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Effect of surface chemistry of carbons from pine sawdust for the adsorption of acid, basic and reactive dyes and their bioregeneration using *Pseudomona putida*

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ABSTRACT

The adsorption of acid blue 74 (AB74), basic green 1 (BG1) and reactive blue 4 (RB4) on carbons from pine sawdust (Ps) using single carbonization (C-Ps) and modification of Ps with a calcium chloride 1 M (C-Ps-Ca) was studied. Also the effects of the type of adsorbate (acid, basic and reactive dye) on the bioregeneration of exhausted carbons using *Pseudomona putida* were investigated. Characterization of the samples was performed using Nitrogen adsorption isotherms at 77 K, elemental analysis, FT-IR spectroscopy and SEM-EDX analysis. For this study, the maximum adsorption capacity obtained for the two types of carbons were for C-Ps: 12.8, 4.6 and 51.68 mg g^{-1}, and for C-Ps-Ca: 38.3, 48.6 and 155.1 mg g^{-1}, for AB74, RB4 and BG1 dyes respectively. The bioregeneration process showed that is possible to renovate 25% of original adsorption capacity of the carbon C-Ps-Ca, equivalent to the adsorption capacity of C-Ps carbon. Among the dye-loaded adsorbents, the bioregeneration efficiency of C-Ps-Ca using the bacteria *Pseudomona putida* showed a better capacity for the degradation of BG1 compared with AB74 and RB4. Modelling of the adsorption results using a non-linear regression approach and performing the global minimization showed that both Langmuir and Sips models showed an adequate description of the acid, basic and reactive dyes adsorption.

1. Introduction

The presence of color in wastewaters is a common problem in the textile industry (Senthilkumaar et al., 2006; Nethaji and Sivasamy, 2011). In this context, adsorption is considered an attractive process for treating textile wastewaters due to its low cost, simplicity of design and ease of operation (Ip et al., 2008; Cengiz et al., 2012). Activated carbon is the preferred adsorbent for the removal of dyes. Therefore, in recent years, there is a growing interest in the production of activated carbon from natural wastes due to their abundance and low cost (Ip et al., 2008). Several inexpensive natural materials have been used for prepare carbonaceous materials for the removal of dyes in aqueous solutions. For example bamboo (Ip et al., 2008), the apricot stone (Demirbas et al., 2008), sunflower oil cake (Karagöz et al., 2008), guava seed (Elizalde-González and Hernández-Montoya, 2009), grape seed (Jeon et al., 2009), durian peel (Nuithitikul et al., 2010), crop residues (Xu et al., 2011), swede rape straw (Feng et al., 2012), oil palm empty fruit (Sajab et al., 2013), palm bark, coconut epicarp (Vieira et al., 2011) and eucalyptus (Sun et al., 2013).

A common drawback of the adsorption process is related with the regeneration of the exhausted adsorbents. Although there exist different technologies for the regeneration of activated carbons, namely, re-activation, thermal regeneration by wet air oxidation, etc. they all require large capital investment and the operation costs are high. An ideal regeneration process would consist of the renovation of active sites without any change in the textural properties of the adsorbent. This ideal process would be accompanied by the

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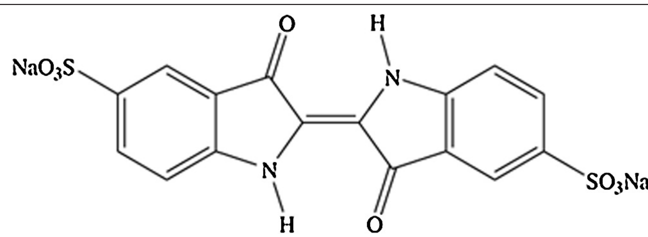
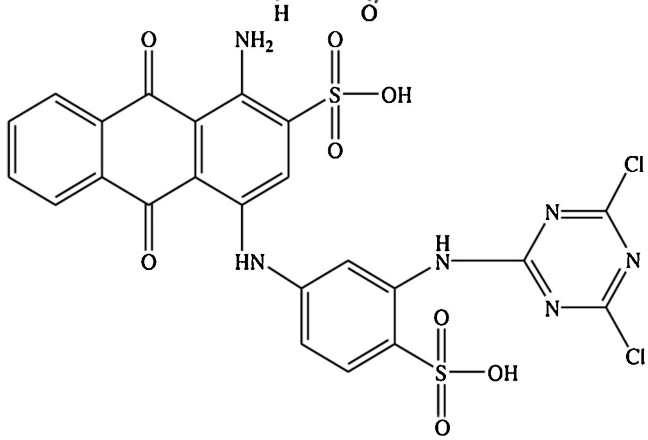
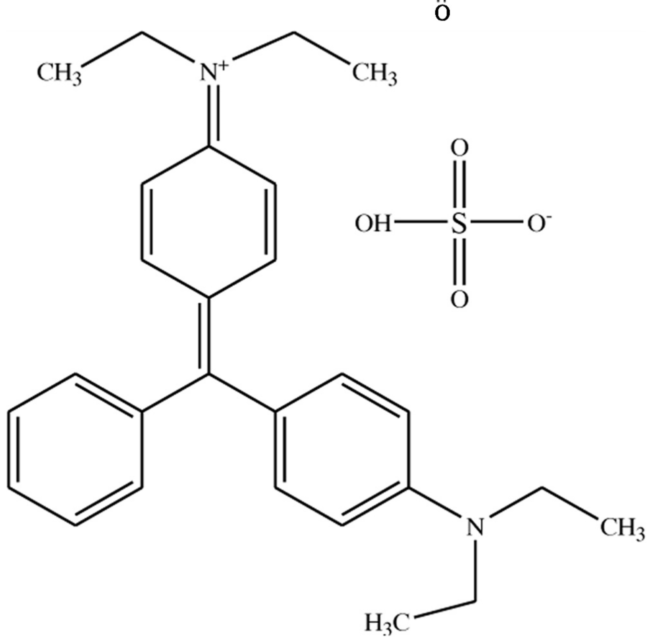
mineralization of the adsorbate to some innocuous compounds. In this context, the biodegradation of the organic compounds is an alternative to regenerate adsorbents saturated with dyes. This process is called bioregeneration and it made use of microorganisms that are capable of degrading the adsorbate on the adsorbent (Vargas et al., 2012). *Pseudomona sp*. is a large bacterium species used effectively for the degradation of various dyes while avoiding the generation of toxic compounds (Chang et al., 2001; El-Naggar et al., 2004; Ben Mansour et al., 2007; Kalme et al., 2007). For these reasons, the purpose of this work is to prepare carbon from pine sawdust (*Pinus cembroides*) for the adsorption of various dyes: acid blue 74 (AB74), reactive blue 4 (RB4) and basic green 1 (BG1) and to study the possible bioregeneration of the exhausted carbons using *Pseudomona putida* bacteria.

2. Materials and methods

2.1. Preparation of carbons

Pine sawdust (Ps) was collected from different plants of the furniture industry in Aguascalientes (Ags., México). It was ground and sieved to obtain a particle size of 1 mm. It was then washed with deionized water at 25 °C until pH was constant and, finally, it was dried at 70 °C for 24 h. Two types of carbons were obtained from Ps. The first sample was prepared by single carbonization of Ps (C-Ps). The second sample (C-Ps-Ca) was obtained by chemical impregnation plus carbonization of the precursor, using a calcium chloride solution (1 M) as impregnant. The carbonization process of the two samples was performed in a horizontal tubular furnace Carbolite

Table 1
General characteristics of the dyes acid blue 74 (AB74), basic green 1 (BG1) and reactive blue 4 (RB4).

Dye	No. Index color	Estructure	λ_{max}, nm	Volume, nm^3	Surface area, nm^2
AB74	73015		608	0.92	5.51
RB4	61205		595	1.35	7.48
BG1	42040		622	1.43	8.29