



Microplastics and Human Health: Emerging Concerns and Future Perspectives

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ABSTRACT

Microplastics, defined as plastic particles smaller than 5 mm, have become one of the most widespread environmental pollutants of the twenty-first century. Their persistence in terrestrial, aquatic, and atmospheric environments has raised significant concerns regarding their potential effects on human health. Humans are exposed to microplastics through ingestion, inhalation, and dermal contact. Recent studies have detected microplastics in human blood, lungs, placenta, breast milk, and gastrointestinal tissues, indicating their ability to enter and circulate within the body. Microplastics may induce oxidative stress, inflammation, endocrine disruption, and cellular toxicity. In addition, they can serve as carriers of hazardous chemicals and pathogenic microorganisms. This review discusses the sources, classification, environmental distribution, exposure pathways, health effects, detection methods, and future research directions associated with microplastics. Understanding their biological impacts is essential for developing effective strategies to reduce exposure and safeguard public health.

1. Introduction

Plastic has become an indispensable material in modern society because of its durability, versatility, and affordability. It is widely used in packaging, construction, healthcare, agriculture, electronics, and transportation. Global plastic production has increased dramatically over the past few decades, resulting in significant environmental accumulation of plastic waste. As larger plastic items degrade through physical, chemical, and biological processes, they fragment into smaller particles known as microplastics.



Microplastics are generally defined as plastic particles less than 5 mm in diameter. They are categorized into primary microplastics, which are intentionally manufactured in small sizes, and secondary microplastics, which result from the breakdown of larger plastic materials. Due to their small size and widespread occurrence, microplastics have been detected in oceans, rivers, lakes, soil, food products, drinking water, and even atmospheric dust.

The growing presence of microplastics in the environment has raised concerns about their potential impact on human health. Human exposure occurs through multiple pathways including ingestion of contaminated food and water, inhalation of airborne particles, and dermal contact. Recent research has demonstrated the presence of microplastics in various human tissues, suggesting that these particles can cross biological barriers and accumulate within the body.

Although the long-term consequences of microplastic exposure remain uncertain, experimental and epidemiological studies indicate possible associations with inflammation, oxidative stress, immune dysfunction, reproductive toxicity, and metabolic disorders. Consequently, microplastics have emerged as a major environmental and public health issue requiring extensive scientific investigation.

2. Sources and Classification of Microplastics

2.1 Primary Microplastics

Primary microplastics are intentionally manufactured as microscopic particles for industrial and commercial applications. Common sources include:

- Cosmetic microbeads
- Toothpaste abrasives
- Industrial cleaning agents
- Plastic pellets used in manufacturing
- Synthetic textile fibers

These particles are directly released into wastewater systems and eventually enter natural ecosystems.

2.2 Secondary Microplastics

Secondary microplastics originate from the degradation of larger plastic products. Environmental factors such as sunlight, temperature fluctuations, mechanical abrasion, and microbial activity contribute to fragmentation.



Major sources include:

- Plastic bottles
- Plastic bags
- Food packaging
- Fishing nets
- Agricultural mulch films
- Disposable consumer products

Secondary microplastics represent the largest proportion of environmental microplastic contamination.

3. Environmental Distribution

Microplastics are now considered ubiquitous environmental contaminants.

Marine Environment

Large quantities of plastic waste enter oceans annually through rivers, coastal activities, and maritime operations. Marine organisms often ingest microplastics, leading to accumulation within aquatic food chains.

Freshwater Systems

Rivers and lakes act as transport pathways, carrying microplastics from urban and industrial areas into marine ecosystems.

Soil Environment

Agricultural activities, plastic mulching, sewage sludge application, and improper waste disposal contribute to soil contamination.

Atmosphere

Atmospheric microplastics originate from synthetic textiles, tire wear, industrial emissions, and urban dust. These particles can travel long distances through air currents and settle in remote regions.

4. Human Exposure Pathways

Ingestion



Food and drinking water represent major routes of exposure. Microplastics have been identified in:

- Seafood
- Table salt
- Bottled water
- Tap water
- Fruits and vegetables
- Processed foods

Consumption of contaminated food products may result in continuous intake of microplastic particles.

Inhalation

Airborne microplastics can be inhaled into the respiratory tract. Indoor environments often contain elevated concentrations due to synthetic fabrics, carpets, and household dust.

Dermal Contact

Although the skin serves as an effective barrier, exposure through cosmetics and personal care products may contribute to limited uptake.

5. Detection of Microplastics in Human Tissues

Recent scientific investigations have reported microplastics in several human tissues including:

- Blood
- Placenta
- Lungs
- Liver
- Breast milk
- Gastrointestinal tract

Advanced analytical methods used for detection include:

- Fourier Transform Infrared Spectroscopy (FTIR)
- Raman Spectroscopy
- Scanning Electron Microscopy (SEM)
- Pyrolysis Gas Chromatography-Mass Spectrometry (Py-GC-MS)



These technologies enable identification of particle size, shape, concentration, and polymer composition.

6. Health Effects of Microplastics

Oxidative Stress

One of the most frequently reported effects of microplastic exposure is oxidative stress. Microplastics may stimulate excessive production of reactive oxygen species (ROS), leading to cellular damage, DNA injury, and mitochondrial dysfunction.

Inflammation

Exposure to microplastics can activate inflammatory pathways. Chronic inflammation is associated with numerous diseases including cardiovascular disorders and metabolic abnormalities.

Endocrine Disruption

Many plastic products contain additives such as bisphenol A (BPA) and phthalates. These chemicals may interfere with hormonal signaling pathways and disrupt endocrine function.

Respiratory Toxicity

Inhaled microplastics may accumulate in respiratory tissues and contribute to irritation, inflammation, and impaired pulmonary function.

Gastrointestinal Effects

Microplastics can interact with intestinal tissues and alter gut microbiota composition. Disturbances in microbial communities may affect digestion, immunity, and metabolic regulation.

Reproductive and Developmental Effects

Research suggests that microplastics may cross reproductive barriers and influence fertility, embryonic development, and fetal health. Detection of microplastics in placental tissues has intensified concerns regarding maternal and fetal exposure.

7. Microplastics as Carriers of Toxic Pollutants

Microplastics possess large surface areas capable of adsorbing environmental contaminants. They may transport:



- Heavy metals
- Pesticides
- Persistent organic pollutants
- Antibiotic residues
- Pathogenic microorganisms

Consequently, microplastics may act as vectors that increase the bioavailability and toxicity of harmful substances.

8. Methodology

This review was prepared through an extensive examination of published scientific literature related to microplastics and human health. Peer-reviewed research articles, review papers, international reports, and environmental health studies were consulted. Relevant information was collected from scientific databases using keywords such as “microplastics,” “nanoplastics,” “human exposure,” “toxicity,” “environmental pollution,” and “public health.” Data were organized into themes including sources, exposure pathways, detection methods, biological effects, and future perspectives.

9. Observation and Discussion

The literature consistently demonstrates that microplastics are present in virtually every environmental compartment. Human exposure appears unavoidable due to widespread contamination of food, water, and air. Detection of microplastics in human tissues confirms biological uptake and distribution.

Current evidence suggests that microplastics may contribute to oxidative stress, inflammation, endocrine disruption, and tissue toxicity. However, many studies rely on laboratory models and controlled exposure conditions. The precise relationship between environmental exposure levels and disease development remains unclear.

Another major concern is the interaction between microplastics and toxic chemicals. Their ability to adsorb contaminants may enhance overall toxicity. Furthermore, the emerging field of nanoplastics presents additional challenges because smaller particles can potentially penetrate biological membranes more effectively.

Despite growing evidence, significant knowledge gaps remain regarding chronic exposure, dose-response relationships, and long-term health outcomes.



10. Future Scope

Future research should focus on:

1. Standardized analytical techniques for microplastic detection.
2. Long-term epidemiological studies assessing human exposure.
3. Investigation of nanoplastic toxicity.
4. Development of biodegradable plastic alternatives.
5. Improved waste management and recycling technologies.
6. Assessment of microplastic impacts on vulnerable populations.
7. International policies aimed at reducing plastic pollution.

Interdisciplinary collaboration among microbiologists, toxicologists, environmental scientists, and policymakers will be essential for addressing this global challenge.

11. Conclusion

Microplastics have emerged as a significant environmental and public health concern. Their widespread distribution across ecosystems and detection in human tissues highlight the urgency of understanding their biological effects. Evidence indicates potential associations with oxidative stress, inflammation, endocrine disruption, respiratory toxicity, and reproductive effects. However, further research is required to establish definitive causal relationships and determine safe exposure limits. Reducing plastic pollution, improving waste management practices, and advancing scientific knowledge are critical steps toward protecting both environmental sustainability and human health.

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