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Research Article

Study of the Contributions of Non-Specific and Specific Interactions during Fluoxetine Adsorption onto Activated Carbons

The adsorption of fluoxetine onto activated carbons (ACs) prepared from almond tree pruning by steam and CO_2 activation under different temperature conditions (650–950°C), was studied. In both series increasing the temperature caused an increase in the BET apparent surface area, yielding ACs with S_{BET} up to 870 and 710 $m^2 g^{-1}$ after steam and CO_2 activation, respectively. Also, a slight widening of the porosity was found in both cases. In order to modify the functionality of the ACs, two of them were impregnated with triethylenediamine (TEDA) prior to the adsorption process, which caused a decrease in the AC apparent surface mainly due to micropore blockage. The fluoxetine adsorption isotherms at 25°C showed maximum adsorption capacities between 110 and 224 mg g^{-1}. The adsorption isotherms were analyzed using Langmuir and Freundlich models. Although the impregnation reduced the pore volume, it did not cause a decrease in the fluoxetine maximum adsorption capacity, but a modification in the adsorption mechanism was observed.

Keywords: Adsorption; Activated carbon; Fluoxetine; Surface modification

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1 Introduction

The effects of pharmaceutical disposal residues on the environment have been progressively recognized as a major threat to public health. Drugs are released to the environment by non-proper disposal or excretion of the metabolites and non-metabolized molecules.

The disposal of these products to the terrestrial or aquatic environment is a major pollution problem. Of particular concern is the introduction of endocrine disruptors to the food chain via the aquatic environment, mainly due to their physicochemical characteristics such as solubility, polarity, low volatility, etc. [1]. Moreover, they are bioresistant and easily retain their chemical properties for many years remaining in the environment for extended periods of time [2]. The presence of pharmaceuticals has already been reported in surface or ground waters in several European countries, namely Spain [3, 4], France [5], United Kingdom [6], Germany, and Greece [7], as well as in countries of other continents. However, the full extent and magnitude of pharmaceutical compounds which are environmentally active is unknown. A large number of these compounds are bioaccumulative and toxic to several species [6]. Also, a potential negative impact on the human immunological system needs to be considered. The removal of such contaminants is urgently needed and a very hot topic for research.

Activated carbons (ACs) have been widely used in wastewater and drinking water treatment plants for the removal of various pollutants via adsorption processes, in particular for the adsorption of some pharmaceutical compounds [8–10].

ACs can be produced from a great variety of raw materials, such as wood, coal, lignite, fruit stones, and synthetic materials; however, the possibility of using agricultural or industrial residues for preparing ACs is interesting since it allows the reduction of production costs. Selecting the most suitable method to produce ACs which have potential to adsorb pharmaceuticals requires a deep knowledge about the textural and chemical properties needed to maximize their adsorption capacity. This work aimed to prepare ACs from almond tree pruning (ATP), a residue, i.e., very abundant in the Iberian Peninsula by means of physical activation processes with steam and carbon dioxide and to use selected samples to perform the adsorption of fluoxetine from aqueous solutions.

The choice of using physical instead of chemical activation is related to the fact that the second one involves extra costs derived from the recovery of chemicals from washing processes, as a result of the use of chemicals (phosphoric acid, zinc chloride, potassium hydroxide, etc.). Among the various activating agents used in physical activation, carbon dioxide and water steam were chosen because they have proven to be suitable for the development of micro and mesoporosity during the activation of biomass derived adsorbents [11–14].

One of the most used pharmaceutical compounds nowadays are the selective serotonin reuptake inhibitors (SSRIs drugs), which are used to treat a variety of major psychiatric pathologies such as depression, eating disorders, anxiety, and obsessive-compulsive

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Abbreviations: ACs, activated carbons; ATP, almond tree pruning; pzc, point of zero charge; SEM, scanning electron microscopy; TEDA, triethylenediamine