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Preparation, characterization of modified wheat residue and its utilization for the anionic dye removal

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ABSTRACT

The utilization of modified wheat residue (MWR) as sorbent to remove the anionic dye (Reactive Red-24, RR-24) from aqueous solution was studied. MWR was prepared and characterized by specific surface area, SEM, zeta potential, FTIR and elemental analysis. Sorption experiments were carried out as a function of sorbent dosage, pH, contact time and concentration of dye. Results indicated that a mass of amine groups were grafted into the framework of MWR. It was shown that pseudo-second-order kinetic equation could best describe the sorption kinetics. The equilibrium sorption data were well represented by the Langmuir isotherm equation. The maximum sorption capacity of MWR for RR-24 was 200.0 mg/g, which showed higher capacity than those of previous work and a similar capacity compared to those of commercial activated carbon. The results indicated that MWR could be employed as an excellent and low-cost sorbent for removal of anionic dye from aqueous solution.

1. Introduction

The textile industry produces large amount of colored effluents, in which dyes are highly visible and can be carcinogens and toxic to aquatic life in water. Reactive dyes have been identified as the most problematic compounds in textile dye effluents, as they tend to pass through conventional treatment systems unaffected. Conventional biological treatment processes are not very effective for their high solubility and non-biodegradability [1,2]. Therefore many methods, such as coagulation–flocculation, chemical oxidation, membrane processes, and adsorption [1,3–7], are used for the removal of the dyes. Of all these, activated carbon is the most commonly used sorbent for the treatment of dye bearing wastewaters. However, this process is proved to be uneconomical due to the high cost of activated carbon and also the additional cost involved in regeneration [8]. Therefore, further development of sorbents has been investigated, which focuses on the research of sorbents prepared from agricultural residues (AR), including bagasse [8], rice husk [9], orange peel [10], pine sawdust [11], coconut husk [12], pomelo peel [13] and apple pomace [14].

In North China, wheat is a very common and abundant crop and its by-product wheat residue (WR) is being considered as a significant waste disposal problem nowadays. The idea of converting wheat residue into a sorbent is based on the predominant composition of cellulose (32.1%), hemicellulose (29.2%), lignin (16.4%) and extractives (22.3%) in WR [15–17]. Due to a large amount of easily accessible hydroxyl groups that exist in cellulose, hemicellulose and lignin structures, a series of chemical reactions, such as condensation, etherification and copolymerization can easily happen [17,18].

In the present work, a new sorbent based on WR is present, which comprises first of etherification at alkaline condition, then an introduction of amine groups into the framework of WR. MWR bearing amine groups was characterized in relation to its physico-chemical structure and then used as sorbent for the removal of anionic dye (RR-24) from aqueous solution. Batch studies were performed to evaluate the effect of various experimental parameters on the removal of RR-24. In addition, kinetic studies were carried out taking the initial dye concentration into account. The sorption capacities of MWR for RR-24 were investigated by the equilibrium isotherms. Thermodynamics of sorption process were studied and the changes in Gibbs free energy, enthalpy and entropy of sorption were also determined.

2. Materials and methods

2.1. Preparation of MWR

Biomass WR, collected from Liao Cheng, Shandong, China, was washed with tap water followed by distilled water, and oven dried at 105 °C for 24 h, and then sieved, finally the particles ranging from 150 to 380 μm were selected for further chemical modification.

Six grams of WR was dispersed in 100 mL of 15%NaOH (w/w) in a 500 mL three-neck round bottom flask and stirred for 1 h at room temperature followed by adding 40 mL of epichlorohydrine and the mixture was stirred for 3.5 h at 30 °C. The reaction product was

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washed with distilled water to remove residual chemicals, and dried at 60 °C in a vacuum drier for 12 h. The dried product was then reacted with 50 mL 40% dimethylamine solution (w/w) for 5 h at 30 °C. The reaction product was washed twice with distilled water until the eluant was neutral and then dried at 60 °C in a vacuum drier for 12 h. The final product MWR was obtained and used in all sorption experiments. The chemical reactions using cellulose as a starting material are shown in Fig. 1.

2.2. Preparation of dye solution

RR-24, obtained from Bin Zhou Dye Printing Co. (Shandong, China), in commercial purity, was used without further purification. The chemical structure of RR-24 is shown in Fig. 2. The dye stock solutions were prepared by dissolving accurately weighted dyes in distilled water to the concentration of 1000 mg/L and subsequently diluted when necessary.

2.3. Characterization of MWR

Specific surface area measurements were performed with an automatic BET surface area analyzer (Model F-Sorb 2400, Beijing Jinaipu Technical Apparatus Co., Ltd, China). The detection limit of this instrument, using N^2, is 0.01 $m^2\ g^{-1}$.

SEM of the sample was obtained by Scanning electron microscope JSM-7600 F, JEOL, Japan). The samples were mounted on metal grids and coated with platinum in vacuum evaporator before observation. The accumulation voltage and current were 3.0 kV and 10 μA, respectively.

Zeta potential measurements were carried out using a microelectrophoresis apparatus (JS94H, Shanghai Zhongchen Digital Technical Apparatus Co., Ltd, China) to determine the zeta potentials of MWR and WR.

FTIR spectra were recorded on an Avatar 370 spectrometer (Thermo Nicolet, USA) to investigate the functional groups present in MWR. For the spectra, 5 mg of samples was encapsulated in 400 mg of spectroscopically pure KBr and the specimens were pressed into small translucent discs. IR spectra were obtained by averaging 60 scans from 4000–400 cm^{-1} region at 2 cm^{-1} resolution.

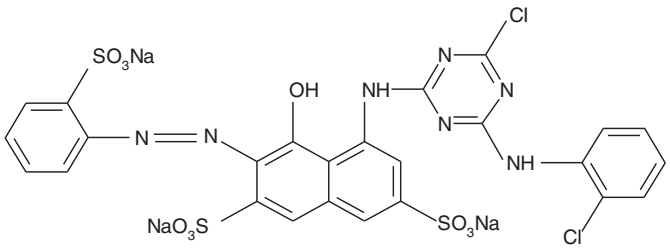

Fig. 2. Chemical structure of RR-24 (chemical formula: $C_{25}H_{14}N_7Cl_2O_{10}S_3Na_3$ molecular weight: 808.5).

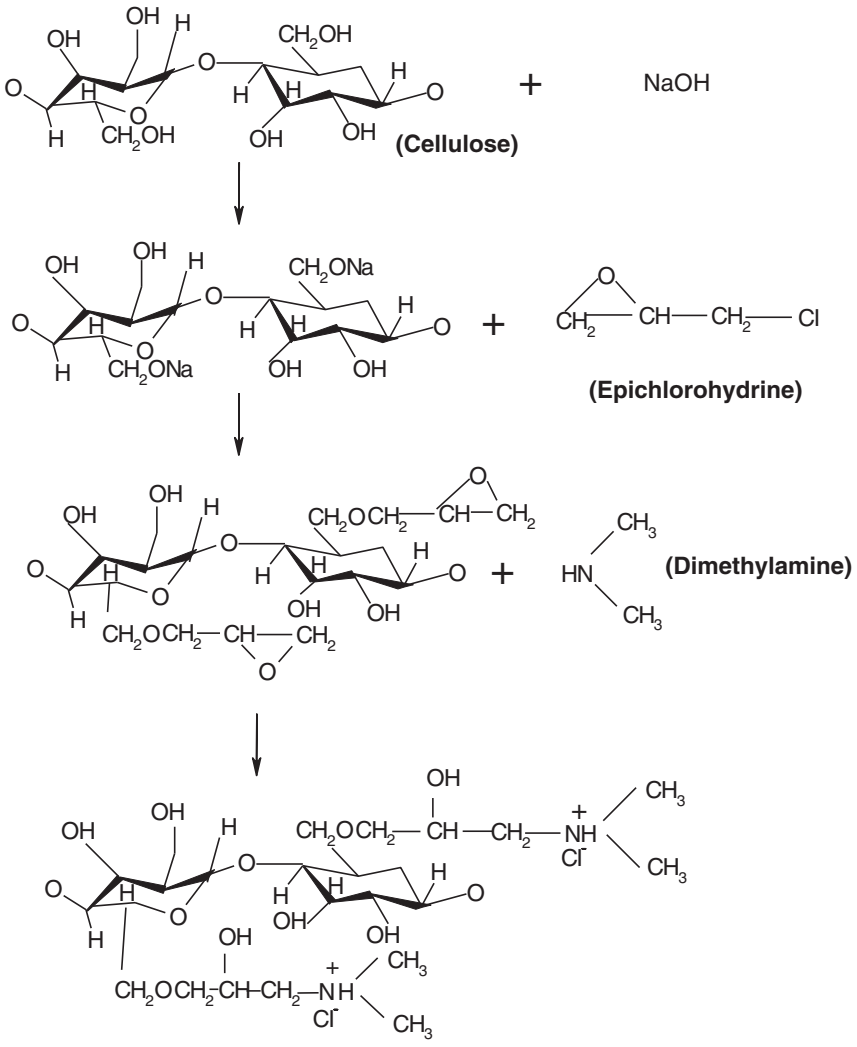

Fig. 1. Surface chemical modification of cellulose.