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Preparation of activated carbon from peanut shell by conventional pyrolysis and microwave irradiation-pyrolysis to remove organic dyes from aqueous solutions

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ABSTRACT

Activated carbon samples were prepared from peanut shell by conventional pyrolysis (P sample) and microwave irradiation followed by pyrolysis (MW-P sample). These samples as well as peanut shell were characterized by N_2 adsorption/desorption isotherms (BET), Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM), being applied to remove Direct Black 38 (DB38) and Reactive Red 141 (RR141) dyes from aqueous solutions. In order to evaluate the performance of adsorption process, pH effect, kinetic, equilibrium and desorption studies were carried out in this work. It was found that the MW-P sample exhibited superior characteristics such as texture, surface area, pore volume and pore size than the peanut shell and P sample. In addition, MW-P presented higher values of adsorption capacity, mainly at pH 2.5. The pseudo-second order kinetic model was suitable to represent the adsorption of DB38 and RR141 dyes on the MW-P sample. The Sips isotherm model was adequate to represent the adsorption of DB38 and RR141 on the MW-P sample, being the maximum adsorption capacities of 110.6 and 284.5 mg g^{-1}, respectively. The dyes were desorbed from MW-P sample using an alkaline solution. The results demonstrated that the microwave irradiation followed by pyrolysis is an alternative way to prepare an activated carbon with interesting characteristics and high adsorption capacities for organic dyes.

1. Introduction

Dye-containing effluents from the textile and leather industries can cause various environmental impacts, due to their high toxicity and carcinogenic aspects [1]. Approaches to remove organic pollutants, such as, dyes from wastewaters are based on chemical oxidation, physicochemical and biological processes. Some of these processes include coagulation–flocculation [2], filtration [3], adsorption [4,5], advanced oxidation processes [6,7], ion-exchange [8], biological treatment [9] and magnetic separation [10]. Among these, adsorption is considered one of the most promising alternatives for the removal of organic pollutants from wastewaters, because of its simplicity, ease of operation, high removal efficiency and regeneration capacity [11]. Among several adsorbents listed in the literature, activated carbon is a well-known adsorbent that has been used effectively for the removal of organic pollutants, because it is a highly porous material and possesses an extensive surface area [12].

In order to make the process of activated carbon preparation more attractive in terms of production costs, various bio-waste materials, such as, palm shells [12], *Aegle marmelos* fruit shell [13], groundnut shell [14], coconut shell [15], *Ricinus communis* seed shell [16], coffee residue [17] and sky fruit husk [18], have been used as low-cost precursors for the preparation of this material. Recently, microwave heating has been used as energy source in the preparation of activated carbon from several biomasses [19–25]. Based on this approach, there are few studies regarding the preparation of activated carbon from peanut shells using chemical treatment via microwave irradiation followed by pyrolysis. Among several advantages, microwave-assisted activation method leads to a more efficient carbonization, resulting in a material with higher surface area and well-developed porosity [19–21].

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In order to verify the additional effect of chemical treatment via microwave irradiation on the properties of activated carbon particles as well as their dye removal efficiency, two routes for the preparation of activated carbon from peanut shells were developed in this work. One activated carbon sample was obtained by conventional pyrolysis from peanut shells and, a second sample was obtained by chemical treatment via microwave irradiation followed by pyrolysis. Both samples were characterized by different techniques and tested in the removal of textile and leather dyes. The effects of pH and adsorbent type (peanut shells, P and MW-P samples) on the adsorption efficiency of DB38 and RR141 dyes were investigated. The adsorption kinetic studies were performed using the pseudo-first and pseudo-second order models. Freundlich, Langmuir, Redlich–Peterson and Sips isotherm models were used to study the adsorption equilibrium.

2. Material and methods

2.1. Dyes

In this work, two organic dyes were used as model compounds. The characteristics of respective dye molecules are described as follows. Direct Black 38 (herein denoted as DB38) (C.I. 30235; CAS number 1937-37-7; empirical formula $C_{34}H_{25}N_9Na_2O_7S_2$) is a dye quite used in the leather industry and, Reactive Red 141 (herein denoted as RR141) (CAS number 61931-52-0; empirical formula $C_{52}H_{34}O_{26}S_8Cl_2N_{14}$) is a dye extensively used in the textile industry. The chemical structures of the dyes are shown in Fig. 1.

2.2. Adsorbent preparation

The peanut shells were obtained from a local farm at Brazil southern (Santa Maria—RS). The shells were washed with distilled

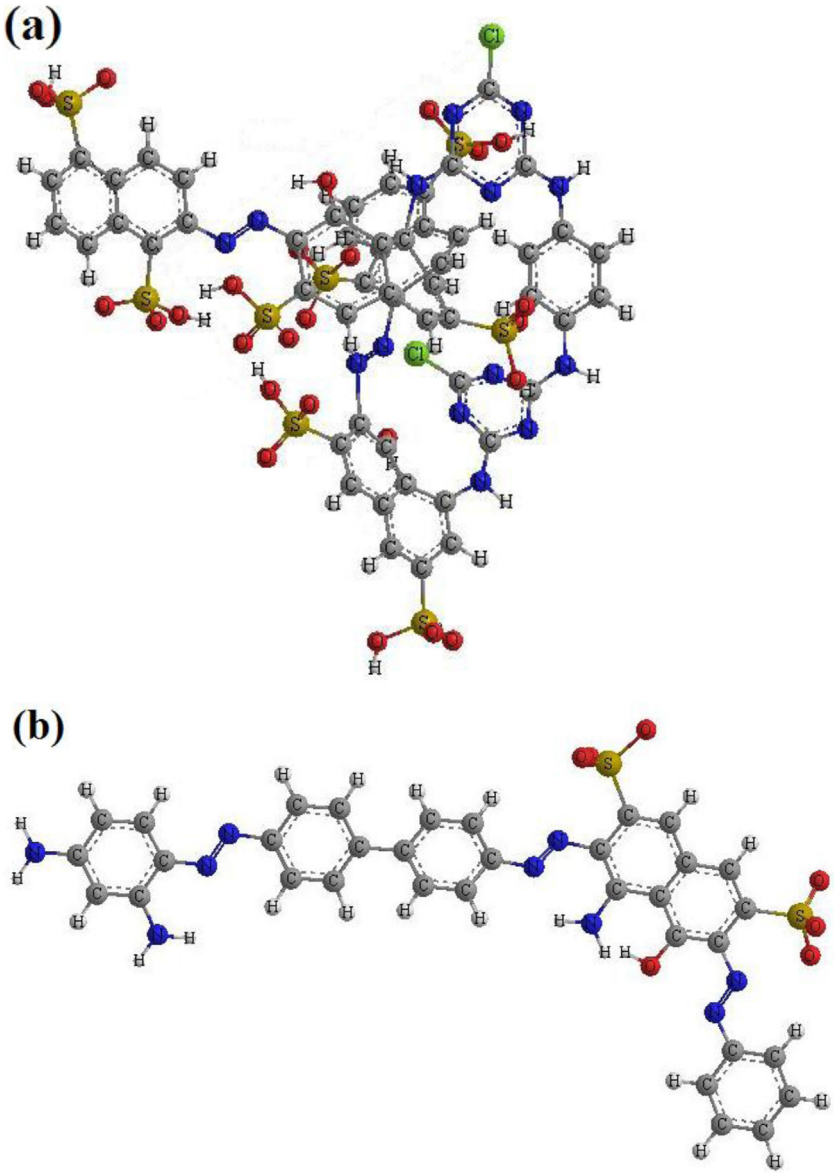

Fig. 1. Three-dimensional chemical structure of (a) Reactive Red 141 dye and (b) Direct Black 38 dye (obtained by the ChemBio 3D Ultra version 11.0 program). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)