ABSTRACT

Contaminants of emerging concern (CECs), such as microplastics (MPs) and antibiotics, have become pressing global environmental challenges due to their persistence, bioaccumulative potential, and ability to induce ecological risks even at trace concentrations. Among them, synthetic polyester (PES) microfibers, originating primarily from domestic and industrial laundry effluents, and sulfamethoxazole (SMZ), a widely prescribed sulfonamide antibiotic, are of particular concern in aquatic systems. Their simultaneous presence in riverine environments and wastewater highlights the urgent need for both occurrence assessments and the development of effective treatment strategies capable of mitigating their ecological impacts. In the present study, a fourfold approach was adopted that combined field occurrence monitoring with electrochemical treatment methods for MPs and SMZ. First, the occurrence of MPs and SMZ was investigated along six sites of the Yamuna River, one of the most polluted rivers in India. Bulk water sampling for MPs and grab sampling for SMZ were conducted across upstream and downstream stretches. The MPs were separated through density-based methods, filtered, and characterized using optical microscopy and micro-Raman spectroscopy. Risk characterization indicated medium ecological risk at selected sites, underscoring the localized threat posed by SMZ. Building on these findings, electrocoagulation (EC) was evaluated as a remediation strategy for PES microfibers in synthetic wastewater using stainless-steel (SS) electrodes. Mechanistic analysis suggested that physical adsorption, charge neutralization, and flotation were the primary removal pathways, with negligible metal leaching into treated water, ensuring environmental safety. Further, electro-oxidation (EO) using a titanium-based ruthenium dioxide (Ti-RuO_2) anode and a SS cathode was applied for SMZ degradation. Collectively, this study provides an integrative perspective on the environmental occurrence and risks of MPs and SMZ in the Yamuna River while simultaneously establishing electrochemical processes, EC for MPs and EO for SMZ, as promising post-treatment strategies for wastewater treatment plants. The novelty of this work lies in its combined approach, which bridges field-based occurrence data with advanced treatment solutions, thereby offering a sustainable framework for mitigating the long-term ecological and human health risks associated with CECs in aquatic environments.