Environ. Health Pollut. Res., 2026, 1(2), 109-119

Environmental Health and Pollution Research

Homepage: www.ehpr.ir



ISSN: 3115-9281

Microplastics and human health: A review of sources, exposure pathways, toxicological evidence, and risk assessment challenges

M. Rezaee [1]

[1]Department of Biology, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran

ARTICLE INFO

Paper Type: Review Paper

Received: 03 September 2026
Revised: 04 November 2026
Accepted: 05 November 2026
Published: 05 November 2026

Keywords
Emerging Contaminants
Human Exposure
Human Health
Microplastics
Risk Assessment
Toxicity

Corresponding author:
M. Rezaee
mehran.r72@gmail.com

ABSTRACT

Microplastics (MPs) are plastic particles smaller than 5 mm, detected in aquatic, terrestrial, and atmospheric environments, food, drinking water, and human biological samples, raising concerns about environmental quality and human health. This review examines sources, environmental distribution, human exposure pathways, toxicological evidence, analytical challenges, and health-risk assessment approaches. Ingestion and inhalation are considered the principal exposure pathways in human-health assessments, while evidence for dermal uptake remains less developed. MPs have been reported in human blood, placental tissue, gastrointestinal samples, and other biological matrices, indicating internal exposure; however, detection in human tissues should not be interpreted as evidence that MPs cause a particular disease. Experimental studies report oxidative stress, inflammation, cytotoxicity, immune responses, and reproductive or respiratory effects, but much evidence comes from cellular and animal models. Human epidemiological evidence remains limited and heterogeneous; a 2024 rapid systematic review identified only three human observational studies alongside 28 animal studies addressing reproductive, respiratory, and digestive outcomes. Major uncertainties arise from differences in polymer composition, particle size and shape, surface properties, environmental aging, additives, associated contaminants, sampling procedures, and analytical detection limits, restricting study comparability and complicating quantitative risk assessment. Future research should prioritize harmonized sampling and analytical methods, improved characterization of small MPs and nanoplastics, environmentally relevant exposure scenarios, longitudinal human studies, and integrated exposure-hazard frameworks. Current evidence supports continued environmental monitoring and source-control measures, while conclusions regarding specific human diseases should remain proportionate to available evidence.

Highlights

- Microplastics are widely detected in environmental, food, water, and human matrices.
- Ingestion and inhalation are the main exposure pathways in human-health assessments.
- Experimental studies show oxidative stress, inflammation, cytotoxicity, and immune effects.
- Limited human evidence and methodological heterogeneity hinder quantitative risk assessment.
- Harmonized analytical methods and longitudinal human studies are needed to reduce uncertainty.

Citing:
Rezaee, M. (2026). Microplastics and human health: A review of sources, exposure pathways, toxicological evidence, and risk assessment challenges. *Environmental Health and Pollution Research*, 1(2), 109-119. doi: 10.22034/ehpr.2026.599137.1018

1. Introduction

Plastic pollution has generated a persistent environmental contamination problem because plastic materials can remain in the environment and undergo fragmentation into progressively smaller particles. Microplastics (MPs) are commonly defined as plastic particles smaller than 5 mm. They may be generated directly as small particles or formed

secondarily through the degradation and fragmentation of larger plastic materials. Their physical and chemical characteristics vary according to polymer type, size, shape, surface properties, and environmental history (Gowda et al., 2023; Thisakya & Dissanayake, 2025).

MPs have been reported in water, sediments, soil, atmospheric particles, food, and drinking water. Their occurrence in multiple environmental compartments creates several potential pathways for human exposure. A systematic review of food, drinking water and human samples found substantial variation in the polymer types and shapes reported across studies and showed that the particle-size range investigated differed considerably among environmental and human samples (Kuijer et al., 2010; Jayakrishnan et al., 2013).

The health implications of this exposure remain an active area of investigation. MPs have been detected in human biological samples, including blood and placental tissue, demonstrating that environmental exposure can result in internal contact with plastic particles. At the same time, the detection of MPs in a biological matrix does not establish that they produce a specific adverse health outcome (Akdogan & Guven, 2019; Basumatary et al., 2025).

The distinction between exposure, biological response and disease is particularly important because a substantial part of the current toxicological literature is based on experimental models. In a rapid systematic review, (Carvajal et al., 2026; Chartres et al., 2024) identified three human observational studies and 28 animal studies addressing reproductive, respiratory and digestive outcomes. The authors concluded that microplastic exposure was suspected to adversely affect sperm quality and digestive immunosuppression, while the available human evidence remained limited.

The objective of this review is to evaluate MPs from an environmental-health perspective by linking their sources and environmental occurrence with human exposure, biological effects, analytical limitations, and risk-assessment requirements. Particular attention is given to the distinction between established observations and hypotheses that still require confirmation (Christodoulou et al., 2026; Eberhard et al., 2024).

2. Definition and classification of microplastics

The 5-mm threshold is widely used to define MPs, although terminology and size boundaries vary among scientific studies. The distinction between microplastics and nanoplastics is particularly relevant because analytical methods that can identify larger MPs may not adequately characterize particles at the nanoscale (Akdogan & Guven, 2019; Epeslidou et al., 2026).

MPs are commonly divided according to their origin. Primary MPs are produced or used at microscopic dimensions, whereas secondary MPs result from the fragmentation of larger plastic materials. The environmental characteristics of secondary particles can differ from those of commercially produced particles because weathering changes their surface properties and physical structure. A review of micro- and nanoplastic toxicology noted that many experimental studies have relied on commercially available primary particles rather than particles that have undergone environmental weathering (Fitch et al., 2025; Garcia et al., 2026).

Particle shape is another relevant characteristic. Fragments, fibers, films, foams, and pellets have all been reported in environmental and biological samples. In the systematic review by (Arfin & Nakhate, 2026). fibers were frequently reported in human samples, while fragments and other morphologies were also observed in food and drinking-water studies (Guo et al., 2026). Table 1 summarizes the main characteristics used to describe MPs, including size, polymer type, shape, origin, surface condition, and associated chemicals.

Table 1 Main characteristics used to describe microplastics

Characteristic	Common categories	Relevance
Size	Micro-scale particles; smaller particles approaching the nanoscale	Influences transport, detection, and potential biological interactions
Polymer	PE, PP, PET, PS, PVC, PA and others	Influences density, chemical properties and environmental behavior
Shape	Fragment, fiber, film, foam, pellet	Affects transport, deposition and biological interaction
Origin	Primary or secondary	Reflects production source or environmental fragmentation
Surface condition	Pristine or weathered	Environmental aging can change surface characteristics
Associated chemicals	Additives and environmental contaminants	May modify the chemical exposure associated with particles

Compiled from the reviewed literature (14)

3. Sources and environmental pathways

The release of MPs can occur at different stages of plastic production, use, disposal, and environmental degradation. Larger plastic materials can fragment through mechanical abrasion and weathering, while small particles can also be released directly from products and human activities. Synthetic textiles, plastic materials, urban dust, and industrial activities are among the sources considered in studies of airborne MPs (Hore et al., 2026; Hunt et al., 2024).

Once released, MPs can move among environmental compartments. Water can transport particles from terrestrial sources toward rivers, lakes and marine environments. Atmospheric transport can redistribute particles through deposition, while soils may receive MPs through wastewater-derived materials, agricultural practices, atmospheric deposition, and other pathways. A 2025 review of MP and nanoplastic dynamics emphasized that environmental transport occurs across aquatic and terrestrial systems and that interactions with environmental contaminants can further complicate their behavior (Hore et al., 2026; İçöz et al., 2026). Fig. 1 summarizes the sources, environmental transport routes, and human exposure pathways of MPs.

Airborne MPs have received particular attention because inhalation provides a direct route into the respiratory system

(Jenner et al., 2022). reviewed indoor and outdoor airborne MP and nanoplastic studies and identified major data gaps in exposure measurement and standardization (Johari et al., 2026).

A 2026 review likewise described airborne MPs as particles associated with sources such as textile fibers, urban dust and industrial emissions and emphasized that their atmospheric transport and deposition remain insufficiently characterized (Knol et al., 2010).

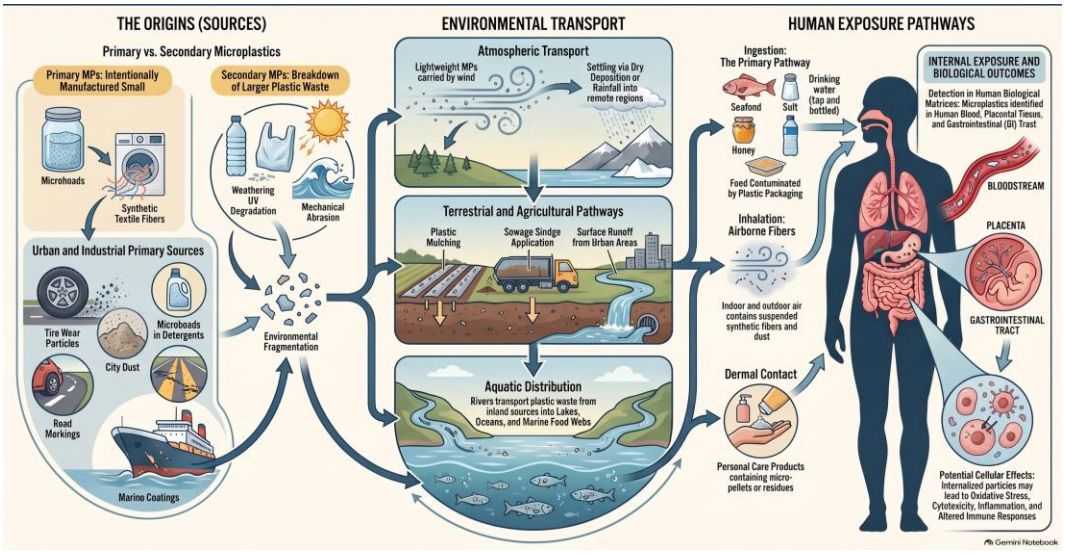


Fig. 1 Sources, environmental transport and human exposure pathways

4. Occurrence in environmental matrices

4.1 Water and drinking water

Drinking water is an important exposure medium because MPs can enter water supplies from environmental sources and potentially persist through parts of the water-treatment and distribution system. A 2024 review of drinking-water studies reported wide variation in MP concentrations among investigations and identified methodological differences as an important reason for the lack of direct comparability (Kumar et al., 2021; Kwon et al., 2020).

The size range considered in monitoring studies is particularly important. Smaller particles can be missed when filtration or identification procedures have relatively high detection limits. The systematic analysis by (Arfin & Nakhate, 2026; Lamas et al., 2026). showed that studies of human samples and drinking water often investigated smaller particles than studies of some food matrices.

4.2 Food

Food can contain MPs originating from environmental contamination, processing, handling, and packaging. Reported particles include several polymer types and morphologies, but quantitative comparisons among food groups remain difficult because analytical procedures differ (Arfin & Nakhate, 2026). Found differences in the types and shapes of MPs reported in food and human samples and emphasized the influence of particle-size detection limits (Li et al., 2024).

The presence of MPs in food is relevant to exposure assessment, but concentration data alone do not provide a direct estimate of absorbed dose. The fate of particles after ingestion depends on particle properties, gastrointestinal conditions, and biological interactions (Basumatary et al., 2025). Reviewed evidence concerning ingestion, distribution, and possible translocation within the human body (McLean et al., 2026).

4.3 Soil and terrestrial systems

Agricultural soils can receive MPs through several pathways, including plastic agricultural materials, wastewater-derived inputs, irrigation and atmospheric deposition. Once present in soil, particles can interact with soil minerals, organic matter, microorganisms, and other environmental constituents. A 2025 review of MP impacts on ecosystems emphasized that MPs can alter soil properties and microbial processes, although the magnitude and direction of these effects depend on particle characteristics and environmental conditions (Hore et al., 2026; Mohasin et al., 2025).

The transfer of MPs from soil to crops and subsequently to humans is an area of continuing investigation. Evidence for environmental occurrence does not automatically establish a quantitatively important contribution to human exposure, because transfer depends on particle size, plant species, soil conditions and other factors (Njema et al., 2026; Novillo-Del Álamo et al., 2026).

4.4 Atmospheric environment

Airborne MPs can originate from synthetic textiles, abrasion, urban dust and industrial sources. They may remain suspended or be deposited on indoor and outdoor surfaces (Jenner et al., 2022). concluded that substantial gaps remain in the quantitative characterization of human inhalation exposure (Parveen et al., 2026). The atmospheric pathway has two implications. First, inhalation can provide direct exposure to humans. Second, atmospheric deposition can redistribute particles into soil and water, connecting the atmospheric compartment with other environmental systems (Knol et al., 2010; Parveen et al., 2026).

5. Human exposure pathways

5.1 Ingestion

Ingestion is one of the principal pathways considered in human MP exposure assessments. Contaminated drinking water, food, and deposited particles can contribute to ingestion. However, exposure estimates vary according to consumption patterns, particle concentrations, particle-size ranges and analytical recovery (Paul et al., 2020; Piroozfar et al., 2026).

Li et al. (2024) reviewed human exposure through ingestion, inhalation and skin contact and discussed the subsequent distribution and possible translocation of MPs (Akdogan & Guven, 2019).

5.2 Inhalation

Airborne MPs can enter the respiratory tract. The available literature includes both indoor and outdoor environments, but estimates of inhaled dose remain uncertain because air-sampling methods, sampling duration, and particle-size detection vary substantially (Jenner et al., 2022). Standardized exposure measurement has been identified as a major research need (Płuciennik et al., 2024).

Evidence that airborne MPs can reach human respiratory tissues has also been reported (Akdogan & Guven, 2019; Rajput et al., 2026). Summarized evidence concerning inhalation and distribution, while earlier human tissue research has reported airborne MPs in lung tissue. These observations support the plausibility of internal respiratory exposure but do not by themselves establish adverse clinical outcomes (Rehman et al., 2026; Saha et al., 2026).

5.3 Dermal exposure

Dermal contact has been considered as a possible exposure route, particularly during contact with contaminated water or products containing plastic particles. However, compared with ingestion and inhalation, the evidence base for systemic uptake through intact human skin is less developed (Akdogan & Guven, 2019; Shao et al., 2026). included skin contact among the exposure pathways considered in their review but also emphasized the uncertainties surrounding MP transport and biological effects (Shiry et al., 2026). Table 2 summarizes the main human exposure pathways considered in this review, including ingestion, inhalation, dermal contact, and internal exposure.

Table 2 Main human exposure pathways (Li et al., 2024; Vdovchenko & Resmini, 2024)

Exposure pathway	Potential sources	Current evidence	Main uncertainty
Ingestion	Food, drinking water, environmental particles	Well documented as an exposure pathway	Absorbed dose and contribution of different sources
Inhalation	Indoor and outdoor airborne particles	Increasing evidence	Long-term inhaled dose and small-particle exposure
Dermal contact	Water and consumer products	Possible exposure route	Systemic uptake through intact skin
Internal exposure	Blood, placenta and other biological matrices	MPs have been detected in human samples	Biological significance of detected particles

6. Microplastics in the human body

The detection of MPs in human biological samples has provided direct evidence that exposure can result in internal contact (Akdogan & Guven, 2019; Vdovchenko & Resmini, 2024). reviewed reports of MPs in different tissues and discussed mechanisms that may permit particle translocation, with particle size identified as one factor that can influence biological transport.

The polymer types and particle morphologies reported in human samples are not uniform (Arfin & Nakhate, 2026). showed that polyester, polypropylene, polyethylene, polyamide and other polymers have been reported across food and human samples, while fibers were frequently observed. The review also emphasized that the detection limit strongly affects which particles are identified (Walker-Franklin et al., 2026).

Pregnancy-related samples have received particular attention. Studies have reported MPs in maternal and fetal-associated biological compartments. Such findings indicate exposure during pregnancy but should not be interpreted as evidence that the detected particles caused adverse pregnancy or developmental outcomes unless such associations are independently demonstrated (Wang et al., 2026; Xia et al., 2026).

The interpretation of human tissue studies requires particular attention to contamination control. Because environmental MPs are ubiquitous and fibers can be introduced during sample collection and laboratory processing, appropriate procedural blanks and contamination-control measures are essential (Xiang et al., 2026).

7. Toxicological mechanisms

7.1 Oxidative stress

Oxidative stress is among the biological responses repeatedly investigated in experimental MP studies. The proposed mechanism involves an imbalance between reactive oxygen species and antioxidant defenses. Experimental evidence supports the possibility that particle characteristics and exposure conditions influence oxidative responses (Fitch et al., 2025). reviewed toxicological evidence and emphasized that particle physicochemical characteristics influence MP bioactivity (Xu et al., 2026).

Oxidative stress findings from cells or animals should not be interpreted as evidence that environmental MP exposure causes oxidative-stress-related disease in humans. Human studies capable of linking measured internal MP exposure with validated oxidative-stress biomarkers remain limited (Yang et al., 2024).

7.2 Inflammation and immune responses

Inflammatory responses have been reported in experimental systems exposed to MPs. These responses are biologically relevant because persistent inflammatory signaling can influence tissue function. However, the magnitude of inflammation depends on particle characteristics, exposure concentration and experimental conditions (Yano et al., 2020).

The 2024 rapid systematic review by Chartres et al. separated evidence from human and animal studies and concluded that human evidence remains limited (Carvajal et al., 2026).

7.3 Cellular injury and genotoxic responses

Experimental studies have reported cytotoxic and genotoxic responses under selected exposure conditions. These effects may result from direct particle-cell interactions, oxidative stress or associated chemical constituents. However, the relevance of experimental doses to environmental human exposure is often uncertain (Zhang et al., 2024).

A major issue is that MPs are not chemically identical across studies. Polymer type, additives, surface oxidation and environmental contaminants can alter biological responses. Therefore, a toxicity result obtained with one type of particle should not automatically be generalized to all MPs (Kumar et al., 2021).

7.4 Reproductive effects

Reproductive toxicity has been investigated extensively in experimental models. The rapid systematic review by Chartres et al. (2024) included 11 animal studies addressing reproductive outcomes and two human observational studies. The review concluded that the overall body of evidence for sperm quality supported suspicion of adverse effects, while recognizing the limitations of the human evidence (Carvajal et al., 2026).

A separate systematic review focused specifically on human reproductive outcomes and examined the available evidence concerning MP exposure and reproductive health concluded that the evidence base was limited and that further research was required to clarify the relationship between exposure and reproductive outcomes (Basumatary et al., 2025).

7.5 Respiratory effects

The respiratory tract is a direct target of inhaled airborne MPs. Experimental studies have reported inflammatory and cellular responses, while human studies have provided evidence of exposure. The main unresolved question is whether environmental inhalation produces doses sufficient to cause clinically meaningful chronic disease (Eberhard et al., 2024).

Eberhard et al. (2024) emphasized that quantitative inhalation exposure data are still insufficient for reliable health-risk characterization (Jenner et al., 2022).

7.6 Gastrointestinal effects

Ingested MPs initially interact with the gastrointestinal tract. Experimental evidence has reported inflammatory and immune responses and changes in intestinal function. In the rapid systematic review by Chartres et al. (2024), the evidence concerning digestive immunosuppression was considered sufficient to suspect adverse effects, although much of the underlying evidence was from animal studies (Carvajal et al., 2026; Chartres et al., 2024). Table 3 summarizes the toxicological endpoints reported in experimental and human studies and the current interpretation of the evidence for each endpoint.

2.5.2 Determination of Probability (P)

The probability score was determined by the expert panel based on the observed frequency of accidents in each zone over the 12-year study period, combined with the operational nature of the zone (Szwed et al., 2006). It is important to clarify that accident frequency was not equated with probability; rather, it served as one input among several. The following quantitative criteria (Table 3) were used to translate accident frequency into the categorical P score:

Table 3 Toxicological effects reported in experimental and human research (Chartres et al., 2024; Yang et al., 2024)

Endpoint	Main evidence base	Current interpretation
Oxidative stress	Mainly cellular and animal studies	Biological mechanism supported experimentally
Inflammation	Cellular and animal studies; limited human biomarker evidence	Plausible mechanism; human causal evidence limited
Cytotoxicity	Mainly experimental studies	Depends on particle and exposure conditions
Genotoxicity	Mainly cellular and animal studies	Requires confirmation under environmentally relevant exposure
Reproductive effects	Animal studies and limited human observational studies	Human evidence remains limited
Respiratory effects	Animal, cellular and limited human studies	Exposure is plausible; chronic health effects uncertain
Gastrointestinal effects	Mainly animal studies, with limited human evidence	Some adverse effects are suspected
Endocrine effects	Experimental and emerging human evidence	Requires further human studies
Chronic disease	Limited and inconsistent human evidence	Causality not established

8. Microplastics as carriers of other contaminants

MP surfaces can interact with chemicals present in environmental matrices. The extent and nature of these interactions depend on polymer type, surface properties, environmental conditions and contaminant chemistry. Weathering can modify particle surfaces and therefore change their interaction with surrounding substances.

This issue is relevant to health assessment because exposure to an environmentally aged MP may involve both particle-related effects and exposure to chemicals associated with the particle. A 2026 review of airborne MPs described their potential to interact with contaminants such as heavy metals and persistent organic pollutants and emphasized their role as mobile environmental particles (Knol et al., 2010).

However, the statement that MPs universally increase the toxicity of co-occurring contaminants would be too broad. The direction and magnitude of combined effects depend on particle properties, contaminant identity, exposure conditions, and biological system. Risk assessment should therefore evaluate these interactions experimentally rather than assuming that adsorption automatically produces greater toxicity (Basumatary et al., 2025).

9. Analytical methods for microplastic identification

Reliable exposure assessment requires analytical methods that can detect and identify MPs with sufficient sensitivity and specificity. Microscopy can provide information on particle number, size, and morphology, while spectroscopic and thermal methods provide chemical information (Vdovchenko & Resmini, 2024; Wang et al., 2026).

Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy are widely used for polymer identification. Thermal analytical approaches such as pyrolysis-gas chromatography/mass spectrometry provide chemical information based on polymer decomposition products. These techniques answer different analytical questions and cannot always be considered interchangeable (Vdovchenko & Resmini, 2024; Wang et al., 2026). Fig. 2 presents a general analytical workflow for microplastic determination, from sample preparation to detection and polymer identification.

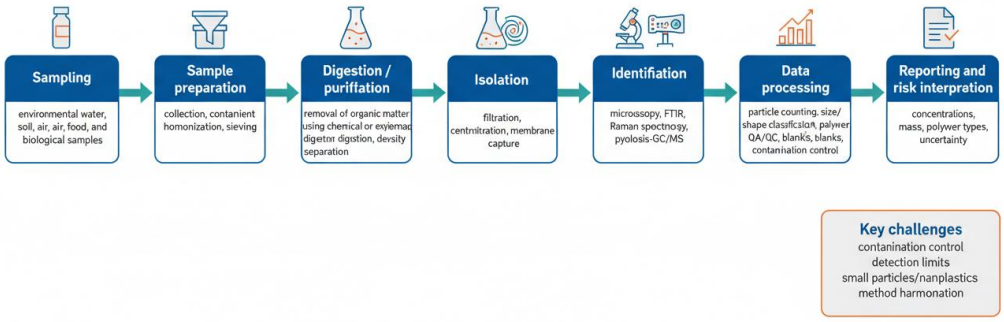


Fig. 2 General analytical workflow for microplastic determination

Particle-size detection is one of the most important limitations (Arfin & Nakhate, 2026). showed that the analytical detection limit strongly influences the size distribution reported in the literature. Studies examining human samples tended to include smaller particles than several studies of food matrices.

The analytical workflow varies with sample type and research objective. No single method currently provides complete characterization of all relevant particle sizes and polymer classes (Vdovchenko & Resmini, 2024; Yang et al., 2024).

10. Quality assurance and contamination control

MP research is particularly vulnerable to laboratory contamination because plastic materials are common in laboratory environments and airborne fibers can enter samples. Contamination can alter particle counts and morphology distributions, especially when the target concentration is low.

Reliable studies therefore require procedural blanks, appropriate field blanks where relevant, controlled sample handling and transparent reporting of contamination-control procedures. These measures are especially important for fiber analysis and for biological samples in which the expected particle concentration may be low (Vdovchenko & Resmini, 2024; Yang et al., 2024).

Differences in quality-control procedures can contribute to variation between studies. For this reason, a numerical concentration should not be interpreted independently of the analytical method, particle-size range, recovery rate and blank correction (Vdovchenko & Resmini, 2024; Yang et al., 2024; Vogel et al., 2024).

11. Human-health risk assessment

Health-risk assessment for MPs presents a different problem from risk assessment for a single chemical substance. MPs are heterogeneous particles that vary in polymer type, size, shape, surface properties, additives, and environmental aging. Consequently, a single concentration value does not fully characterize the exposure (Li et al., 2024; Yang et al., 2023; Vogel et al., 2024).

Vogel et al. (2024) proposed a framework for assessing the risks of micro- and nanoplastic particles to human health. They emphasized the need to consider particle properties, exposure, and hazard together (Vogel et al., 2024).

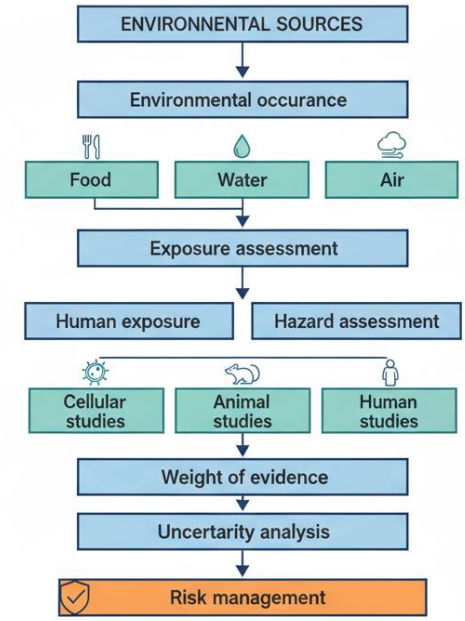


Fig. 3 Conceptual framework for microplastic health-risk assessment

The first component of risk assessment is exposure characterization. This requires information on environmental concentrations, particle size, polymer composition, exposure route, and exposure duration. The second component is hazard characterization, which requires dose-response information and biologically relevant endpoints. Risk characterization then integrates the two while considering uncertainties (Vogel et al., 2024; Yang et al., 2023). Fig. 3 presents a conceptual framework for microplastic health-risk assessment that integrates exposure characterization, hazard characterization,

and risk characterization. In addition, Table 4 summarizes the main components of human-health risk assessment and the principal uncertainties associated with each component.

Table 4 Main components and uncertainties in human-health risk assessment (Vogel et al., 2024)

Component	Required information	Main uncertainty
Exposure assessment	Concentration, size, shape, polymer and exposure route	Inconsistent sampling and reporting
Internal dose	MP concentration in biological matrices	Limited longitudinal measurements
Hazard identification	Biological effects associated with defined particle properties	Heterogeneous experimental conditions
Dose-response relationship	Exposure level and biological response	Limited human dose-response data
Population assessment	Age, exposure patterns and susceptibility	Limited population-specific evidence
Risk characterization	Integration of exposure and hazard	Uncertainty in external-to-internal dose relationships
Uncertainty analysis	Analytical and biological sources of uncertainty	Often incompletely quantified
Risk management	Source reduction and exposure control	Effectiveness differs among sources

12. Human evidence versus experimental evidence

One of the most important issues in MP research is the difference between evidence obtained from humans and evidence obtained from experimental systems (Chartres et al., 2024; Yang et al., 2023).

Animal and cellular studies are useful for identifying possible mechanisms and biological endpoints. They can help determine whether a particle can interact with a biological system and under what experimental conditions a response occurs. They cannot, by themselves, establish that the same effect occurs in environmentally exposed humans (Chartres et al., 2024; Li et al., 2024; Yang et al., 2023).

The rapid systematic review by Chartres et al. (2024) provides a clear example. The review included only three human observational studies compared with 28 animal studies. The evidence was therefore much larger for experimental models than for humans (Eberhard et al., 2024).

More recent human-focused evidence continues to show the same problem. A systematic review of human studies published in 2025 reported associations between MP exposure and inflammatory, oxidative-stress and endocrine-related biomarkers but emphasized that causal relationships with specific diseases remained unestablished (Ririe et al., 2025).

Therefore, statements such as “microplastics cause cancer,” “microplastics cause cardiovascular disease,” or “microplastics cause infertility” would exceed the evidence available for most of these outcomes. A scientifically appropriate formulation is that MPs have been associated with biological changes in some human studies and have produced specific adverse effects in experimental models, while causal relationships with most clinical diseases remain unresolved (Chartres et al., 2024; Ririe et al., 2025; Yang et al., 2023).

13. Environmental and public-health management

The management of MP pollution should begin with source reduction. Preventing plastic materials from entering the environment reduces the opportunity for fragmentation and secondary MP formation. Measures addressing plastic waste management, industrial losses, synthetic fibers, and abrasion-derived particles can therefore reduce environmental inputs (Basumatary et al., 2025; Yang et al., 2023).

Water and wastewater treatment can also influence MP concentrations, but removal efficiency varies according to treatment configuration and particle characteristics. Monitoring should therefore consider the entire pathway from source water through treatment and distribution rather than treating the final concentration as independent of upstream conditions (Vdovchenko & Resmini, 2024; Yang et al., 2024).

Airborne exposure requires a different set of controls. Because indoor environments can contain synthetic fibers and other plastic-derived particles, source reduction, ventilation and appropriate filtration may reduce exposure, although the quantitative effectiveness of individual interventions requires further evaluation (Eberhard et al., 2024; Saha et al., 2025).

The environmental-health perspective also requires separation of pollution control from disease-prevention claims. Reducing MP emissions is justified because it reduces persistent plastic contamination. Demonstrating that a specific control measure prevents a specific human disease requires epidemiological evidence that is currently limited (Basumatary et al., 2025; Yang et al., 2023; Chartres et al., 2024; Ririe et al., 2025).

14. Research gaps and priorities

14.1 Standardization of analytical methods

Different studies use different filters, digestion procedures, identification methods, detection limits and reporting units. Standardized methods are needed to make results comparable (Vdovchenko & Resmini, 2024; Yang et al., 2024).

14.2 Detection of smaller particles

Particles at the lower end of the microplastic size range and nanoplastics remain difficult to quantify. Their exclusion from routine monitoring may lead to underestimation of exposure (Chartres et al., 2024). emphasized the effect of detection limits on reported particle distributions.

14.3 Environmentally relevant particles

Many experimental studies use commercially produced particles with relatively uniform characteristics. Environmental particles may be weathered, irregular and chemically different. Toxicological studies using environmentally representative particles would improve the relevance of experimental evidence (Ririe et al., 2025).

14.4 Longitudinal human studies

Cross-sectional studies can identify associations but are limited in their ability to establish temporal relationships. Longitudinal cohorts that measure external exposure, internal

exposure and health outcomes would provide stronger evidence (Chartres et al., 2024; Ririe et al., 2025).

14.5 Vulnerable populations

Pregnancy, infancy, childhood, and occupational exposure require further investigation. Early-life exposure is of particular interest because developing biological systems may respond differently to environmental stressors. Research in this area should combine exposure measurements with appropriate developmental outcomes rather than relying solely on experimental toxicity (Chartres et al., 2024; Eberhard et al., 2024; Hunt et al., 2024; Li et al., 2024; Ririe et al., 2025).

14.6 Integrated risk assessment

Environmental monitoring, human exposure assessment and toxicology are often conducted separately. A more useful framework would connect these components so that measured environmental concentrations can be related to realistic human doses and then evaluated against experimentally and clinically relevant hazard information (Chartres et al., 2024; Li et al., 2024; Vogel et al., 2024; Yang et al., 2023).

Fig. 4 illustrates the proposed research pathway for integrating environmental monitoring, human exposure assessment, and toxicological evidence within an environmental-health assessment framework.

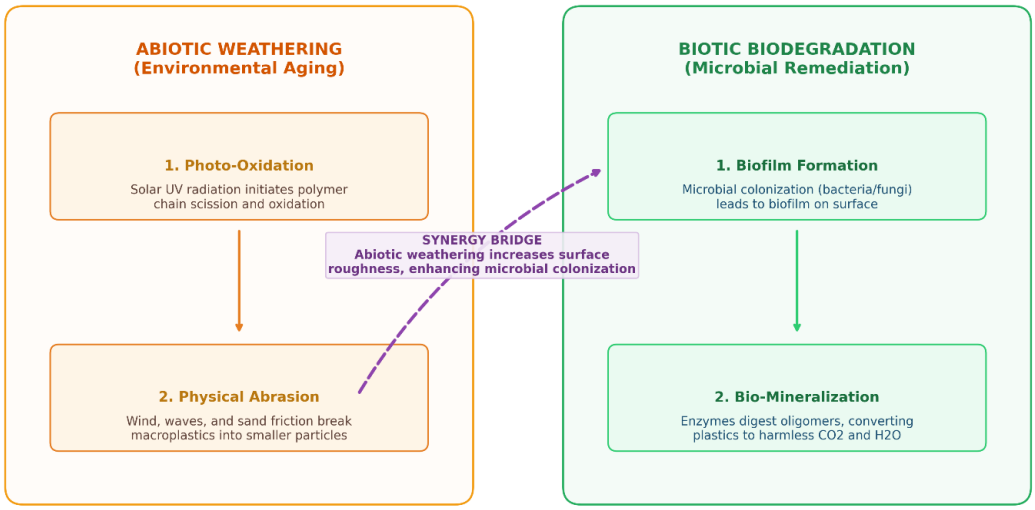


Fig. 4 Proposed research pathway for environmental-health assessment

15. Proposed priorities for future studies

Future MP research would benefit from a shift from isolated concentration measurements toward integrated exposure assessment. Environmental studies should report particle size, shape, and polymer composition together with concentration and analytical recovery. Human studies should report the analytical detection limit and contamination-control procedures in sufficient detail to permit comparison (Li et al., 2024; Vdovchenko & Resmini, 2024; Vogel et al., 2024; Yang et al., 2024).

Toxicological studies should also report particle characteristics in detail. Polymer identity alone is not enough to reproduce an exposure because particles with the same polymer may differ in size, morphology, surface condition and environmental history (Li et al., 2024; Vogel et al., 2024; Yang et al., 2023).

Human epidemiological studies should prioritize measured exposure rather than relying only on assumed environmental concentrations. Where biological samples are used, repeated measurements would help distinguish transient exposure from persistent internal presence (Li et al., 2024; Ririe et al., 2025; Vogel et al., 2024).

Finally, systematic reviews should maintain a clear distinction between human observations, animal evidence and mechanistic findings. This separation makes it possible to identify which conclusions are established and which remain hypotheses (Chartres et al., 2024; Ririe et al., 2025; Vogel et al., 2024; Yang et al., 2023).

16. Conclusions

Microplastics are widely distributed environmental contaminants that can enter human exposure pathways through water, food and air. Their detection in human biological samples demonstrates internal exposure, but detection alone does not establish that MPs cause a particular disease. Experimental evidence indicates that MPs can produce oxidative stress, inflammatory responses, cellular effects and reproductive, respiratory or gastrointestinal alterations under specific conditions. Human evidence is considerably more limited. The 2024 rapid systematic review by Chartres et al. illustrates this difference, with three human observational studies compared with 28 animal studies for the selected health outcomes. The reliability of future risk assessments will depend on better exposure measurements, standardized analytical procedures, and improved characterization of small MPs and nanoplastics. Environmental aging, polymer composition, particle morphology and associated chemicals should be considered when interpreting toxicological results. Current evidence supports continued monitoring and reduction of MP emissions. It also supports further investigation of possible human-health effects. Claims concerning specific chronic diseases should, however, remain limited to what human evidence can currently support.

Statements and Declarations

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the author.

Data availability

Data will be made available on request.

Conflicts of interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contribution

M. Rezaee: Writing the main Draft, Writing – Review & Editing, Conceptualization, Methodology, Review, and Final Proof.

AI Use Declaration

During the preparation of this manuscript, the authors used artificial intelligence (AI) tools solely to assist in the design of the graphical abstract. The authors reviewed and approved the final graphical abstract and take full responsibility for the accuracy, integrity, and content of the manuscript.

References

Akdogan, Z., & Guven, B. (2019). Microplastics in the environment: A critical review of current understanding and identification of future research needs. *Environmental Pollution, 254*, 113011. https://doi.org/10.1016/j.envpol.2019.113011

Anik, A. H., Oishy, M. N., Murshed, M. F., Abdullah, R. B., & Khan, M. R. (2025). Distribution and health impacts of micro- and nanoplastics (MNPs) in human organs: Accumulation, translocation, and toxicity: A systematic review of current evidence. *Journal of Hazardous Materials: Plastics*. 100002. DOI: Not identified.

Arfin, T., & Nakhate, P. A. (2026). Airborne microplastics: Environmental prevalence, human health risks, and mitigation strategies. *Analytical Methods, 18*(6), 1181–1200. https://doi.org/10.1039/D5AY01884F

Barman, A., Ghosh, S., Saha, N. C., & Bej, S. (2026). Microplastics in the web of life: Unseen impacts on ecosystems and human health. *Next Research*. 101731. https://doi.org/10.1016/j.nexres.2026.101731

Basumatary, T., Biswas, D., Boro, S., Nava, A. R., Narayan, M., & Sarma, H. (2025). Dynamics and impacts of microplastics (MPs) and nanoplastics (NPs) on ecosystems and biogeochemical processes: The need for robust regulatory frameworks. *ACS Omega, 10*(17), 17051–17069. https://doi.org/10.1021/acsomega.5c01175

Carvajal, B., Vivero Sun, R., Piderit, F., Zazueta, A., Tapia, C. V., Gotteland, M., et al. (2026). Microplastics in female reproductive and pregnancy organs: A systematic review. *Life, 16*(5), 746. https://doi.org/10.3390/life16050746

Chartres, N., Cooper, C. B., Bland, G., Pelch, K. E., Gandhi, S. A., BakenRa, A., et al. (2024). Effects of microplastic exposure on human digestive, reproductive, and respiratory health: A rapid systematic review. *Environmental Science & Technology, 58*(52), 22843–22864. DOI: Not identified.

Christodoulou, M. C., Stylianou, M., Voukkali, I., Naddeo, V., Barceló, D., Kepertis, C., et al. (2026). Unveiling the presence of micro and nanoplastics in human biological matrices: A systematic review covering the latest five years from 2020 to 2025. *Science of the Total Environment, 1013*, 181304. https://doi.org/10.1016/j.scitotenv.2025.181304

Eberhard, T., Casillas, G., Zarus, G. M., & Barr, D. B. (2024). Systematic review of microplastics and nanoplastics in indoor and outdoor air: Identifying a framework and data needs for quantifying human inhalation exposures. *Journal of Exposure Science & Environmental Epidemiology, 34*(2), 185–196. https://doi.org/10.1038/s41370-023-00634-x

Epeslidou, E., Scott, J. S., de Klein, B., Cudia, J. T., Melgert, B., & Prekovic, S. (2025). Microplastics as environmental modifiers of lung disease. *EMBO Molecular Medicine, 18*(2), 381. https://doi.org/10.1038/s44321-025-00353-w

Fitch, S., Rogers, J., Marty, S., Norman, J., Schneider, S., Rushton, E., et al. (2025). Systematic review of potential developmental and reproductive toxicity of microplastics. *Toxicological Sciences, 207*(2), 289–305. DOI: Not identified.

Garcia, R. F. L., Pickler, J. G., Garcia, C. E., Junior, H. F., Silva, B. L., Weingrill, R. B., et al. (2026). Systemic translocation of micro- and nanoplastics in humans: Evidence, mechanisms and future perspectives. *Science of the Total Environment, 1053*, 182314. DOI: Not identified.

Guo, Y., Guo, Y., Du, X., Yan, Y., Ding, D., Yang, J., et al. (2026). Respiratory risks of microplastics and nanoplastics: Where? What? How? *The Innovation, 7*(5), 101309. DOI: Not identified.

Hossain, R., & Sahajwalla, V. (2026). A comprehensive toolkit for micro- to nanoplastic analysis. *Environmental Science: Nano, 13*(1), 122–149. https://doi.org/10.1039/D5EN00856E

Hore, M., Paul, A., Pramanik, P., Alahee, A., Mahara, A., Barman, S., et al. (2026). Atmospheric microplastics: Detection technologies, respiratory exposure pathways, multi-organ health effects, and standardized risk assessment frameworks. *Water, Air, & Soil Pollution, 237*, 962. https://doi.org/10.1007/s11270-026-09646-3

Hunt, K., Davies, A., Fraser, A., Burden, C., Howell, A., Buckley, K., et al. (2024). Exposure to microplastics and human reproductive outcomes: A systematic review. *BJOG: An International Journal of Obstetrics & Gynaecology, 131*(5), 675–683. https://doi.org/10.1111/1471-0528.17756

İçöz, H., Lisiecka, N., Ciesielski, T., Woźniak-Karczewska, M., Parus, A., Heipieper, H. J., et al. (2026). Microplastics as vectors of chemical additives: A critical evaluation of experimental assumptions, environmental realism, and risk interpretation. *Journal of Hazardous Materials Advances, 24*, 101527. https://doi.org/10.1016/j.hazadv.2026.101527

Jenner, L. C., Rotchell, J. M., Bennett, R. T., Cowen, M., Tentzeris, V., & Sadofsky, L. R. (2022). Detection of microplastics in human lung tissue using μFTIR spectroscopy. *Science of the Total Environment, 831*, 154907. https://doi.org/10.1016/j.scitotenv.2022.154907

Johari, A. S., Budihardjo, M. A., Puspita, A. S., Chegenizadeh, A., & Saputro, A. B. (2026). Human biomonitoring evidence of microplastics: What do we really know about internal exposure and health risk? *Hybrid Advances, 13*, 100669. https://doi.org/10.1016/j.hybadv.2026.100669

Knol, A. B., Slottje, P., van der Sluijs, J. P., & Lebret, E. (2010). The use of expert elicitation in environmental health impact assessment: A seven-step procedure. *Environmental Health, 9*, 19. https://doi.org/10.1186/1476-069X-9-19

Kumar, R., Sharma, P., Manna, C., & Jain, M. (2021). Abundance, interaction, ingestion, ecological concerns, and mitigation policies of microplastic pollution in riverine ecosystem: A review. *Science of the Total Environment, 782*, 146695. https://doi.org/10.1016/j.scitotenv.2021.146695

Kwon, J.-H., Kim, J.-W., Pham, T. D., Tarafdar, A., Hong, S., Chun, S.-H., et al. (2020). Microplastics in food: A review on analytical methods and challenges. *International Journal of Environmental Research and Public Health, 17*(18), 6710. https://doi.org/10.3390/ijerph17186710

Lamas, M., Rodrigues, F., Oliveira, M., & Fernandes, V. C. (2026). Microplastics in human biological matrices: Occurrence, analytical approaches, and health implications. *Microchemical Journal, 230*, 119926. DOI: Not identified.

Li, Y., Chen, L., Zhou, N., Chen, Y., Ling, Z., & Xiang, P. (2024). Microplastics in the human body: A comprehensive review of exposure, distribution, migration mechanisms, and toxicity. *Science of the Total Environment, 946*, 174215. https://doi.org/10.1016/j.scitotenv.2024.174215

McLean, P., Christopher, E. A., Sleeuwenhoek, A., Lofty, M., Dixon, K., & Galea, K. S. (2026). Dermal exposure: Review of current knowledge on the uptake of micro- and nanoplastics. *Microplastics and Nanoplastics, 6*, 12. https://doi.org/10.1186/s43591-025-00163-4

Mohasin, M., Habib, K., Rao, P. S., Ahmad, M., & Siddiqui, S. (2025). Microplastics in agricultural soils: Sources, impacts, and mitigation strategies. *Environmental Monitoring and Assessment, 197*(6), 684. https://doi.org/10.1007/s10661-025-14114-2

Njema, G. G., Agoro, M. A., & Kibet, J. K. (2026). A critical evaluation of nano- and microplastics: Sources, health risks, and mitigation strategies. *Advances in Materials Science and Engineering, 2026*, 1357400. https://doi.org/10.1155/amse/1357400

Novillo-Del Álamo, B., Martínez-Varea, A., Ontoria-Oviedo, I., Ruiz-Gaitán, A., Cosemans, C., Plusquin, M., et al. (2026). Micro and nanoplastics and obstetric outcomes in humans and animals: A systematic review. *International Journal of Environmental Research and Public Health, 23*(5), 672. https://doi.org/10.3390/ijerph23050672

Parveen, N., Akbarsha, M. A., & Shadab, G. G. H. A. (2026). Micro- and nanoplastics as vectors of aquatic pollutants and genotoxicity: An integrated review across aquatic and mammalian systems with special reference to the scenario in India. *Mutation Research - Genetic Toxicology and Environmental Mutagenesis, 912*, 503945. https://doi.org/10.1016/j.mrgentox.2026.503945

Paul, M. B., Stock, V., Cara-Carmona, J., Lisicki, E., Shopova, S., Fessard, V., et al. (2020). Micro- and nanoplastics: Current state of knowledge with the focus on oral uptake and toxicity. *Nanoscale Advances, 2*(10), 4350–4367. https://doi.org/10.1039/D0NA00539H

Piroozfar, F., Abbasi, S., & Turner, A. (2026). The presence and nature of microplastics in human and animal airways: A systematic review. *Journal of Hazardous Materials Advances, 23*, 101275. https://doi.org/10.1016/j.hazadv.2026.101275

Płuciennik, K., Sicińska, P., Misztal, W., & Bukowska, B. (2024). Important factors affecting induction of cell death, oxidative stress and DNA damage by nano- and microplastic particles in vitro. *Cells, 13*(9), 768. https://doi.org/10.3390/cells13090768

Rajput, P., Kumar, P., Banerjee, S., Rajput, V. D., Qin, C., Kumar, H., et al. (2026). A systematic review on emission, accumulation, mechanism, and toxicity perspective of micro-nanoplastics in the soil–plant nexus. *Land Degradation & Development, 37*(10), 4433–4456. DOI: Not identified.

Rehman, Z. U., Song, J., Pastorino, P., Wang, C., Kazmi, S. S. U. H., Fan, C., et al. (2026). From kitchen to cell: A critical review of microplastic release from consumer products and its health implications. *Toxics, 14*(1), 94. https://doi.org/10.3390/toxics14010094

Saha, G., Priya, A. K., & Chandrasekaran, N. (2026). Airborne microplastics and its impact to environmental health. *Water, Air, & Soil Pollution, 237*, 215. https://doi.org/10.1007/s11270-025-08898-9

Shao, H., Cao, H., Zhang, K., Wang, H., Chen, S., Li, Q., et al. (2026). Micro- and nanoplastics across the plant-food-human continuum: Plant uptake, phytotoxicity, food safety, human-health implications, and mitigation strategies. *Plant Nano Biology, 17*, 100338. https://doi.org/10.1016/j.plana.2026.100338

Shiry, N., Shirmohammadi, M., Multisanti, C. R., & Faggio, C. (2026). Dynamics of microplastic transport: A comprehensive review of atmospheric, terrestrial, and aquatic environments. *Water Biology and Security*, 100746. https://doi.org/10.1016/j.watbs.2026.100746

Szwed, P., van Dorp, J. R., Merrick, J. R. W., Mazzuchi, T. A., & Singh, A. (2006). A Bayesian paired comparison approach for relative accident probability assessment with covariate information. *European Journal of Operational Research, 169*(1), 157–177. https://doi.org/10.1016/j.ejor.2004.04.047

Tu, C., Yang, J., Liao, J., Hu, R., Feng, Y., Wu, D., et al. (2026). Exposure to micro- and nano-plastics: From human internal burden to systems-level health-risk interpretation. *iMeta, 5*(4), e70156. https://doi.org/10.1002/imt2.70156

Vdovchenko, A., & Resmini, M. (2024). Mapping microplastics in humans: Analysis of polymer types, and shapes in food and drinking water: A systematic review. *International Journal of Molecular Sciences, 25*(13), 7074. https://doi.org/10.3390/ijms25137074

Vogel, A., Tentschert, J., Pieters, R., Bennet, F., Dirven, H., van den Berg, A., Lenssen, E., Rietdijk, M., Broßell, D., & Haase, A. (2024). Towards a risk assessment framework for micro- and nanoplastic particles for human health. *Particle and fibre toxicology*, *21*(1), 48. https://doi.org/10.1186/s12989-024-00602-9

Walker-Franklin, I., Krovi, A., Redmon, J. H., Weitz, K., Bernard, V., Parker, J. P., et al. (2026). Where in the plastic life cycle can microplastic and nanoplastic release be reduced? *Chem Circularity, 1*(5), 100119. https://doi.org/10.1016/j.checir.2026.100119

Wang, S., Mintenig, S. M., Wu, J., & Koelmans, A. A. (2026). Implications of method- and instrument-based size detection limits in µFTIR-based microplastic analysis. *Talanta, 296*, 128417. https://doi.org/10.1016/j.talanta.2025.128417

Xia, H., Li, Y., Wang, F., Li, G., Tan, Z., & Song, M. (2026). Human exposure to micro- and nanoplastics: Trans-barrier transport, tissue accumulation, and health risks. *Environment & Health, 4*(10), 2184–2198. https://doi.org/10.1021/envhealth.6c00122

Xiang, Y., Bai, C.-L., Ma, L., Liu, L.-Y., Zhang, Z.-F., & Guo, Y. (2026). Evidence of microplastics in human lung tissue: Relationship with clinical indicators. *Journal of Environmental Sciences*. DOI: Not identified.

Xu, H., Yu, Z., & Xie, Y. (2026). Quantitative human biomonitoring of micro- and nanoplastics: Exposure profiles, mechanistic insights, and health implications. *Journal of Hazardous Materials, 502*, 141054. https://doi.org/10.1016/j.jhazmat.2026.141054

Yang, L., Kang, S., Luo, X., & Wang, Z. (2024). Microplastics in drinking water: A review on methods, occurrence, sources, and potential risks assessment. *Environmental Pollution, 348*, 123857. https://doi.org/10.1016/j.envpol.2024.123857

Yano, K., Reyes, N., & Geronimo, F. K. F. (2020). A comprehensive review of microplastics: Sources, pathways, and implications. *Journal of Wetlands Research, 22*(2), 153–160. DOI: Not identified.

Zhang, Y., Hu, G., Zhang, Q., Hong, S., Su, Z., Wang, L., et al. (2024). Cellular senescence mediates hexavalent chromium-associated lung function decline: Insights from a structural equation model. *Environmental Pollution, 349*, 123947. https://doi.org/10.1016/j.envpol.2024.123947

© Authors, Published by *Environmental Health and Pollution Research*. This is an open-access article distributed under the CC BY (license: http//creativecommons.org.licenses.by.4.0).