Ecotoxicological impacts of micro(nano)plastics in the environment: biotic and abiotic interactions

microplastics

Editorial

Ecotoxicological Impacts of Micro(Nano)plastics in the Environment: Biotic and Abiotic Interactions

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Plastic and microplastic pollution is a complex, muti-faceted challenge that has engaged a broad alliance of stakeholder groups who are concerned with environmental, biotic and human health [1]. The urgency surrounding this topic is evidenced by the ongoing negotiations regarding a global Plastics Treaty agreement [2,3]. The research area is rapidly expanding, with more questions being posed as we increase our knowledge on the environmental presence, fate and effect of plastics, microplastics (<5 mm) and now nanoplastics (defined as <1000 or 100 nm, depending on the definition used [4]). The issue of MNPs (micro(nano)plastics) is no longer confined to the marine environment, with their presence long having been established within freshwaters [5] and terrestrial habitats [6]. Exposure to MNPs remains subject to much investigation, but the effects of long-term exposure on environmental and human health are not well established [7,8]. The recent UNEP technical report "Chemicals in Plastics" [9] now notes "that more than 13,000 chemicals have been identified as associated with plastics and plastic production", of which, 3200 are known to be toxic. Once released, MNPs may sorb many other chemical groups (metals, pharmaceuticals and organic pollutants) and facilitate their transfer to biota [10–12], but knowledge gaps persist regarding the role of MNPs as chemical carriers, particularly when considering the vast array of polymer types, chemicals, environmental transformations, organisms and species-specific physiological parameters that interact with each other [11]. Adverse outcomes from plastic exposure are shared cross-species, indicating common mechanisms of toxicity. Marine species with individuals ingesting naturally disparate levels of plastic present valuable opportunities for researchers to understand the real-world impacts of plastic [13]. A recent study in sea birds coined the term 'plasticosis' to indicate the first recorded instance of plastic-induced fibrosis in wild animals [14]. The discovery of microplastics in our foods [15] and our bodies [16] has added to feeling that we are in the midst of a 'plastics crisis'. Within this atmosphere of heightened awareness and activity, our Special Issue invited contributions covering all aspects of MNP research encompassing (i) environmental presence; (ii) the effects of exposure to biota, alone and in combination with co-contaminants; and (iii) human health impacts.

Although it is more commonly established as a freshwater contaminant, MNP research within freshwaters remains limited compared to that in the marine environment, according to the review presented by Badea et al., 2022 [17]. The authors detail the main physical (density, size, color, shape and crystallinity) and chemical (chemical composition and surface modifications) properties of MPs, the mechanism of biodegradation and the

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consequences for autotrophic organisms and fauna exposed within the freshwater environment. The toxicity mechanisms triggered by MPs are related to the critical parameters of particles, namely size, concentration, type and form, but they are also dependent on species exposed to MPs and the exposure route. Thus, the review highlights the importance of recognizing both the physical particle and species-specific physiology as essential elements in an exposure scenario.

Such considerations can be further complicated when accounting for additional pollutants in the environment. Krais et al., 2022 [18] exposed freshwater chironomid larvae (*Chironomus riparius*) to polystyrene microplastic particles (<50 µm; 150,000 and 1,000,000 particles/L) alone or in combination with the hydrophilic pesticide thiacloprid (TH, 1 µg/L) for 96 h. Observing burrowing behavior and mortality as endpoints, the results showed that TH elevated the mortality rate, but exposure to PS alone did not affect the survival of the larvae. In the co-exposure of TH and PS, a concentration of 150,000 particles/L significantly reduced the toxicity of 1 µg/L TH after 96 h, but this effect that was not observed at 1,000,000 particles/L. The authors hypothesize that this modulation of the TH toxicity may have resulted from a combination of a 'protective MP layer' in the gut and a higher retention time of particles in larvae exposed at the lower MP concentration compared to those larvae exposed at the higher concentration where MPs' passage through the gut was faster owing to the greater opportunity to feed continuously.

The digestive tract, and specifically the small intestine, was the focus of two studies by Mbugani and colleagues, who investigated the long-term impact of MP ingestion. In the first study (Mbugani et al., 2022 [19]), juvenile Wami Tilapia (*Oreochromis urolepis*) were exposed to MPs (0 (control), 1, 10 and 100 PE MPs/mL) for 65 d and then allowed to recover in clean water for an additional 60 days. During exposure, MPs' ingestion and retention was proportional to the exposure dose, as were degenerative changes, determined histomorphologically, in the small intestine. Villi height and width and epithelial cell height were significantly affected and differed between treatment groups, as did the derived indices of damage to the small intestine wall. Importantly, the study found that whilst MPs were no longer observed in the small intestine following depuration, some of the degeneration of the wall of the small intestine remained even after 60 days. This study highlights that the damage caused by MP ingestion does not dissipate after the removal of the particle stressor. The study advocates for the assessment of long-lasting damage.

This leads to the second study by Mbugani et al. (2022) [20], in which juvenile Wami Tilapia were again exposed to MPs for 65 days to translate the adverse effects previously reported into impacts on growth. The small intestine histomorphological lesion index scores correlated significantly with growth pattern, condition factors, final weight, weight gain and total length across the different treatment groups (0, 1, 10 and 100 PE MPs/mL). Together, these studies describe the long-term damage afflicted to the structure of the small intestine which is slow to recover from. Moreover, the damage disrupted growth parameters, which could have been a result of impaired digestion and nutrient absorption functions.

Seafood is a purported pathway for MNPs to pass into humans [21], but MPs have been found in numerous foodstuffs [15], including honey [22]. A new review by Katsara et al., 2022 [23] takes a 'deep-dive' into the factors that can lead to the presence of MNPs in honey, and particularly the migration of plastics from packaging, which is particularly relevant for long-lasting consumer products. Different types of honey and their properties (viscosity, pH value and moisture content) or their storing conditions (temperature, humidity, light and time) can affect the degradation of the packaging and the migration of MPs from packaging to product. Moreover, whilst spectroscopic and analytical techniques like Raman, FTIR, HPLC and GC-MS are in the spotlight with regard to MNP detection and identification, a universal method of isolation, detection, characterization, and quantification remains elusive. Thus, more research is needed to understand the movement of MNPs from packaging into the food we eat.

The impacts of MNPs on human health are not yet fully understood, and there is heightened concern as nanoplastics, unlike larger microplastics, are in a size range that allows for cellular internalization [24]. To assess the effects of internalized micro- and nanoplastics on human gene transcription, Pellegrino et al. (2023) [25] used an in vitro assay to quantify CREB (cAMP response element-binding protein)-mediated transcription. The authors demonstrated that a strong CREB-mediated stimulation of transcription was diminished by micro- and nanoplastics in any chosen setting, thus indicating a threat to human health via the deregulation of transcription induced by internalized micro- and nanoplastics. The test system could be further utilized to screen for toxic substances and non-toxic alternatives.

In summary, this collection of articles provides a valuable addition to the global mosaic of plastic and MNP research. The combination of environmental, biotic and human health investigations points toward the need for greater integration between these disciplines to fully understand the many facets of plastic pollution. Such an integration is central to the One Health Approach [26], which certainly warrants further consideration. The studies presented in this Special Issue add to the weight of evidence that recognizes MNPs as a significant environmental and public health problem that requires, and is receiving, immediate attention.

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