SUMMARY

Oilfield produced water (OPW) is one of the largest and most complex wastewater streams generated during oil and gas production. It typically contains high salinity, dispersed oil droplets, and persistent organic contaminants such as phenol and ammonia–nitrogen (NH_3–N), which pose serious environmental risks if discharged without proper treatment. Conventional treatment technologies often struggle to remove these recalcitrant compounds effectively, motivating the development of advanced and integrated remediation strategies. In this study, a multifunctional treatment system combining adsorption, photocatalysis, and nanofiltration membrane technology was developed to improve contaminant removal efficiency while mitigating membrane fouling during OPW treatment.

A novel Z-scheme Ag-doped $WO_3/BiVO_4$ nanocomposite (Ag@WB) was successfully synthesized using a sol–gel–solvothermal approach. The synthesized photocatalyst exhibited a highly mesoporous structure with a large surface area of 423.67 $m^2\ g^{-1}$ and a reduced band gap of 2.23 eV, enabling efficient activation under visible-light irradiation. Adsorption studies indicated that pollutant removal followed a Langmuir isotherm model, suggesting monolayer chemisorption on the catalyst surface. Under visible-light irradiation, the Ag@WB nanocomposite achieved removal efficiencies of 81.51% for phenol and 84.63% for NH_3–N. The enhanced photocatalytic activity was attributed to the Z-scheme heterojunction structure, which facilitated efficient charge separation, while the plasmonic effect of Ag nanoparticles improved light absorption and electron transfer, as supported by density functional theory (DFT) analysis. The photocatalyst also demonstrated good stability and reusability over multiple cycles.

To further improve treatment performance, Ag@$WO_3/BiVO_4$ nanocomposites were incorporated into a PVDF nanofiltration membrane, resulting in improved pore structure, hydrophilicity, and photocatalytic activity. The optimized membrane exhibited a high permeate flux of 112.69 LMH and excellent removal efficiencies of 97.72% for NH_3–N, 95.04% for phenol, 93.46% for TDS, and 91.89% for COD during visible-light-assisted OPW filtration. Additional polydopamine (PDA) surface modification further enhanced membrane hydrophilicity and antifouling properties, reducing irreversible fouling and improving flux recovery through the formation of a hydration layer. Moreover, H-ZSM-5 adsorption pre-treatment effectively reduced contaminant load, improving flux stability and pollutant removal**.** Overall, the synergistic combination of adsorption, photocatalysis, and PDA-modified nanofiltration membranes offers a promising and sustainable strategy for efficient OPW treatment.

Keywords: *Oil-field produced water treatment, photocatalytic nanofiltration membrane, Ag-doped $WO_3/BiVO_4$ nanocomposite, polydopamine (PDA) surface modification, adsorption-photocatalysis synergy*