

POINT OF VIEW

Microplastics: A Complex Research Field for Analytical Chemistry?

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In 2005, I began my master's project evaluating endocrine-disrupting compounds in surface waters.¹ This was among the first studies on emerging contaminants in Brazil, aligning with the strong international trend in Environmental Chemistry. Since then, I have closely followed the evolution of this field both in our country and worldwide.

Advances in methodologies for quantifying emerging contaminants, such as pharmaceuticals, personal care products, plasticizers, pesticides, etc., at nanogram-per-liter concentrations across different environmental matrices have significantly driven progress in sample preparation for organic substances. After starting with the technologies available in research laboratories, liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS) has consolidated its role as the primary analytical tool, ensuring accuracy and precision in assessing the occurrence and transport of these contaminants in water and soil. Later, the advent of high-resolution mass spectrometry has further enhanced the evaluation of environmental scenarios, introducing untargeted analysis as a valuable approach to elucidate the fate and behavior of chemicals in surface water, groundwater, and drinking water supplies. However, this process has faced numerous barriers within the sphere of public policy, particularly when confronting large corporations. A paradigmatic example is the case of per- and polyfluoroalkyl substances (PFAS), extensively documented and brought to public attention through the film *Dark Waters*.

Approximately 10 years ago, attention was drawn to a new (or perhaps not entirely new) class of emerging contaminants: Microplastics! Remarkably, plastics began to be mass-produced around 60 years ago, and while they revolutionized lifestyle, healthcare, food production, and engineering, the environmental consequences of inadequate waste management have become increasingly evident. Society has played a key role in addressing this issue, driven by pressure from the scientific community, governmental agencies, and diverse stakeholders to develop solutions for plastic pollution. Unlike other categories of emerging contaminants, microplastic pollution is not an invisible problem; its tangible presence makes it easier to convey the urgency of understanding the environmental and health implications associated with plastics and, consequently, microplastics in the environment.

Omnipresent in our life, all polymers previously classified as particles with dimensions less than 5 mm, and more recently redefined as those with sizes between 1 and 1000 μm , are microplastics.² However, we are not talking about one substance or a group of substances with the same characteristic. Size, format, color, type of polymer, level of degradation, additives, all that combination brings a particle, a different physical chemistry characteristic, behavior, toxicity, capacity to interaction with another contaminants, including microorganisms and biofilm formation. Consequently, assessing the risks associated with microplastics in the environment is an intrinsically complex task.³

Cite: Montagner, C. C. Microplastics: A Complex Research Field for Analytical Chemistry? *Braz. J. Anal. Chem.* 2026, 13 (52), pp 13-15. <https://doi.org/10.30744/brjac.2179-3425.PoV.CCM.N52>

This Point of View is part of the BrJAC Special Issue dedicated to the 21st ENQA and 9th CIAQA.

As observed in the beginning of research on other emerging contaminants, it was essential to understand how to quantify microplastics in environmental samples, as this provides an important foundation for future regulatory frameworks. Early studies began with traditional approaches that relied heavily on visual inspection under optical microscopy, which was time-consuming and prone to bias, for analyzing beach sand or other samples containing large microplastics (1-5 mm). Today, because of the advances in methodologies: from sampling and sample preparation (such as optimized digestion protocols and density separation techniques that help preserve particle morphology and minimize fragmentation) to instrumental analysis, we can detect and report the presence of microplastics across a wide range of matrices: water, soil, air, biological samples, tissues, organs, etc., opening new horizons for understanding the impacts of microplastics on ecosystems and human health.^{4,5} The recent innovations in analytical methods aim to enhance the accuracy, efficiency, and representativeness of results, particularly in the detection of small microplastics and nanoplastics (<1 μm).

Advanced spectroscopic techniques such as micro-attenuated total reflectance Fourier transform infrared spectroscopy ($\mu\text{-ATR-FTIR}$), Raman microscopy, and near-infrared hyperspectral imaging (NIR-HSI) allow precise chemical characterization of particles at increasingly smaller scales. Among thermoanalytical techniques, gas chromatography pyrolysis coupled with mass spectrometry (Py-GC-MS) or flame ionization (Py-GC-FID) has emerged also as a powerful technique by retaining chemical signatures of the original material, including polymers, additives and other adsorbed compounds.

Then, automated scanning modules and chemometric tools have reduced analysis time while improving reproducibility, enabling simultaneous detection of multiple polymer classes directly on filters. Studies on behavior, degradation, and removal in environmental matrices, as well as the engineering of new materials, have begun to be explored in greater detail at the microscopic scale.

In other dimensions, classical molecular dynamics and density functional theory calculations have been used for advancing microplastic analysis providing a molecular-level understanding of contaminant interactions that cannot be fully captured by experimental methods alone. Molecular dynamics simulations allow researchers to model the dynamic behavior of microplastics in aqueous environments, revealing how parameters such as temperature, salinity, and pH influence sorption and desorption processes. Density functional theory complements these insights by quantifying the electronic and energetic aspects of interactions, such as hydrogen bonding, van der Waals forces, and electrostatic contributions, thereby clarifying the mechanisms that drive contaminant binding to polymer surfaces. Together, these are examples as computational approaches bridge experimental observations with theoretical predictions, enabling more accurate assessments of microplastic behavior across diverse environmental matrices.^{6,7}

This explains why the number of publications on microplastics listed in the Web of Science (now exceeding 32,000) has grown exponentially over the past decade, reflecting the state of the art across multiple dimensions of this field. Most of these studies fall within Environmental Sciences, followed by Environmental Engineering, Marine and Freshwater Biology, Toxicology, and Analytical Chemistry. There is not a standardized method, nor an easy question to answer. This trend shows that concerns about microplastic contamination are driving innovation across disciplines, propelling scientific advancement on a global scale, with Analytical Chemistry playing a crucial role in this science. Thus, the complexity of the topic also represents an opportunity to further explore new analytical methodologies across different scientific fields.

REFERENCES

- (1) Montagner, C. C.; Jardim, W. F. Spatial and Seasonal Variations of Pharmaceuticals and Endocrine Disruptors in the Atibaia River, São Paulo State (Brazil). *J. Braz. Chem. Soc.* **2011**, 22 (8), 1452-1462. <https://doi.org/10.1590/S0103-50532011000800008>
- (2) International Organization for Standardization (ISO). *Plastics — Environmental aspects — State of knowledge and methodologies*. ISO Technical Report No. 21960:2020. Available at: <https://www.iso.org/standard/72300.html> (accessed May 07, 2026).
- (3) Sodr e, F. F.; Arowojolu, I. M.; Canela, M. C.; Ferreira, R. S.; Fernandes, A. N.; Montagner, C. C.; Vidal, V.; Dias, M. A.; Abate, G.; da Silva, L. C.; et al. How natural and anthropogenic factors should drive

- microplastic behavior and fate: The scenario of Brazilian urban freshwater. *Chemosphere* **2023**, *340*, 139813. <https://doi.org/10.1016/j.chemosphere.2023.139813>
- (4) Montagner, C. C.; Dias, M. A.; Paia, E. M.; Vidal, C. Microplásticos: ocorrência ambiental e desafios analíticos. *Quim. Nova* **2021**, *44* (10), 1328-1352. <http://dx.doi.org/10.21577/0100-4042.20170791>
- (5) Fernandes, A. N.; Bertoldi, C.; Lara, L. Z.; Stival, J.; Alves, N. M.; Cabrera, P. M.; Grassi, M. T. Microplastics in Latin America ecosystems: a critical review of the current stage and research needs. *J. Braz. Chem. Soc.* **2022**, *33* (4), 303-326. <http://dx.doi.org/10.21577/0103-5053.20220018>
- (6) Dias, M. A.; Batista, P. R.; Ducati, L. C.; Montagner C. C. Insights into sorption and molecular transport of atrazine, testosterone, and progesterone onto polyamide microplastics in different aquatic matrices. *Chemosphere* **2023**, *318*, 137949. <https://doi.org/10.1016/j.chemosphere.2023.137949>
- (7) Madeira, C. L.; Cho, J.; Gomez, R. D. B.; Montagner, C. C. Natural organic matter decreases the sorption capacity of fipronil and its degradation products onto polyethylene microplastics: combined experimental and theoretical insights. *ACS EST Water* **2025**, *5* (7), 3710-3718. <https://doi.org/10.1021/acsestwater.4c01261>

Acknowledgments

The São Paulo Research Foundation (FAPESP #2022/12104-4) and National Council for Scientific and Technological Development (CNPq #304993/2023-9).

Disclosure

To be truthful to the point of view, I declare that artificial intelligence was used to edit, improve, and proofread the text.



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