Analytical and Bioanalytical Chemistry (2023) 415:2869–2871
https://doi.org/10.1007/s00216-023-04747-y

EDITORIAL

Advances in chemical analysis of micro- and nanoplastics

Natalia P. Ivleva[1] · **Sebastian Primpke**[2] · **Jennifer M. Lynch**[3,4]

Accepted: 10 May 2023 / Published online: 26 May 2023

Microplastics and nanoplastics are tiny fragments of synthetic polymers (plastics), found in the environment (including sea- and fresh water, sediments, biota, soils, and air) as well as in drinking water and food, and therefore recognized as emerging particulate anthropogenic contaminants. Plastic particles, including fibers, in the size range of 5 mm to 1 mm are referred to as large microplastics, from 1 mm to 1 µm are defined as microplastics, and smaller than 1 µm are nanoplastics (ISO/TT 21960). The numerous reports on the occurrence of microplastics and, recently, nanoplastics raised concerns about their impacts on the environment and human health. Generally, more hazardous effects are expected from smaller microplastics and, especially, from nanoplastics. In order to adequately and systematically address these issues, reliable information on the ambient concentrations of microplastics and nanoplastics are required.

The diversity and complexity of plastic sources, material properties, usage patterns, and emission pathways are reflected in the diversity of microplastic and nanoplastic particles found in the environment. These particles exhibit a large variety of chemical and physical characteristics (e.g., polymer type, size, shape, density, surface properties, additives, extent of weathering, etc.). Therefore, advanced methods are required for the reliable analysis of microplastics and nanoplastics, and they are probably some of the most challenging analytes to measure in environmental samples. The analysis must include representative sampling and efficient sample preparation, as well as chemical identification, quantification, and characterization of the particles in the entire size range and in different media. All together, these challenges make it necessary to optimize existing and develop and validate new efficient methods. Time- and cost-efficiency of methods must be considered, and high throughput analysis is ideal for monitoring studies. Furthermore, methods providing detailed information on the chemical composition, particle number, size distribution, shape, surface properties, associated additives, and sorbed contaminants, weathering state, etc., are needed for better understanding of the micro- and nanoplastic fate in the environment and for thorough assessment of the potential eco-toxicological risks.

Comparison, harmonization, and standardization within the same/similar methods (e.g., mass-based and/or particle-based) as well as between principally different, but complementary approaches, are greatly needed. However, the availability of suitable reference materials for microplastics and nanoplastics which mimic real analytes, including different polymer types, broad size range, and different shapes is still limited, hampering the development of harmonized and standardized methods for the analysis of microplastics. Methods for the identification and quantification of nanoplastics are still under development, and their comparison and harmonization will be a topic of future studies.

Therefore, we organized this Topical Paper Collection "*Advances in Chemical Analysis of Micro- and Nanoplastics*" and invited worldwide experts working in this field to highlight the development, optimization, validation, application, and harmonization of advanced methods for

Published in the topical collection *Advances in Chemical Analysis of Micro- and Nanoplastics* with guest editors Natalia P. Ivleva, Jennifer M. Lynch, and Sebastian Primpke.

✉ Natalia P. Ivleva
natalia.ivleva@tum.de

✉ Sebastian Primpke
sebastian.primpke@awi.de

✉ Jennifer M. Lynch
jennifer.lynch@nist.gov

1 Institute of Water Chemistry, Chair of Analytical Chemistry and Water Chemistry, Technical University of Munich, Lichtenbergstr. 4, 85748 Garching, Germany

2 Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research, Biologische Anstalt Helgoland, Kurpromenade 201, 27498 Helgoland, Germany

3 National Institute of Standards and Technology, Chemical Sciences Division, Waimanalo, HI 96795, USA

4 Hawaii Pacific University, Center for Marine Debris Research, Waimanalo, HI 96795, USA

the analysis of microplastics and nanoplastics in different matrices.

This topical paper collection includes 12 research articles and one critical review. The research articles cover all steps of micro- and nanoplastic analysis, including sampling, sample preparation, polymer identification, quantification, and characterization. Here, mass-based approaches (pyrolysis-gas chromatography/mass spectrometry (py-GC/MS) and proton nuclear magnetic resonance (^{1}H-NMR)) are further developed, optimized, and applied for the analysis of micro- and nanoplastics in environmental samples, as well as for the characterization of test/reference materials. As particle-based approaches, vibrational spectroscopy methods are strongly presented, including μ-Raman, μ-FTIR spectroscopy and NIR hyperspectral imaging enabling the reliable analysis of microplastics down to approx. 1 μm (for detailed analysis), 10 μm and 100 μm to 300 μm (for high-throughput monitoring), respectively. Furthermore, approaches for the physicochemical analysis of nanoplastics are presented and critically evaluated. Finally, essential topics on the production of reference materials for microplastics, their characterization and application for interlaboratory comparison exercises are discussed.

We sincerely thank all authors for contributing their valuable work and the reviewers for critically assessing and improving the papers for this topical collection "*Advances in Chemical Analysis of Micro- and Nanoplastics*". We are also very grateful to the editorial office for the efforts in helping create and compile this collection. We are proud of the quality of contributions and strongly believe that this topical collection will be of great interest to researchers not only in the interdisciplinary field of microplastics and nanoplastics, but also far beyond.

Funding Open Access funding enabled and organized by Projekt DEAL.

Natalia P. Ivleva is a senior researcher at the Chair of Analytical Chemistry and Water Chemistry, Institute of Water Chemistry (IWC), TUM School of Natural Sciences, Technical University of Munich. She studied chemistry and biology at the Southern Federal University (Rostov-on-Don, Russia). After receiving her Ph.D. in Physical Chemistry in 1997 from the Institute of Chemical Physics (Chernogolovka, Russia), she started her postdoc at the same institute. In 2003, she joined the IWC-TUM, where she is now leading Raman & SEM Group. In 2019, Dr. Ivleva accomplished her habilitation "Raman Microspectroscopy for Environmental Analysis". Her research interests focus on the analysis of complex environmental and industrial samples by means of Raman microspectroscopy, surface-enhanced Raman scattering, and stable isotope approach, with special attention on online/high-throughput analytics. She combines Raman-based methods with techniques based on electron microscopy and also with different separation and fractionation approaches for the identification, quantification, and characterization of various analytes/pollutants, ranging from biofilms and microorganisms through engineered (magnetic) nanoparticles to micro- and nanoplastics. She is a part of several German and international working groups for the harmonization and standardization of microplastic analysis as well as for the development and characterization of reference/testing materials for micro- and nanoplastics.

Sebastian Primpke is a polymer chemist and senior researcher in the Marine Microbiological Ecology - Microplastics group of the section Shelf Seas Systems Ecology at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI). He studied chemistry at the University of Göttingen and received his doctoral degree with a focus on polymer science in 2015 from the same university. Afterwards, he switched into the field of environmental analysis at the Biologische Anstalt Helgoland of the AWI. Since 2015 his research interests are in the development, harmonization, and evaluation of analytical methods for the identification and quantification of microplastics within various environmental compartments (e.g. water, sediments, biota, sea ice, snow). These methods are covering different (FT)-IR imaging methods, Raman microcopy and ATR-FTIR measurements. He is part of different international working groups for the development of monitoring guidelines and measurement standards. Moreover, he is one of the developers of the software tool “Systematic Identification of MicroPLastics in the Environment (siMPle)” available on www.simple-plastics.eu.

Jennifer M. Lynch is a research biologist in the Chemical Sciences Division of the National Institute of Standards and Technology (NIST). She studied biology and environmental sciences at Indiana University (Bloomington, Indiana, USA) and earned her Ph.D. in marine environmental toxicology from Duke University (Beaufort, North Carolina, USA). In 2003, she began a National Research Council postdoctoral fellowship at NIST, and now she is the co-director of the Center for Marine Debris Research (CMDR), established in 2019 as a partnership between NIST and Hawaii Pacific University. The CMDR was intentionally located in Hawaii, one of Earth’s most plastic polluted marine environments, and is a part of the NIST Circular Economy Program. Dr. Lynch’s research is focused on improving the quality of measurements in the field of marine environmental toxicology and chemistry. She has used multiple analytical chemistry techniques, including gas and/or liquid chromatography mass spectrometry (GC/MS and LC/MS/MS), pyrolysis-GC/MS, and FTIR and Raman microscopy, to analyze environmental samples for organic chemicals of emerging concern. These pollutants include flame retardants (e.g. PBDEs), perfluoroalkyl acids (e.g. PFOS), other plastic additives, and plastic pollution of all sizes. Optimizing these methods to quantify and chemically characterize plastic pollution is her current goal so that answers about its sources, fate, transport, and effects are accurate and inform the best policy.