Microplastic impacts on soil and sediment bioturbation: insights from microcosm experiments across diverse ecosystems

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Abstract :

Microplastics (MPs) are pervasive environmental contaminants that accumulate in terrestrial, freshwater, and marine ecosystems, threatening habitat integrity and ecosystem functioning. Bioturbation, the physical reworking of soils and sediments by fauna and flora, is a key mechanism maintaining ecosystem structure, function, and biodiversity. Despite its importance, the effects of MPs on bioturbation remain poorly understood.

To address this gap, we conducted three laboratory microcosm experiments across terrestrial, freshwater, and marine ecosystems, using three key ecosystem engineers: *Aporrectodea caliginosa* (earthworm), *Tubifex tubifex* (freshwater worm), and *Hediste diversicolor* (marine worm). Each system was exposed to a mixture of polystyrene and polyamide MPs, including fragments and fibers ranging from 10 to 1000 µm, at two concentrations: 0 and 100 mg kg^{-1} soil/sediment (dry weight). Luminophore tracer particles were applied to quantify soil and sediment reworking over a 21-day period. Several bioturbation proxies were measured, including maximum penetration depth, surface reworking, particle displacement, cast production, and both biodiffusion-like and non-local reworking coefficients.

Our results highlighted contrasting impacts of MPs on bioturbation, which varied according to ecosystem type and ecosystem engineer species. In terrestrial ecosystems, earthworm surface reworking was largely unaffected, although cast production by *A. caliginosa* increased by ~28%, suggesting potential compensatory behaviors. Freshwater tubificid worms (*T. tubifex*) were strongly impacted, with particle displacement reduced nearly fourfold and luminophore penetration markedly decreased. In marine systems, *H. diversicolor* maintained substantial particle reworking, but gallery-biodiffusion activity tended to decline in the presence of MPs.

These findings indicate that the impact of MPs on bioturbation is context-dependent, likely influenced by the ecological traits and size of the engineering species, with smaller organisms (*T. tubifex*) being the most vulnerable.

Our results highlight the potential for MPs to disrupt fundamental ecosystem processes across diverse habitats, emphasizing the need for laboratory experiments that include multiple species and ecosystems to achieve a holistic understanding of their ecotoxicological impacts.