Microplastics and Human Health: Exposure Pathways, Biological Fate, Toxicity, and Knowledge Gaps

Authors: [Author(s) Name(s)]

Affiliation(s): [Institution(s)]

Corresponding author: [Name, email]

# Abstract

Microplastics (MPs; particles <5 mm) and nanoplastics (NPs; <1 µm) are ubiquitous in the environment and have been detected in water, air, food, and human tissues. Growing evidence from environmental monitoring, experimental toxicology and limited human studies suggests plausible pathways for human exposure (ingestion, inhalation, dermal) and indicates potential for local and systemic effects mediated by physical particle properties, sorbed chemicals (plastic additives, pollutants, microbes) and secondary inflammatory/oxidative responses. However, current human evidence is limited by inconsistent sampling/analytical methods, low-quality epidemiological data, and uncertain dose–response relationships. This review synthesizes recent literature on exposure routes, analytical challenges, mechanisms of toxicity, reported health outcomes, and research and public-health priorities. We conclude that microplastics are a plausible health concern requiring prioritized harmonized monitoring, mechanistic human-relevant studies, and interim exposure-reduction actions.

Keywords: microplastics, nanoplastics, exposure, inhalation, ingestion, toxicity, human health, review

# 1. Introduction

Since the mid-20th century the global production of plastics has risen exponentially, resulting in pervasive environmental contamination with plastic fragments. Microplastics (MPs) arise from primary sources (manufactured small particles) and secondary fragmentation of larger plastics. Because MPs and smaller nanoplastics (NPs) can be transported through water, air and food chains, concerns about human exposure and potential health effects have intensified, prompting reviews by international bodies and rapid growth in the scientific literature.

# 2. Methods (Search strategy)

For this narrative review we prioritized authoritative reviews, systematic reviews, and primary studies published from 2019–2025. Searches were performed in PubMed, Google Scholar and organizational websites (WHO, major journals).

# 3. Sources and Human Exposure Pathways

Environmental reservoirs and food: MPs are present in seafood, water, agricultural soils, and packaging. Inhalation: indoor and outdoor air contain substantial concentrations of MPs, primarily fibres. Dermal: limited evidence but possible NP penetration.

# 4. Analytical Challenges and Detection in Humans

Reliable measurement is hampered by inconsistent methods. MPs have been detected in human stool, placenta, lung, and blood, but detection methods need standardization.

# 5. Mechanisms of Biological Interaction and Toxicity

Mechanistic pathways include: physical effects, inflammation and oxidative stress, translocation, chemical toxicity from additives, and endocrine/reproductive disruption. Evidence mainly from in vitro and animal studies.

# 6. Reported and Suspected Human Health Effects

Gastrointestinal: microbiome and barrier effects. Respiratory: airway inflammation, fibrosis. Reproductive/Endocrine: animal evidence, limited human data. Cancer: DNA damage in models, human data lacking.

# 7. Evidence Quality and Major Limitations

Current evidence limited by methodological inconsistencies, contamination risk, and lack of longitudinal epidemiological studies. International bodies (WHO) emphasize insufficient data for risk assessment.

# 8. Research Priorities and Recommendations

Research: standardized methods, reference materials, human-relevant chronic exposure studies. Policy: precautionary exposure reduction, consumer guidance, reduction of single-use plastics.

# 9. Conclusions

Microplastics are measurable across environmental media and human tissues. Experimental evidence indicates plausible mechanisms of harm, but human causality remains unproven. Harmonized monitoring and precautionary measures are needed.

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[Detail contributions]

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