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Removal of caffeine and diclofenac on activated carbon in fixed bed column

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ABSTRACT

The occurrence of emerging contaminants in wastewaters, and their behaviour during wastewater treatment and production of drinking water are key issues in the re-use of water resources. The objective of this study was the adsorption of caffeine and diclofenac from aqueous solutions on fixed beds of granular activated carbon. Several operation conditions on the shape of breakthrough curves were investigated. Adsorption equilibrium is reached after 3 days for caffeine and after 14 days for diclofenac. In caffeine, breakthrough times, corresponding to $C/C_0 = 0.02$ were found to be 19.1, 47.6 and 48.5 h for the columns operating with bed weights of 0.6, 0.8 and 1.0 g, respectively. Saturation times (corresponding to $C/C_0 = 0.95$) were found to be 91.8, 114.3 and 121.0 h, respectively. The activated carbon is not an efficient adsorbent for diclofenac.

Keywords: Adsorption; Activated carbon; Caffeine; Diclofenac; Water

1. Introduction

In recent years it has been recognized that among the so-called emerging contaminants, pharmaceuticals and personal care products, present in waters are problematic compounds in regard to their disposal. Such substances are not removed completely by conventional methods of purification, moreover, are bioaccumulated and therefore may present a potential risk to human health and aquatic animals (Bolong et al., 2009). Some of these compounds are ofloxacin, diclofenac, carbamazepine, metoprolol, etc. (Fatta-Kassinos et al., 2011).

A variety of technologies have been developed for the treatment of these contaminants in water (Beltrán et al., 2009; Vergili and Barlas, 2009). The major technologies include precipitation-coagulation, membrane separation, ion exchange and adsorption. Adsorption techniques are widely used to remove several pollutants from water, especially those that are not easily biodegradable and it can be used in small scale household units (Ferrari et al., 2003). Adsorbents must have appropriate characteristics, such as high selectivity, high surface area, high adsorption capacity, good capacity for regeneration, high lifetime and low cost (Aboul-Kassim and Simoneit, 2001). Granular activated carbon (GAC) is a particularly good adsorbent due to its high surface area to volume ratio. Activated carbon will effectively remove many organic compounds and the United States Environmental Protection Agency (USEPA) has designated GAC as a best available technology for the treatment of many regulated organic pollutants (Westerhoff et al., 2005).

Several features of the dynamics of fixed bed adsorption columns make the modeling task particularly demanding. These include strong nonlinearities in the adsorption equilibrium isotherms, interference effects due to the competition of solutes for adsorbent sites, mass transfer resistances between the fluid phase and the solid phase and fluid-dynamic dispersion phenomena. Kananpanah et al. (2009) evaluate the overall mass transfer coefficient (K_La) from the experimental breakthrough curves and equilibrium data with the following equation:

$$\left(\frac{dx}{dt}\right)_{x=0.5} = \frac{\varepsilon \cdot K_L a}{\rho \cdot k \cdot {C_0}^{n-1}} \cdot (x - x^{1/n}) \quad (1)$$

where C_0 is the initial concentration, ε is the porosity of the granular activated carbon bed, K_La is the overall mass transfer coefficient, ρ

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