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Editorial: Addressing microplastic contamination: sustainable solutions for resilient food systems

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Editorial on the Research Topic
Addressing microplastic contamination: sustainable solutions for resilient food systems

As the global population is projected to reach approximately 10.3 billion people by the end of the century (United Nations, 2024), there is an urgent need to increase food production, by at least 50%, to match the consumption demand. It is expected that this increase will inevitably add pressure to food producers and supply chains (FAO, 2018). Agriculture, aquaculture and related food industries rely heavily on plastics for different uses, such as irrigation (land), aquaculture pens (sea), storage (big bags) and packaging (food trays). Waste generation across the food sector is significant (Rao et al., 2024; WEF, 2024), and it can be distinguished between natural and synthetic waste (Dokl et al., 2024), with the latter being the focus of this Research Topic. Food production systems can either be exposed to natural elements, or be protected under greenhouses to facilitate best growth conditions, particularly for agriculture systems. Regardless of production, both systems can facilitate the wear and tear of plastics, particularly due to weathering or exposure to environmental conditions. As a consequence, fragmentation of larger plastic items into smaller items known as micro- and nanoplastics (MNPs), can potentially pose exposure risks to humans and the environment (Yates et al., 2025).

In this Research Topic "*Addressing Microplastic Contamination: Sustainable Solutions for Resilient Food Systems*," the contributing studies focussed on microplastic occurrence, analytical challenges, and management strategies across food production systems. The papers address methodological innovations in the extraction and quantification of microplastics within complex organic matrices, such as anaerobic digestates (Whitney et al.) and in composts derived from food waste (Hobson et al.). They also evaluate the range of analytical techniques to detect microplastics in soils emphasizing the need for harmonized data and standardized protocols (Gündoğdu et al.); or conducted field-scale investigations into the co-occurrence of microplastics and heavy metals in agricultural soils, demonstrating interactions between pollution gradients and soil properties (Shi et al.).

The review from Brander et al., highlighted the growing challenge of the use of plastic materials in agriculture and aquaculture systems, and underscored the urgent need for circular frameworks that can reduce or mitigate the leakage of plastics from land to sea, to be widely implemented across the industry.

Collectively, these studies provide a new perspective on the pathways, analytical barriers, and industry dimensions of microplastic contamination within global food systems, contributing to the foundation of sustainable, resilient, and contamination-aware food production (Figure 1).

The geographic distribution of the papers has a higher representation of authors from the United States of America (56.8%), China (25.0%), and Türkiye (9.1%). Authors from other European countries, including Belgium, Spain, Italy, and the United Kingdom, had a combined representation (9.1%). The main findings explore the resilience and economic feasibility of value chains in food systems, particularly in complex socio-economic dynamic global systems. These align with global regulatory processes (e.g. plastics legislation, agro-soil regulations, packaging controls, and sludge-use policies).

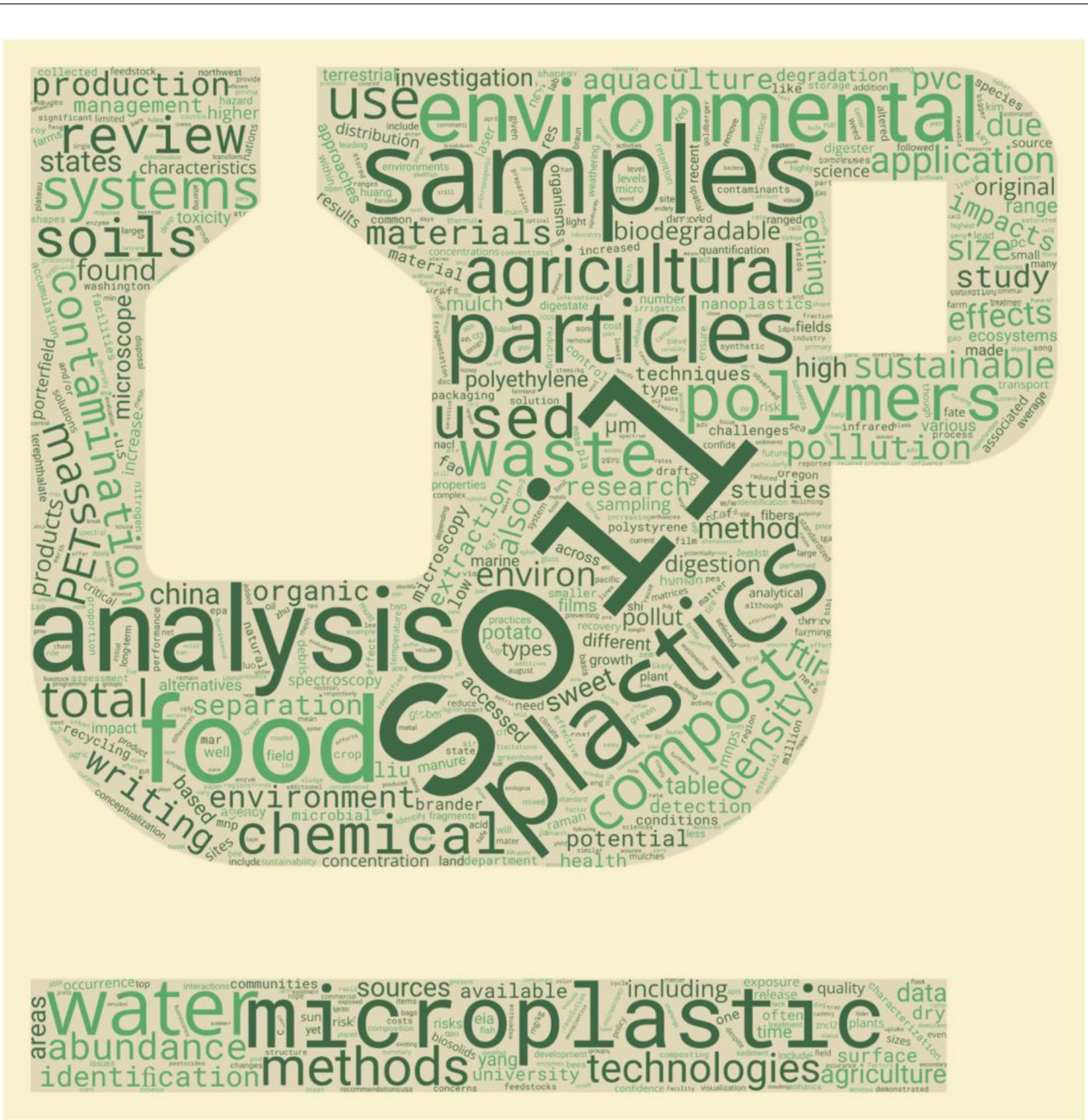


FIGURE 1
Word cloud generated from the keywords and most recurring terms in the five papers published within the Research Topic [Generated from a PDF file containing all papers in wordclouds.com].

The first paper explored the abundance of microplastics (MPs) in anaerobic co-digestion food waste and dairy manure (Whitney et al.). The results showcase MP concentrations ranging from approximately 120 particles kg^{-1} (wet weight) in manure, to high concentrations above 3,300 particles kg^{-1} in the lagoon. Matrices in this paper were dominated by polyethylene terephthalate (PET) fibers. The main results of this paper were the estimation of potential MP loading that could exceed 20 million particles ha^{-1} and the conclusion that waste treatment pathways can act as vectors for redistribution of MP into soils. Wastewater treatment systems recover high quantities of MPs during treatment (Mahon et al., 2017, Iyare et al., 2020), however, the lack of circular economy solutions may cause an additional input of MPs into a clean system, through use of sludges in agriculture production.

The second paper explores the dual contamination of both MPs and cadmium in Chinese sweet potato fields, where 30 sites were explored to have very high MP abundances, mean ~112,400 items kg^{-1} soil, with a maximum ~197,153 items kg^{-1} (Shi et al.). The majority of MPs were fragments (48%) and films (41%), with polyamide (PA) the dominant polymer in three cities. The concentrations of cadmium were explored in 215 field sites and had a mean concentration of 0.15 mg kg^{-1}. One of the interesting results of this paper was the fact that cadmium was negatively correlated with MP abundance. These findings indicate that microplastics can influence the behavior of metals by altering soil properties and that mixed contamination scenarios should be examined with regard to food safety. The study suggests that MPs are already present in high concentrations in agronomic soils, and that they can have antagonistic effects with trace metals, such as cadmium. This is particularly relevant because sweet potato plays an important role in China's food systems, as they represent approximately 84% of the global production for this carbohydrate.

The third paper explored 20 commercial composts in a survey in Vermont, USA (Hobson et al.). The composts were compared based on the percentages of food-waste input (≥15% vs. <5%). The concentrations of plastics and MPs ranged from 0 to 1,201 particles kg^{-1}, which represents a range from 0 to 0.06% w/w. No statistical differences were found between the high and low food-waste input, due to a high variability. Plastics identified were mainly films (~45%−50%) and fragments (~25%−30%), with a high polymer diversity that included polyethylene (PE), PET, PA, polyvinylchloride (PVC), polystyrene (PS), polypropylene (PP), etc. One of the recommendations of the paper was to combine methods, particularly FTIR and GC-MS workflows, to account for both the number and mass of particles, as the study demonstrated that particle count on its own was a poor predictor of plastic mass.

The fourth and fifth papers were both reviews that explored analytical methods in soil and use of plastics in both land and marine systems, with particular focus on agriculture and aquaculture. The fourth paper synthesized the analytical approaches to extract, identify, and quantify MPs in soil (Gündoğdu et al.). This review evaluations sieving, density separation, chemical digestion and spectroscopic and thermal methods, by their strengths and limitations. The paper emphasizes that inconsistent QA/QC practices undermine compatibility between studies. The paper calls on the adoption of emerging standards such as ISO 24187:2023 (ISO, 2023), that adopts the principles for the analysis of MPs present in the environment.

The fifth and final paper in this Research Topic, focusses on the Pacific Northwest and how plastic is used across agriculture and aquaculture. In the review, plastics used in agriculture account for 3%−5% of global production in 2018 (between 10 and 18 million tons), while aquaculture use amounted to about 2.1 million tons. Due to the widespread use of films, mulches, nets, cages and ropes, the paper highlighted a need for a regional recycling or recovery system that would minimize environmental accumulation and microplastic release. Another aspect that the review mentioned was the ongoing consumer packaging reforms that do not address farm plastics, and therefore create a regulatory loophole. Biodegradable alternatives that are emerging in the food sectors, and that are often replacing fossil fuel plastics also need to undergo assessment to determine safety concerns, particularly because research is highlighting that these alternatives also can accumulate POPs and other contaminants. In the meanwhile, food systems still rely heavily on plastics, due to their lightweight nature which is beneficial to reduce transport costs.

Despite the small number of publications in this Research Topic, the five contributions collectively address similar concerns and challenges that food producers and value chains have regarding MNP pollution.

Each study explored either value chains, environmental samples or waste management solutions, concluding that microplastic contamination is not isolated nor incidental. In fact, it seems to be linked across food production systems and subproducts from wastewater management. The five studies address the urgent need for harmonized and/or standardized methodologies to allow comparisons among research studies; but also the need to integrate and expand linkages between food systems and other industrial systems that may have interconnections (e.g. wastewater management, sludge-use, emissions of effluents into water bodies, etc.), and to bring circularity models into the policy and regulatory discussions worldwide. The original studies and the reviews refer to how inconsistent extraction, detection limitations, and even different QA/QC practices may affect comparability of datasets.

The interconnections between systems and the policy discussions, are somehow connected, as there are many initiatives that target circular economy efforts, and even regulatory on-going processes and frameworks that should encompass material design and eco-design principles; the reduction of upstream sources; the creation of feedstock purity standards; the development of end-of-life recovery mechanisms, and the need for coordinated monitoring systems, that communicate with one-another.

As global food systems will not only face population growth, but also potential limitations on resource stocking due to climate change, addressing emerging contaminants such as MNPs is a priority to secure food safety and food quality.

Inter- and transdisciplinary collaborations, investment in standardized analytical methods, and improvement of collaborations, can bring additional data and information to inform ongoing and future policy efforts into food systems. Circularity and economic feasibility of food systems are already an integral part of sustainable development, however, socio-economic

models of transition require to be rethought and organized with goals that specifically focus on the food safety and quality across value chains, while at the same time, having environmental health in mind, and reducing the potential contamination from synthetic materials such as plastics and microplastics.

Author contributions

JF: Project administration, Writing – original draft, Conceptualization, Writing – review & editing, Supervision. SG: Writing – review & editing, Writing – original draft, Conceptualization, Project administration, Methodology, Supervision. AM: Writing – original draft, Project administration. AK: Writing – original draft, Writing – review & editing, Project administration, Supervision.

Conflict of interest

AM was employed by the company Blue Spark, Ližnjan, Croatia.

The remaining authors(s) declared that the research this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. Artificial intelligence tools (Grammarly) were used solely to support orthography and language editing during editorial preparation. All content, interpretation, data analyses and scientific conclusions remain the author's own. The authors reviewed and verified all AI-assisted edits for accuracy. No confidential, personal, or unpublished data were entered into AI tools at any stage.

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