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Harmonization and Standardization in Plastic Exposure and Hazard Assessment

About PlasticsFatE

Embedded within the Horizon 2020 Research and Innovation programme, the project PlasticsFatE (Plastics Fate and Effects in the human body) (duration: April 1st, 2021 – March 31st, 2025) aims to improve the present understanding of the impact of micro- and nanoplastics (MNPs) and associated additives/adsorbed contaminants (A/C) in the human body. It also addresses uncertainties in MNPs-related issues and provides an insight into the suitability and performance of different methodologies and potential blind spots in the study of the fate and effects of MNPs in humans. Within this project, the studies of Kokalj et al. (2023), Lou et al. (2022), Schvartz et al. (2023), and Wieland et al. (2022) utilize different methodologies for risk assessment and indicate the necessity for further harmonization of exposure and hazard assessment regarding MNPs, thus shedding light not just on health and environmental concerns but also on the shortcomings of current methods and offering outlooks for future research.

Key Messages

Rising Concern:

The increasing release of various types of micro- and nanoplastics (MNPs) poses unknown risks to human health, ecosystems, and the environment and can ultimately be seen as also crossing a planetary boundary with MNPs present everywhere due to degradation from plastic waste.

These particles are pervasive throughout the life cycle of plastic products. Despite growing attention, definitive knowledge about the effects of MNPs especially on human health remains limited, creating pressure on regulatory bodies to address the associated risks in a precautionary way.

Policy Relevance:

Increased harmonization and standardisation in exposure and hazard assessments will improve the performance of measurement and testing methods, facilitate their robustness and reliability, and enhance the precision, accuracy and comparability of research outcomes. This will lead to more informed decision-making and regulatory actions.

Policy Recommendations

Promote International Standards: Advocate for the development and adoption of global standards for MNP sampling, processing, analysis and testing, and reporting to ensure data consistency and comparability across studies.

Fund Method Development: Allocate funding to support the creation of standardized methods and quality assurance practices for MNP research to enable more reliable, comparable, and actionable data.

Enhance Interlaboratory Comparisons: Encourage interlaboratory comparisons to assess and improve the trueness and reliability of MNP measurements across different laboratories to know the type and characteristics of the MNPs we are testing.

Support Transparency and Data Sharing: Implement policies that mandate detailed reporting and transparency of plastic production and MNP research methodologies, including the creation of publicly accessible databases that involve also plastic additives & contaminants.

Encourage Collaboration: Foster collaboration among researchers, policymakers, and industries to harmonize and coordinate research efforts and share knowledge on the performance of MNP exposure and hazard assessment methodologies.

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Importance of Harmonization and Standardization

Harmonization

Consistent Methodologies: Harmonization is crucial to ensure that results from different studies on MNPs are comparable, especially when no standardized methods are available.

Key Areas:

Exposure Research: Harmonize sampling, processing, and analytical methods for different media (air, water, soil) to improve data comparability.

Hazard Research: Use human exposure-relevant MNPs, develop protocols reflecting realistic concentrations, doses and conditions, and harmonize toxicity testing that reflects different exposure routes and any possible changes during testing in a highly reproducible way.

Standardization

Global Standards: Develop and implement international standards for MNP research to ensure consistency, reliability, and reproducibility of results.

Key Areas:

Measurement Techniques: Standardize analytical techniques and reference materials for detecting and quantifying MNPs and for providing well characterized test materials for toxicity testing.

Quality Assurance: Mandate detailed QA/QC measures and promote interlaboratory comparisons to ensure the accuracy of MNP assessments.

With the rise in plastic-related pollution, which has now surpassed planetary boundaries, a boundary where the integrity of Earth system processes is upheld (Persson et al., 2022); micro- and nanoplastics (MNPs) have garnered increasing attention from both policymakers and researchers.

Avoiding MNP pollution is nearly impossible, as it occurs already at a global scale and at every stage of a product's life cycle—from resource extraction and polymer production to product manufacture, use, and eventual disposal and remediation (Fernandez & Trasande, 2023).

Furthermore, released MNPs not only pose risks to human and non-human organisms but can also disrupt ecosystems by altering soil properties, affecting food chains, and ultimately impacting humans once again (Wei et al., 2023).

Despite the wealth of knowledge we have obtained, there are still many uncertainties about the effects of MNPs on the environment and especially on human health, especially in the longer term.

As concerns about the potential risks posed by MNPs grow, there is mounting pressure on regulatory bodies and manufacturers to mitigate and minimize these risks. Numerous studies are being conducted using various methodologies to explore the potential impacts of MNPs on the environment and human health.

In this context, standardization plays an ever more crucial role in ensuring that test results are consistent across different measurement procedures and are traceable to recognized standards, such as those defined by the International System of Units (SI). However, in the absence of standardized methods, harmonization becomes essential.

Harmonization aims to make test protocols and the resulting data more comparable regardless of the analytical techniques used, which is particularly important when no reference measurement and testing procedure or primary reference material is available. By harmonizing methodologies, the comparability of study results could be improved, leading to more robust and reliable conclusions about the risks associated with MNPs.

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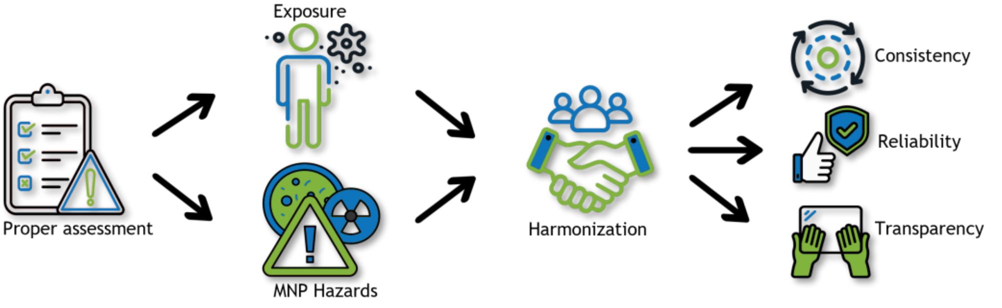
The Need for Harmonization and Standards

Proper assessment of exposure and the associated hazard of MNPs requires harmonization in order to increase (1) consistency, (2) reliability, and (3) transparency. These qualities must be advanced in both exposure related as well as hazard related research. This is critical for future research, as it makes data and results from different studies comparable, gives policy makers, scientists and the public the ability to understand and trust the results, their scope and possible shortcomings, and ultimately facilitates more informed, sustainable and safe decision-making and regulatory actions (Metz et al., 2020; Muthukumaran et al., 2021).

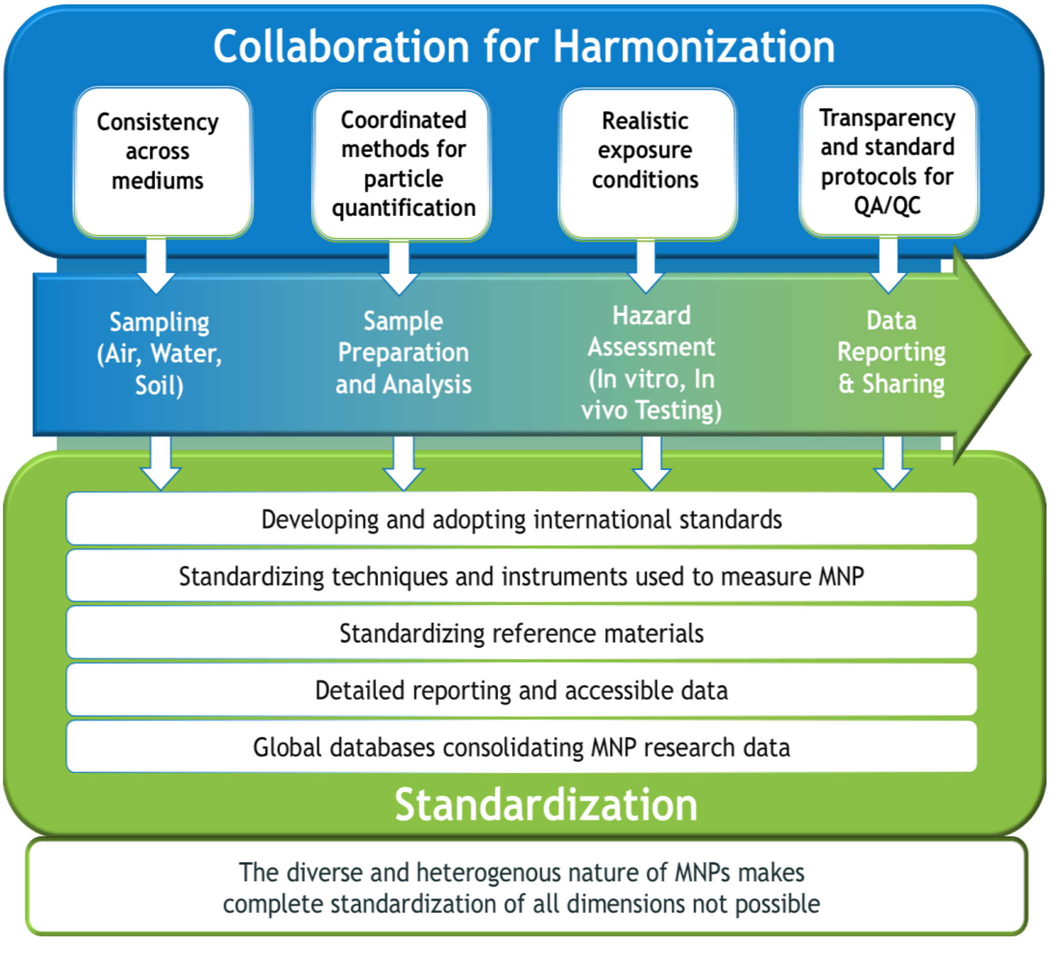


Key areas for harmonization and quality assurance of MNP-exposure related research include:

1. Standardized Methods (Kokalj et al., 2023; Wieland et al., 2022)
    - Develop and adopt international standards (e.g., ISO, CEN, OECD) for sampling, sample preparation, and analyzing MNPs
    - Create guidelines for representative and reliable sampling in different relevant media (air, water, soil, food, tissue etc.)
    - Agree on relevant measures for reporting exposure (e.g., particle mass vs. particle number) (Monikh et al., 2022)
    - Standardize methods to detect and quantify chemicals and contaminants leaching from MNPs
2. Quality Assurance and Quality Control (QA/QC) (Kosuth et al., 2023)
    - Mandate detailed reporting on QA/QC measures in all studies in a systematic and standardized way.
    - Implement interlaboratory comparisons (ILCs) to validate methods and assess and improve reliability and accuracy and comparability of the data between laboratories and researchers
3. Measurement Techniques (Lou et al., 2022; Monikh et al., 2022; Schvartz et al., 2023; Ramsperger et al., 2023)
    - Standardize analytical techniques for detecting MNPs, including particle number-based and mass-based methods (Lou, 2022; Wieland, 2022)
    - Develop reference materials for instrument calibration, identify detection limits and ensure these are consistently reported in studies (Kokalj, 2023).
    - Validate dispersion, digestion/extraction protocols including the use of blanks, to prevent contamination and ensure integrity of MNPs.
4. Data Reporting and Transparency (Monikh et al., 2022)
    - Ensure detailed reporting of methodologies, including sampling, sample preparation, and analytical procedures.
    - Promote transparency in the production of plastics and the supply chain to provide more information on possible end-of-life treatment of the product, and on the hazard potential of associated additives and contaminants of high concern.
    - Develop databases of typical additive contents and toxicological profiles for different polymers (Nelis et al., 2023)
    - Use of a standardized data reporting sheet, such as proposed by Kokalj et al. (2023), based on the study of Kokalj et al. (2021)

Key areas for harmonization and quality assurance of MNP-hazard related research include:

1. Selection of Relevant MNPs:
   - Use human exposure-relevant MNPs and media for testing (Lou et al., 2022).
   - Ensure test materials reflect naturally weathered/aged particles in terms of size, shape, surface properties, and concentrations (Wieland et al., 2022).
   - Thoroughly characterize MNPs before and after testing (Zhang et al., 2021; Wieland et al., 2022)
   - Address the challenge of mimicking particle aging in controlled laboratory conditions.
2. Standardized Reference Materials (Kokalj et al., 2023; Kosuth et al., 2023; Monikh et al., 2022):
   - Develop suitable reference materials for testing, particularly for nanoplastics.
   - Develop standardized reference materials for positive and negative controls.
   - Ensure the use of natural control particles to compare MNP toxicity to natural particulate matter and homologues.
   - Data reporting sheet proposed by Kokalj et al., 2023 and Kokalj et al., 2021, to increase data FAIRness, in particular its completeness, findability and reusability
3. Toxicity Testing and Experimental Design (Lou et al., 2023; Schvartz et al., 2023)
   - Adapt toxicity tests to reflect all relevant human (worker, consumer, vulnerable groups) and environmental exposure routes (water, air, food, etc).
   - Harmonize protocols for in vitro and in vivo studies to estimate any biological effects or no effects of MNPs to humans (Adler et al., 2024).
   - Test MNP toxicity in relation to physico-chemical properties (e.g., size, shape) using cell culture and animal models.
   - Standardize dispersions and avoid changes of measurand and cross-contamination.
   - Usage of a standardized data reporting sheet such as proposed by Kokalj et al., 2023 and Kokalj et al., 2021, to increase the completeness and findability of data



The graphic (left) summarizes key points from Adler et al. (2024), Kokalj et al. (2023), Lou et al. (2023), Monikh et al. (2022), Wieland et al. (2022), and Zhang et al. (2021).

It highlights various aspects of harmonization across different research stages and presents measures for standardization.

Given the diverse and heterogeneous nature of MNPs, full standardization is neither feasible nor practical, making context-specific approaches essential.

Conclusions for Policy

To ensure future research employs relevant and representative MNPs and determines hazard potential for realistic exposure conditions, the expanded scope of methodologies must be complemented by increased harmonization of exposure and hazard assessments. This harmonization will improve the precision and accuracy of measurements across laboratories, develop further standardized testing methods and protocols, and enhance the reliability of measurements and models. It can be achieved through the development of standards covering all aspects of MNP characterization, measurement, and toxicity testing. Additionally, promoting interlaboratory comparisons and knowledge sharing can improve consistency between laboratories, standardize QA/QC practices, and foster collaboration among researchers. However, due to the complex nature of MNPs and the significant differences between particles in particular caused by their associated chemicals; any selected methods will need to be individualized - it is highly unlikely that there will be a one-size-fits-all solution. Harmonization and, in the longer term, standardization, addresses not only the analytical and testing part, but even more the necessity to develop and agree on reliable sampling and sample preparation methods to arrive at precise exposure estimates.

This calls for dedicated funding of method development and validation, quality assurance and standardization to support the production of more reliable, comparable, and actionable data that are fit for policy and regulatory purposes.

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