Functionalized Cellulose for Selective Removal of NSAID Microcontaminants from Wastewater

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Abstract:
Non-steroidal anti-inflammatory drugs (NSAIDs) such as diclofenac, naproxen, and aspirin are widely detected as pharmaceutical microcontaminants in wastewater and surface waters. Even at low concentrations, these compounds can persist in aquatic environments and pose risks to ecosystems. However, their removal remains challenging using conventional treatment systems. This study investigates low-cost, bio-based adsorbents derived from cellulose—an abundant material found in agricultural waste—for the selective removal of three common NSAIDs: diclofenac, naproxen, and aspirin. Two functionalized cellulose materials were evaluated: one modified with quaternary ammonium groups (c-q) and another further enhanced with benzyl groups (c-q-benz) to improve hydrophobic and π–π interactions. Diclofenac showed the highest adsorption capacity (up to 1143 mg/g), with adsorption behaviour well described by the Sips isotherm model. The benzyl-modified material demonstrated faster adsorption kinetics due to increased hydrophobic interactions. Diclofenac removal remained stable in the presence of competing anions, while naproxen and aspirin were more sensitive to water chemistry, indicating different removal mechanisms. Regeneration studies showed that c-q retained performance over multiple cycles, while c-q-benz experienced some decline due to stronger binding. Overall, these functionalized cellulose materials outperformed

comparable bio-based adsorbents and demonstrate strong potential for sustainable removal of pharmaceutical microcontaminants from wastewater. The approach also supports biomass valorisation and circular resource use, contributing to SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), and SDG 14 (Life Below Water).

Keywords:
Wastewater treatment, NSAIDs, pharmaceutical microcontaminants, cellulose adsorption, circular bioeconomy, SDGs.