INTERNATIONAL JOURNAL OF NEXT-GENERATION ENGINEERING AND TECHNOLOGY (IJNGET)

eISSN: 3087-4319

Volume. 02, Issue. 09, pp. 27-31, September 2025

Human Exposure to Microplastics: Pathways, Internal Distribution, Analytical Detection, and Emerging Toxicological Implications

Dr. Elena Marovic

Department of Environmental Health Sciences, University of Belgrade, Serbia

Article received: 01/09/2025, Article Accepted: 15/09/2025, Article Published: 30/09/2025

ABSTRACT

The global proliferation of plastic materials has led to an unprecedented accumulation of microplastics and nanoplastics in natural ecosystems, with growing evidence indicating their pervasive presence within the human body. Recent advancements in analytical detection have confirmed microplastics in human blood, lung tissue, liver tissue, and other biological matrices, raising profound concerns regarding their potential health implications. This article presents a comprehensive and theoretically grounded examination of human exposure to microplastics, focusing on environmental sources, exposure pathways, internal distribution mechanisms, detection methodologies, and emerging toxicological evidence. Drawing strictly on peer-reviewed references, this work synthesizes atmospheric, dietary, and occupational exposure routes, while critically examining the physicochemical properties of microplastics that influence bioavailability and biological persistence. Particular emphasis is placed on analytical challenges in detecting microplastics in complex human samples, including the application of μFTIR, GC-MS pyrolysis, and nanoparticle tracking analysis. The article further explores mechanistic insights into tissue translocation, inflammatory responses, oxidative stress, reproductive toxicity, and potential synergistic effects with co-exposed pollutants such as metals and metalloids. By integrating findings from environmental science, toxicology, and biomedical research, this study highlights critical knowledge gaps, methodological limitations, and future research priorities essential for understanding the long-term implications of microplastic exposure on human health. The analysis underscores the urgent need for standardized definitions, harmonized methodologies, and interdisciplinary approaches to accurately assess risk and inform public health policy.

Keywords: Microplastics, Human exposure, Toxicology, Analytical detection, Atmospheric pollution, Biodegradation

INTRODUCTION

The rapid expansion of plastic production since the mid-twentieth century has fundamentally altered material consumption patterns and environmental chemistry on a global scale. Plastics, valued for their durability, flexibility, and low cost, have become integral to modern life, yet these same properties contribute to their environmental persistence. Over time, larger plastic items undergo physical, chemical, and biological degradation, fragmenting into microplastics typically defined as particles smaller than 5 millimeters (Frias et al., 2019). Continued fragmentation results in nanoplastics, which exist at scales capable of interacting directly with cellular and molecular systems (Andrady, 2017). While early research focused predominantly on marine ecosystems, recent studies have shifted attention toward atmospheric transport, terrestrial contamination, and direct human exposure pathways.

The recognition that microplastics are not confined to environmental compartments but are detectable within the human body marks a critical turning point in environmental health research. Seminal studies have reported the presence of plastic particles in human blood (Leslie et al., 2022), lung tissue (Amato-Lourenço et al., 2021), and liver tissue (Horvatits et al., 2022), providing empirical evidence that environmental plastic pollution has crossed biological barriers previously considered robust. These findings challenge traditional assumptions regarding the inertness of plastics and raise urgent questions about long-term health consequences.

Despite growing public and scientific concern, the health implications of chronic microplastic exposure remain insufficiently understood. The complexity arises from the heterogeneity of microplastics themselves, which vary in polymer composition, size, shape, surface chemistry, and associated chemical additives (Andrady, 2017). Furthermore, microplastics can act as vectors for environmental pollutants, including heavy metals and organic contaminants, potentially amplifying toxic effects through combined exposure (Chen et al., 2020). The interaction between microplastics and biological systems is therefore multifaceted, involving physical irritation, chemical toxicity, and immunological responses.

Another challenge lies in the lack of standardized methodologies for detecting and quantifying microplastics in human tissues. Analytical techniques such as μFTIR spectroscopy, GC-MS pyrolysis, and nanoparticle tracking analysis each present distinct advantages and limitations, particularly when applied to complex biological matrices (Gomiero et al., 2021; Kutralam-Muniasamy et al., 2023). The absence of harmonized protocols complicates cross-study comparisons and risk assessment.

This article aims to address these challenges by providing an in-depth, theoretically elaborated synthesis of current knowledge on microplastics in the human body. By integrating evidence from environmental monitoring, analytical chemistry, toxicology, and biomedical research, the study seeks to identify critical gaps in understanding, explore mechanistic pathways of toxicity, and outline directions for future research. The focus remains strictly on peer-reviewed sources, ensuring scientific rigor while emphasizing the urgent need for interdisciplinary collaboration in addressing this emerging public health concern.

METHODOLOGY

The methodological framework of this study is grounded in a qualitative, integrative review approach, synthesizing peer-reviewed literature to construct a comprehensive understanding of human exposure to microplastics. Rather than employing experimental or statistical modeling techniques, this article relies on in-depth theoretical analysis and critical interpretation of existing empirical findings, consistent with the nature of emerging and heterogeneous research in this field.

The selection of references was strictly limited to the provided literature, encompassing studies published in high-impact journals across environmental science, toxicology, analytical chemistry, and biomedical research. These references collectively represent foundational discoveries, methodological advancements, and recent breakthroughs in the detection and assessment of microplastics in human tissues. Emphasis was placed on studies that directly investigated human exposure or provided mechanistic insights relevant to human health outcomes.

Analytical methodologies discussed in this article, such as μFTIR spectroscopy, GC-MS pyrolysis, and nanoparticle tracking analysis, were examined through a comparative lens. This involved evaluating their theoretical principles, detection limits, strengths, and constraints when applied to biological samples. The methodological challenges associated with sample contamination, polymer identification, and size discrimination were critically analyzed based on reported experimental practices (Rodriguez-Saona and Allendorf, 2011; Filipe et al., 2010).

Toxicological evidence was synthesized from both human observational studies and controlled animal experiments. While animal models cannot fully replicate human physiology, they provide essential mechanistic insights into reproductive toxicity, oxidative stress, and inflammatory responses induced by microplastic exposure (Hou et al., 2021). Human studies examining tissue accumulation and co-exposure with metals and metalloids were analyzed to contextualize potential health risks (Calogero et al., 2021).

Environmental exposure pathways were explored through atmospheric, dietary, and waterborne studies, with particular attention to the role of airborne microplastics as an underappreciated route of inhalation exposure (Chen et al., 2020). The methodological implications of measuring microplastics in air and drinking water were discussed in relation to human intake estimates and internal dose assumptions.

Throughout the analysis, methodological limitations and uncertainties were explicitly acknowledged, including small sample sizes, variability in detection thresholds, and the absence of longitudinal human health data. This reflective approach ensures that conclusions are framed within the current state of scientific knowledge while highlighting areas requiring further methodological refinement and empirical investigation.

RESULTS

The synthesis of existing literature reveals a consistent and compelling body of evidence demonstrating the presence of microplastics across multiple human biological matrices. One of the most significant findings is the detection of plastic particles in human blood, which provides direct evidence of systemic exposure and internal distribution (Leslie et al., 2022). The polymers identified in blood samples, including polyethylene terephthalate and polystyrene, reflect common consumer plastic materials, suggesting that everyday environmental exposure is sufficient to facilitate internalization.

Inhalation emerges as a critical exposure pathway, supported by the detection of airborne microplastics in urban and indoor environments (Chen et al., 2020). The study by Amato-Lourenço et al. (2021) provided histological evidence of microplastics embedded within human lung tissue, particularly in individuals residing in highly polluted urban areas. The morphology of these particles, often fibrous, aligns with atmospheric deposition patterns and highlights the respiratory system as a primary interface for exposure.

Beyond the respiratory system, evidence of microplastics in liver tissue indicates the capacity for translocation from initial entry points to internal organs (Horvatits et al., 2022). The liver’s role in detoxification makes it a critical organ for assessing potential metabolic and inflammatory consequences. The detection of microplastics in cirrhotic liver tissue raises questions about whether plastic accumulation exacerbates existing pathology or preferentially accumulates in compromised tissues.

Analytical studies examining drinking water systems have demonstrated the presence of microplastics across treatment stages, suggesting that ingestion represents another continuous exposure route (Gomiero et al., 2021). The polymer types identified in water samples often mirror those found in human tissues, reinforcing the plausibility of ingestion-driven internalization.

From a toxicological perspective, experimental evidence indicates that microplastics can induce reproductive toxicity, oxidative stress, and inflammatory responses. Hou et al. (2021) demonstrated that polystyrene microplastics caused testicular damage and impaired spermatogenesis in mice, suggesting potential risks to male reproductive health. While direct extrapolation to humans remains uncertain, these findings align with broader concerns regarding endocrine disruption and fertility outcomes.

The interaction between microplastics and other environmental contaminants further complicates the exposure landscape. Studies on combined exposure to metals and metalloids indicate that co-contaminants may amplify biological effects through additive or synergistic mechanisms (Calogero et al., 2021). Microplastics, by virtue of their surface properties, can adsorb and transport such contaminants, potentially altering their bioavailability and toxicity profiles.

Overall, the results synthesized in this article underscore the ubiquity of microplastics in human-relevant environments and tissues, while highlighting significant variability in detection outcomes due to methodological differences. Despite these uncertainties, the convergence of evidence across independent studies strongly supports the conclusion that microplastic exposure is a measurable and biologically relevant phenomenon in humans.

DISCUSSION

The detection of microplastics within human tissues represents a paradigm shift in our understanding of environmental pollution and its interface with human health. Historically, plastics were regarded as largely inert materials, posing minimal risk beyond physical litter and ecological harm. However, the emerging evidence synthesized in this article challenges this assumption, revealing complex interactions between microplastics and biological systems that warrant serious consideration.

One of the most significant implications of these findings is the confirmation that microplastics can cross biological barriers previously thought to be selectively impermeable. The presence of plastic particles in blood implies translocation across epithelial surfaces, potentially via endocytosis, paracellular transport, or microfold cell-mediated uptake. While the precise mechanisms remain incompletely characterized, the ability of particles to enter systemic circulation raises concerns regarding chronic, low-dose exposure and cumulative effects over the human lifespan.

The respiratory system appears particularly vulnerable, given continuous exposure to airborne microplastics in urban and indoor environments. Fibrous particles, similar in morphology to known respiratory hazards, may induce localized inflammation, tissue remodeling, or impaired pulmonary function over time (Amato-Lourenço et al., 2021). The long-term consequences of such exposure remain unknown, particularly in sensitive populations such as children, the elderly, and individuals with pre-existing respiratory conditions.

The liver findings reported by Horvatits et al. (2022) introduce additional complexity, as they suggest that microplastics may accumulate preferentially in diseased tissues or contribute to disease progression. While causality cannot be established based on current evidence, the co-occurrence of microplastics and liver pathology underscores the need for mechanistic studies exploring interactions between plastic particles, immune responses, and metabolic processes.

Toxicological evidence from animal models provides valuable insights but must be interpreted cautiously. The reproductive toxicity observed in mice exposed to polystyrene microplastics (Hou et al., 2021) suggests potential endocrine-disrupting effects, yet differences in exposure routes, doses, and physiology limit direct translation to human risk. Nonetheless, these findings align with broader concerns regarding declining reproductive health and environmental exposures.

Analytical challenges remain a central limitation in advancing this field. The lack of standardized definitions and detection protocols hampers comparability across studies and undermines quantitative risk assessment (Frias et al., 2019; Kutralam-Muniasamy et al., 2023). Techniques such as μFTIR and GC-MS pyrolysis offer robust polymer identification but struggle with detecting the smallest particles, while nanoparticle tracking analysis introduces uncertainties related to particle composition and aggregation (Filipe et al., 2010).

Future research must therefore prioritize methodological harmonization, longitudinal human studies, and interdisciplinary collaboration. Integrating environmental monitoring with clinical and epidemiological research will be essential for elucidating exposure-response relationships and identifying vulnerable populations. Additionally, advances in biodegradation and microbial degradation of plastics, while promising from an environmental remediation perspective, must be evaluated for their potential to generate smaller, more bioavailable particles (Wei et al., 2020; Xiang et al., 2023).

CONCLUSION

The body of evidence reviewed in this article unequivocally demonstrates that microplastics have transitioned from an environmental contaminant to a detectable component of the human internal environment. The presence of plastic particles in blood, lung tissue, and liver tissue underscores the permeability of human biological systems to anthropogenic pollutants and challenges longstanding assumptions about the inertness of plastics.

While definitive conclusions regarding health outcomes remain premature, the convergence of exposure data, analytical advancements, and toxicological evidence signals a pressing need for precautionary approaches. Chronic exposure to microplastics, particularly in combination with other environmental contaminants, represents a complex and potentially significant public health concern.

Addressing this challenge will require sustained interdisciplinary efforts, encompassing standardized analytical methodologies, mechanistic toxicology, and long-term human studies. As plastic production continues to rise globally, understanding and mitigating the human health implications of microplastic exposure must become a central priority within environmental health research and policy development.

REFERENCES

1. Amato-Lourenço, L.F., et al. (2021). Presence of airborne microplastics in human lung tissue. Journal of Hazardous Materials.
2. Andrady, A.L. (2017). The plastic in microplastics: A review. Marine Pollution Bulletin.
3. Calogero, A.E., et al. (2021). Exposure to multiple metals/metalloids and human semen quality: A cross-sectional study. Ecotoxicology and Environmental Safety.
4. Chen, G., et al. (2020). Mini-review of microplastics in the atmosphere and their risks to humans. Science of the Total Environment.
5. Frias, J.P.G.L., et al. (2019). Microplastics: Finding a consensus on the definition. Marine Pollution Bulletin.
6. Gomiero, A., et al. (2021). Application of GCMS-pyrolysis to estimate the levels of microplastics in a drinking water supply system. Journal of Hazardous Materials.

7. Horvatits, T., et al. (2022). Microplastics detected in cirrhotic liver tissue. EBioMedicine.

8. Hou, B., et al. (2021). Reproductive toxicity of polystyrene microplastics: In vivo experimental study on testicular toxicity in mice. Journal of Hazardous Materials.

9. Kutralam-Muniasamy, G., et al. (2023). Microplastic diagnostics in humans: Progress, problems, and prospects. Science of the Total Environment.

10. Leslie, H.A., et al. (2022). Discovery and quantification of plastic particle pollution in human blood. Environment International.

11. Rodriguez-Saona, L.E., Allendorf, M.E. (2011). Use of FTIR for rapid authentication and detection of adulteration of food. Annual Review of Food Science and Technology.

12. Filipe, V., et al. (2010). Critical evaluation of nanoparticle tracking analysis by NanoSight for the measurement of nanoparticles and protein aggregates. Pharmaceutical Research.

13. Wei, R., et al. (2020). Possibilities and limitations of biotechnological plastic degradation and recycling. Nature Catalysis.

14. Xiang, P., et al. (2023). A novel bacterial combination for efficient degradation of polystyrene microplastics. Journal of Hazardous Materials.