

Enhancing the affinity of zeolite-based adsorbents for anionic pesticides through surface hydrophobization

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The dissemination of micropollutants in natural water bodies is becoming a serious environmental problem of the 21st century. Various emerging pollutants spread in aquatic environments, among which pesticides are of particular concern. Pesticides are predominantly detected in water matrices, including agricultural runoff and municipal wastewater. Prolonged exposure to trace concentrations of these compounds has been associated with an elevated risk of adverse health effects, including carcinogenic and cardiovascular disorders. On the other hand, pesticides play a vital role in sustaining high agricultural productivity by mitigating pests and safeguarding crop yields. Therefore, limiting the levels of pesticides discharged into the environment is a crucial element of sustainable development. This could be achieved by applying adsorption, which is an efficient method for micropollutant immobilization. Zeolites emerge as efficient, highly porous materials for removing various pollutants in adsorption-based systems.

This study focuses on the modification of natural zeolite (NZ), fly ash-based zeolite (AUP), and a fly ash-based carbon–zeolite composite (P1-C) through surface hydrophobization using the surfactant hexadecyltrimethylammonium bromide (HDTMA). Unmodified and modified materials are then evaluated for their efficacy in removing two structurally analogous anionic pesticides: 2-(dichloro phenoxy)acetic acid (2,4-D) and 2-(4-chloro-2-methylphenoxy) acetic acid (MCPA).

Surface hydrophobization of materials is evidenced by the Fourier infrared spectroscopy. Modified materials exhibit fresh bands at the 3000 to 2800 cm⁻¹, which is attributed to the antisymmetric and symmetric stretching vibrations of the methylene groups (–CH₂) present in the hydrocarbon tails of the surfactants. Thermal gravimetry combined with mass spectrometry analysis shows the additional thermal effect for modified materials between 250–650 °C, which results from the oxidation of carbon tails of HDTMA present on the surface of the adsorbent. Adsorption of both 2,4-D and MCPA increases significantly upon HDTMA introduction, with the highest adsorption capacity observed for HDTMA-modified P1-C material (4.51 mg/g for 2,4-D and 3.57 mg/g for MCPA). Additionally, pesticide adsorption capacity rises with increasing adsorbate concentration across all adsorbents. However, this trend is less pronounced for AUP, which exhibits considerably lower adsorption capacities in modified and unmodified forms.

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