

SYNTHESIS AND CHARACTERIZATION OF IRON OXIDE-BASED MAGNETIC NANOCOMPOSITES FOR REMOVAL OF DICLOFENAC AND SULFAMETHOXAZOLE FROM WATER

Abstract

The continued presence of pharmaceutical contaminants in drinking water sources, such as diclofenac and sulfamethoxazole, poses a threat to public health. Although iron oxide (FeO_4) nanoparticles have been studied for the treatment of water, their low adsorption efficiency and poor durability preclude their widespread application. This study designed and employed three novel iron oxide-based magnetic nanocomposites; $\text{FeO}_4/\text{SnO}_2\text{-MgO}$, $\text{FeO}_4/\text{SnO}_2\text{-AlO}_3$, and $\text{FeO}_4/\text{SnO}_2\text{-CeO}_2$ to enhance the removal of diclofenac and sulfamethoxazole. The nanocomposites were produced by co-precipitation method and characterized using XRD, SEM/EDX, MPMS, ImageJ, and point of zero charge techniques. Response Surface Methodology (RSM) was used to optimize the adsorption parameters, such as contact duration, adsorbent dose, pH, and initial concentration. Among the materials that were produced, $\text{Fe}_3\text{O}_4/\text{SnO}_2\text{-MgO}$ and $\text{Fe}_3\text{O}_4/\text{SnO}_2\text{-CeO}_2$ shown exceptional removal efficiency for diclofenac ($97.31 \pm 0.04 \%$ and $93.53 \pm 0.02 \%$, respectively), whereas $\text{Fe}_3\text{O}_4/\text{SnO}_2\text{-MgO}$ and $\text{Fe}_3\text{O}_4/\text{SnO}_2\text{-Al}_2\text{O}_3$ accomplished total removal ($100.0 \pm 0 \%$) of sulfamethoxazole. The iron oxide based magnetic nanocomposites displayed remarkable reusability, preserving high removal efficiencies for both diclofenac and sulfamethoxazole across three consecutive cycles, with only a minor drop in performance, demonstrating their promise for practical water treatment applications. For both diclofenac and sulfamethoxazole, kinetic studies used pseudo-second-order models ($R^2 \geq 0.998$) by the best-performing adsorbents ($\text{Fe}_3\text{O}_4/\text{SnO}_2\text{-MgO}$ and $\text{Fe}_3\text{O}_4/\text{SnO}_2\text{-CeO}_2$ for diclofenac and $\text{Fe}_3\text{O}_4/\text{SnO}_2\text{-MgO}$ and $\text{Fe}_3\text{O}_4/\text{SnO}_2\text{-Al}_2\text{O}_3$ for sulfamethoxazole), indicating chemisorption as the predominant mechanism. Monolayer coverage was suggested as the major mechanism using Langmuir isotherm models ($R^2 \geq 0.99$), which provided the best description of the diclofenac adsorption processes. For sulfamethoxazole, the Freundlich isotherm model ($R^2 \geq 0.9978$) shows multilayer adsorption on a heterogeneous surface of the best-performing adsorbents. The practical efficacy of the top-performing nanocomposites was also confirmed by application to actual water samples from Lake Victoria, where both contaminants were completely removed under optimal conditions. These results demonstrate the potential of iron oxide-based magnetic nanocomposites as sustainable and efficient adsorbents for enhancing the safety of drinking water sources tainted with pharmaceutical pollutants.

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