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Advanced functional materials in membrane and photocatalytic systems for PFAS and microplastics remediation

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ABSTRACT

The growing detection of microplastics and nanoplastics (MPs/NPs) and persistent pollutants like per- and polyfluoroalkyl substances (PFAS) in water systems poses serious ecological and human health challenges. Conventional water and wastewater treatment plants, including desalination systems, are not equipped to effectively remove these emerging contaminants. This project explores the synergistic use of membrane filtration and photocatalysis, employing advanced functional materials to enhance removal efficiencies of both MPs/NPs and PFAS. In this research, a range of nanomaterials—including metal-organic frameworks (MOFs), MXenes and zwitterionic agents—have been developed and tested either embedded within polymeric membranes or used as surface modification agents through plasma and graft polymerisation techniques. These materials were selected for their known hydrophilicity, high surface area and tunable surface functionalities, which are critical for addressing the complex fouling behaviours associated with MPs/NPs and organic contaminants and the chemical persistence of PFAS.

Comprehensive material and membrane characterisation was conducted using SEM, TEM, FTIR, XRD, BET, AFM, contact angle analysis and streaming potential measurements. Testing against model wastewater streams containing MPs/NPs, dyes and PFAS revealed enhanced rejection efficiencies and antifouling properties in the modified membranes. Furthermore, the incorporation of photocatalytic materials enabled partial degradation of PFAS and disintegration of adsorbed organic matrices around MPs/NPs, highlighting the dual functionality of the developed systems. Our findings revealed that functionalised membranes not only reduced flux decline but also demonstrated high recovery rates, attributed to improved surface properties and reduced contaminant-membrane interaction. The integration of membrane filtration with photocatalytic nanomaterials presents a promising approach for simultaneous physical removal and chemical degradation of microplastic and PFAS contaminants, offering new insights into hybrid water treatment technologies suitable for future-proofing against emerging pollutant risks.

KEY WORDS

Microplastics, PFAS, Photocatalysis, Membrane filtration, Advanced functional materials

BIOGRAPHY

Dr Masoumeh Zargar is a Senior Lecturer and ARC DECRA Fellow at Edith Cowan University, with internationally recognised expertise in advanced functional materials, membrane technologies and environmental remediation. Her research focuses on innovative solutions for the removal of emerging contaminants such as microplastics and PFAS from water systems. She leads several industry-funded projects focused on water treatment, resource recovery and sustainable materials and has authored over 80 high-impact publications in leading journals. Dr Zargar’s interdisciplinary work—spanning materials science, membrane engineering and photocatalysis—positions her as a prominent researcher tackling critical challenges in water sustainability and environmental protection.

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