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Unveiling the effect of polymer-selective interactions with perovskite nanomaterials on the transport of microplastics in saturated porous media

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ABSTRACT

Microplastics (MPs) have attracted global concern due to their persistence, mobility, and ecological risks in subsurface environments. Meanwhile, perovskite nanomaterials are also increasingly released into the environment due to their widespread use in material industry. However, the co-existence and potential interactions between perovskites and MPs remain poorly understood. This study systematically investigates and elucidates how perovskite nanoparticles influence the transport behaviors of four representative MPs, including polystyrene (PS), polyethylene terephthalate (PET), polyethylene (PE), and polypropylene (PP), in saturated porous media. A sorts of column experiments, extreme gradient boosting (XGBoost) regression model, zeta potential analysis, density functional theory (DFT) calculations, size distribution measurements, and adsorption experiments were used to conduct the exploration and elucidation. The findings indicated that $BaTiO_3$ and $SrTiO_3$ significantly inhibited the transport of PE and PP, but had negligible effects on PS and PET. Polymer type of MPs was confirmed to be the key factor dominating their transport with perovskites. This selective inhibition was verified to originate from the weaker electrostatic repulsion and stronger adsorption affinity between the perovskites and the PE and PP, compared to their interactions with PS and PET. These findings provide a mechanistic understanding of heterogeneous MPs-nanoparticle interactions and emphasize the importance of polymer type in controlling MPs mobility in soil-underground environments.

1. Introduction

Perovskite nanomaterials have recently attracted increasing attention due to their unique crystal structures and outstanding physicochemical properties. Benefiting from their tunable perovskite lattice, these nanomaterials exhibited remarkable optical, electrical, and magnetic performance, offering broad application prospects across diverse fields [1,2]. For instance, perovskite-based solar cells had emerged as promising candidates for next-generation photovoltaic devices owing to their high photoelectric conversion efficiency [3], while their catalytic activities had been extensively explored for addressing energy and environmental challenges [4]. Among them, barium titanate ($BaTiO_3$) and strontium titanate ($SrTiO_3$) are representative perovskite oxides, widely studied for their excellent dielectric, piezoelectric, and photocatalytic properties [5,6]. However, the growing use of these nanomaterials inevitably led to their environmental release, raising concerns about potential ecological and human health risks [7].

Meanwhile, plastic production continues to rise sharply, reaching 400.3 million tons in 2022, with microplastics (MPs, <5 mm) being ubiquitously detected as a result of polymer degradation [8]. Owing to their persistence, mobility, and potential ecotoxicity, MPs has become a major emerging contaminant of global concern [9]. The co-occurrence of perovskite nanoparticles and MPs was particularly relevant in environments impacted by electronic waste disposal and related activities [10,11].

Soils, as the largest sink of pollutants in terrestrial ecosystems [12],

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