

Microplastics and human health: a narrative review of current evidence, knowledge gaps, and future research directions

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ABSTRAK

Microplastics (MPs) have become widespread in food, water, air, and various consumer products, raising concerns about their potential impact on human health. Although research on this topic has grown rapidly, existing evidence remains fragmented, and the extent of associated health risks is not well understood. This narrative review aims to synthesize current evidence on human exposure to MPs, their biological mechanisms, and potential health effects, while identifying key knowledge gaps and future research priorities. This narrative review synthesized recent findings from peer-reviewed studies published between 2015 and 2025. Literature was identified through major scientific databases and manual reference checks, focusing on exposure pathways, biological mechanisms, and possible health outcomes related to MPs. Because this review relies solely on previously published data, ethical approval was not required. The literature shows that humans are exposed to MPs primarily through ingestion and inhalation. Experimental studies indicate that MPs can cross epithelial barriers, induce oxidative stress, and provoke inflammatory responses, although human evidence remains limited. Potential health implications include gastrointestinal disturbances, respiratory irritation, and possible reproductive or metabolic effects. However, inconsistent detection methods and limited epidemiological data hinder clear risk assessment. While MPs may pose emerging health risks, substantial knowledge gaps remain. Future research should prioritize standardized analytical methods, realistic exposure assessments, and long-term human studies. Strengthening preventive policies and reducing plastic pollution will be essential to protect public health.



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1. Introduction

Plastics have become inseparable from modern life. From packaging and clothing to electronics and medicine, they shape the way we live, work, and consume (Zurub et al., 2024). Yet, the same qualities that make plastics so useful—their durability and resistance to breakdown—have turned them into one of the world's most pressing environmental challenges (Campanale et al., 2020; Okoffo et al., 2021). Over time, discarded plastics

fragment into tiny particles called MPs (less than 5 mm) and even smaller nanoplastics (NPs), which are now found almost everywhere: in oceans and rivers, in soil, in the air we breathe, and even in remote environments once thought to be pristine (Bora et al., 2024; Ragusa et al., 2021; C. Wang et al., 2021). In 2018 alone, according to Hirt and Body-Malapel, global plastic waste was estimated at over 359 million metric tons, with at least 4.8 to 12.7 million tons entering the oceans every year (Hirt & Body-Malapel, 2020). These wastes are predicted to double by 2040 (Statista Research Department, 2025). On land, mismanaged plastic waste has accumulated in rivers, soils, and landfills, creating a persistent source of MPs pollution that cycles back into food chains and the human environment (Bora et al., 2024; Zurub et al., 2024).

What is more concerning is that humans are not only surrounded by these particles but are also directly exposed to them. We ingest MPs through food and water—studies have identified them in seafood, ready-to-eat meals, table salt, and bottled water (Kwon et al., 2020; Li et al., 2024; Praveena & Laohaprapanon, 2021). We inhale them from household dust, textiles, and city air (Zhao et al., 2023). And evidence now shows that they do not simply pass through the body unnoticed. Micro- and nanoparticles (MNPs) have been detected in human blood, lungs, placenta, gastrointestinal tract, and even penetrate the blood-brain barrier, suggesting that these particles can cross biological barriers and linger in tissues (Amato-Lourenço et al., 2021; Ibrahim et al., 2021; Ragusa et al., 2021; Turrone et al., 2021).

The health implications of this are only beginning to surface. Laboratory studies suggest that MPs can trigger oxidative stress, inflammation, and hormonal disruption, and may interfere with the gut microbiome (Liu et al., 2023; Winiarska et al., 2024). These biological changes are linked with a wide range of health outcomes—from digestive and respiratory issues to reproductive and metabolic disorders (Amato-Lourenço et al., 2021; Bora et al., 2024; Liu et al., 2023). Epidemiological evidence is scarce, fragmented, and often inconsistent, leaving many questions about how much exposure is harmful, who is most at risk, and what the long-term consequences might be.

One of the biggest challenges in this field is that researchers still lack a common language and approach. Different studies use different methods to detect and measure MPs, making comparisons difficult (Gimiliani & Izar, 2022; Huang et al., 2024). The smallest particles—NPs—are especially hard to trace, yet they may pose the greatest risk because of their ability to penetrate cells and tissues (Adhikari et al., 2022; Lai et al., 2022). Vulnerable populations, such as children and pregnant women, have received little focused attention, despite being potentially more sensitive to environmental hazards. And in low- and middle-

income countries, where plastic waste is high and waste management often inadequate, the health impacts of MPs are likely underestimated.

These uncertainties do not mean the issue can be ignored. On the contrary, they emphasize the importance of bringing together researchers from toxicology, epidemiology, clinical sciences, and public health to map what we know, expose what we do not, and inform future research. MPs are more than just an environmental problem—they are emerging as a public health concern that cuts across borders, disciplines, and generations.

Despite the growing number of studies on MPs and human health, the evidence remains fragmented across disciplines and often focuses on isolated exposure pathways or experimental findings. Differences in detection methods and study designs further complicate the interpretation and comparison of results. Therefore, a comprehensive synthesis of the available evidence is needed to clarify current knowledge, identify key gaps, and guide future research and public health policy.

This narrative review takes stock of the current evidence on MPs and human health. We examine how humans are exposed, the biological mechanisms proposed, the findings of toxicological and epidemiological studies to date, and how these findings inform public health and risk assessment. Most importantly, we highlight the critical knowledge gaps that remain and point toward the directions research and policy must take to protect health in a world increasingly saturated with plastic.

2. Methods

This review was conducted as a narrative synthesis rather than a systematic review, to map what is currently known about MPs and human health. Relevant literature was identified through searches in PubMed, ScienceDirect, Google Scholar, and direct searches on Google, focusing on articles published between 2015 and 2025 to capture the most recent developments. Search terms included combinations of “MPs,” “nanoplastics,” “human health,” “exposure,” “toxicology,” “epidemiology,” and “risk assessment.” The initial search results were screened based on titles and abstracts to identify studies relevant to microplastics and human health. We considered peer-reviewed original studies, reviews, and authoritative reports that explored human exposure pathways, toxicological or epidemiological findings, and public health implications. Articles focusing exclusively on ecological or marine impacts without relevance to humans were excluded. Duplicate records and clearly irrelevant articles were also removed during the screening stage. Because the evidence base is still emerging and diverse in scope, we did not apply rigid inclusion criteria;

instead, we aimed to integrate insights across disciplines to provide a comprehensive overview of current evidence, highlight key knowledge gaps, and suggest future research directions. Because this work is based solely on a review of existing literature and does not involve human participants, animals, or personal data, ethical clearance was not required.

3. Results and Discussion

The rapid increase in global plastic production and waste generation has led to the widespread presence of MPs in air, water, soil, and food chains. Recent studies have detected MP particles in drinking water, seafood, table salt, and even the human placenta, underscoring that exposure is practically unavoidable in daily life (Kosuth et al., 2018; Ragusa et al., 2021; Schymanski et al., 2018). Although many studies have been conducted, much of the existing evidence remains fragmented, focusing on specific pathways or short-term biological effects. The growing body of research collectively suggests that MPs may have implications for human health, but the mechanisms of harm and the extent of real-world risk remain poorly understood.

Humans are exposed to MPs through multiple environmental routes, most notably ingestion, inhalation, and, to a lesser extent, dermal contact (Prata et al., 2020; Rahman et al., 2021; W. Wang & Wang, 2018). Ingestion is considered the primary route, as MPs have been found in a wide range of foods such as fish, shellfish, salt, and bottled water (Karami et al., 2017; Kosuth et al., 2018; Schymanski et al., 2018). A study by Cox et al. has estimated that the average adult and children may consume tens of thousands of MP particles annually through food and beverages alone (Cox et al., 2019). Airborne MPs from sources like synthetic fabrics, tire wear, and urban dust can be inhaled—especially in crowded or industrial areas—with indoor spaces often posing even greater exposure due to fiber buildup from clothing and household materials (Bhat, 2024; Dris et al., 2015, 2017; Islam et al., 2024; Kacprzak & Tijing, 2022). Dermal exposure, although less studied, can occur through personal care products containing microbeads or contact with contaminated water (Enyoh et al., 2020; Han & Kim, 2025). Collectively, these findings highlight the pervasive nature of MP exposure and emphasize the need for a more comprehensive understanding of how these particles interact with the human body.

Once MPs enter the body, they can interact with biological systems in ways that may influence normal physiological processes (Jiao et al., 2025). Smaller particles, especially NPs, are capable of crossing epithelial barriers in the gut and respiratory tract (Danopoulos et al., 2020; Winiarska et al., 2024). Experimental studies have shown that these particles

can enter the bloodstream and potentially reach secondary organs, including the liver, kidneys, and heart (Horvatits et al., 2022; Pironti et al., 2022; Yang et al., 2023). Laboratory evidence consistently demonstrates that MPs can induce oxidative stress, inflammation, promote apoptosis, and cellular damage—processes that have been linked to various chronic diseases (Amato-Lourenço et al., 2021; Enyoh et al., 2020; Xu et al., 2019). Also, a study by Lee et al. found that MP¹ particle exposure significantly alters coagulation and inflammatory markers (D.-W. Lee et al., 2024). MPs can also carry pollutants or release chemicals like phthalates and bisphenol A (BPA), which may worsen their harmful effects by disrupting hormones and interfering with lipid balance and blood vessel function (Abbas et al., 2025; Nouri et al., 2025). Although most findings come from in vitro and animal models, they raise important concerns about how these particles may behave in the human body over time.

Although clear evidence in humans is still limited, MP exposure may affect multiple organs, with studies suggesting it can disrupt gut balance, increase intestinal permeability, and trigger localized inflammation (Lazaridis et al., 2025; Wibowo et al., 2021; Zhou et al., 2025). Respiratory exposure may contribute to airway irritation or inflammation, particularly among individuals in high-exposure environments such as industries handling synthetic materials (Saha & Saha, 2024). Emerging evidence from reproductive and developmental studies suggests that certain plastic particles and chemicals may interfere with hormonal activity or sperm quality, although human data remain scarce (Calogero et al., 2021; Hou et al., 2021; Virtanen et al., 2017). A study by Guo et al. found that 34 of 45 sperm samples have MPs, which significantly affect motility, and do not significantly affect total sperm count (Guo et al., 2025). While these findings do not establish direct causal links, they present plausible pathways through which MPs could influence human health, emphasizing the urgent need for more robust studies.

Despite growing research, major gaps remain in understanding MPs health risks, largely because we still lack reliable, standardized methods to detect and measure them—especially the tiniest particles—in both the environment and the human body (Raju K. Chalannavar et al., 2025). Differences in analytical techniques, particle size definitions, and sampling protocols lead to inconsistencies across studies, making comparison difficult (Sharma et al., 2024). Many laboratory experiments also rely on exposure concentrations far higher than those encountered in real-life settings, raising questions about the relevance of their findings to human populations (Pulusu et al., 2025; Zhang et al., 2025). Furthermore, epidemiological studies remain limited in number and scope, largely due to the difficulty of accurately assessing long-term exposure (Lalrinfela et al., 2024; Y. Lee et al., 2023). These

methodological limitations highlight the need for more harmonized research frameworks to advance the field.

Future research should focus on more realistic exposure assessments, improved detection technologies, and well-designed human studies to clarify the long-term health effects of MPs. Advances in spectroscopy, imaging, and particle tracking may improve identification of MNPs in human tissues, while longitudinal cohort studies are needed to examine links between chronic exposure and disease, especially in vulnerable groups such as pregnant women, children, and those in high-pollution areas. At the same time, public health efforts should incorporate MPs monitoring into environmental, food safety, and occupational policies to reduce exposure, supported by strong collaboration between scientists, policymakers, and healthcare professionals.

4. Conclusion

MPs are now widely present in food, water, and air, making human exposure increasingly unavoidable. Current evidence suggests that these particles may induce biological effects such as inflammation and oxidative stress, but the extent of their health impacts in humans remains uncertain due to limited and inconsistent data. Future research should prioritize standardized detection methods, realistic exposure assessments, and long-term epidemiological studies to clarify potential health risks. From a public health perspective, efforts to reduce plastic pollution, improve waste management, and strengthen environmental monitoring are essential to minimize human exposure and protect population health.

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