

$$t = \left(\frac{N_o}{C_o U}\right) H \qquad (2)$$
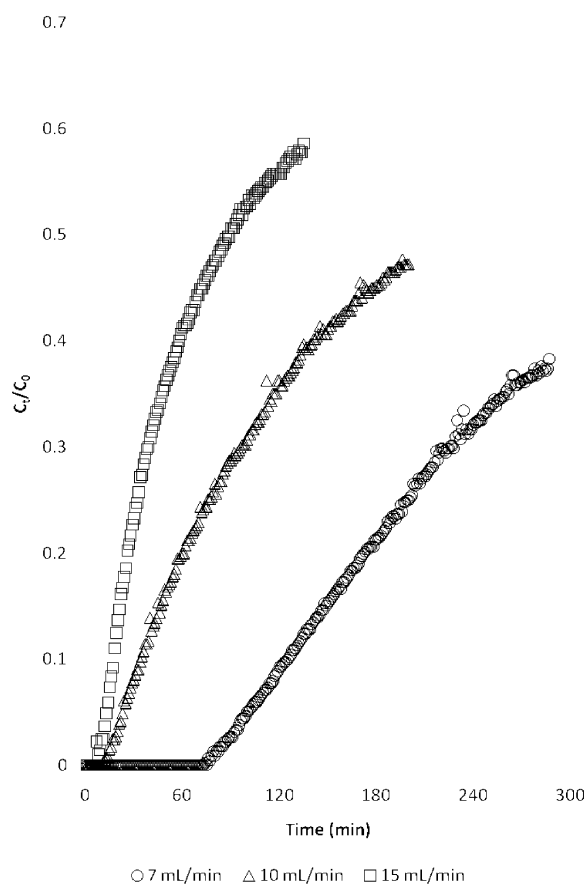
or

$$t = \text{constant} \times H \qquad (3)$$

Fig. 4: Effect of flow rate on the breakthrough curve

A plot of BDST (t) at breakthrough volume $(C_t/C_o) = 0.1$ and 0.2 at different bed depths (H) with constant flow rate was shown in Figure 3. Theoretically, a plot using equation (3) should be a straight line passing through the origin, provided the sorption data follow the model. However, as shown in Figure 3, the plot of t against H is a straight line that does not pass through the origin. This deviation from the BDST model is similar to that reported in the sorption of Cu and Pb by tartaric acid modified rice hull [15], the sorption of As(V) using quaternized rice husk [16] and the sorption of Congo Red using ethylenediamine modified rice hull [10]. The nonconformity of the BDST model may be due to the presence of more than one rate limiting step in the sorption process [2,15,17].

Effect of flow rate: With the introduction of the same influent concentration, varying the flow rate appeared to have a great effect on the breakthrough profiles of MB. The highest flow rate, 15 mL/min shows an earlier breakthrough time, whereas the lowest flow rate 7 mL/min shows a longer retention time of dye in the sorbent before the sorbent is exhausted (Figure 4). This could be explained by the slow interaction between DH and MB. With lower flow rate, the contact time between the sorbent and sorbate will be longer, thus more sorbate can be retained within this interaction period.

CONCLUSION

DH has been shown to be a potentially useful and attractive sorbent for the removal of MB from aqueous solution. However, the full potential of this application can only be realized after more operational variables and mathematical modeling have been undertaken.

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