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Removal of Congo Red from Aqueous Solution by Waste Banana Pith

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ABSTRAK

Eksperimen tentang penggunaan sisir batang kayu pisang sebagai penjerap untuk Congo merah telah dijalankan. Parameter yang dikaji termasuk kepekatan larutan pewarna, masa tindakan, dos penjerap dan pH larutan. Pemalar kadar penjerapan ditetapkan sebagai 1×10^{-1} min^{-1} pada kepekatan pewarna 50 mg l^{-1}. Lebih daripada 92% pewarna dijerap pada pH 2-11. Mekasime penjerapan sistem pewarna-sisir batang kayu pisang adalah, khususnya, erapan kimia.

ABSTRACT

The ability of waste banana pith to remove Congo red from aqueous solution was investigated. Various parameters such as initial dye concentration, contact time, adsorbent dosage and pH effect were studied. The adsorption rate constant was found to be 1×10^{-1} min^{-1} at 50 mg l^{-1} dye concentration. Above 92% removal was observed in the pH range 2-11. The removal of dye by banana pith is mostly due to chemisorption.

Keywords: Adsorption, banana pith, Congo red, intra particle diffusion

INTRODUCTION

The textile industry occupies a unique place in the industrial map of India and the total production of cloth from both cotton and synthetic fibres was 10527 million metres in 1980 (Badrinath *et al.* 1983). Textile mills require a large volume of water for their processes and the wastewater discharged from the mill is equally large and of a polluting nature. Colour imparts visible pollution, persists for long distances in streams, decreases re-aeration capacity of the stream, and retards photosynthetic activity. The treatment of dyeing wastewater poses several problems as the dyes are generally stable to light and oxidation and hence they cannot be treated by conventional methods of aerobic digestion.

The adsorption process provides an attractive alternative especially if the adsorbent is inexpensive and readily available. By far, activated carbon has been the most favoured material for adsorption of various materials like herbicides, chemical pollutants, dyes etc. (Venkata Rao and Sastry 1987). Various other non-conventional adsorbents like Fuller's earth and

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fired clay, silica (Mckay *et al.* 1987), biogas residual slurry (Namasivayam and Yamuna 1992a), Fe^{3+}/Cr^{3+} hydroxide sludge (Namasivayam and Chandrasekaran 1990), China clay (Gupta *et al.* 1989), peat moss and rice hulls (Nawar and Doma 1989), coconut husk (Low and Lee 1990) and fly ash (Khare *et al.* 1987; Gupta *et al.* 1988) have also been reported as efficient adsorbents in removing colour.

In India 80% of the population depends on the land for their living. The utilization of agricultural waste is of great significance and can play an important role in the national economy. India is the second largest banana producer after Brazil. It produces about 2.34 million tonnes from a cultivated area of 164,000 hectares (Manoharan 1988). The white central portion of the banana stem, called banana pith, is used to treat persons bitten by poisonous snakes (Pushpangadan *et al.* 1989). The stems have been used for biogas generation (Elorteguri *et al.* 1987; Sharma *et al.* 1987 1989), ethanol production (Tewari *et al.* 1987) and paper making (Geopaul 1980) etc. After cutting off the bunch most of the residues are either used as manure, simply thrown away or burnt off to reduce the volume. The approximate amount of dry matter produced per banana plant is about 1, 1.3 and 5 g of leaf, pseudostem and fruit respectively (Hegde and Srinivas 1991). In order to make the dyeing wastewater treatment economical, it is imperative to go for low cost adsorbents. The aim of this paper is to assess the ability of waste banana pith to adsorb Congo red from aqueous solution.

MATERIALS AND METHODS

Waste banana pith was prepared from the white central portion (banana pith) of banana stems collected from a farm. The banana pith was cut into pieces and dried in sunlight. The powdered waste banana pith was found to be in the range of 1 mm to 53 μ size. Congo red was obtained from Hindustan Ciba-Geigy, Bombay. Tap water was used for the preparation of dye solutions throughout.

Batch adsorption experiments were performed by agitating 1 g adsorbent with 100 ml of aqueous Congo red solution at desired initial dye concentration for a predetermined time interval at 140 rpm using a shaker machine. The residual dye was removed by centrifugation at 8000 rpm and dye removal was determined by monitoring absorbance changes by means of Hitachi spectrophotometer (model U-3210).

The effect of adsorbent dosage was studied by varying adsorbent dosage from 0.25 to 2.00 g while the dye concentration was maintained at 50 mg l^{-1}. The influence of pH on the adsorption capacity of the adsorbent was investigated by adjusting the pH of 50 ml dye solution and 50 ml of water containing 1g adsorbent using 1:1 HCI or dilute NaOH solutions. After equilibration the two solutions were mixed and agitated to equilib-

rium time. Desorption experiments were performed by shaking 1 g of used adsorbent containing 1.83 mg of Congo red with 100 ml of various desorbing media like distilled water, 2N sulphuric acid and 50% (v/v) acetic acid.

RESULTS AND DISCUSSION

In order to find out whether there is any chemical reaction between the dye used and the aqueous extract of waste banana pith, the following experiment was carried out. Dye solution and the aqueous extract were prepared at different levels of pH from 4.81 to 9.23. Absorbances were measured before and after mixing the dye solution and the extract. It was found that there was no significant change in the absorbances (Table 1). This shows that there is no chemical reaction between Congo red and the aqueous extract of waste banana pith.

TABLE 1
Interaction of Aqueous extract of adsorbent with Congo red[1]

pH before treatment	Absorbance at 495.6 nm (λ max)			Abs. of 1:1 extract/dye mixture	After correction for dilution factor (3)32
	Dye	Aqueous extract of adsorbent			
	(1)	(2)	(1) + (2)	(3)	
4.81	0.39	0.47	0.86	0.44	0.88
5.61	0.55	0.52	1.07	0.55	1.10
7.85	0.58	0.65	1.23	0.62	1.24
8.41	0.59	0.77	1.36	0.66	1.32
9.23	0.59	0.84	1.43	0.69	1.38

[1]Conditions: concentration of dye, 20 mg l^{-1}; agitation time, 10 min; weight of adsorbent, 1g; temperature, 30 ± 2°C.

Effect of Contact Time and Initial Dye Concentration

Effect of contact time and initial dye concentration on adsorption of Congo red is shown in *Fig.1*. The curves are single, smooth and continuous, indicating the formation of monolayer coverage on the outer surface of the adsorbent (Mckay *et al.* 1980). The increase in the rate of colour removal with agitation time may be attributed to a decrease in the diffusion layer thickness surrounding the adsorbent particles (Asfour *et al.* 1985). The time required to reach equilibrium increased considerably as the initial dye concentration was increased. For an initial dye concentration of 20 mg l^{-1}, saturation was achieved at 10 minutes, where as for the dye concentration of 100 mg l^{-1} the time required to reach saturation was 140 minutes. A similar trend was observed for the adsorption of Congo red on biogas waste slurry (Namasivayam and Yamuna 1992a).

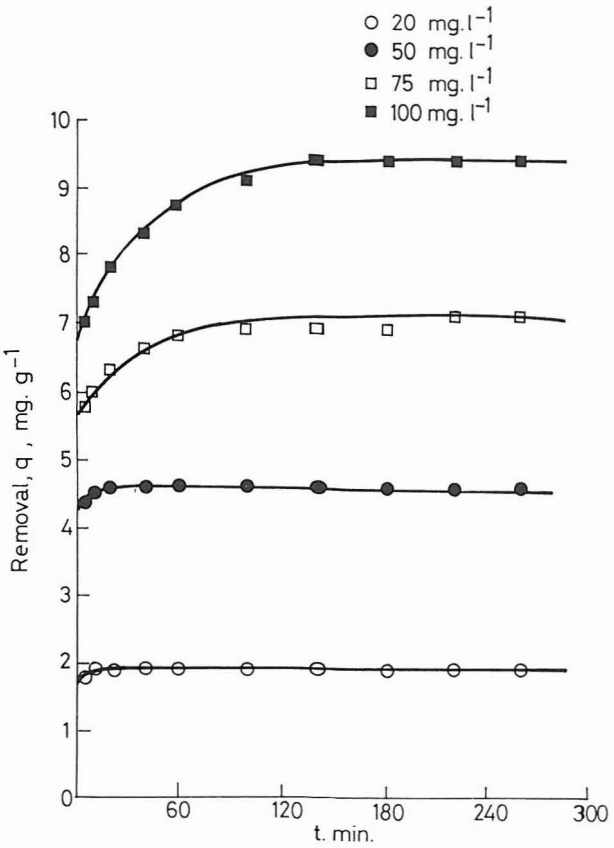

Fig. 1. Effect of agitation time and dye concentration on removal of dye by waste banana pith; conditions: pH 8.97, 30 ± 2 °C.

Adsorption Dynamics

Adsorption dynamics were studied using various concepts of rate controlling step. The rate at which the dissolved dye is adsorbed by the waste banana pith is an important factor for utilization of this adsorbent for the removal of dyes from wastewater.

Adsorption Rate Constants

The rate constants for adsorption of Congo red on waste banana pith were determined using the following rate expression (Khare *et al.* 1987).

$$\log (q_e - q) = \log q_e - \frac{K'}{2.303} t \qquad [1]$$

where q_e and q are the amount of dye adsorbed (mg g^{-1}) at equilibrium and at time t, respectively. A straight line plot of log $(q_e - q)$ vs t shows the

applicability of the Lagergren equation (*Fig.2*). Values of rate constant were calculated from the slope and are presented in Table 2. Maximum K' value of 1.06×10^{-1} min^{-1} was observed for Congo red at 50 mg l^{-1}. The K' value for the adsorption of Congo red on biogas waste slurry was reported as 2.8×10^{-2} min^{-1} (Namasivayam and Yamuna 1992a).

The possibility of Congo red being transported within the pores of waste banana pith was studied by plotting the amount of dye adsorbed (mg g^{-1}) at different dye concentrations against the $t^{1/2}$ (*Fig. 3*). The double nature (curved and linear) plots show that the mechanism of adsorption is complex. The initial curved portion is attributed to boundary layer

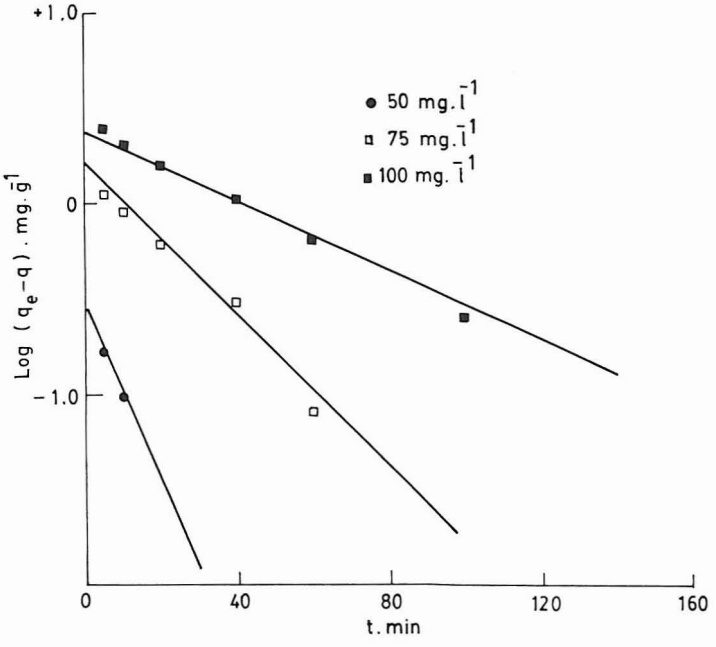

Fig. 2. Lagergren plot for the adsorption of Congo red by waste banana pith; conditions: pH 8.97, 30 ± 2 °C.

TABLE 2
Adsorption rate constant for Congo red[1]

Dye concentration, mg l^{-1}	Rate constant, K' min^{-1}
50	0.106
75	0.046
100	0.022

[1]Conditions: weight of adsorbent, 1g; pH 8.97; temperature 30 ± 2°C.

adsorption while the final linear portion is attributed to intraparticle diffusion. Values of rate constant of intraparticle diffusion at 20, 50, 75 and 100 mg l^{-1} were determined from the slopes of the plots and are presented in Table 3. The Kp value for intraparticle diffusion was in the range of 0.05 to 0.15 mg g^{-1} min. 1/2 for Congo red at dye concentrations from 20 to 100 mg l^{-1}. Kp value for the adsorption of Congo red on biogas waste slurry was reported as 0.18 mg g^{-1} min 1/2 at a dye concentration of 50 mg l^{-1} (Namasivayam and Yamuna 1992a).

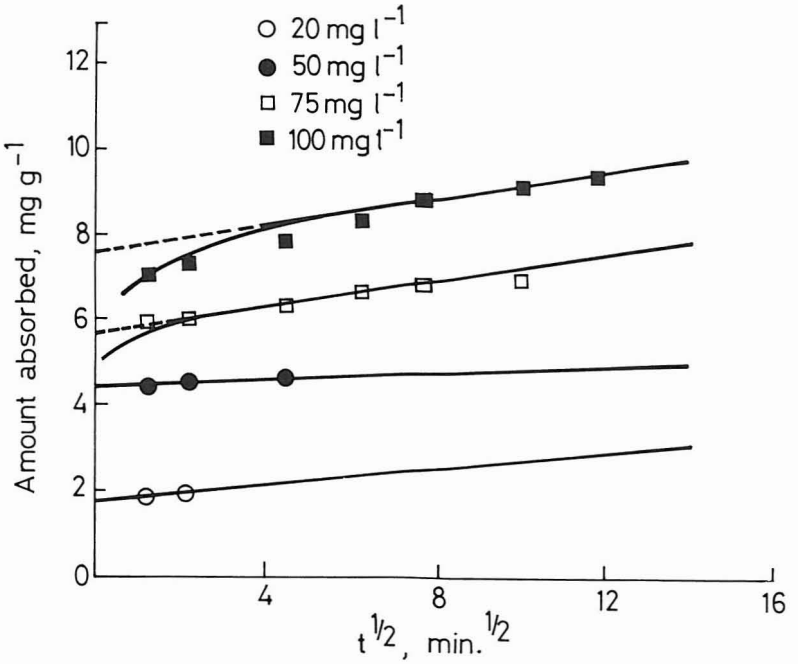

Fig. 3. Amount of dye adsorbed (mg dye per g adsorbent) versus $t^{1/2}$ for the intraparticle transport of Congo red by waste banana pith; conditions: pH 8.97, 30 ± 2 °C.

TABLE 3
Rate Constants for Intraparticle Diffusion of Congo Red[1]

Dye concentration, mg l^{-1}	Rate constants, Kp mg g^{-1} $min^{1/2}$
20	0.10
50	0.046
75	0.153
100	0.154

[1]Conditions: weight of adsorbent, 1g; pH 8.97; temperature 30 ±2°C.

Effect of Adsorbent Dosage

The Freundlich plot was employed to plot the adsorption isotherm (Gupta *et al.* 1989)

$$\log \frac{x}{m} = \log k + 1/n \log Ce \qquad [2]$$

where x is the amount of dye adsorbed (mg l^{-1}), m is the weight of the adsorbent used (g l^{-1}), Ce is the equilibrium concentration of the dye in solution (mg l^{-1}) and k and n are constants incorporating all the factors affecting the adsorption process such as adsorption capacity and intensity of adsorption. In general, as the k value increases the adsorption capacity of the adsorbent for a given dye increases (Manjunath and Indu Mehrotra 1981). The linear plots for log x/m Vs log Ce (*Fig.4*) show that the dye Congo red obeys Freundlich isotherm. k and n values calculated from the intercept and the slope were found to be 1.46 and 1.21, respectively. Value of $1 < n < 10$ represents beneficial adsorption (McKay *et al.* 1982). The k and n values for the adsorption of Congo red on biogas waste slurry were reported as 1.2 and 1.5 respectively (Namasivayam and Yamuna 1992a).

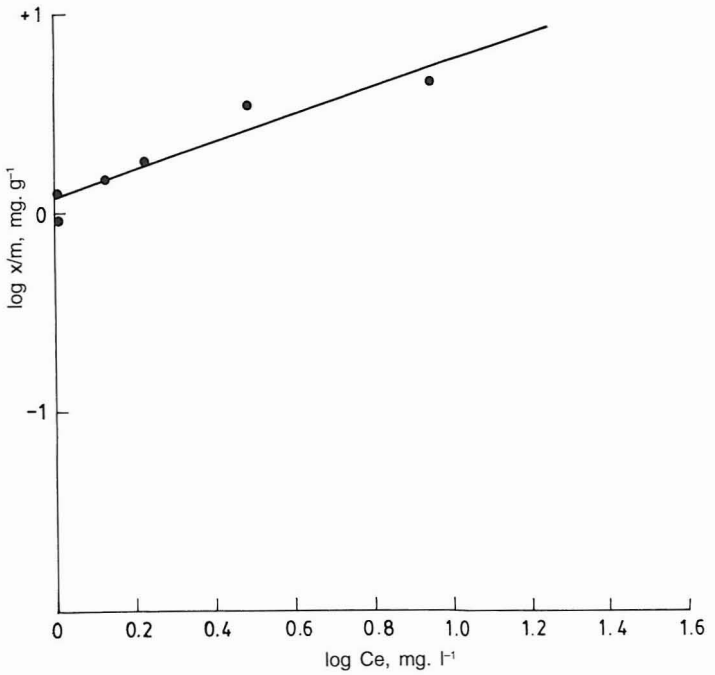

Fig. 4. Freundlich plot for adsorption of Congo red by waste banana pith; conditions pH 8.97, 30 ± 2 °C.

Effect of pH

The effect of pH on the percentage removal of dye is shown in *Fig. 5.* pH has no significant effect on the percentage removal of the dye. Above 92% removal was observed in the entire pH range from 2 to 11. It was reported that above 90% removal of Congo red by biogas waste slurry occurred in the pH range 2 to 9.4 (Namasivayam and Yamuna 1992a).

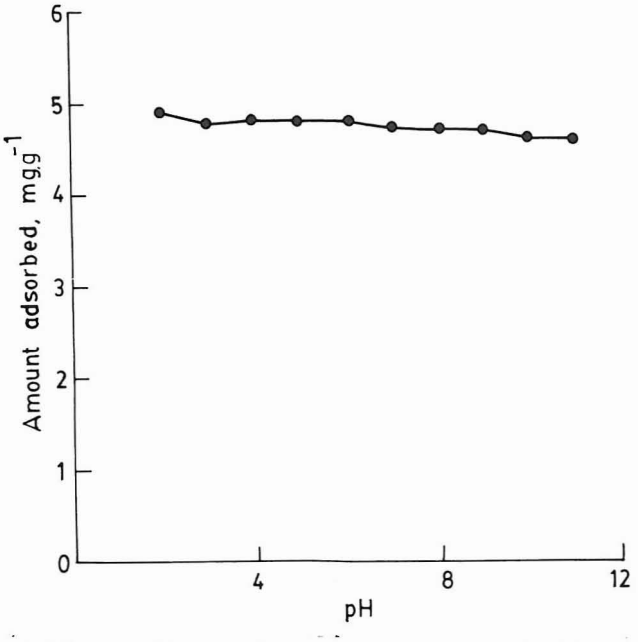

Fig. 5. Removal of Congo red by waste banana pith as a function of pH (mg per g adsorbent versus pH); conditions: dye concentration, 50 mg l^{-1} adsorbent 1g, 30 ±2 °C.

Desorption Studies

Desorption studies aid in elucidating the mechanism of adsorption of dyes on the adsorbent. The extent of desorption of Congo red with distilled water, 2 N sulphuric acid and 50% (v/v) acetic acid was found to be 5.56, 1.67 and 1.85% respectively. The small amount of desorption in distilled water indicates the occurrence of physisorption to a small extent involving weak bonds. The weak desorption in 2N sulphuric acid rules out the possibility of ion exchange. A small percentage of desorption in 50% acetic acid indicates that the dye seems to be held by the adsorbent, mostly by chemisorption.

CONCLUSION

Banana pith has considerable potential as an adsorbent for the removal of dyestuffs from waste waters. The removal of Congo red was above 92% in

the pH range of 2 to 11. The treated water is still coloured due to the aqueous extract of banana pith. Since the wastewater after treatment is rich in macro and micro nutrients due to the extract of banana pith it can be used for irrigational purposes.

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