Ag-TiO2@HNT Photocatalytic Composites for Highly Efficient and Eco-Friendly Organic Pollutant Degradation

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Organic pollutants, such as synthetic dyes and petroleum-based contaminants, pose ecological risks due to their chemical stability and resistance to biodegradation. Nanotechnology offers solutions for remediation, yet progress is hindered by complex and costly fabrication. This study presents a highly efficient Ag-TiO2 nanocomposite adhered onto halloysite nanotubes (HNTs) for rapid pollutant degradation and oil spill dispersion. HNTs are naturally abundant aluminosilicate clays with hydroxyl-rich surfaces. TiO2, a widely used photocatalyst, was UV-activated to generate reactive oxygen species, while Ag nanoparticles enhanced charge separation and light absorption via localized surface plasmon resonance. Functionalization and structural integrity were confirmed using FTIR and XRD. Ag-TiO2@HNTs achieved 91.7%, 45.8%, and 96.2% ($p<0.01$) degradation within 60 minutes for methylene blue, methyl orange, and indigo carmine, respectively; >85% efficiency was retained after three cycles. Degradation followed pseudo-first-order kinetics, and Langmuir isotherm modeling showed strong pollutant interactions. Incorporation of Lecithin-Tween80 surfactant enabled oil droplet emulsification and dispersion, achieving 91.5% effectiveness at 25 mg/g. With a production cost of $0.22/g and benign byproducts (H2O, CO2), this nanocomposite offers an eco-friendly, scalable solution for wastewater remediation and oil spill recovery. The use of food-grade surfactant and naturally sourced clays aligns with green chemistry and sustainability principles. Future research could explore performance in complex wastewater matrices and optimize industrial scalability for sustainable environmental applications in industrial and coastal environments.

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