Chapter 14

Microplastic Pollution and Its Impact on Fishes and Human

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ABSTRACT

Pollution poses a significant global issue, with acute impacts in developing countries, primarily due to human activities that adversely affect the environment and natural resources. This article explores the severe consequences of pollution, highlighting it as a major offense against humanity. Human-induced pollution affects diverse ecosystems, leading to harmful effects. Major water pollution sources include human settlements, industries, and agriculture, with the impact depending on pollutant levels, ecological effects, and water use patterns. Although some pollutants originate naturally, such as from volcanic activities, most are due to terrestrial human activities. These pollutants can cause immediate environmental damage or gradual disruptions in the biological food chain, often detectable only over time. The spread of plastic waste in aquatic ecosystems represents a prominent but under-researched problem. Despite plastics' benefits, their resilience, overuse, and poor disposal have resulted in widespread environmental accumulation. Plastic debris's mobility allows for its global distribution, affecting even remote marine areas. This review thoroughly examines microplastic pollution in aquatic settings and its consequences for fisheries and aquaculture. It discusses microplastics' environmental dispersion, their presence in freshwater and estuaries, and their impact on fish populations and human health.

Keywords: Plastic, Microplastics, Aquatic pollution, Human, Fishes.

INTRODUCTION

Pollution remains a critical global issue, particularly severe in developing countries, primarily caused by human activities that adversely affect the environment and natural resources (Mendil and Uluözlu, 2007). The impact of pollution is seen as one of the most significant self-inflicted harms by humanity, with human activities leading to widespread contamination across various ecosystems (Bashir *et al.*, 2020).

Aquatic ecosystems, central to water-based biotic and abiotic interactions, are divided into freshwater and marine ecosystems. Freshwater ecosystems cover less than 1% of the Earth's surface, encompassing rivers, lakes, and wetlands, while marine ecosystems include oceans, estuaries, coral reefs, and coastal areas. These ecosystems, particularly freshwater ones, are increasingly threatened by human activities such as deforestation, construction, industrial operations, and agriculture (Demirak *et al.*, 2006; Fernandesa *et al.*, 2007).

Water pollution is primarily caused by human settlements, industries, and agriculture, with its extent dependent on the volume of pollutants, their ecological impacts, and water usage patterns. Although some pollutants are natural, like those from volcanic activity, the majority are due to human actions. These pollutants can cause both immediate and long-term environmental damage, disrupting the biological food chain balance (Sharma, 2012; Al Naggar *et al.*, 2014; Ghani, 2015).

The accumulation of plastic waste is a significant, yet under-researched, issue affecting aquatic ecosystems. Despite their benefits, plastics' durability and poor disposal lead to widespread environmental pollution (Andrady and Neal, 2009; Barnes *et al.*, 2009). Plastic debris has reached even the most remote marine areas, including polar zones and the deep sea (Barnes *et al.*, 2009; Ivar do sul *et al.*, 2013; Van Cauwenberghe *et al.*, 2013). An estimated 70 to 80% of marine litter, mainly plastics, comes from land sources, transported to the sea by rivers (GESAMP 2010; Moore *et al.*, 2005; Lechner *et al.*, 2014). This issue is exacerbated in low-income countries with poor waste management. Plastics affect marine life through entanglement and ingestion and pose aesthetic problems (Gregory 1999; Gregory, 2009). Protecting aquatic ecosystems from plastic pollution is a critical challenge facing global society (Hampel *et al.*, 2015).

Since the 1970s, the negative effects of plastics on marine environments have been known, but it's only recently that plastic pollution in both marine and freshwater areas has received global attention (Carpenter and Smith, 1972). Single-use plastics, such as bags and microbeads, are major pollution sources (Desforges *et al.*, 2014; Perkins, 2015).

MICROPLASTIC POLLUTION

The term "Microplastic Pollution" was first used by Thompson et al. (2004) to raise awareness about the dangers of plastic particles, known as microplastics or microbeads, being introduced into oceanic environments. Microplastics, defined as plastic particles smaller than 5 mm in diameter, can include even nano-sized particles as small as 1 nm (Frias *et al.*, 2019). Due to their reduced size, often requiring microscopy for analysis (Browne *et al.*, 2015), microplastics have been found across various environments, including the atmosphere, soil, freshwater, and marine ecosystems. These particles pose a significant threat to the food chain and human health as they are ingested by aquatic organisms and can accumulate within their systems (Bajt, 2021). Microplastics can bypass conventional water treatment methods due to their small size, leading to consumption by invertebrates and causing pathological effects, oxidative stress, reproductive disruption, enzyme dysfunction, and growth retardation (Auta *et al.*, 2017). Moreover, microplastics have been detected in the digestive systems of aquatic organisms, potentially entering the human diet through the food chain, exemplified by zooplankton consuming microplastics and being eaten by fish (Karami *et al.*, 2017; Panti *et al.*, 2015).

SOURCES OF MICROPLASTICS IN AQUATIC ENVIRONMENTS

Key sources of microplastic pollution include textile fibers, microbeads, and the breakdown of large plastic debris into microplastics over time (Browne *et al.*, 2015). Other potential origins are wastewater treatment plants, runoff from urban, agricultural, tourist, and industrial areas, sewage sludge, and maritime activities such as beach litter, fishing, and harbors (GESAMP, 2010).

1. Textile Fibers: Synthetic textiles like polyester and nylon release minute fibers into wastewater during washing. These microplastic fibers often bypass wastewater treatment facilities and enter aquatic environments, making them a common type of microplastics found in aquatic organisms.
2. Microbeads: Tiny plastic particles found in cosmetics, household cleaners, and industrial abrasives, microbeads are prevalent in exfoliating products and toothpastes. In the UK, an estimated 16-86 tonnes of microplastics are emitted into the environment yearly from facial exfoliants alone.
3. Large Plastic Debris: Significant plastic waste enters freshwater bodies and oceans through littering or mishandling by waste disposal systems. This includes fishing equipment lost at sea and pre-production plastic pellets, known as nurdles, which are small enough to be considered microplastics. Data on the loss rates of these pellets in aquatic environments is limited.

Sources of Microplastic in Fisheries and Aquaculture

In the fishing and aquaculture sectors, Abandoned, Lost, or Discarded Fishing Gears (ALDFG) are the main contributors to plastic waste, though the extent of their contribution is uncertain at both regional and global levels. During microplastic production, certain chemicals and additives are incorporated, which then attract and hold onto persistent bioaccumulative and toxic pollutants (PBTs) from their environment. Microplastics are frequently found in the gastrointestinal tracts of aquatic organisms (FAO, 2017), suggesting that removing seafood's gut content could reduce microplastic ingestion risks. Nonetheless, exposure remains a concern, particularly with bivalves and small fish species consumed whole.

ENVIRONMENTAL DISPERSION OF MICROPLASTICS

Plastic waste in the environment is dynamic, moving across different areas, with residence times varying by compartment. Factors like weather, proximity to rivers, and land cover influence the journey of plastics from land to river systems. Lambert (2013) noted significant plastic litter accumulation in roadside habitats, exacerbated in some regions by mowing practices that fragment larger debris. River hydrology, including flow conditions and discharge rates, dictates the movement and accumulation of plastics within waterways. River morphology, such as vegetation and physical barriers, affects litter distribution, with microplastics degrading and dispersing at different rates compared to larger plastic items.

Dispersal of Microplastics in Freshwater and Estuarine Environments

Recent studies highlight the presence of microplastics in freshwater environments like lakes, rivers, and estuaries, with their occurrences and impacts increasingly documented (Dris *et al.*, 2015). Sediments often show higher microplastic concentrations than water samples, mirroring trends seen in coastal marine habitats. Urban and industrial areas near lakes tend to have higher microplastic levels, though this pattern doesn't uniformly apply to rivers, where flow dynamics and flooding can alter distribution (Klein *et al.*, 2015). Poor waste management and wind dispersion contribute to microplastic pollution in secluded freshwater ecosystems (Free *et al.*, 2014).

EFFECTS OF MICROPLASTIC POLLUTION ON FISHERIES

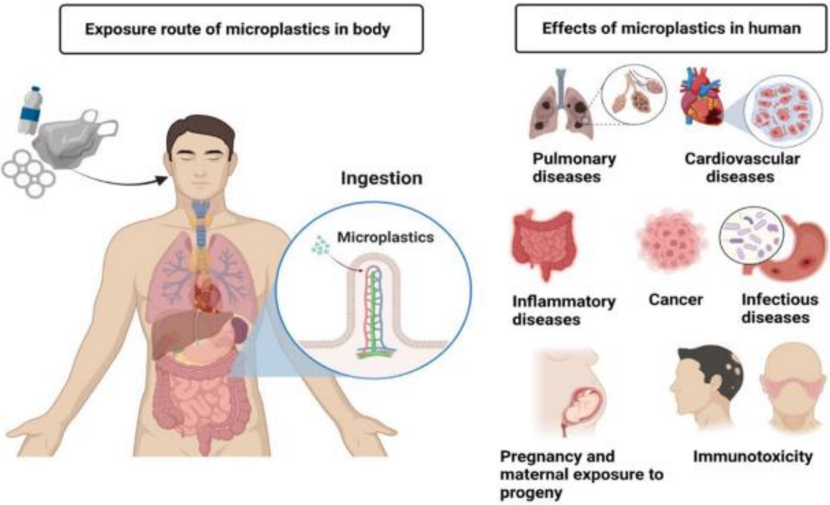
Microplastics are a significant pollutant across aquatic and marine environments, impacting essential habitats like estuaries critical for many fish species (Bakir *et al.*, 2014). This pervasive contamination affects over 690 marine species across all levels of the food chain, from zooplankton

to seabirds and marine mammals (Carbery *et al.*, 2018). These tiny pollutants are found in vital commercial fish species inhabiting various global waters, including the English Channel, North Sea, and Mediterranean Sea, among others (Bråte *et al.*, 2017). Deep-sea fish in the South China Sea have shown microplastic contamination in every sample tested. Similarly, fish in the Persian Gulf have microplastics in different body parts, even within the muscle tissue of tiger prawns, indicating a widespread issue (Sajjad *et al.*, 2018).
Microplastic fibers from synthetic clothing and ropes have been found in the digestive systems of wild fish and their larvae in the English Channel (Lusher *et al.*, 2013). Moreover, 63% of shrimp samples from the North Sea and Channel area, particularly the important Crangon crangon species, contained these fibers (Devriese *et al.*, 2015). Consuming whole shellfish and other aquatic life poses risks of human microplastic exposure (Madeleine *et al.*, 2018). Microplastics in water and sediment expose aquatic and marine organisms directly, while even smaller nanoplastics can infiltrate food chains, exacerbating the problem (Chae, 2018).

EFFECTS ON HUMAN HEALTH

Microplastics can migrate across various environmental sectors, eventually entering the food chain and reaching humans. Contaminated food, especially seafood, is a significant route of human exposure to microplastics (Toussaint *et al.*, 2019). Additionally, humans can encounter microplastics through inhalation or contact with the skin. When ingested or inhaled, microplastics may induce local particle toxicity, prompting immune reactions (Enyoh *et al.*, 2020).

Detection of microplastics in humans is possible via biological samples like faeces, sputum, and the placenta. The consumption of microplastic-laden food might pose several health risks, including cancer, immunotoxicity, gastrointestinal and pulmonary diseases, cardiovascular issues, inflammatory conditions, and complications during pregnancy due to maternal transfer (Osman *et al.*, 2023).



Detrimental effects of microplastic ingestion on human health (Osman *et. al.*, 2023)

Microplastics have been associated with a range of health issues in humans, including toxicity and potential carcinogenic effects (Gasperi *et al.*, 2018; Blackburn and Green 2022). Due to their small size, they possess a large surface area relative to volume, which can lead to DNA damage within cells, thus being highly cytotoxic and potentially causing mutations that may result in cancer (Campanale *et al.*, 2020). The use of heavy metals like arsenic, cadmium, chromium, mercury, and lead in plastic production, recognized as carcinogens by the International Agency for Research on Cancer (IARC), adds to the concern (Osman *et. al.*, 2023).

Microplastic particles can enter the gastrointestinal system through food contaminated with microplastics. Increased intake (either through ingestion or inhalation) can lead to various negative health effects, including increased gut permeability, alterations in gut microbiome composition, and changes in metabolism causing inflammation and gut barrier dysfunction (Salim *et al.*, 2014). An in vitro study using various sizes of polystyrene particles found that larger particles (202 nm and 535 nm) produced inflammatory effects on human A549 lung cells (Brown *et al.*, 2001)

Inhalation of microplastics can affect the respiratory system, potentially leading to pulmonary diseases (Levermore *et al.*, 2020). Occupational exposure in industries like synthetic textiles has been linked to respiratory issues, including lung diseases and chronic obstructive pulmonary disease, due to the inflammation and disruption they cause (Osman *et. al.*, 2023). Furthermore, microplastics exposure has been linked to cardiovascular toxicities, increasing the risk of conditions such as hypertension and coronary artery disease (Osman *et. al.*, 2023).
Current knowledge on the impact of microplastics on human health is limited, highlighting the need for further research to understand their harmful effects, identify risk factors, and develop effective mitigation strategies to safeguard public health.

CONCLUSION

Microplastics pervade numerous ecosystems, including freshwater, marine, terrestrial, and atmospheric systems, originating in situ or from the degradation of larger plastic items. Their distribution from the source is facilitated by environmental factors such as weather and currents, leading to either their widespread dispersion or accumulation in specific areas like soils and sediments. The behavior and ultimate fate of microplastics are influenced not only by their physical, chemical, and biological properties but also by their interactions within the environment. To fully understand the causes, scale, and impacts of microplastic pollution comprehensively, future research must explore the complex interplay between microplastics and the environment across various contexts, considering how their distribution affects ecological systems.

RECOMMENDATION

To mitigate aquatic pollution, the following preventative measures are recommended:

i. Exercise caution when disposing of chemicals, oils, plastics, paints, and medications, avoiding sinks or toilets as microplastics are prevalent in many environments.
ii. Select environmentally friendly cleaning products for use at home and in communal areas.
iii. Support the enforcement of water quality regulations that set permissible pollutant levels and ban their discharge into aquatic ecosystems.
iv. Advocate against the dumping of industrial waste into local rivers, streams, and beaches to prevent neighborhood water pollution.
v. Adhere to existing environmental laws, which provide comprehensive guidelines to reduce pollution in waterways. These laws often apply to entities such as businesses, hospitals, schools, and marketplaces, setting standards for sewage disposal, treatment, and management.
vi. Avoid discarding non-biodegradable items like plastic wrappers or bags into water bodies.

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