ELSEVIER

Journal of Hazardous Materials B135 (2006) 171–179

Journal of Hazardous Materials

www.elsevier.com/locate/jhazmat

Equilibrium and kinetics studies for the adsorption of direct and acid dyes from aqueous solution by soy meal hull

Mokhtar Arami[a,b,*], Nargess Yousefi Limaee[a,1], Niyaz Mohammad Mahmoodi[a], Nooshin Salman Tabrizi[a]

[a] *Environmental Science and Engineering Department, Iran Color Research Center, Tehran, Iran*
[b] *Textile Engineering Department, Amirkabir University of Technology, Tehran, Iran*

Received 16 August 2005; received in revised form 13 November 2005; accepted 14 November 2005
Available online 24 January 2006

Abstract

This paper deals with the application of Soy Meal Hull (SMH), an agricultural by-product, for the removal of direct and acid dyes from aqueous solutions. Four textile dyes, C.I.Direct red 80 (DR80), C.I.Direct red 81 (DR81), C.I.Acid blue 92 (AB92) and C.I.Acid red 14 (AR14) were used as model compounds. Physical characteristics of SMH such as surface area, Fourier transform infra-red (FTIR) and scanning electron microscopy (SEM) were obtained. The surface area of SMH was found to be 0.7623 m^2/g and the presence of functional groups such as hydroxyl, amine and carbonyl groups were detected. The effect of initial dye concentration, pH, contact time and SMH doses were elucidated at 20 ± 1 °C. Results show that the pH value of 2 is favorable for the adsorption of all four dyes. The data evaluated for compliance with the Langmuir, Freundlich and BET isotherm models. It was found that data for DR80 and DR81 fitted well with Langmuir isotherm, for AB92, BET isotherm is preferred, while for AR14, the Freundlich isotherm is the most applicable. The adsorption capacities of SMH for DR80, DR81, AB92 and AR14 were, 178.57, 120.48, 114.94 and 109.89 mg/g of adsorbent, respectively. Also, adsorption kinetics of dyes was studied and the rates of sorption were found to conform to pseudo-second order kinetics with good correlation ($R^2 \geq 0.9977$). Maximum desorption of ≥99.8% was achieved for DR80, DR81 and AB92 and 86% for AR14 in aqueous solution at pH 10. Based on the data of present investigation, one could conclude that the SMH being a natural, eco-friendly and low-cost adsorbent with relatively large adsorption capacity might be a suitable local alternative for elimination of dyes from colored aqueous solutions.

Keywords: Natural adsorbent; SMH; Isotherms; Kinetics; Dye removal

---

1. Introduction

Presence of numerous dyestuffs with various chemical properties and adverse effects in surface and underground waterways have been concern of elite section of public and government all around the world. The discharge of dye-bearing wastewater into environmental natural waterway from textile, paper, leather, tannery, plastics and cosmetics is the first contaminant that are recognized and due to being colored and turbid, are highly visible and cause damage to the aesthetic nature of the environment [1–3]. Also these dyes may drastically affect photosynthetic phenomenon in aquatic life due to reduced light penetration [4,5]. As a result, the removal of color from waste effluents has become environmentally important [6,7]. Various methods including coagulation [8], chemical oxidation [9], photocatalysis [10,11], electrochemical [12] and adsorption techniques have been examined. Among the above mentioned methods, adsorption is considered to be relatively superior to other techniques because of low cost, simplicity of design, availability and ability to treat dyes in more concentrated form [13,14]. Activated carbon has been widely studied and proved to have high adsorption abilities to remove a large number of organic compounds. However, its use is limited mainly because of its high cost [15,16]. To find an effective and ideal adsorbent, researchers have exploited many low cost and biodegradable substitutes obtainable from natural resources for the removal of different dyes from aqueous solutions at different operating conditions (Table 1).

---

[*] Corresponding author. Tel.: +98 21 77706373; fax: +98 21 22535206.
E-mail addresses: mokhtar_arami@yahoo.com (M. Arami), NYLima888@yahoo.com (N.Y. Limaee).
[1] Tel.: +98 21 77706373; fax: +98 21 22535206.

0304-3894/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.jhazmat.2005.11.044

Table 1
Some low cost adsorbents studied to remove dyes from aqueous solutions

Adsorbents	Dyes	Maximum monolayer adsorption capacities (mg/g)	BET surface area (m^2/g)	References
Soy meal hull	Direct re d 80	178.57	0.7623	In this work
Soy meal hull	Direct re d 81	120.48	0.7623	In this work
Soy meal hull	Acid blue 92	114.94	0.7623	In this work
Soy meal hull	Acid Red 14	109.89	0.7623	In this work
Peat	Basic blue 69	184–233	–	[17]
Peat	Acid blue 25	5–9	–	[17]
Orange peel	Direct red 23	10.72	0.8771	[18]
Orange peel	Direct re d 80	21.05	0.8771	[18]
Orange peel	Acid violet 17	19.88	–	[19]
Flyash	Methylene blue	4.48	15.6	[20]
Banana peel	Methyl orange	21.0	20.6–23.5	[21]
Banana peel	Methylene blue	20.8	20.6–23.5	[21]
Banana peel	Rhodamine B	20.6	20.6–23.5	[21]
Banana peel	Congo red	18.2	20.6–23.5	[21]
Banana peel	Methyl violet	12.2	20.6–23.5	[21]
Banana peel	Amido black 10B	6.5	20.6–23.5	[21]
Rice husk	Acid yellow 36	86.9	272.5	[7]
Eucalyptus bark	Remazol BB	90.0	–	[22]
Baggase pith	Acid blue 25	17.5 ± 0.5	–	[23]
Baggase pith	Acid red 114	20.0 ± 0.5	–	[23]
Baggase pith	Basic blue 69	152 ± 5	–	[23]
Baggase pith	Basic red 22	75 ± 2	–	[23]
Sepiolite	Reactive blue 221	3.0–17.05	250–357 (105–700 °C)	[24]
Sepiolite	Acid blue 62	3.67–8.86	250–357 (105–700 °C)	[24]
Indian Rosewood sawdust (sulphuric acid treated)	Methylene blue	24.3	98	[25]
Carbonized coir pith	Congo red	6.7	–	[26]
Fungus *Aspergillus niger*	Congo red	14.72	–	[27]

Few studies have been appeared in literature on the application of SMH for the removal of metal ions [28,29]. To our knowledge, there is not a reported research paper dealing with the dye removal from colored wastewater by SMH. In our previous study, the effects of operational parameters on the adsorption of direct dyes on orange peel were investigated [18]. The aim of the present research is to investigate the dye removal capacity and potential of SMH from colored wastewater in detail.

2. Experimental

2.1. Chemicals and methods

SMHs were obtained from Behpak Co., Behshahr, Iran. The samples were left for 24 h at room temperature and then was sieved to the particle size of <0.125 mm. Direct dyes (DR80, DR81) and acid dyes (AR14, AB92) were provided by Ciba Ltd. All dyes were used without further purification. The chemical specifications of these dyes are shown in Fig. 1. All other chemicals were of analar grade and purchased from Merck (Germany). The pH measurements were made using a pH meter (Hach). The dye solutions were centrifuged for 10 min in a Hettich EBA20 centrifuge (6000 rpm). UV–vis spectrophotometer CECIL 2021 was employed for absorbance measurements of samples. The maximum wavelength (λ_{max}) used for determination of residual concentration of DR80, DR81, AB92 and AR14 at pH_0 2 in supernatant solution using UV–vis spectrophotometer were 542.5, 510.5, 595.0 and 517.0 nm, respectively. Only linear range of calibration curve is used in this research. In order to investigate the surface characteristics of SMH, FTIR (Perkin-Elmer Spectrophotometer Spectrum One) in the range 450–4000 cm^{-1} was studied. Fig. 2 shows the FTIR spectrum of SMH. The peak positions are noticed at 3377.39, 2930.63, 1647.54, 1540.18, 1400.65, 1245.91 and 1059.12 cm^{-1}. The bands at 3377.39 are due to O–H and N–H stretching. While the band at 2930.63 represents the CH_2 asymetric stretching vibration. The bands at 1647.54 and 1540.18 reflect the carbonyl group stretching (amide) and N–H bending, respectively. Bands at 1400.18 and 1059.12 correspond to C–N and C–O stretchings [30,31].

Scanning electron microscope of SMH and adsorbed SMH with DR80, DR81, AB92 and AR14 dyes for comparison were obtained using LEO 1455VP scanning microscope. Adsorbent samples were removed from the dye solution after equilibration and freed from the water by drying at 30 °C for 48 h in preparation for the SEM analysis. The SEM of the dried solids, were then recorded. The surface area of SMH was obtained by using the Brunauer, Emmett and Teller (BET) method with Gemini 2375 micrometrics instrument.

2.2. Sample preparation

The adsorption measurements were conducted by mixing various amounts of SMH (0.01–0.15 g) for DR80 and DR81, (0.05–0.175 g) for AR14 and AB92 in jars containing 250 mL of a dye solution (50 mg/L) at various pH_0 (2–10). The solution pH