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A Magnetic 2D MOF@C@FeO heterostructure for Rapid Removal of Microplastics and Chlorpyrifos from Aquatic Systems

Mohammad Aslam[1], Muhammad Haris[1], Nasir Mahmood[2], & Nicky Eshtiaghi[1]

[1]Department of Chemical and Environmental Engineering, RMIT University, Melbourne Victoria, Australia

[2]School of Science, RMIT University, Melbourne Victoria, Australia

E-mail

S3983157@student.rmit.edu.au

ABSTRACT

Microplastics and pesticides are widespread contaminants in water and pose significant risks to aquatic ecosystems and human health. Microplastics can accumulate in marine organisms and enter the food chain, while chlorpyrifos, a neurotoxic organophosphate pesticide, has been associated with adverse neurodevelopmental effects, particularly in children. In natural water environments, microplastics can also act as carriers for pesticides, leading to combining pollutants with enhanced toxicity. In this study, we developed a magnetic adsorption material for the simultaneous removal of these contaminants. Iron oxide nanoparticles (Fe_3O_4) were synthesized using a co-precipitation method, coated with two-dimensional carbon sheets to form C@FeO, and further integrated into a metal-organic framework to produce a hybrid material (2D MOF@C@FeO). Batch adsorption experiments demonstrated that this material can effectively remove different types of microplastics, including simple polystyrene (PS) and carboxylated PS, with particle sizes of 1000 nm, 500 nm, and 100 nm. The material showed excellent performance across a wide range of microplastic concentrations, from 1 g/L down to 1 mg/L and was effective in both deionised (DI) water and seawater. Under varying adsorbent dosages, contact times, and pollutant concentrations, the system achieved approximately 99% removal efficiency for both microplastics and chlorpyrifos, with near-complete adsorption occurring within 60 minutes. Advanced analytical techniques, including Dynamic Light Scattering (DLS), UV–Visible spectroscopy, and Pyrolysis Gas Chromatography–Mass Spectrometry (Py-GCMS), were employed for accurate identification and quantification of microplastics and pesticides. Overall, the findings highlight the potential of the 2D MOF@C@FeO composite as a multifunctional adsorbent for the simultaneous removal of microplastics and pesticides, offering a promising strategy to improve water quality, protect public health, and reduce treatment costs for both industrial and domestic water treatment applications.

KEY WORDS

Magnetic adsorption, microplastics removal, pesticides removal, metal organic framework, magnetic adsorbent, 2D carbon sheets and waste water treatment

BIOGRAPHY

Mohammad Aslam is a Ph.D. candidate in chemical and environmental engineering at RMIT University, Australia. His current research focuses on the design and development of magnetic materials for the removal of micropollutants such as microplastics, pesticides, and other emerging pollutants from wastewater. He is the recipient of five prestigious, fully funded scholarships for his Ph.D. studies in Australia. Over the past 4 years, Mohammad has been actively publishing high-impact research articles in peer-reviewed journals, focusing on materials science and wastewater treatment. He holds an M.Sc. degree from Universiti Sains Malaysia and a Bachelor of Technology from Aligarh Muslim University, India.

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