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Editorial: Plastic pollution in a changing marine environment: effects and risk

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Editorial on the Research Topic
Plastic pollution in a changing marine environment: effects and risk

Plastic litter is persistent in marine environments, which leads to accumulation and potential effects in biota. The estimate of risk of plastic particles in the marine environment, based on a quantitative analysis of the probability of exposure of biota and magnitude of effects, needs high quality data on exposure (OSPAR, 2010; GESAMP, 2019) and effects (Redondo-Hasselerharm et al., 2023). Currently there are important data gaps concerning litter densities in some geographical areas, which are essential to inform authorities on plastic litter hotspots and on the efficiency of mitigation measures. Besides accumulation zones of macrolitter, it is essential to have an improved understanding of microplastic (<5mm) formation mechanisms for estimating plastic particle sizes in the environment, and establish their potential for ingestion by marine organisms (Kooi and Koelmans, 2019). The ubiquity of microplastics in marine ecosystems requires further contextualization within a multi-stressor framework, as combined stressors can lead to synergistic effects (Catarino et al., 2022; Khan et al., 2022), and a broader vision of the plastic pollution impacts' magnitude is crucial for understanding and quantifying risks and effects in marine ecosystems. The goal of this research topic was to provide an overview of high-quality data collection (useful for risk assessment) and procedures, to report plastic litter and particles accumulation in the environment and biota, to investigate microplastic formation due to UV exposure, as well as to discuss potential interactions of plastic particles and climate change in future scenarios.

Data infrastructures are vital for aggregating standardized information and providing insights on litter accumulation zones in the marine environment. For example, Vanavermaete et al. (2023) used data available in the ICES DATRAS (International Council for the Exploration of the Sea, Database of Trawl Surveys) on collected field surveys on seafloor macrolitter, both at regional and local scales. The authors focused on the OSPAR Greater North Sea and Celtic Seas, as well as the Belgian Part of the North Sea. The analysis highlighted that litter consisted primarily of plastic. At the local level, half of the collected litter could be linked to fishing activities. A significant correlation between marine litter and fishing activities was observed at local but not at regional level, while establishing further correlations of litter densities and human activities was not possible.

In terms of addressing data gaps, citizen science programs have the potential to play a significant role. By adhering to standardized protocols, initiatives that engage the public in scientific research objectives, particularly concerning stranded plastics, may provide substantial contributions to field observations of plastic litter (Severin et al., 2023). In Catarino et al. (2023), the authors developed sampling methodologies for high quality data acquisition, which included FAIR data management for establishment of interoperability procedures for school children (15-18 y.o.) in Africa (Benin, Cabo Verde, Côte d'Ivoire, Ghana, Morocco, Nigeria) and Asia (Malaysia). The researchers presented the workflow of the COLLECT citizen science initiative, which aimed to acquire data on plastic litter in sandy beaches, following the WIOMSA (Barnardo et al., 2020) and OSPAR (OSPAR, 2010) guidelines. The project targeted areas where much of this information is lacking (Tekman et al., 2023), aiming at filling in gaps on litter levels and distribution in the environment, and contributing to informing local authorities and risk assessors.

Furthermore, to fully grasp the impact of plastic pollution in a multiple stressor context, it is crucial to simultaneous acquire information on plastic pollution and other stressors. In the marine environment, microplastics can interact with chemical contaminants, which can potentially lead to organisms co-exposure to various pollutants. Liu et al. (2022) studied the levels of contaminants, such as heavy metals, benzo(a)pyrene (B[a]P) and microplastics, in three species of wild seahorses across seven coastal provinces in China. The major polymer types of microplastics observed accumulating in the seahorses were polyethylene and polyamide. The authors observed significant correlations between concentrations of heavy metals, but also between benzo(a)pyrene and microplastics, suggesting potential co-exposure and synergistic effects. It is unclear whether the co-exposure of benzo(a)pyrene and microplastics can be attributed to increased sorption of this contaminant to the microplastics in the marine environment or whether this occurs earlier in freshwater environments or wastewater effluents. Regional differences and habitats could contribute to the differences in bioaccumulation between the different seahorse species, but this was not further quantified within the study.

Environmental abiotic stressors can lead to degradation of plastics and induce microplastic formation. The study by Tang et al. (2022) investigated the effects of thermal- and photo-degradation on small polyoxymethylene pellets in simulated marine environments. In treatments lasting from 30 to 42 months, the morphology and chemical properties of the pellets was significantly altered. Solar and UVB degradation resulted in severe erosion of the pellet surfaces which was reflected by the visualization of cracking and the analysis hydroxyl groups formation on the surface of polyoxymethylene. Sunlight specifically caused surface cracking and subsequent fragmentation to finer material highlighting how the breakdown into nanoplastics occurs under marine conditions. The altered morphology of the microplastics could also explain how marine plastics act as a vector for waterborne pollutants and microbes.

Microplastics may also affect carbon fluxes and other ecosystem services. For example,Kvale et al. (2023) quantified the effect of microplastic on the transfer of organic matter in the form of fecal pellets, from surface waters to deeper layers of the ocean. By using a complex earth system model, it was estimated that microplastic pollution has the potential to slow down the vertical export of fecal pellets in certain regions, and as such alter this long-term carbon sink (i.e., 4.4 Pg C between the years 1950-2100). The results of this study are likely to encourage further investigation into the subject. A good starting point to do so is in the profoundly discussed limitations of the model and the request for additional experimental work.

In tropical areas, the complex root systems of mangroves act as sieves to impede water flow, leading to high organic carbon and primary productivity. Conversely, they can trap pollutants, including microplastics, such as in the observations reported by Zhang et al. (2022) of microplastics in the sediments of mangroves in the Beibu Gulf (China). Across four sampling locations, each sampled at the high, middle and low tidal zones, microplastic abundances varied greatly, but significantly correlated with particulate organic carbon. Tides and human activities (including aquaculture and fisheries) were found to be important factors influencing the distribution of microplastics. How plastic particles may influence the ecosystem services provided by mangroves warrants further investigation.

Plastic pollution is recognized as a significant environmental challenge that requires urgent action to mitigate and reduce its effects on biota and ecosystems. A contextualized vision of the magnitude of the impact of microplastic together with other environmental stressors is urgently needed, both in the context of chemical pollution co-exposure but also of climate change. Within this Frontiers research topic authors have contributed to a broader view on standardized methodologies for litter observations, assessing sources of plastic litter accumulation in the marine environment, providing (co) exposure data, discussing microplastic formation mechanisms, and discussing the potential for microplastics to interact with carbon sinks. The works presented are therefore crucial for informing evidence-based mitigation policies that promote sustainable measures aligned with the safe operating space of planetary boundaries (Persson et al., 2022; Villarrubia-Gomez et al., 2022).

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

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