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Editorial: Life in the "Plastisphere": linking the biodiversity of microbial communities to the risk of micro-(nano-)plastics and related new contaminants

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Editorial on the Research Topic
Life in the "Plastisphere": linking the biodiversity of microbial communities to the risk of micro-(nano-)plastics and related new contaminants

Introduction

Micro-(nano-) plastics (MNPs; MPs <5 mm; NPs <1 μm) are a type of emerging environmental contaminant, and they are ubiquitous in various environmental compartments worldwide (Kumar et al., 2021; Wu et al., 2024), including the oceans, intertidal zones, forests, and freshwater systems, and even extend to remote regions across the globe (Wu et al., 2022). These pathways cause severe threats to the structural integrity and functional stability of ecosystems (Wu et al., 2022). The Research Topic compiled a series of innovative research findings in the field of MNP research. Specifically, they contained three core categories of literature: critical review papers (2), perspective articles (2), and original research papers (5). The related research findings delved into the complex attributes of MNP pollution, which are reflected in multiple aspect: Distribution characteristics, migration patterns, and multiple toxicity. The publications specifically involved the diverse sources of MNPs, their environmental migration pathways, as well as the far-reaching impacts they had on the ecological environment, socioeconomics, and human health (Thompson et al., 2004; Wu et al., 2024; Zhu and Huang). These studies not only contribute to gain a deeper and more comprehensive understanding of MNP pollution, and clarifies the research priorities for future in-depth multi-dimensional studies and cross-disciplinary management.

Core consensus

The core consensus of the studies could be categorized into three aspects: First, the overall understanding of MNP pollution were deepen through multi-perspective analyses in each environmental media; Second, the key mechanisms driving MNP transport and their multiple toxic effects were tried to clarified; Third, targeting the urgency and effectiveness of MNP pollution control were discussed and proposed by a series of governance strategies.

The notable contribution firstly lied in its systematic occurrence of multiple environmental media, including marine, freshwater, intertidal zones and forests, which deepening the overall understanding the ecological specificity of MNP pollution in existing multi-perspective analyses. Bel Hassen et al. investigated that MNP with main types of polyethylene (PE), polypropylene (PP), and polystyrene (PS) could be flowed into ocean through land-based inputs, river discharge, marine activities, and atmospheric depositions, and finally accumulated both on the surface water and seafloor. They also found almost 94% of marine plastic debris persisted on the seafloor, much higher than that existing on surface waters. The finding changed the previous view that MNPs mainly contaminate the ocean surface. The threat of MNPs in freshwater systems is equally worthy of attention (Eid et al.; Schubert et al.). Discarded paper cups in the Nile River release ions, heavy metals, and MNPs. These substances can accumulate in aquatic organisms such as fish intestines (Eid et al.) and subsequently enter the food chain, posing potential risks to human health. Another study focused on freshwater bacterial communities (Schubert et al.) and explored the effects of leachates from synthetic polymers on the growth and community dynamics of freshwater bacterial communities. Shabib et al. conducted the bibliometric analysis of MNP research globally and within the coastal region, and call for more attentions on the necessity of investigating the occurrence and distribution of MNPs in specific regions, like coastal zones.

The second insight of this Research Topic concentrated on exploring the cognition of the key driving mechanisms of MNPs transportation. For example, Jingya et al. stimulated the systematic experiments on retention and remobilization behaviors of original and aged PS MNPs in unsaturated porous media. The results showed that the migration capacity of aged PS particles decreased with retention degree, especially after multiple wet-dry cycles. In contrast to the laboratory experiments, Sun et al. constructed a three-dimensional hydrodynamic-Lagrangian particle tracking coupled model to explore the migration and diffusion characteristics of MNPs in Beibu Gulf, and revealed that MNP transportations were extremely complex, which jointly controlled by ocean circulation, monsoons, vertical movement and extreme weather, finally exhibiting complex spatiotemporal variation characteristics. Similar to the above-mentioned results, Huang et al. reported that the terrestrial conditions would also affect MNP migration. Especially in the intertidal zones, MNPs exhibited complex transportation behaviors according to the intertidal types, being roughly categorized as mudflats, sandy beaches, rocky beaches, and biological beaches. Most of the MNPs were stranded in the mudflats under the conduciveness of low water velocity. While in the sandy beaches, MNPs influenced by both the external conditions and intrinsic characters, illustrating drifting, beaching, settling, burying and/or resuspending processes. During the migration process, parts of MNPs could be casted onto and then incorporated into the rocky beaches, resulting in the contamination of plastiglomerate, pyroplastic and plasticrust. Parts of MPs might be ingested by the coastal organisms directly or indirectly. Similar to MNPs in biological beaches, MNP pollution could also have the multifaceted hazards in forest ecosystems (accounting for 32% of the global land area), but with main input pathways of atmospheric deposition (Tao et al.).

The third crucial discovery of the Research Topic mainly focused on the ecological effects of MNPs and related leachates (Schubert et al.). MNP particles cause direct damage to forest ecosystems with the following steps: First, soil microporosity was reduced after the uptake of MNPs, which would disrupt the symbiotic relationships between mycorrhizae and tree roots, and finally leading to micronutrient deficiencies in trees. Through the processes, it could be seen a significant decline in the carbon sequestration capacity and biodiversity levels of forest ecosystems (Tao et al.). The presence of MNPs also inhibited the enzyme activity in forest soils, and then directly hinders critical biogeochemical cycling processes (Tao et al.). In marine environments, Bel Hassen et al. conducted a comprehensive review of the impacts of MNPs on marine organisms on various manifestations, including the reduced reproductive capacity of zooplankton due to the ingestion and accumulation of MNPs in the blubber and acoustic fat pads of cetaceans. This ingestion and accumulation impaired their key physiological functions, such as communication and thermoregulation. This research result further confirmed the disruptive effect of MNPs on ecosystem functions. Eid et al. also confirmed the bioaccumulation of MNPs in Nile River fish inducing the biological health risks through physical damage and chemical toxicity through their cross-trophic effects in the food chain. Moreover, relevant studies estimated a substantial economic losses, especially for the affected industries, fisheries and aquaculture. In addition, leachates could also cause impacts on free-living bacterial communities in freshwater environments, during which the total bacterial biomass was stable through the weathering process. Another important phenomenon that chemical composition could influence the free-living aquatic bacteria, resulting in altering microbial loop functioning and biochemical cycles of aquatic ecosystems.

The relevant studies in this Research Topic also remind a series of governance strategies for the urgency and effectiveness of MNP pollution requiring interdisciplinary collaboration, policy innovation, and public participation among other elements. Traditional treatments for plastic wastes contained landfilling and incineration, taking the proportion about 40% and 25%, respectively. Landfilling needed large space along with releasing large numbers of MNPs under the weathering processes, while incineration would also discharge abundant MNPs and other hazardous substances (e.g., dioxins) into the atmosphere (Zhu and Huang; Bel Hassen et al.). Especially for the surge of plastic waste during/after the COVID-19 pandemic, they advocated circular economy frameworks as a new pathway for whole-lifecycle supervision of plastics, covering all stages of their production, use, and disposal. Moreover, Huang et al. further explored the artificial intelligence-based MNP mapping tools to track the sources, spatiotemporal distribution and migration paths of MNPs, thereby identifying the pollution hotspots, driving mechanisms and ecological risk correlations, finally providing scientific support for precise governance. The targeted policy recommendations should be discussed and conducted for the formulation of forest-specific monitoring protocols (Tao et al.), including subsidizing biodegradable agricultural mulch films, upgrading the capture systems of submicron particles in sewage treatment plants, integrating MNP monitoring network into the protected areas, and promoting reusable alternatives. Particularly in the post-pandemic era, policies needed to balance public health and sustainability goals, such as levying plastic taxes to fund recycling infrastructure, highlighting the application potential of thermochemical recycling technologies and emphasizing the bio-based alternative materials (Zhu and Huang). Advocating the citizens to strengthen public educational efforts regarding the environmental risks of hidden plastics (Shabib et al.; Eid et al.). All studies called for the establishment of a more robust and collaborative manage system. The aforementioned measures can not only reduce MNP input but also foster a shared sense of responsibility among the public for planetary health.

Conclusion

This article systematically discussed the extensive presence characteristics, complex migration patterns and multi-dimensional hazards of MNPs in various environmental media such as the marine, freshwater and forest ecosystems. In the ocean, most plastic waste were finally found accumulating on the seabed, while the fate of MNPs together with the related leachate in freshwater generally interfere with the structure and function of free-living bacterial communities, and then threaten the human health. In contrast, MNPs in intertidal zones showed various migration patterns according types of coastlines, and caused directly or indirectly effects after being ingested. In forest ecosystems, MNPs mainly entered through atmospheric deposition, disrupting soil microbial communities and carbon cycling functions. To reduce the risk of such pollution, scientists, policymakers and the public had to work together to transform existing scientific insights into practical governance outcomes. For scientists, future efforts should be paid on developing sustainable plastic transformation techniques, including thermochemical recycling and biological degradation technologies. For governments, related environmentally friendly policies should be enacted for the treatment of waste segregation standards under environmental monitoring networks. Meanwhile, governments also had sought to minimize plastic use by raising public awareness of the. Through outreach and advocacy, the public awareness on the negative consequences of MNPs pollution should be promoted, and should be encouraged to reduce plastic consumption through daily life decisions such as giving up plastic consumer products, applying reusable materials and recycling plastic wastes for multiple purposes. The Research Topic not only contribute to gain a deeper and more comprehensive understanding on the occurrence, distribution, fate, and ecotoxicity of the MNPs in oceans, intertidal zones, forests, and freshwater systems, but also urging more in-depth multi-dimensional techniques and cross-disciplinary managements on the treatments of plastic wastes.

Author contributions

SZ: Writing – original draft, Writing – review and editing. HT: Writing – review and editing. XZ: Writing – review and editing, Writing – original draft. TY: Writing – review and editing. GC: Writing – review and editing, Supervision. PW: Writing – review and editing, Supervision.

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Conflict of interest

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