International Journal of Geography, Geology and Environment

P-ISSN: 2706-7483
E-ISSN: 2706-7491
IJGGE 2022; 4(2): 242-244
https://www.geojournal.net
Received: 13-11-2022
Accepted: 17-12-2022

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Evaluating the impact of microplastics on aquatic food chains and human health

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Abstract
Microplastics, small plastic particles less than 5 mm in size, have become ubiquitous in marine and freshwater environments. This review examines the current understanding of microplastics' effects on aquatic food chains and human health. The paper discusses the sources and distribution of microplastics, their ingestion by aquatic organisms, bioaccumulation, and biomagnification within food webs. Furthermore, it explores the potential human health risks associated with microplastic contamination, considering recent studies on the presence of microplastics in seafood and drinking water. Finally, the review highlights research gaps and suggests future directions for studying the ecological and health impacts of microplastics.

Keywords: Microplastics, marine environments, freshwater environments

Introduction
Microplastics, defined as plastic particles less than 5 mm in size, have emerged as a significant global environmental pollutant. First identified in the 1970s, these particles are now found in almost all aquatic environments, from surface waters and deep sea sediments to freshwater systems. Microplastics originate from various sources, including the breakdown of larger plastic debris, microbeads in personal care products, and synthetic fibers from clothing. With global plastic production reaching approximately 367 million tonnes in 2020, the influx of plastic waste into the oceans is substantial, with an estimated 8 million tonnes entering annually. This results in widespread pollution affecting marine ecosystems globally. Research has detected microplastics in surface waters, coastal areas, and deep-sea sediments, driven by ocean currents, wind patterns, and particle density. Aquatic organisms, from plankton to large marine mammals, ingest these particles, leading to bioaccumulation and biomagnification within food webs. The ecological risks include physical damage and chemical harm to organisms, while human health risks arise from consuming contaminated seafood and drinking water. The pervasive presence of microplastics in aquatic environments raises critical questions about their impact on food chains and the potential risks to human consumers, necessitating comprehensive research and effective mitigation strategies.

Objective of the study
The main objective of this study is to evaluate the impact of microplastics on aquatic food chains and human health by synthesizing existing research on their sources, distribution, and ingestion by aquatic organisms, bioaccumulation, and potential risks to human consumers.

Global production and environmental presence
The production of plastics has seen a dramatic rise over the past few decades, transforming from a relatively minor industry in the mid-20th century to a global manufacturing behemoth today. In 2020, global plastic production reached approximately 367 million tonnes, a substantial increase from the 1.5 million tonnes produced in 1950 (PlasticsEurope, 2021) [8]. This exponential growth is driven by the material's versatility, low cost, and wide range of applications, spanning from packaging and construction to automotive and electronics industries. However, the durability that makes plastics so useful also means they persist in the environment, leading to significant pollution issues.

A substantial proportion of the plastic produced annually ends up as waste, with inadequate management and disposal contributing to its entry into natural environments. It is estimated that around 8 million tonnes of plastic waste enter the oceans each year (Jambeck *et al.*,

2015) [3], creating pervasive pollution that affects marine ecosystems globally. This plastic waste breaks down into smaller particles over time, forming microplastics. These particles, defined as plastics less than 5 mm in size, have become a major focus of environmental research due to their widespread distribution and potential impact on aquatic life and human health.

Microplastics are found in various aquatic environments, including oceans, rivers, lakes, and even polar ice. Studies have documented their presence in the world's remotest regions, from the Arctic to the deep sea. For example, microplastic concentrations in surface waters of the world's oceans are estimated to range from 0.1 to 10.5 particles per cubic meter (Lusher *et al*., 2014) [4]. In coastal regions, where human activity is more concentrated, these concentrations can be significantly higher. The San Francisco Bay, for instance, has been reported to contain up to 300,000 particles per square kilometer (Sutton *et al*., 2016) [10].

In addition to surface waters, microplastics have also been discovered in the deep sea, indicating their pervasive spread. Sediment samples from the Atlantic and Mediterranean seafloor, taken at depths greater than 2,000 meters, have revealed microplastic concentrations of up to 6,400 particles per kilogram of dry sediment (Woodall *et al*., 2014) [13]. This widespread distribution is influenced by a variety of factors, including ocean currents, wind patterns, and the density of the plastic particles themselves.

Microplastics originate from both primary and secondary sources. Primary microplastics are manufactured as small particles for use in products like exfoliating beads in personal care products, industrial abrasives, and pre-production plastic pellets. These microplastics enter aquatic environments through wastewater discharges and runoff. Secondary microplastics, on the other hand, result from the fragmentation of larger plastic debris due to physical, chemical, and biological processes. Common sources include plastic packaging, discarded fishing gear, and synthetic textiles. A notable contributor to secondary microplastic pollution is the washing of synthetic fabrics, which can release up to 700,000 microplastic fibers in a single wash cycle (Napper & Thompson, 2016) [6].

Once in the environment, microplastics can be transported long distances by water currents and wind. Their small size and buoyancy allow them to remain suspended in the water column, where they are ingested by a variety of aquatic organisms, from plankton to fish and marine mammals. This ingestion can lead to physical and chemical harm to the organisms, as well as the potential for bioaccumulation and biomagnification of microplastics and associated pollutants through the food web.

The ubiquitous presence of microplastics in aquatic environments poses significant ecological and human health risks. Ecologically, microplastics can cause physical damage to organisms' digestive tracts, reduce feeding efficiency, and impair growth and reproduction. Chemically, they can adsorb and concentrate toxic substances from the surrounding water, which can then be released into the tissues of organisms upon ingestion. Human health concerns arise from the consumption of seafood contaminated with microplastics, as well as potential exposure through drinking water. Studies have detected microplastics in various seafood products, including fish, mussels, and shrimp, which are consumed by humans worldwide (Davidson & Dudas, 2016) [2]. Additionally, microplastics have been found in both bottled and tap water, raising concerns about daily exposure through drinking water (Mason *et al*., 2018) [5].

The persistent and pervasive nature of microplastics in aquatic environments highlights the need for comprehensive strategies to manage and mitigate their impact. This includes improving waste management practices to reduce plastic waste entering the environment, developing biodegradable alternatives to conventional plastics, and implementing policies to limit the use of microplastics in products. Furthermore, continued research is essential to fully understand the long-term effects of microplastics on both ecosystems and human health, and to develop effective mitigation strategies.

Microplastic sources

Microplastics are classified into primary and secondary categories. Primary microplastics are intentionally manufactured as small particles, such as microbeads used in exfoliating personal care products or industrial abrasives. These primary microplastics enter aquatic environments through wastewater discharge and runoff. Secondary microplastics, on the other hand, result from the degradation of larger plastic items due to physical, chemical, and biological processes. Sources include plastic packaging, fishing gear, and synthetic textiles, which shed fibers during washing. For example, a single wash of synthetic clothing can release up to 700,000 microplastic fibers (Napper & Thompson, 2016) [6].

Distribution in aquatic environments

Microplastics have been detected in various aquatic environments worldwide. In the open ocean, studies have found microplastic concentrations ranging from 0.1 to 10.5 particles per cubic meter (Lusher *et al*., 2014) [4]. Coastal waters and estuaries often exhibit higher concentrations due to proximity to urban and industrial sources. For instance, microplastic concentrations in the San Francisco Bay have been reported to reach 300,000 particles per square kilometer (Sutton *et al*., 2016) [10]. Additionally, microplastics are not confined to surface waters; they have been found in deep-sea sediments at depths of over 2,000 meters, indicating their widespread distribution (Woodall *et al*., 2014) [13].

Ingestion by aquatic organisms

A wide range of aquatic organisms, from plankton to large marine mammals, have been documented to ingest microplastics. Zooplankton, which form the base of the marine food web, have been shown to ingest microplastic particles, mistaking them for food (Cole *et al*., 2013) [1]. Similarly, filter-feeding organisms such as bivalves and crustaceans are susceptible to microplastic ingestion due to their feeding mechanisms. A study on mussels in the North Sea found an average of 0.2 microplastic particles per gram of tissue (Van Cauwenberghe & Janssen, 2014) [11]. Fish, both wild and farmed, have also been found to ingest microplastics, with studies reporting the presence of these particles in the gastrointestinal tracts of commercially important species (Rochman *et al*., 2015) [9].

Bioaccumulation and biomagnification

The ingestion of microplastics by aquatic organisms raises concerns about bioaccumulation and biomagnification within food webs. Bioaccumulation occurs when organisms retain microplastics and associated chemicals in their tissues over time, potentially leading to higher concentrations within individual organisms. Biomagnification refers to the increasing concentration of microplastics and their associated contaminants at higher trophic levels in the food chain. For example, predatory fish and marine mammals can accumulate significant burdens of microplastics and toxic chemicals by consuming contaminated prey (Nelms *et al*., 2018) [7].

Human health implications

Humans are exposed to microplastics primarily through the consumption of contaminated seafood and drinking water. Recent studies have detected microplastics in various seafood products, including fish, mussels, and shrimp, which are consumed by humans worldwide. For instance, microplastics were found in 83% of samples from fish markets in Malaysia (Davidson & Dudas, 2016) [2]. Additionally, microplastics have been detected in both bottled and tap water, raising concerns about daily exposure through drinking water (Mason *et al*., 2018) [5]. The potential health risks associated with microplastic ingestion include physical damage to the gastrointestinal tract, inflammation, and the transfer of toxic chemicals and pathogens associated with microplastic particles.

Conclusion

Microplastics represent a pervasive environmental pollutant with significant implications for aquatic ecosystems and human health. Despite the growing body of research on microplastics, many questions remain unanswered regarding their long-term ecological and health impacts. This review aims to provide a comprehensive overview of the current state of knowledge on microplastics, highlighting key findings and identifying areas where further research is needed to better understand and mitigate their effects.

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