Stormwater Remediation of 6PPD and 6PPD-Quinone Using Sustainable Citric Acid and Aluminum Crosslinked Nanocellulose Hydrosponges

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6PPD is an antiozonant ubiquitously used in global tire manufacturing that reacts with ground-level ozone to form 6PPD-quinone (6PPDQ). 6PPDQ is a compound acutely lethal to coho salmon—a species vital to ecosystems, fisheries, and Indigenous cultures—at concentrations as low as 0.8 µg/L. Current literature has reported 6PPDQ removal, using non-biodegradable materials, tested at concentrations 100–10,000x above environmental relevance. This research evaluated cellulose nanofiber (CNF) hydrosponges, synthesized via the zero-waste nitro-oxidation process from jute waste, as a novel biodegradable adsorbent for 6PPDQ tested at environmentally relevant concentrations. Hydrosponges were crosslinked with aluminum and citric acid (CA) to form a 3D polymer network. Batch experiments assessed contact time (5–180 min) and pH (5–9) using synthetic tire wear particle (TWP) leachate, followed by column trials. Both samples achieved >60% removal of 1 ppm 6PPDQ, with the CA crosslinked sponge reaching >75% removal within 15 minutes, quantified by LC-MS/MS. FTIR confirmed greater carboxyl density in the CA sponge, corroborating its superior performance. XPS revealed a hybrid mechanism of physical entrapment and chemisorption via carboxyl–amine interactions. SEM-EDX confirmed particulate TWP capture within 5 minutes, with elemental analysis indicating retention of tire-associated heavy metals and particulate matter. This research is the first to demonstrate biodegradable hydrosponge-based removal of 6PPD and 6PPDQ at environmentally relevant concentrations, offering a 98% cost reduction and 85% lower synthesis energy versus alternatives—establishing CNF hydrosponges as a scalable and sustainable material to protect aquatic ecosystems from tire-derived water contaminants.

Awards Won:

First Award of $6,000

Regeneron Young Scientist Awards

YM American Academy: Second Award of $1000