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Kinetic study of tetracycline adsorption on sludge-derived adsorbents in aqueous phase

R. Ocampo-Pérez, J. Rivera-Utrilla *, C. Gómez-Pacheco, M. Sánchez-Polo, J.J. López-Peñalver

Inorganic Chemistry Department, Faculty of Science, University of Granada, 18071 Granada, Spain

HIGHLIGHTS

- ▶ The first-order kinetic fits tetracycline (TC) adsorption on sludge adsorbents.
- ▶ The rate constants vary in a linear manner with their macro-and mesopore volumes.
- ▶ The TC adsorption rate on all adsorbents is controlled by intraparticle diffusion.
- ▶ Pore volume diffusion represents more than 80% of the total intraparticle diffusion.
- ▶ Diffusion of TC in the pore volume increases with larger meso and macropore volume.

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ABSTRACT

This study investigated the global adsorption rate of tetracycline on adsorbents obtained from treatment sludge. Experimental data on tetracycline concentration decay curves were interpreted with kinetic models (first-order, second-order, Langmuir, and intraparticle diffusion) and diffusional models (pore volume diffusion model and surface diffusion model). The first-order kinetic model provided the best interpretation of tetracycline adsorption kinetics on all adsorbents, and its rate constant varied in a linear manner the macro- and mesopore volume of the adsorbents. It was also found that the tetracycline adsorption rate is controlled by intraparticle diffusion and that diffusion in the pore volume represents >80% of total intraparticle diffusion. This indicates that surface diffusion does not play a major role in tetracycline diffusion on the different adsorbents. Furthermore, the effective tetracycline diffusion coefficient in the pore volume gradually increased with greater meso- and macropore volume and larger surface area of the adsorbent, indicating that the tetracycline adsorption rate is directly related to the accessibility of this molecule to the microporous structure of the materials.

1. Introduction

Tetracyclines (TCs) are bacteriostatic agents that act by inhibiting bacterial protein synthesis. They show activity against a wide variety of microorganisms and are used as antibiotics in humans and animals [1,2]. Due to their low cost, TCs are also used as a food additive to enhance the growth rate of animals, adding a further pathway for their entry into the environment alongside emissions from the manufacture and formulation of the compounds and the disposal of unused or expired products.

In surface waters, TCs were detected at concentrations ranging from 0.11 to 4.20 μg/L [3], while concentrations in effluent of a wastewater treatment plant ranged from 46 to 1300 ng/L for tetracycline, 270 to 970 ng/L for chlortetracycline, and 240 ng/L for oxytetracycline [2–6]. Batt et al. [7] and Ternes et al. [5] found that biodegradation and chlorination processes only slightly degrade TCs, explaining their presence in the treatment plant effluent. Importantly, the presence of traces of these compounds in the environment can lead to the appearance of microorganisms that are resistant to these antibiotics and to which humans may be exposed via drinking water [6].

Activated carbon is the most commonly used adsorbent for removing organic compounds from wastewater [8,9], but few studies have been carried out on its capacity for TC adsorption [10]. In general, activated carbon remains an expensive treatment process for large-scale application, and major research efforts have been devoted to the production of activated carbons from available sources. These include: the shells of nuts, including peanuts and almonds; the stones from olives, dates, apricots and cherries; waste from the production of cereals, olive cakes, sugar cane, and sugar beet bagasse, coconut coir pith, palm oil; and various seed wastes already in use for this purpose [9]. Sewage sludge is also potentially suitable for the production of activated carbon because of

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* Corresponding author. Tel.: +34 958248523; fax: +34 958248526.
E-mail address: jrivera@ugr.es (J. Rivera-Utrilla).

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