



Adsorption of Reactive Dyes Remazol Red F-3B and Remazol Blue from Aqueous Solution by Coconut Coir Activated Carbon

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ABSTRACT

Activated carbon was prepared from coconut coir and adsorption of reactive dyes Remazol Red F-3B and Remazol Blue by the activated carbon was examined. Batch adsorption test showed that extent of dye adsorption was dependent on dye concentration, contact time, pH and carbon dose. Equilibrium adsorption was attained in 3 h and maximum adsorption occurred in the acidic pH range of 1 to 3. Adsorption capacity of the activated carbon for the dyes was evaluated by batch equilibrium test and compared with that of a commercial activated carbon. According to Langmuir and Freundlich adsorption isotherms, the coconut coir activated carbon showed higher capacity for adsorption of Remazol Red F-3B than that of the commercial activated carbon. For Remazol Blue, both the activated carbons showed comparable adsorption capacity. Coconut coir activated carbon is a suitable substitute for commercial activated carbon in the removal of reactive dyes from aqueous solution.

INTRODUCTION

Due to their strong interaction with natural and synthetic fibres, reactive dyes are used for dyeing wool, cotton, nylon, silk, and modified acrylics (Al-Degs et al. 2008). Reactive dyes consist of a chromophore and a functional group that binds the dyestuff to the fibre. The functional group, when applied to a fibre in an alkaline dye bath, forms a chemical bond with a hydroxyl group on the fibre which is much more resistant to unusual conditions of use than the physicochemical bond between other classes of dyes and cellulose. However, reactive dyes have a low degree of utilization, since the functional group also bonds to water, creating hydrolysis, and hence 10-50% of the dye is unexhausted and remains in the dye bath waste.

A considerable amount of research on wastewater treatment has focused on the removal of reactive dyes from dye bath waste, essentially for three reasons: reactive dyes represent 20-30% of the total dye market, large fraction of reactive dyes (10-50%) are wasted during the dyeing process and conventional wastewater treatment methods, which rely on adsorption and biodegradation, were found to be inefficient for complete elimination of many reactive dyes (Al-Degs et al. 2008).

Adsorption is an effective treatment method which is widely used in the removal of contaminants from water and wastewater. This method has also been proven to be an important way to treat coloured effluents (Gerçel et al. 2009).

Adsorption of reactive dyes on coal-based commercial activated carbon has been studied (Al-Degs et al. 2000, 2008). The use of coal-based commercial activated carbon is limited because of its relatively high price and its feedstock is nonrenewable (Gerçel et al. 2009). Low-cost, renewable, and easily available plant-based materials are to be used as a source in the production of activated carbon. Adsorption of reactive dyes on activated carbon prepared from peach stones (Gerçel et al. 2009), coconut tree flower and jute fibre (Senthilkumar et al. 2006), coir pith (Santhy & Selvapathy 2006) and bagasse fly ash (Rachakornkij et al. 2004) have been studied.

In this study, activated carbon was prepared from coconut coir and its capacity for adsorption of reactive dyes from aqueous solution was studied and compared with that of a commercial activated carbon.

MATERIALS AND METHODS

Activated carbon: Coconut coir activated carbon was prepared according to a method used by Santhy & Selvapathy (2006) for preparing coir pith activated carbon. Washed and dried coconut coir was treated with concentrated sulphuric acid and kept in a hot-air oven at $105 \pm 5^\circ\text{C}$ for 24 h. Thereafter, the char was washed with water followed by washing with 2% sodium bicarbonate solution until effervescence had ceased and then kept in a 2% sodium bicarbonate solution overnight. The char was then separated and washed with water until free from bicarbonate and dried at $105 \pm 5^\circ\text{C}$ for

24 h. It was then subjected to activation at 900°C for 30 min in an atmosphere of nitrogen. The activated carbon obtained was repeatedly washed with distilled water and soaked in 10% hydrochloric acid to remove calcium oxide, followed by repeated washing with water to remove free acid and drying at $105 \pm 5^\circ\text{C}$ for 24 h. The carbon was ground to a finer size of 0.4-0.5 mm and used in adsorption tests.

A commercial activated carbon (Merck) was obtained from Benua Sains Sdn. Bhd., Puchong, Selangor, Malaysia and used as received.

Reactive dyes: Reactive dyes, Remazol Red F-3B (C. I. Reactive Red 180) and Remazol Blue (C. I. Reactive Blue 19), were obtained from TCB Batik and Songket Sdn. Bhd., Kuala Terengganu, Terengganu, Malaysia.

Concentration of dye was determined by measuring the absorbance at the wavelength of maximum absorbance (Remazol Red F-3B: 540 nm; Remazol Blue: 600 nm) against a standard curve.

Adsorption test: Batch adsorption test was carried out by shaking 100 mL of dye solution with 0.5 g of activated carbon in a stoppered glass bottle placed in an orbital shaker at 150 rpm and room temperature (22°C). After a predetermined contact time, the bottle was removed from the shaker and the supernatant was filtered through Whatman No. 1 filter paper and analysed for dye concentration. The effect of contact time (1-4 h), dye concentration (5-40 mg/L), pH (1-10) and carbon dose (2-12 g/L) on adsorption were evaluated by batch adsorption test.

Adsorption isotherm was determined by batch equilibrium test at the optimum pH and contact time for adsorption with 100 mL of 10-100 mg/L of dye solution and 1.0 g of activated carbon for Remazol Red F-3B and 0.6 g of activated carbon for Remazol Blue.

RESULTS AND DISCUSSION

Effect of contact time and dye concentration: Effects of contact time and dye concentration on adsorption of Remazol Red F-3B and Remazol Blue by coconut coir activated carbon are shown in Figs. 1 and 2. Extent of dye adsorption increased with decrease in dye concentration and increase in contact time. Equilibrium adsorption was attained in 3 h. Similar results for adsorption of reactive dyes on activated carbon prepared from peach stones (Gerçel et al. 2009), coconut tree flower and jute fibre (Senthilkumar et al. 2006), coir pith (Santhy & Selvapathy 2006), and bagasse fly ash (Rachakornkij et al. 2004) have been reported. A contact time of 3 h was used in all the subsequent adsorption tests.

Effect of pH: Fig. 3 shows the effect of pH on adsorption of Remazol Red F-3B from a 5 mg/L solution and Remazol

Blue from a 40 mg/L solution by coconut coir activated carbon. Maximum adsorption occurred in the acidic pH range 1-3. Similar observations have been reported by Santhy & Selvapathy (2006) for adsorption of reactive dyes on coir pith activated carbon. The coconut coir activated carbon is an H-type activated carbon resulting from activation at high temperature (900°C) in nitrogen atmosphere and exhibits positive surface charge in water. In the acidic pH range 1-3, the positive surface charge increases and this would attract the negatively charged functional groups on the reactive dyes. A pH of 3.0 was used in all subsequent adsorption tests.

Effect of carbon dose: Fig. 4 shows the effect of carbon dose on adsorption of Remazol Red F-3B from a 10 mg/L solution, and Remazol Blue from a 40 mg/L solution by coconut coir activated carbon. Adsorption increased with carbon dose and attained 96% for Remazol Blue, and 84% for Remazol Red F-3B at 10 g/L carbon dose.

Adsorption isotherms: In adsorption in a solid-liquid system, the distribution ratio of the solute between the liquid and the solid phases is a measure of the position of equilibrium. The preferred form of depicting this distribution is to express the quantity q_e as a function of C_e at fixed temperature, the quantity q_e being the amount of solute adsorbed per unit weight of the solid adsorbent, and C_e the concentration of solute remaining in solution at equilibrium. An expression of this type is termed an adsorption isotherm (Weber 1972). The Langmuir adsorption isotherm is

$$q_e = \frac{Q^o b C_e}{1 + b C_e}$$

in which Q^o is the number of moles of solute adsorbed per unit weight of adsorbent in forming a complete monolayer on the surface (monolayer adsorption capacity) and b is a constant related to the energy of adsorption.

The Freundlich adsorption isotherm is

$$q_e = K C_e^{1/n}$$

in which K and n are constants, K is roughly an indicator of adsorption capacity, and $1/n$ of adsorption intensity.

Adsorption isotherms of Remazol Red F-3B and Remazol Blue adsorption by the coconut coir activated carbon and commercial activated carbon were fitted to the linear form of the Langmuir and Freundlich adsorption isotherms:

$$(C_e/q_e = 1/(bQ^o) + C_e/Q^o) \text{ (Figs. 5 and 6), and}$$

$$[\log q_e = \log K + (1/n) \log C_e] \text{ (Figs. 7 and 8)}$$

The values of Langmuir constants Q^o and b , and Freundlich constants K and n for Remazol Red F-3B and Remazol Blue adsorption by the coconut coir activated car-

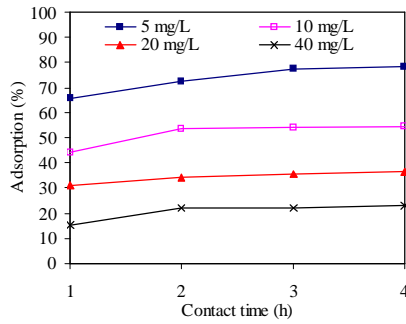


Fig. 1: Effect of contact time and dye concentration on adsorption of Remazol Red F-3B.

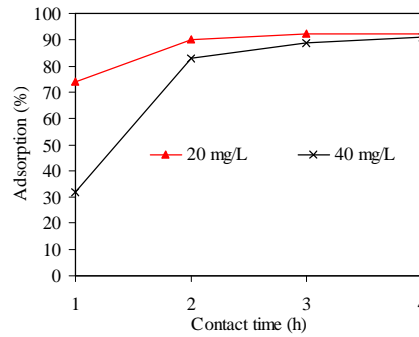


Fig. 2: Effect of contact time and dye concentration on adsorption of Remazol Blue.

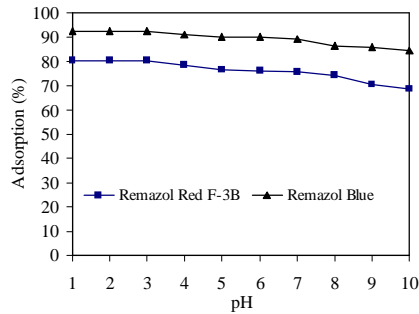


Fig. 3: Effect of pH on adsorption of Remazol Red F-3B and Remazol Blue.

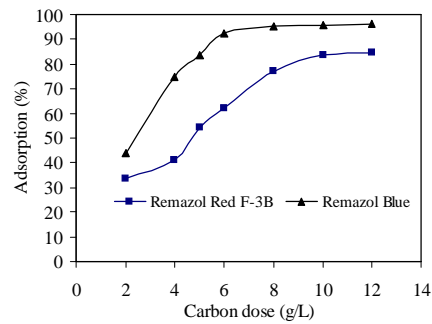


Fig. 4: Effect of carbon dose on adsorption of Remazol Red F-3B and Remazol Blue.

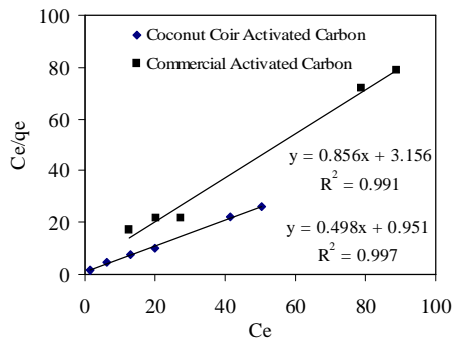


Fig. 5: Langmuir adsorption isotherm for Remazol Red F-3B adsorption.

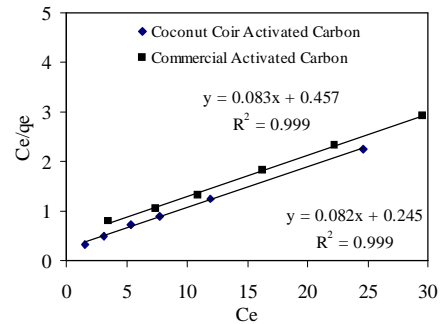


Fig. 6: Langmuir adsorption isotherm for Remazol Blue adsorption.

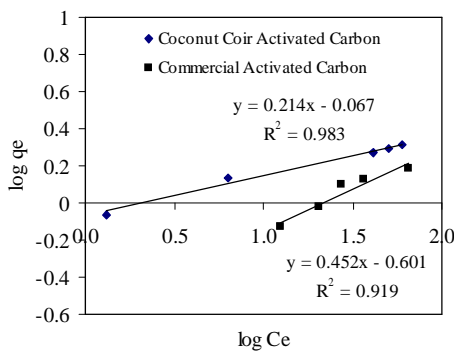


Fig. 7: Freundlich adsorption isotherm for Remazol Red F-3B adsorption.

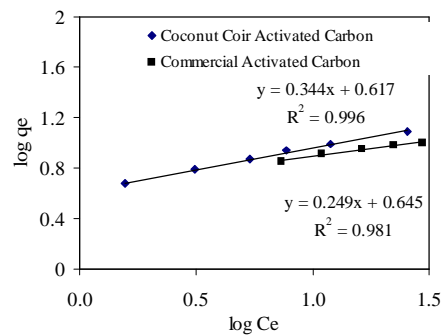


Fig. 8: Freundlich adsorption isotherm for Remazol Blue adsorption.

Table 1: Langmuir constants Q^o and b for Remazol Red F-3B and Remazol Blue adsorption.

Activated Carbon	Remazol Red F-3B		Remazol Blue	
	Q^o	b	Q^o	b
Coconut coir	2.01	0.52	12.19	0.33
Commercial	1.17	0.27	12.05	0.18

Table 2: Freundlich constants K and $1/n$ for Remazol Red F-3B and Remazol Blue adsorption.

Activated Carbon	Remazol Red F-3B		Remazol Blue	
	K	$1/n$	K	$1/n$
Coconut coir	0.86	0.21	4.13	0.34
Commercial	0.25	0.45	4.41	0.25

bon and commercial activated carbon are given in Tables 1 and 2, respectively. Values of Q^o and K indicate that the coconut coir activated carbon has higher adsorption capacity for Remazol Red F-3B than that of the commercial activated carbon, whereas for Remazol Blue, both activated carbons have comparable adsorption capacity.

CONCLUSIONS

In adsorption test, the coconut coir activated carbon showed higher adsorption capacity for Remazol Red F-3B than that of a commercial activated carbon and comparable adsorption capacity for Remazol Blue. Coconut coir activated carbon is a suitable substitute for commercial activated carbon in the removal of reactive dyes from aqueous solution.

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