Nanocellulose Aerogel-Supported Zero-Valent Iron Enables Synergistic Adsorption–Degradation of Organic Contaminants

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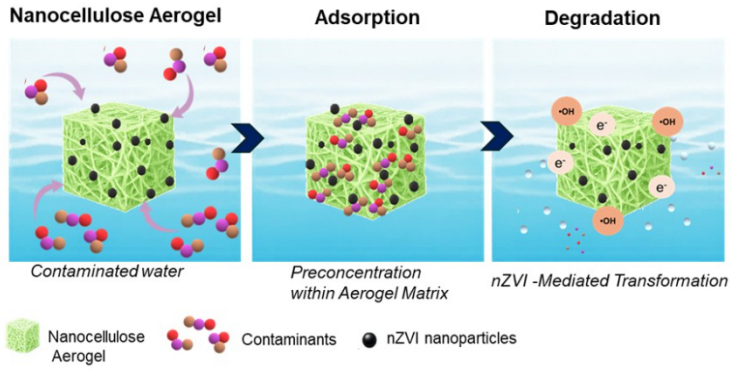
Persistent organic pollutants in aquatic environments remain extremely challenging to eliminate using conventional treatment techniques, which are primarily driven by adsorption equilibria and often result in secondary waste without complete elimination.[1] This constraint highlights the need for material platforms that integrate interfacial adsorption with localized transformation processes. In this study, we propose a hierarchically porous framework comprising a reactive colloidal phase of nanoscale zero-valent iron (nZVI) within a nanocellulose-based aerogel. The nanocellulose aerogel has a highly porous[2], interconnected three-dimensional structure with extensive surface functions [3], facilitating effective adsorption and preconcentration of organic pollutants from aqueous solutions [4]. This adsorption-driven interfacial enrichment increases the local concentration of pollutants near embedded nZVI, promoting electron-transfer-mediated reactions and Fenton-like reactivity associated with in situ Fe^{2+} generation. [5]

Crucially, the aerogel matrix governs the colloidal behavior of nZVI by suppressing nanoparticle aggregation and promoting uniform spatial dispersion, thereby preserving reactive surface area. The integration of nZVI within the nanocellulose aerogel enhances pollutant removal relative to the pristine matrix through the synergistic coupling between interfacial adsorption and localized redox transformation within the porous framework. This system illustrates how adsorption-induced interfacial concentration gradients, combined with controlled nanoparticle dispersion, influence the efficiency of coupled adsorption–reaction processes. In summary, this study demonstrates that nanocellulose-supported nZVI aerogels are an effective platform for the integration of adsorption and redox transformation within a confined porous architecture. This presents an intelligent strategy for the fabrication of high-efficiency and sustainable water treatment materials.

Keywords:
Nanocellulose aerogel, Zero-valent iron (nZVI) nanoparticles, Water remediation, Adsorption–degradation



Schematic illustration of nanocellulose aerogel-supported nZVI nanoparticles for combined adsorption and degradation of organic pollutants in water.

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