Polydimethylsiloxane-Coated Polysaccharide Hydrogels for Sustainable Oil Spill Remediation

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Oil spills cause large-scale destruction of marine ecosystems and economies. Current remediation methods primarily rely on mechanical recovery, typically recovering only 2-6% of spilled oil. An emerging solution uses hydrogels coated with oleophilic materials, but current formulations use synthetic hydrogels and a toxic coating of octadecyltrichlorosilane (OTS). This research investigates whether ecofriendly polysaccharide hydrogels coated with nontoxic oleophilic materials can achieve absorption characteristics comparable to conventional solutions. Polydimethylsiloxane (PDMS) was selected as a hydrophobic, oleophilic, and non-toxic coating material. Ten PDMS-polysaccharide hydrogel systems were designed and analyzed for selective oil absorption using molecular docking simulations and density functional theory. From these, three PDMS-hydrogel systems were selected for physical synthesis and experimental evaluation: pectin crosslinked with calcium ions, guar gum crosslinked with sodium tetrahydroxyborate, and agarose crosslinked with citric acid. 225 samples (75 per hydrogel) were tested across three oil viscosities. Scheirer-Ray-Hare tests revealed both oil type and hydrogel type were significant for absorption capacity. Dunn's post hoc comparisons confirmed absorption of high-viscosity oils (1.39–2.88 g/g) differed significantly from those of lower-viscosity oils. Absorption capacity was positively correlated with viscosity (Rsquare=0.57), while water uptake remained negligibly low (0.027–0.079 g/g) across all hydrogels. These absorption capacities are comparable to existing OTS-hydrogels, while eliminating toxic materials. This offers a sustainable remediation approach that surpasses mechanical recovery methods and enhances oil reusability due to minimal water uptake.

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