



# Microplastics in Food and Drinking Water: Exposure, Toxicity and Health Risks: A Review

K. Maria Das<sup>1</sup>, P Chanikya<sup>2</sup>, J. Krishna Kishore<sup>3</sup>, M.V. Raju<sup>4\*</sup>

<sup>1</sup>Assistant Professor, Department of Chemistry, School of ASH, Vignan's Foundation for Science Technology and Research, Deemed to be University, Guntur, Andhra Pradesh, India.

<sup>2</sup>Research Scholar, Department of Civil Engineering, Vignan's Foundation for Science Technology and Research, Deemed to be University, Guntur, Andhra Pradesh, India.

<sup>3</sup>Associate Professor, Department of Chemistry, St. Ann's College of Engineering and Technology, Chirala, Prakasam, Andhra Pradesh, India.

<sup>4\*</sup>Assistant Professor, Department of Civil Engineering, Vignan's Foundation for Science Technology and Research, Deemed to be University, Guntur, Andhra Pradesh, India.

**Corresponding Author:** M.V. Raju

Assistant Professor, Department of Civil Engineering, Vignan's Foundation for Science Technology and Research, Deemed to be University, Guntur, Andhra Pradesh, India.

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## ABSTRACT:

The widespread use of plastic materials over the past several decades has resulted in the accumulation of microplastics (MPs) across environmental systems. Increasing evidence indicates that these particles are present in multiple environmental compartments, including water, soil, air, and food products, enabling their entry into the human food chain. Plastics are widely used in packaging, processing, and storage due to their durability, light weight, and economic advantages; however, their degradation produces persistent microplastics that pose emerging environmental and health concerns. This review critically examines the occurrence, sources, and transfer pathways of microplastics in the food chain, with particular emphasis on food commodities, packaging materials, and agricultural inputs. Despite growing research attention, significant uncertainties remain regarding the mechanisms of microplastic transfer, bioaccumulation, and long-term human health effects. Addressing these knowledge gaps is essential for developing effective monitoring strategies and mitigation policies.

## 1. Introduction

Plastic production has increased dramatically over the past few decades due to its durability, low cost, and widespread applications in packaging, textiles, and industrial products. Global plastic production exceeded 400 million tons annually, leading to the accumulation of plastic waste in natural ecosystems (Huang, Hu, and Wang 2023) (Anand et al. 2023) (Osman et al. 2023) (Eze et al. 2024). Microplastics (MPs) having < 5 mm in size (Osman et al. 2023), generated due to external factors included physical and chemical weathering,

mechanical abrasion, and biological transformations (Novotna et al. 2019).

### 1.1. Microplastics are Categorized into Two Types:

Primary microplastics, which are intentionally manufactured small plastic particles used in cosmetics, industrial abrasives, and personal care products (Boucher and Friot 2017) (Padervand et al. 2020).

Secondary microplastics, which originate from the fragmentation of larger plastic materials such as bottles, packaging materials, fishing nets, and synthetic fibers



(Crawford and Quinn 2017). The release of Secondary MPs into the biotic environment occurs via 3 mechanisms discussed below:

- Natural disintegration of microplastics by weathering and microbial activity;
- Decomposition of microplastics by direct organism activity;
- Resuspension of past microplastic contamination in soil or sediment (Sundt, P., Schulze, P. E., & Syversen 2014).

Recent studies have reported the presence of microplastics in drinking water (World Health Organization 2019), freshwater ecosystems (Neelavannan and Sen 2023), marine environments (Marcharla et al. 2024), atmospheric particles, and agricultural soils (Liyu Yang et al. 2025). These particles have been detected in several food items and drinking water sources, indicating widespread contamination of the human food chain (Cverenkárová et al. 2021). Fresh water ecosystems has been identified as a significant pathway for microplastic exposure, with studies reporting the presence of polymer types such as polyethylene terephthalate (PET), polyethylene (PE), and polypropylene (PP) (Neelavannan and Sen 2023).

Furthermore, humans may ingest thousands of microplastic particles annually through food and water consumption, highlighting the urgent need to assess their potential health risks.

## 2. Sources of Microplastics in Food and Drinking Water

### 2.1. Microplastics in Drinking Water

Drinking water is considered one of the major sources of microplastic exposure (World Health Organization 2019). Both tap water and bottled water have been reported to contain microplastic particles worldwide.

Several studies have reported the presence of microplastics in both bottled and tap water, indicating that conventional drinking water treatment processes may not completely eliminate these particles. Microplastics can enter drinking water systems during water abstraction from contaminated surface or groundwater sources, as well as through the distribution network where plastic pipes and storage materials may

contribute to additional particle release. In bottled water, contamination may also occur from plastic packaging materials and bottle caps during manufacturing, storage, or transportation.

The efficiency of drinking water treatment plants in removing microplastics varies depending on the treatment technologies employed. Conventional treatment processes such as coagulation, flocculation, sedimentation, and filtration have been shown to remove a substantial proportion of microplastic particles. Advanced treatment methods including membrane filtration (Poerio, Piacentini, and Mazzei 2019), activated carbon adsorption (Laca et al. 2025), and advanced oxidation processes (S. Kim et al. 2022), may further enhance removal efficiency. However, very small particles, particularly nano plastics, can still pass through treatment barriers due to their minute size and stable physicochemical properties. Studies show that drinking water commonly contains microplastic polymers such as PET, PE, and PP, with particle sizes typically smaller than 300  $\mu\text{m}$  (Ling Yang et al. 2024).

The concentration of microplastics in drinking water varies significantly across regions, ranging from less than one particle per liter to thousands of particles per liter depending on environmental and treatment conditions.

Although the concentrations of microplastics in drinking water are generally lower compared to other environmental compartments, continuous exposure through daily consumption raises concerns about potential health risks (Pivokonsky et al. 2018). Once ingested, microplastics may interact with biological systems through physical irritation, chemical leaching of additives, or adsorption of environmental contaminants such as heavy metals and organic pollutants (Mason, Welch, and Neratko 2018). Furthermore, microplastics can act as carriers for microorganisms, potentially facilitating the transport of pathogens or antibiotic-resistant bacteria (Karbalaee et al. 2018).

Despite the growing body of research, significant uncertainties remain regarding the occurrence, fate, and health implications of microplastics in drinking water. Variations in sampling techniques, analytical methodologies, and reporting units make it difficult to



compare results across studies. Therefore, the development of standardized monitoring protocols and improved analytical methods is essential for accurately assessing microplastic contamination in drinking water systems. Future research should also focus on understanding the long-term health impacts of chronic exposure and improving treatment technologies capable of effectively removing micro- and nanoplastic particles from drinking water supplies.

## 2.2. Microplastics in Food

### 2.2.1. Occurrence of Microplastics in Food Products

Microplastics have been increasingly detected in a wide range of food commodities, indicating their extensive presence within the human food chain (Eze et al. 2024). Contamination may occur through environmental exposure, food processing, packaging materials, and atmospheric deposition during handling and storage (Chinglenthoba et al. 2025). Recent studies have reported the presence of microplastics in seafood (Rochman et al. 2019), table salt, sugar, honey, milk, and packaged food products, suggesting that dietary intake represents an important pathway of human exposure.

#### 2.2.2. Seafood

Marine ecosystems are major sinks for plastic debris, which leads to the ingestion of microplastics by aquatic organisms. Fish, mollusks, and crustaceans may ingest microplastics either directly from contaminated water or indirectly through trophic transfer in the food chain. These particles are frequently detected in the gastrointestinal tract of marine organisms and may occasionally translocate to other tissues.

Research conducted by Chelsea Rochman et al. 2019 (Rochman et al. 2019) reported the occurrence of microplastics in commercially available fish species collected from international seafood markets, highlighting the potential transfer of plastic particles to humans through seafood consumption. Similarly, studies by Francesco De Falco (De Falco et al. 2021) identified synthetic fibers and plastic fragments in edible marine organisms.

#### 2.2.3. Table Salt

Sea salt is produced through the evaporation of seawater, which may contain suspended plastic debris originating from marine pollution (Karami et al. 2017). Because the crystallization process does not completely remove these particles, microplastics may remain in the final salt product.

A global survey conducted by Lehel et al. (Lehel and Murphy 2021) detected microplastic contamination in multiple commercial salt brands collected from several countries similar to personalized cosmetics and pharmaceuticals (Lu Yang et al. 2021). An international survey of commercial salt products revealed that more than 90% of analyzed samples contained microplastic particles, with concentrations ranging from tens to hundreds of particles per kilogram (J.-S. Kim et al. 2018).

#### 2.2.4. Packaged Foods

Plastic packaging materials represent another possible source of microplastic contamination in food products. Mechanical abrasion, temperature changes, and prolonged storage may cause plastic packaging materials to release microplastic particles into food (Chinglenthoba et al. 2025).

A study conducted by Lisa Zimmermann (Zimmermann et al. 2025) demonstrated that plastic packaging materials can release polymer fragments and chemical additives during storage and processing conditions. Research published in Environment International has further shown that packaging films may contribute to the migration of plastic particles into food matrices.

Ragusa et al. 2022 revealed laboratory experiments have shown that repeated mechanical stress and heating of plastic packaging materials can significantly increase the release of microplastic particles into packaged food products (Ragusa et al. 2022).

#### 2.2.5. Agricultural Crops

Microplastics can enter agricultural soils through several pathways including plastic mulch films, biosolid fertilizers, and irrigation using contaminated water (Sajjad et al. 2022). Once present in soil systems, these particles may accumulate and interact with plant roots.

Conti et al. 2020 (Oliveri Conti et al. 2020) study revealed that certain crop species may interact with



microplastics present in soil environments. Studies by Hurley et al. 2024 (Hurley et al. 2024) have estimated that large quantities of microplastics are introduced into agricultural lands annually through the application of sewage sludge. Greenhouse studies have shown that microplastic particles in soil may affect plant growth and could potentially be transported through root systems under certain environmental conditions.

### 2.3. Human Exposure Pathways

Humans may be exposed to microplastics through multiple environmental pathways including ingestion, inhalation, and dermal contact.

#### 2.3.1. Ingestion

Consumption of contaminated food and drinking water is considered the primary pathway for human exposure to microplastics. Studies estimate that individuals may ingest thousands of microplastic particles annually through diet.

Research conducted by Cox et al. 2019 (Cox et al. 2019) estimated that an average individual may ingest between 39,000 and 52,000 microplastic particles each year through food and beverages.

#### 2.3.2. Inhalation

Airborne microplastics are present in both indoor and outdoor environments and can be inhaled through breathing (Dris et al. 2017). Sources include synthetic textiles, household dust, carpets, and industrial emissions. Allen et al. 2019 (Allen et al. 2019) have detected microplastic fibers in atmospheric particulate matter.

#### 2.3.3. Dermal Contact

Dermal exposure may occur through contact with personal care products containing plastic microbeads or through interaction with contaminated environmental surfaces (Revel, Châtel, and Mouneyrac 2018). However, dermal exposure is generally considered a minor pathway compared to ingestion and inhalation.

### 2.4. Toxicological Mechanisms of Microplastics in Humans

The potential health impacts of microplastics are associated with several biological mechanisms. Once ingested or inhaled, microplastic particles may interact with biological tissues through physical and chemical processes.

One of the major mechanisms involves oxidative stress, where microplastic particles stimulate the production of reactive oxygen species that may damage cellular structures. Another mechanism involves inflammatory responses, which can occur when microplastics accumulate in tissues and trigger immune reactions. Microplastics may also act as carriers for toxic substances such as heavy metals, persistent organic pollutants, and plastic additives, including phthalates and bisphenol compounds. These chemicals may leach into biological systems and interfere with endocrine functions.

Recent studies (Leslie et al. 2022), have also reported the detection of microplastic particles in human tissues such as blood, placenta (Ragusa et al. 2022), and arterial plaques (Marfella et al. 2024), suggesting the possibility of systemic distribution within the human body.

## Global Occurrence of Microplastics in Food and Drinking Water

**Table 1 - Global Overview of Microplastic (MP) Concentrations in Tap Water, Bottled Water, and Food Products**

Study	Location	Sample	MP Concentration	References
Synthetic Polymer Contamination in Bottled Water	USA	Bottled water	325 particles/L	(Mason, Welch, and Neratko 2018)
Human Consumption of	USA	Food + Water	39,000–52,000	(Cox et al. 2019)



Microplastics			particles/year intake	
Microplastics contamination in Food and Beverages: Direct Exposure to humans	China	Food and Beverages	Drinking water -0 – 61 MPs/L Tap water - 0 to 6292 MPs/L	(Jin et al. 2021)
Discovery and quantification of plastic particle pollution in human blood	Netherlands	Human blood	MPs detected in 80% samples	(Leslie et al. 2022)
Plastics contamination of store-bought rice	Australia	Pre-cooked rice	Unwashed rice -3.7 mg/100 g serve Washed rice – 2.8 mg/100 g serve	(Dessi et al. 2021)
Branded milks – Are they immune from microplastics contamination	Mexico	Milk sample	$6.5 \pm 2.3$ particles $L^{-1}$	(Kutralam-Muniasamy et al. 2020)
Microplastic contamination in large migratory fishes collected in the open Atlantic Ocean	Southern Atlantic Ocean	Fish gills and gastrointestinal tract	$18 \pm 11$ MPs/fish	(Pereira et al. 2023)
Microplastic Contamination of Surface Water-Sourced Tap Water in Hong Kong—A Preliminary Study	Hongkong	Tap water	$2.181 \pm 0.165$ MPL <sup>-1</sup>	(Lam et al. 2020)

### 3. Research Gaps and Challenges

Major research challenges include:

- Lack of standardized sampling protocols
- Difficulty in detecting nano-plastics (<1  $\mu\text{m}$ )
- Limited toxicological data for chronic exposure
- Variability in analytical detection methods
- Insufficient regulatory guidelines

### 4. Future Research Directions and Policy Recommendations

Despite the growing body of research on microplastics, several critical knowledge gaps remain regarding their environmental distribution, human exposure levels, and long-term health effects. Future research should focus on developing standardized analytical techniques for

detecting microplastics in food, water, and biological tissues.

There is also a need for comprehensive toxicological studies to understand the long-term effects of chronic microplastic exposure on human health. In addition, more research is required to evaluate the interactions between microplastics and associated chemical contaminants.

From a policy perspective, governments and international organizations are increasingly recognizing the need to address plastic pollution. Regulatory actions such as restrictions on single-use plastics, improved waste management systems, and the development of biodegradable alternatives may help reduce environmental microplastic contamination.

International initiatives led by organizations such as the United Nations Environment Programme are currently



working toward global agreements aimed at controlling plastic pollution and promoting sustainable plastic management practices.

Recent studies have detected microplastic particles in human tissues including lungs, gastrointestinal tract, placenta, and blood, suggesting that these particles may enter the circulatory system and accumulate in organs.

## 5. Conclusion

Microplastic contamination in food and drinking water represents a growing environmental and public health challenge. Increasing evidence suggests that humans are continuously exposed to microplastics through dietary intake and environmental pathways. Although current research indicates potential toxicological risks such as inflammation, oxidative stress, and endocrine disruption, the long-term health effects remain uncertain. Comprehensive research, improved monitoring methods, and stronger regulatory frameworks are essential to mitigate microplastic pollution and protect human health.

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