GENERAL HEALTH

Microplastics in Drinking Water: Emerging Health Concerns and Public Health Implications

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Abstract

Microplastics (MPs), or synthetic polymer particles less than 5 mm in size, are becoming increasingly recognized as a contaminant of global concern. Microplastics have now been widely found in freshwater bodies, bottled drinking water, and municipal supplies of drinking water. Their microscale size and chemical nature allow them to penetrate biological barriers, get deposited into tissues, and serve as vectors for harmful substances and microbes. Increasing evidence is implicating MPs in endocrine disruption, changes in the digestive system, and immune dysregulation. Uncertainties still surround their long-term health risks for humans, exposure levels with no adverse effects, and possible synergistic outcomes with other pollutants. This review sets out sources and routes of MPs into drinking water, detection methods, potential health effects, and mitigation strategies. It further indicates current knowledge gaps and the need for a pressing interdisciplinary research drive, legislative measures, and public awareness. MP contamination in drinking water needs to be addressed in order to safeguard both ecosystem and human health.

I. Introduction

Plastics have revolutionized contemporary life because of their longevity, flexibility, and inexpensiveness. However, these same features render them environmentally persistent. Plastic production worldwide exceeded 350 million tons per year, much of which spills into the environment. Weathering and fragmentation over time transform larger plastics into microplastics (MPs), which have been found in oceans, rivers, soils, and even the atmosphere today.

MPs are designated as primary (produced small plastics like microbeads in cosmetics or industrial abrasives) or secondary (fragments produced by the deterioration of larger plastics). Their pervasiveness has elicited increasing concern about potential ecological and human health impacts.

One of the most serious routes of human exposure is drinking water. MPs have been reported in tap water, groundwater, and notably bottled water, with concentrations at times in the range of thousands of particles per liter. The findings underscore the need to recognize MPs as a public health issue rather than an environmental one.

This review integrates up-to-date understanding of MPs in drinking water, potential impacts on human health, and reduction measures, and establishes key research needs.

II. Sources and Pathways of Microplastics into Drinking Water

A. Environmental and Anthropogenic Sources

1. Primary MPs ? deliberately manufactured small plastics, e.g., microbeads in cosmetics, resin pellets for production, and textile fibers.

2. Secondary MPs ? formed from breakdown of bulk plastics by UV radiation, mechanical wear, and chemical degradation.

Major contributors are:

Industrial operations: production of plastic, resin handling, and illegal dumping.

Sewer discharge: effluent sewer releases microfibers from washing synthetic clothing.

Storm runoff: stormwater transports plastic pieces from roads and packaging litter.

Atmospheric deposition: particulate MPs fall into surface waters.

B. Drinking Water Systems

Surface waters (lakes, rivers, reservoirs) get MPs from industrial and municipal sources and are the primary sources of municipal water supply.

Groundwater is comparatively less polluted but can be affected by soil, landfills, or agricultural plastics leaching.

Water distribution networks (treatment systems, pipes) can introduce MPs by corrosion or leaching of plastic fittings.

Bottled water has demonstrated extremely elevated MP concentrations, largely due to plastic packaging shedding and bottling operations. Mason et al. (2018) quantified a maximum of 10,000 MP particles per liter in bottled samples.

III. Detection and Quantification

MP analysis is hindered by methodological inconsistencies. Existing approaches are:

Microscopy (light, SEM, fluorescence) ? permits viewing of particle shape and size but finds it challenging to detect particles with diameters smaller than 20 ?m.

Spectroscopy (FTIR, Raman) ? generally used to quantify polymer composition, with Raman being more sensitive for smaller particles.

Thermal analysis (pyrolysis-GC/MS, TGA) ? gives polymer-specific quantitation but degrades the sample.

Each has its pros and cons. For instance, spectroscopy can differentiate between polymers but involves tedious sample preparation. Establishing standardized global protocols is critical for comparable and consistent data.

IV. Health Impacts of Microplastics

A. Endocrine Disruption

Plastics generally incorporate additives such as phthalates, bisphenol A (BPA), and flame retardants, recognized endocrine-disrupting chemicals (EDCs). MPs have the potential to release these chemicals or adsorb environmental contaminants, serving as exposure vectors.

Animal studies: Zebrafish exposed to polystyrene MPs exhibited disrupted estrogen signaling. Rodent models reported reproductive toxicity, such as decreased sperm count and ovarian dysfunction.

Cell studies: In vitro studies demonstrated disruption of thyroid hormone pathways and changed steroidogenesis.

Implication: Although there is limited direct human evidence, the possibility of MPs disrupting reproductive and metabolic well-being is a cause of concern.

B. Digestive System Effects

When ingested, MPs tend to accumulate in the gastrointestinal tract.

Rodent studies: Intestinal inflammation, barrier disturbance, and changes to gut microbiota composition were observed in mice treated with MPs.

Microbiome disruption: Dysbiosis is associated with metabolic disease, obesity, and inflammatory conditions. MPs could increase these risks by impacting microbial diversity.

Human implications: Low-level chronic exposure via drinking water can aggravate gastrointestinal problems, although epidemiological evidence is still missing

C. Immune System Effects

The immune system recognizes MPs as a foreign body.

In vitro: Human macrophages treated with MPs exhibited oxidative stress, cytokine secretion, and inflammatory signaling.

Animal models: Mice evidenced systemic immune activation, including inflammation of spleen and liver.

Hypothesis: Long-term exposure might lead to chronic inflammation, autoimmunity, or immune suppression.

V. Knowledge Gaps

Despite increasing publications, critical questions remain:

1. Human exposure levels ? Estimates vary (hundreds to thousands of particles per person daily) but depend on water source and methodology.

2. Toxicological thresholds ? Safe levels of MP ingestion are unknown; most evidence is from acute high-dose animal studies, not chronic low-dose exposures.

3. Interactions with co-pollutants ? MPs can carry heavy metals, persistent organic pollutants, and microbes, complicating toxicity.

4. Translocation and accumulation ? Whether MPs move from gut to blood and organs (liver, placenta, kidney) remains not fully established.

5. Standardization issues ? Absence of harmonized detection methods weakens risk comparisons between regions.

VI. Mitigation Strategies

A. Policy and Regulation

Governments are starting to move:

EU Drinking Water Directive (2020) recognized MPs as a concern, urging enhanced monitoring.

WHO report (2019) suggested prioritizing decreasing total plastic pollution and enhancing wastewater treatment over immediate regulation.

Microbead bans have been implemented in some countries, a small but significant step.

B. Water Treatment Technologies

Traditional treatment (coagulation, sedimentation, filtration) can eliminate bigger MPs but is less efficient on particles below 10 ?m.

Advanced treatment: membrane filtration, activated carbon, and advanced oxidation processes are more efficient but expensive.

Upgrading treatment plants and creating cost-effective technologies for removal is crucial for safe drinking water.

C. Public and Industry Roles

Reducing plastic manufacturing and encouraging biodegradable options.

Enhancing recycling infrastructure and circular economy.

Public education campaigns discouraging bottled water consumption and reusable alternatives.

VII. Conclusion

Microplastics constitute a rising contaminant of emerging concern in drinking water. Data from animal and cell studies suggest possible endocrine, gastrointestinal, and immune effects, though direct human evidence is unavailable. Key challenges are sparse exposure data, inadequate toxicological data, and lack of standardized detection protocols.

Bridge these gaps through an interdisciplinary approach:

- Scientific inquiry to derive exposure-response relationships.
- Policy measures to control plastic manufacture and ensure water safety.
- Advances in technology in water purification and waste treatment.
- Public awareness to minimize the use of plastic and demand safe drinking water.
- Protection of drinking water against microplastic contamination is a scientific imperative and a public health priority.

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Competing interests

The authors declare that they have no competing interests.

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