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Phenol removal onto novel activated carbons made from lignocellulosic precursors: Influence of surface properties

J.M. Valente Nabais[a,*], J.A. Gomes[a], Suhas[a], P.J.M. Carrott[a], C. Laginhas[a], S. Roman[b]

[a] Centro de Química de Évora & Departamento de Química, Universidade de Évora, Rua Romão Ramalho number 59, 7000-671 Évora, Portugal
[b] Departamento de Física Aplicada, Universidad de Extremadura, 06071, Badajoz, Spain

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ABSTRACT

The adsorption of phenol from dilute aqueous solutions onto new activated carbons (AC) was studied. The novel activated carbon was produced from lignocellulosic (LC) precursors of rapeseed and kenaf. Samples oxidised with nitric acid in liquid phase were also studied. The results have shown the significant potential of rapeseed and kenaf for the activated carbon production. The activated carbons produced by carbon dioxide activation were mainly microporous with BET apparent surface area up to 1350 $m^2 g^{-1}$ and pore volume 0.5 $cm^3 g^{-1}$. The effects of concentration (0.1–2 mM) and pH (3–13) were studied. The phenol adsorption isotherms at 25 °C followed the Freundlich model with maximum adsorption capacities of approximately 80 and 50 mg g^{-1} for the pristine and oxidised activated carbons, respectively. The influence of pH on the adsorption has two trends for pH below and above 10. It was possible to conclude that when phenol is predominantly in the molecular form the most probable mechanism is based on the π–π dispersion interaction between the phenol aromatic ring and the delocalised π electrons present in the activated carbon aromatic structure. When phenolate is the major component the electrostatic repulsion that occurs at high pH values is the most important aspect of the adsorption mechanism.

1. Introduction

Lignocellulosics (LC) are widely used raw materials for activated carbon (AC) production with wood and coconut shell being the major precursors, and accounting for more than 165,000 ton/year of AC production [1]. Besides these commonly used raw materials, a number of lignocellulosic agricultural by-products such as eucalyptus wood, almond shell, vetiver grass, peanut shells, coir pith, chest nut, pistachio-nut shells, corncobs and palm stones have also been investigated for the production of ACs [2–9]. The search for new precursors is needed in order to produce activated carbons from low cost materials, such as industrial and agricultural residues. Our research group has also been working on some lignocellulosic materials like cork and coffee endocarp [10–12].

In the present study two lignocellulosic precursors, kenaf (*Hibiscus cannabinus*) and rapeseed (*Brassica napus*), were used for the production of ACs and the influence of the surface properties of the ACs on the adsorption of phenol was investigated. Phenol is an important toxic material listed as a priority pollutant by the US Environmental Protection Agency (EPA) [13], and also by the EU. The 80/778/EEC directive of the European Commission states a maximum admissible concentration of 0.5 μg l^{-1} for phenol in water intended for human consumption. Phenol is considered to be very toxic to humans through oral exposure with symptoms including muscle weakness and tremors, loss of coordination, paralysis, convulsions, coma, liver and kidney damage, headache, fainting and other mental disturbances. The ingestion of 1 g has been reported to be lethal. Inhalation and dermal exposure to phenol is highly irritating to the skin, eyes, and mucous membranes in humans.

Phenol is the basic structural unit for a variety of synthetic organic compounds. It usually enters water sources from various chemical, pesticide, paper and pulp and dye manufacturing industries. Also, the wastewater from other industries such as gas and coke, resin, tanning, textile, plastic, rubber, pharmaceutical and petroleum contain different types of phenols. Besides industrial activity, wastewaters also contain phenols formed as a result of decay of vegetation. In view of the wide prevalence of phenol in different wastewaters and its toxicity to human and animal life even at low concentration, it is essential to remove it before discharge of wastewater into water bodies. Various methodologies have been designed for removal of phenols but among them adsorption using activated carbons is the one most frequently used. It is worthwhile pointing out that despite a vast number of studies including ACs from LCs the mechanism and influence of various factors affecting the phenol uptake is still not clear.

* Corresponding author. Tel.: +351 266745318; fax: +351 255745303.
E-mail address: jvn@uevora.pt (J.M.V. Nabais).

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