Interfacial Crystallization for Oil Spill Remediation Using Divalent Ions $Zn^{2?}$ and $Ca^{2?}$ and Bio-Derived Myristic Acid

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Oil spills are among the most serious environmental threats. They remain difficult to control, and current remediation methods either disperse oil into water or use chemically aggressive treatments, making cleanup methods introduce often causing the cleanup process itself to create further environmental damage. A promising alternative focuses on controlling oil at the oil–water interface through interfacial crystallization by triggering a crystalline layer that shrinks oil into recoverable structures. However, earlier crystallization systems relied on toxic metals, limiting safety. To replace these hazardous materials, a greener approach was developed using the natural derivative myristic acid with $Zn^{2?}$ and $Ca^{2?}$. Interfacial behavior was studied using the pendant drop method on an optical tensiometer, simultaneously monitoring interfacial tension (IFT) and crystal formation. Both ions affected the dynamics at the interface and helped crystallization, but in different ways. $Zn^{2?}$ induced rapid, dense interfacial structures, achieving full crystallization within 30 minutes, while $Ca^{2?}$ acted synergistically to enhance confinement over time. All IFT trends confirmed interfacial crystallization and barrier formation. Remarkably, crystallization occurred at 0.005 M $Zn^{2?}$, a 100× concentration reduction compared to conventional systems, while remaining effective in both model and crude oil tests. XRD and SEM-EDS verified Zn- and Ca-based crystal formation. This method cut costs by more than 97% compared to older crystallization systems. It maintains safe operation while enabling efficient oil recovery. The results highlight a sustainable, innovative pathway with significant potential for a new perspective on safer, scalable, and sustainable oil spill remediation.

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