Plasmonic–Photocatalytic Ophiolite Based Passive System for the Treatment of Oilfield Produced Water

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This study presents the design and evaluation of a solar-driven hybrid plasmonic–photocatalytic system based on ophiolite-supported nanomaterials for the treatment of oilfield produced water. The system integrates TiO2/ZnO with Fe3O4 and HMO-Mn on a porous ophiolite matrix to enhance adsorption, photocatalytic activity, and photothermal performance. The ophiolite acts as a natural mineral support, providing high surface area and active binding sites through Si–O, Mg–O, and Mg–OH interactions, facilitating efficient charge transfer and system stability. Material characterization using SEM revealed a rough, porous structure that enhances adsorption capacity, while XRD confirmed the formation of stable crystalline phases of TiO2, ZnO, and Fe3O4 without altering the original mineral structure. EDS analysis verified the uniform distribution of key elements, confirming successful incorporation of the nanocomposite system. Experimental results demonstrated significant improvements in water quality. Total dissolved solids (TDS) decreased to approximately 72,000 ppm (~64% reduction), and salinity showed a comparable decrease, indicating effective desalination. The pH improved toward near-neutral values (~6.8), while total organic carbon (TOC) decreased significantly, confirming the degradation of organic pollutants. Additional enhancements in temperature and evaporation rate indicated strong photothermal performance. Optical analysis using UV–Vis spectroscopy and Tauc plots showed that the bandgap remained nearly constant (~4.3 to ~4.2 eV), indicating preserved electronic structure, with performance improvements attributed to defect reduction and enhanced charge transfer. Overall, the system demonstrates high efficiency, and potential as a sustainable, low-cost solution.

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