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Sorption behavior and effects of heavy metals on polyethylene microplastics (HDPE, LDPE) under varying mechanical weathering durations using 2D-COS FTIR

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Microplastics (MPs) undergo continuous mechanical weathering in aquatic environments, which alters their physical properties over time. Their coexistence with heavy metals may lead to complex co-contamination that could alter pollutant mobility. This study analyzed the sorption behavior of lead (Pb^{2+}) and cadmium (Cd^{2+}) onto high-density polyethylene (HDPE) and low-density polyethylene (LDPE) microplastics subjected to varying durations of mechanical weathering (light weathering [LW, 1 h] and heavy weathering [HW, 3 h]). Surface characteristics were analyzed using Brunauer-Emmett-Teller (BET) and scanning electron microscopy. Heavy metal concentrations were measured using ICP-OES (Optima 7000DV, PerkinElmer) at Pukyong National University. BET analysis indicated that specific surface area (SSA) increased with weathering duration. HDPE consistently possessed a higher SSA than LDPE across weathering stages. However, Sips isothermal adsorption modeling suggested an inverse relationship: despite its lower SSA, LDPE exhibited significantly higher maximum adsorption capacities (Q_m) for both Pb^{2+} (0.327–0.339 mg/g) and Cd^{2+} (0.334–0.572 mg/g) compared to HDPE (Pb^{2+}: 0.051–0.052 mg/g; Cd^{2+}: 0.040–0.086 mg/g). Two-dimensional correlation spectroscopy (2D-COS) FTIR analysis was utilized to observe adsorption-related structural evolution. The spectral data suggested that metal binding might induce microstructural reorganization within the polymers. These findings imply that despite progressive surface expansion induced by prolonged mechanical weathering, the sorption capacity of PE MPs is likely governed by inherent polymer crystallinity and internal structural properties rather than external surface area alone. Integrating 2D-COS FTIR with isothermal modeling indicates that the internal packing structure of weathered microplastics may be a key factor controlling their vector effects, providing baseline data for predicting biogeochemical fluxes.

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