# POSITION PAPER

## MICROPLASTICS RESEARCH AT A CROSSROADS: FROM UBIQUITY TO UNDERSTANDING

**MICROPLASTICS CONSTITUTE ONE OF THE MOST PERVASIVE AND SCIENTIFICALLY CHALLENGING ENVIRONMENTAL CONTAMINANTS OF THE ANTHROPOCENE. THEIR UBIQUITOUS PRESENCE ACROSS MARINE, FRESHWATER, TERRESTRIAL, AND ATMOSPHERIC COMPARTMENTS IS THE DIRECT OUTCOME OF EXPONENTIAL PLASTIC PRODUCTION COMBINED WITH PERSISTENT STRUCTURAL FAILURES IN GLOBAL WASTE MANAGEMENT.**

With global plastic production exceeding 460 million tonnes per year and less than 10% of plastic waste effectively recycled, environmental leakage has become a chronic and systemic pressure rather than an episodic phenomenon.

Scientific research has unequivocally demonstrated that microplastics occur in sediments, surface and deep waters, biota across trophic levels, and human food items. However, the continued accumulation of occurrence data alone is no longer sufficient. The field has reached a stage where the central challenge is not detection, but interpretation. Microplastics research must now confront its own limitations in order togenerate knowledge that is comparable, mechanistically grounded, and relevant for environmental management.

Methodological heterogeneity remains the primary constraint. Differences in sampling strategies, extraction procedures, analytical techniques, and reporting units severely limit cross-study comparability and synthesis. The coexistence of optical, spectroscopic, and thermal methods, often applied without harmonized protocols or interlaboratory validation, continues to fragment the evidence base. These limitations are particularly critical for complex matrices, such as difficult-to-process animal tissues (e.g. holothurians, lipidic tissues) or organic-rich materials (e.g. wastewaters, egagropiles, compost, etc.), for which matrix-specific and standardized extraction and purification protocols are still lacking.

At the same time, experimental research frequently suffers from limited environmental realism. Laboratory studies commonly employ pristine, spherical polymer standards at concentrations exceeding those observed in natural systems, while environmental microplastics are aged, irregular, chemically altered, and associated with additives, sorbed contaminants, and microbial communities. This disconnect undermines the ecological relevance of toxicity data and weakens extrapolation to ecosystem-level risk. The nanoplastics fraction further amplifies these uncertainties, as formation rates, environmental concentrations, and validated detection methods remain poorly constrained.

In this context, Marine Protected Areas (MPAs) should be explicitly recognized as priority research platforms rather than assumed to represent pristine conditions. MPAs offer controlled management settings in which baseline contamination levels can be defined, long-term trends assessed, and local inputs disentangled from regional and long-range transport.

Research conducted in MPAs is therefore essential to move from descriptive monitoring toward mechanistic understanding of sources, fate, and ecological implications of microplastic contamination. Evidence generated in these areas is essential to improve the modelling of microplastic impacts on ecosystem services and to extrapolate potential effects to relatively pristine environments.

We argue that the future of microplastics research must shift decisively from descriptive occurrence studies to integrative and predictive frameworks. This transition requires harmonized methodologies, environmentally realistic reference materials, long-term monitoring strategies, and explicit consideration of multiple stressors under changing environmental conditions.

Scientific journals have a central role in driving this transition by prioritizing methodological transparency, comparability, and conceptual advancement. Continued publication on microplastics is therefore not optional. It is the only means by which the field can resolve persistent uncertainties, consolidate fragmented evidence, and provide a robust scientific foundation for credible risk assessment and effective environmental governance.

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