High-Capacity Al3+/Fe3+-Crosslinked Nanocellulose Hydrogels for Arsenite Removal: A Zero-Waste Approach to Water Remediation

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Arsenic contamination in groundwater affects over 200 million people globally. Inorganic arsenic, mainly arsenite (As(III)) and arsenate (As(V)), is classified as a Group 1 human carcinogen, with arsenite being more toxic, mobile, and difficult to remove. Chronic exposure leads to cancer, organ damage, cardiovascular complications, and neurological effects. Conventional remediation methods are often costly, inefficient for As(III) removal, and generate toxic waste. This study demonstrates biodegradable, high-capacity adsorbents using carboxylated-cellulose-nanofibers (CNF) derived from jute through a zero-waste nitro-oxidation process (NOP). The NOP simultaneously removes lignin and hemicellulose while introducing carboxyl-groups (–COO-) and producing nitrate-rich effluent suitable for fertilizer application. CNFs were cross-linked with Fe3+ or Al3+ to form hydrogels (direct cross-linking) and hydrosponges (freeze-thaw cross-linking). Al3+-hydrogel demonstrated the highest arsenite adsorption capacity (Langmuir Qmax= 866.79 mg/g), followed by Fe3+-hydrogel (760.64 mg/g), Fe3+-hydrosponge (328.38 mg/g), and Al3+-hydrosponge (215.55 mg/g), significantly outperforming conventional methods. Hydrogels outperformed hydrosponges due to higher functional group density and smaller pores. Competitive ion studies confirmed effectiveness in the presence of phosphate and sulfate. Characterization using potentiometric titration, FTIR, XRD, SEM, TGA, and SEM-EDS confirmed successful functionalization and arsenic uptake. The Al3+-hydrogel system offers a promising, sustainable solution for arsenite removal, combining high adsorption capacity, biodegradability, and zero-waste production. Future work will optimize hydrosponge performance and evaluate column treatability tests.

Awards Won:
Second Award of $2,400