Effects of Microplastics on Public Health: A Review

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Abstract
Over the years, it has become evident that microplastics are one of the most important contaminants of concern requiring significant attention. The large abundance of microplastics that are currently in the environment poses potential toxicity risks to all organisms that are exposed to them. Microplastics have been found to affect the physiological and biological processes in marine and terrestrial organisms. As well as being a contaminant of concern in itself, microplastics also have the ability to act as vectors for other contaminants. Microplastics, measuring less than 5 mm in diameter, are now found in various environmental media, including soil, water, and air, and have infiltrated the food chain, ultimately becoming a part of the human diet. This study offers a comprehensive examination of the intricate nexus between microplastics and human health, thereby contributing to the existing knowledge on the subject. Sources of microplastics, including microfibers from textiles, personal care products, and wastewater treatment plants, among others, were assessed. The study meticulously examined the diverse routes of microplastic exposure ingestion, inhalation, and dermal contact offering insights into the associated health risks. Inhalation of airborne microplastics emerges as a critical concern, with possible implications for respiratory and cardiovascular health. Dermal contact, although less explored, raises the prospect of skin irritation and allergic reactions. It can be mitigated by some measures, these measures include Policy interventions, Technological advancements, and Public awareness campaigns etc.

Keywords: Microplastics, Sources, Fate, Behavior, Effects, Public health

1.0 INTRODUCTION

The production of plastic has increased exponentially since the 1950s, leading to approximately 359 million tons of plastic being produced per year. The rise of using plastic materials in everyday life has unintentionally led to the emergence of a contaminant that poses a serious concern to our environment. Microplastics are fragmented plastic pieces that are less than 5 mm in length, and due to their size, once they have been polluted into the environment, they are difficult to remove. Microplastics have been discovered in all corners of the globe, from Antarctica to deserts.

Growing environmental alarm has arisen recently due to the presence of plastic waste in aquatic systems. The generation of anthropogenic waste, 70% of which is plastic, has increased exponentially in the last decades[1]. In fact, more than half of plastic becomes waste in less than a year from production and most of it is not recycled or reused. Microplastics are found all over the world, from the poles to the equator, from coastal regions to aquatic ecosystems[2]. Their diffusion is massive due to transport phenomena such as wind and ocean currents which also lead to their presence in other ecosystems. Since the 3rd industrial revolution in 1950 more than 10 billion tons of plastic have been produced with the annual production rate increasing exponentially[3].

Furthermore, it is estimated that production will further increase to about 600 million tons in 2025. The incredible versatility of plastic materials explains the continuous growth of production year after year as well as their market value[4]. Of all the plastic produced, recent studies have shown that only 9–10% has been recycled, another 10–11% was incinerated and ca. 30% is still in use due to their long lifetime. The remaining 50% has been disposed of in landfills or dispersed into the environment[5]. One of the biggest problems, in this case, is precisely the fact that much of the plastic dispersed in the environment can easily reach the rivers and oceans. In fact, according to the latest survey, plastic waste enters the ocean at a rate of approximately 11 million tons per year[6]. Plastic pollution is particularly acute in estuaries, indicating that terrestrial river input is the preferential way of pollution in coastal and marine environments. Furthermore, the previous pandemic has triggered an estimated global use of 129 billion masks and 65 billion gloves every month, generating a further release of plastics into the environment and therefore into the oceans. Recent studies provide some truly dramatic evidences, trillion macro and micro pieces of plastic float in our ocean with 46 000 pieces in each square mile, weighing up to 269 000 tons.

2.0 Microplastic

Microplastic are tiny plastic particles that result from both commercial product development and the breakdown of larger plastics. As a pollutant, microplastics can be harmful to the environment and animal health. Living organisms tangled in microplastics[7]. In Nigeria, plastic waste is poorly recycled, the majority ends up in landfill where it may take centuries for such material to breakdown and decompose. Despite plastics being an internationally recognized, pollutant with legislation in place aimed to curb the amount of plastic debris entering the marine environment, the problem still persists. Plastic production and consumption are on the increase in annually with 10.3% and 6.5% respectively[8]. Production and consumption stood at 436 kilotons and 1,090 kilotons in 2018 respectively, causing increase in the abundance of plastics in the inland freshwater system. The inland freshwater system was estimated to be about 283,293.47 hectares, of which 70% has been degraded due to the pollution. However, two studies were found; the first focused on method development rather than quantifying the occurrence of microplastics in Elechi Creek, Rivers State, Nigeria[9], while the second study used gastropods collected from Osun River, Nigeria, as a bio-indicator for microplastic pollution[10]. Officially, they are defined as plastics less than five millimeters (0.2 inches) in diameter smaller in diameter than the standard pearl used in jewelry[11].

2.1 Microplastic Pollution and Sources

There are two categories of microplastics: primary and secondary. Primary microplastics are tiny particles designed for commercial use, such as cosmetics, as well as microfibers shed from clothing and other textiles, such as fishing nets. Secondary microplastics are particles that result from the breakdown of larger plastic items, such as water bottles[11]. This breakdown is caused by exposure to environmental factors, mainly the sun's radiation and ocean waves. The problem with microplastics is that like plastic items of any size they do not readily break down into harmless molecules[12]. Plastics can take hundreds or thousands of years to decompose and in the meantime, wreak havoc on the environment. On beaches, microplastics are visible as tiny multicolored plastic bits in sand. In the oceans, microplastic pollution is often consumed by marine animals[11].

2.1.1 Primary sources

The main sources of primary microplastics are tires, road markings, marine coatings, synthetic textiles, personal care products, plastic pellets, city dust, which flow into the environment mainly through domestic sewage, WWTPs or atmospheric events. In particular, transporting tires and road wear particles (TRWP) are dispersed through rainwater as a transport route, synthetic fibers deriving from clothing, personal care products like scrubbers in cosmetics, artificial grass, landfills and waste incineration are carried by the wind in the aquatic environment or deposited in the terrestrial environment[12].

2.1.2 Secondary sources

Secondary microplastics are designed as micro-waste resulting from the breaking up of larger plastic debris through physical, biological and chemical degradation processes. These processes are mainly photo-degradation by sunlight (mainly caused by exposure to UV-B radiation), mechanical degradation such as wave action and sand friction, thermo-oxidative degradation or oxidative erosion, biodegradation by microorganisms that can degrade the hydrocarbons of plastics, and hydrolysis by sea water[13].

3.0 How Does Microplastics Pollute the Aquatic Environment

Microplastic pollution is widespread in rivers and lakes, which may face greater impacts than marine environments, as rivers are key conduits for plastic debris entering oceans. Land-based plastics are a larger contributor to ocean pollution than marine sources[14], yet inland waters have been less studied. Microplastics are ingested by aquatic organisms as they mimic prey, leading to their accumulation through the trophic chain. Over time, this can pose a potential food hazard for humans.

Microplastics (MPs) severely impact aquatic ecosystems, affecting all levels of the food chain through entanglement, smothering, and ingestion. Originating from terrestrial environments, they disrupt the aquatic food chain and ultimately impact human health, creating a cyclical flow with the terrestrial environment as both the starting point and endpoint[14,15].

3.1 Impact on Aquatic Plants

Aquatic plants, like algae, contribute to primary productivity and serve as food for aquatic organisms. Microplastics impact these plants similarly by inhibiting root growth, cell viability, and photosynthesis[16]. MPs are absorbed by plant cells, especially on rough surfaces, through electrostatic forces. Plants with periphytic layers retain more MPs due to higher viscosity, while algae generally accumulate more MPs than plants.

3.2 Impact on Water

Microplastics have significant and far-reaching impacts on water systems, affecting ecosystems, water quality, and even human health. In aquatic environments, many organisms such as fish, zooplankton, and shellfish ingest microplastic particles because they resemble natural food. This accidental ingestion can block digestive tracts, reduce feeding, and impair growth and reproduction. Over time, these effects can disrupt entire food webs, as predators consume prey that already contain microplastics, leading to contamination that moves upward through the ecosystem[17].

Microplastics also alter the physical properties of water, impacting phenomena such as translucency, sedimentation processes, and sediment characteristics, including thermal conductivity[18].

3.3 Impact on Aquatic Birds and Other Aquatic Organisms

Birds, as one of the top predators in aquatic ecosystems, are particularly vulnerable to emerging MP pollution. This highlighted the negative effects of MPs on avian growth, reproduction, and other physiological processes. Commonly detected polymers in birds include polyethylene, polyester, and polypropylene. Beyond avian species, MPs have also been found in wild populations of aquatic mammals, amphibians

4.0 Fate and Accumulation

The spread and cycle of microplastics from urban and industrial settlements to rivers and lakes, as well as transport to the sea and subsequent marine dispersion on the surface and deep in ocean basins have been intensively studied. Plastic waste is usually generated;

(a) by the inhabitants, varying according to their habits, geographic location and existing infrastructures,
(b) from waste management and treatment, also including collection and transport,
(c) from industrial and manufacturing plants[14].

Plastic waste can take different paths spanning from reuse to recycling, to incineration, to landfill disposal and to dispersion into the environment. The most environmentally friendly practices are reuse or recycling, which keep the plastic in a closed loop (i.e. the material remains in the value chain). The local distribution of microplastics is strictly dependent on the complex interactions between the sources of plastics, their dispersion and the current environmental conditions[15]. Therefore, the distribution and fate of microplastics is highly heterogeneous and challenging to monitor. Despite this, predictive models of microplastics diffusion have been developed over the last few years. Diffusion processes can be substantially influenced by the geography of the territory, by physical, chemical and biological processes, mainly related to atmospheric conditions, and by the physical properties of the fragments (e.g. size, shape, density, buoyancy). It has been found that most microplastics particles released to land will finally end up in the marine environment[17].

5.0 Health Impacts of Microplastics

Recent years have seen a significant increase in interest in the detection of ECs at low concentrations (between parts per billion, $\mu g\ L^{-1}$, and parts per trillion, $ng\ L^{-1}$) in a range of environmental matrices, especially on water[18]. Pharmaceutical wastes such as antibiotics when excreted from body of animals and meet environment then it affects the surrounding and the health of human[18]. Similarly, textile and dye industries release hazardous contaminants such as azo dyes, acridine dyes, nitro dyes, etc., causes genotoxicity, carcinogenesis, and mutagenicity[19]. Although the health effects of microplastics are currently under investigation, studies indicate that exposure to these minute plastic particles can potentially lead to various adverse impacts on human health. The different reported health impacts associated with exposure to microplastics are discussed in this section according to their source of ingestion.

5.1 Ingestion

Exposure to microplastics through ingestion has been linked to a number of health impacts, including gastrointestinal issues, endocrine disruption, and toxicity[20].

5.2 Gastrointestinal problems

Gastrointestinal problems have emerged as a significant health concern associated with the exposure to microplastics. Research suggests that the ingestion of microplastic particles, either through contaminated food or water, can lead to various gastrointestinal issues. These problems may include inflammation of the digestive tract, constipation, irritable bowel syndrome, disruption of gut microbiota, and alterations in intestinal permeability[21].

5.3 Inhalation

Exposure to microplastics through inhalation has been linked to respiratory and cardiovascular problems and other health impacts.

5.4 Dermal contact

While there is currently no conclusive evidence demonstrating the adverse effects of microplastics be ruled out.

5.5 Skin irritation

When microplastic particles come into contact with the skin, they can cause irritation, redness, itching, and inflammation. Additionally, microplastics may contain additives or contaminants that further exacerbate skin irritation. Prolonged or repeated exposure to microplastics can lead to chronic skin irritation and potentially worsen existing skin conditions. A toxicity study on rats has, however, shown that chronic exposure to microplastics pollution did not result in either eye or skin irritation[22,23]. However, these observations are from one study and need further research as the possibility of such an effect cannot be ignored. Interaction between MPs and the skin can lead to the presence of allergens and trigger immunological responses. The human immune system may perceive these MP particles as potentially harmful and respond by generating histamines and other inflammatory substances, resulting in allergy symptoms[24,25].

5.6 Allergic reaction

Microplastic particles coming into contact with the skin can also result in allergens and induce immune responses[24]. The body's immune system may perceive these foreign particles as harmful and release histamines and other inflammatory substances, leading to allergic symptoms. These symptoms can include itching, redness, swelling, hives, and even more severe reactions like anaphylaxis in rare cases[25].

6.0 Microplastic mitigation measures

Mitigation measures for microplastics pollution involve a combination of strategies aimed at reducing the input of microplastics into the environment. These measures include Policy interventions, Technological advancements, and Public awareness campaigns, etc.

- **Policy interventions**: Governments can implement regulations to ban or restrict the use of microbeads in personal care products and textiles.
- **Technological advancement**: The use of nanotechnology can help in the capturing of microplastic from water and air.
- **Public awareness campaign**: Education is the powerful tool in mitigating microplastic pollution. Creating awareness about the impact of microplastics on human health and the environment is encouraged.

7.0 Recommendations and Policies for Minimizing Microplastic Pollution in Inland Waters

- **Improvement of Wastewater Treatment Systems**: Wastewater treatment plants should be upgraded to capture microplastics using advanced filtration technologies like membrane bioreactors (MBRs).
- **Monitoring and Research**: Investing in research and developing standardized methods to measure microplastics in freshwater systems is essential.
- **Regulation and Legislation**: Governments should establish legal limits for microplastic concentrations in freshwater systems and set guidelines for industries to reduce emissions.

8.0 Conclusion

The study on the effects of microplastics on human health underscores the urgency and importance of addressing this global environmental issue. By analyzing the origin and routes of microplastic contamination, it becomes clear that plastic waste, microbeads, synthetic textiles, and industrial activities are significant contributors to the discharge of microplastics into the ecosystem. These particles enter the food chain primarily through marine organisms and subsequently make their way to humans via the consumption of contaminated seafood. It is worth emphasizing that microplastic exposure can also occur through alternative pathways such as soil absorption and deposition in the air. Microplastics have been demonstrated to have adverse effects on health, including inflammation, oxidative stress, and the potential for toxicity. While the full scope of the health implications is still being studied, it is evident that addressing the problem of microplastic pollution requires action. As scientists dive deeper into the effects of microplastics on human well-being, it is important for policymakers, industry, and the public to take proactive measures to minimize exposure and mitigate the environmental and health repercussions of microplastics.

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