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Review Article

Microplastics in Water and Terrestrial Environments: A Growing Concern to Public Health

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A B S T R A C T

Marine litter plastics breakdown leads to the formation of microplastics (MPs), plastic particles of less than 5 mm in size. MPs can persist in the environment and transfer from one trophic level to another (bioaccumulation), resulting in damage to the entire ecosystem. The objective of this study is to describe the effects of MPs on aquatic and terrestrial organisms, humans, and their association with coronavirus disease. For many aquatic animals, after ingestion, MPs block the intestine, decrease steroid hormone levels, cause reproductive interference, stunt growth, and decrease the absorption of nutrients. There are MPs below the surface as well, and many living things can help them move by eating, digging, and sticking to them. MPs have a high capacity for contamination, both in water and terrestrial environments, and negatively affect the quality of life of the biota with adverse effects that can result in serious damage to animals, which leads to obstruction and blockage of the intestine. Currently, MP intake rates account for around 20% by mass of the total food ingested every day, generally due to the lack of data on other foods. Most of the living organisms accidentally consume MPs with their food sources in an ecosystem. Two additional variables contributed to the spike in plastic usage after the coronavirus disease outbreak: the suspension of plastic use laws owing to concerns about increased virus transmission and the decline in petroleum prices as a result of decreased global oil demand.

Keywords: Microplastics, Terrestrial Environment, Aquatic Animals, Humans, COVID-19

Introduction

Plastics exist in most aspects of our daily lives, which can be attributed to characteristics of the material such as its mass, durability, low price, and good insulation. They are used in a wide variety of applications, including personal products, household items, clothing, packaging, construction, and transportation materials.[1] Although the social benefits of plastics are undeniable,[2] and although part of this plastic waste is properly managed (recycled or burned), it is estimated that 10% of all plastics produced end up in our oceans and seas.[3]

In the marine environment, plastic debris is exposed to factors of degradation such as ultraviolet B radiation and abrasion-breaking waves.[1] Marine litter plastic breakdown leads to the formation of microplastics (MPs), plastic particles of less than 5 mm in size. The presence of MPs has been demonstrated in different marine compartments around the world, such as intertidal and subtidal sediments, surface waters, beaches, and polar caps. A wide variety of marine invertebrates that are uncommon and vulnerable to larger residues can accidentally consume MPs because of their small size, which is similar to that of planktonic organisms and other suspended particles.[4] These contaminants have caused ongoing concern because they pose a threat to the environment because they can harm mammals, fish, birds, and other animals either directly or indirectly through ingestion by the biota resulting in physical and physiological damage.[5]

MPs are divided into two types: primary and secondary. Primary MPs are already manufactured and are released directly into the environment in the form of small particles.[6] Among them are the microspheres (< 500 µm) used in some cosmetic products, abrasive blasting, drug delivery systems, and 3D printing.

These microparticles pose a serious environmental problem as they enter the sewage network after use, bypassing the sanitation systems and ending up in the seas and oceans.[7] On the other hand, secondary MPs are those larger plastic products that are found either on the surface of the sea, on beaches, or in other environments and are exposed to external conditions such as ultraviolet radiation, which causes degradation.

Apart from the toxic effects of MPs on aquatic biota, terrestrial organisms are also susceptible to pollution through inhalation and ingestion of contaminated food.[8] MPs have the ability to persist in the environment and transfer from one trophic level to another (bioaccumulation), resulting in damage to the entire ecosystem. The problems arising from MP pollution are that the amount of waste generated continues to increase significantly in the environment, and industrial plastic production continues to grow daily.[9] The objective of this study is to describe the effects of MPs on aquatic and terrestrial organisms, humans, and their association with coronavirus disease (COVID-19).

Microplastics in Water Environments

Studies aimed at the ecotoxicological effects of MPs in freshwater and the marine environment are still limited.[8] For many aquatic animals, ingestion is the most likely interaction with MPs. After ingestion, these MPs block the intestine, decrease steroid hormone levels, cause reproductive interference, stunt growth, and decrease the absorption of nutrients.[9,10] The impact on the reproduction of the biota may result in a decrease in offspring, suggesting that such an effect may even lead to the extinction of many species.

MPs can be ingested directly, accidentally, or indirectly by filter feeders, becoming confused with food.[10,11] In vivo studies on mussels showed that MPs made of polystyrene (PS) and polyethylene (PE) move from the intestinal cavity to the bloodstream, where cells enter and cause bad effects at the cellular and tissue levels.[12,13] Plastic debris can accumulate after consumption, which may lead to faecal impaction and be a route of exposure for humans.[14]

MPs also affect conservation-dependent species, such as sea turtles, which are exposed to anthropogenic stressors every day.[15] These animals are exposed to contaminants through direct or indirect ingestion of plastic debris.[16,17] Direct ingestion can occur when MPs are mixed with or adhered to food, while indirect ingestion occurs through food consumption contaminated with MPs.[18,19] On sea turtles, these MPs can cause serious damage to their digestive systems, such as intestinal tract obstruction, reduced food intake, and reduced stomach capacity, which cause malnutrition and lead to death.[19] The large accumulation of MPs in the intestines of turtles can alter swimming behaviour and interfere with buoyancy, which negatively influences predatory activity and the ability to escape predation, in addition to interfering with growth rate, fecundity, fertility, the immune system, and changes in susceptibility to diseases such as fibropapillomatosis.[15]

Fish are widely studied as a bioindicator of response to MPs.[20,21] Generally, fish are directly or indirectly contaminated during normal feeding, however, there are other ways in which MPs become harmful to these animals.[22] Many fish feed on planktonic organisms and aspirate a large volume of water to swallow many objects at the same time; however, this strategy is harmful in the case of dispersed plastic debris in the water and can be accidentally swallowed.[23]

Even though fish have a well-developed palate, many species can't distinguish edible prey from non-edible prey, resulting in accidental ingestion of plastic debris.[23] When fish eat MP

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fragments, bad things happen, like damage to or blockage of the digestive tract, inflammation, oxidative stress, cell damage, slower growth, and problems with the endocrine system.[6,24,25]Japanese rice fish (Oryzias latipes) is used as an indicator organism, and exposure to PE-MPs causes hepatic stress, glycogen depletion, and vacuolisation.[26] MPs caused oxidative stress in the liver of zebrafish (Danio rerio) when they were exposed to them.[27] The contaminant messed up the lipid and energy metabolisms. PE-MPs can lower the activity of the acetylcholinesterase enzyme and lead to oxidative stress in the common goby (Pomatoschistus microps).[9]

Cetaceans, such as whales, are susceptible to the ingestion of plastic debris. Contamination by MPs occurs directly, through the ingestion of water during filtration, or indirectly through trophic transfer.[28,29] Apart from selective feeding by animals, there are higher chances that MPs dispersed on the surface of the water are accidentally ingested, leading to damage to the digestion and obstruction of the gastrointestinal tract.[30,31] In biomagnification, if MPs are once accumulated in animal tissue, they can be transferred to organisms of higher trophic levels (food chain), including humans, so that the toxins contained in the contaminated fish can be absorbed via the diet.[32,33]

Microplastics in Terrestrial Environments

Studies on the toxicity of MPs in terrestrial ecosystems are still limited. Plastic debris is characterised as a potential threat to soil organisms since these micropollutants can cause alterations in the environment.[34]

MPs in terrestrial ecosystems have received little attention; for example, the soil is the main route of MP contamination from agricultural runoff during sewage sludge treatment.[35] Also, untreated wastewater irrigation and urban and road runoff contribute to the increase and accumulation of MPs.[36,37]

As the MPs are not only present on the surface, several living organisms can contribute to the movement of MPs through ingestion, excavation, and adhesion, thus, studies with earthworms,[38] springtails,[39] nematodes,[40] and mites,[41] indicate that these organisms have the possibility of transporting microparticles of low-density polyethylene, polystyrene terephthalate PE, PS, and polyvinyl chloride. Findings about the adverse effects of MPs show that eating or collecting MPs hurts organs and tissues by rubbing against plastic debris, which leads to inflammatory responses, not getting enough nutrients, and having less energy.[42,43]

These contaminants can reach humans through biomagnification. Biomagnification refers to the progressive accumulation of substances between trophic levels along food chains. However, biomagnification negatively affects the food chain of living beings, especially human health, which leads to a reduction in the energy available for growth and reproduction. Also, some studies report the presence of MPs in table salts,[44] drinking water, and freshwater.[45] The main fractions of MPs found in the sea-salt samples are less than 200 µm, being the most common MP.[44]

MPs can interact with humans via ingestion of contaminated food, inhalation of MPs through the air, and thermal exposure.[46] Although inhalation of MPs is not yet reported in humans, inhaled MPs lead to disruption of the immune system in other animals.[47] The inhalation of MPs can affect human health, generating implications in the intestine by causing toxic effects due to the ability to induce intestinal and/ or tissue blockage with fibrosis, congestion, inflammation, and respiratory, and cardiovascular diseases, which can lead to lung cancer.[48]

Effects of Microplastics on Humans

An analysis of 419 chemicals used in foam, soft, and hard plastic toys for children showed that 126 of them had the potential to cause cancer or other health problems in children. As parents and other caregivers, we must be aware of the potential risks associated with microplastics.[49] On a ketogenic diet, patients with cancer, high cholesterol, epilepsy, heart disease, and type 2 diabetes were described as getting healthier.[50,51] The efficacy of omega-3 fatty acid supplements in the treatment of a variety of diseases, such as cancer, diabetes, cardiovascular disease, and inflammation, has been proven.[52–55]

Currently, MP intake rates account for around 20% by mass of the total food ingested every day, generally due to the lack of data on other foods.[56] A few more studies showed MP presence in vegetables and fruits and packed meat after our analysis date, since articles regarding MPs increased dramatically.[57,58] It is important to remember that even a seven-order magnitude increase in this would still only account for 0.004% of the daily mass of inorganic particles consumed.[59]

Microfibers from clothes and other fabrics, as well as tiny pellets of plastic or microbeads intended for commercial use, such as cosmetic items, are the main sources of MPs. The breakdown of bigger plastic particles, such as plastic bottles, into smaller plastic particles (5 mm) as a result of exposure to environmental factors, like direct sunlight and ocean waves, is known as the secondary cause of MPs. MPs can penetrate and spread across rivers, oceans, and groundwater supply networks since wastewater treatment methods are unable to filter them out because of their small size.[60] Furthermore, there are a number of ways that MPs can be passed from an adult to a child, including oral, cutaneous, breastfeeding, inhalation, and placental transfer.[61]

In an ecosystem, most organisms unknowingly ingest MPs

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along with their food products. In the same way, MPs might potentially get into individuals via the supply chain. MPs are bioaccumulated in a food chain by moving up the food chain from fewer trophic-level creatures to greater trophic-level organisms.[62] Furthermore, MPs seeping from various plastic products or food and drinks polluted with MPs during manufacture are other ways that individuals become exposed to MPs.[63]

A Canadian study evaluated human exposure to MP.[64] Based on US food and water intake, they calculated female MP exposure at 203 particles and male MP exposure at 223 particles per day. A study conducted on children from Africa and Asia revealed a single infant's daily ingestion of MP from feeding bottles varies from 14,600 to 4,550,000 particles, with the lowest quantities observed.[65] This wide range demonstrates the considerable uncertainty surrounding human exposure to MPs, especially in the early stages of development, as well as the enormous analytical challenges involved in measuring MP.[66] Therefore, the critical development of the digestive, central neurological, reproductive, immunological, circulatory, and other vital systems in the body happens at the same time as these greater exposure levels.

Association between COVID-19 and Microplastics

COVID-19 is caused by the severe acute respiratory syndrome coronavirus 2,[67–77] which can induce kidney failure. In the most severe phases of the disease, neurological symptoms such as headaches, epilepsy, impaired consciousness, anosmia, and paraesthesia are common in paediatric patients with COVID-19.[78–80] In just over three years, everyone worldwide has had to drastically change their everyday routine. People started working from home during lockdowns and became less social. Thus, social connections and physical activity were severely limited. Social isolation and the COVID-19 pandemic were strongly associated.

To successfully tackle COVID-19 during the pandemic, the World Health Organization recommended boosting personal protective equipment (PPE) manufacturing by 40% every month.[81] In 2020, there were 2,452 billion pieces produced, and the value of European Union face masks increased from 800 million euros in 2019 to 14 billion euros in the same period the following year.[82] As of June 2020, 200 million different varieties of face masks were created daily in China, which is a 20-fold increase in manufacturing volume since the start of 2020.[83] Furthermore, in South Korea alone, the number of manufacturers doubled exponentially between January 2020 and September 2021, from 137 to 1,615.[84] Compared to pre-pandemic 2019, the market for face masks and illness test kits grew tremendously. In 2020–2021, more than three million face masks were used per minute. More than three and a half billion face masks and shields end up in garbage bins each day.[85]

During the pandemic, plastic usage surged from sources other than PPE. Fearing COVID-19, even environmentally conscious individuals who had previously bought personal recyclable bags went toward delivery and individual packing.[86] The use of disinfection and hand sanitisation has led to an increase in the demand for disposable hand sanitiser bottles and disinfectant wipes. 54% of the participants in a South Korean study started using hand sanitiser after the outbreak.[84] As a result of the COVID-19 regulations, the main part of Japanese wet wipe manufacturing observed an increase from 25% (2019) to 76% (2020) within a year, and Thailand reported plastic use increased by almost 62% compared to 2019.[87] As a result of growing takeout and e-commerce usage, plastic production and consumption have increased by 40% and 14% in Spain and the United States, respectively.[88] In 2020, South Korea's delivery of food sales quadrupled from 2019 to 2020 (1,89,39,82,75,00,000.00 South Korean won), leading to a 20% growth in food-related plastic packaging manufacturing (110000000 kilograms).[89]

Two additional variables contributed to the spike in plastic usage after the COVID-19 outbreak: the suspension of plastic use laws owing to concerns about increased virus transmission and the decline in petroleum prices as a result of decreased global oil demand.[90,91] Additionally, as a result of the decline in oil prices, companies were able to avoid recycling plastic at lower costs. Government pricing pressure as well as the requirement for quality control on masks, diagnostic test kits, and vaccine syringes encouraged the manufacturing of virgin plastics from crude oil, which resulted in a higher-quality product at a lower cost.

A new approach to managing plastic is needed globally. Since PPE is not the same as regular home garbage, an exclusive waste management plan needs to be carefully developed for its use. Health and safety concerns require treating face masks, diagnostic test kits, and gloves as medical waste, especially those utilised by patients with COVID-19 who underwent treatments in their homes. Planning for such guidelines may benefit from a detailed examination of the quantity of PPE waste left over from patients with COVID-19 treated in homes as well as the possibility of viral transmission via microplastics in the environment.

Policies and regulations about non-PPE plastics must be reinstituted to decrease the usage of replacement and disposable plastics. Education must play a major role in raising public understanding of the many forms of plastic recycling that are necessary to recycle and be seen as a successful policy against plastic pollution. To reduce the current microplastic pollution, governments should also

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use cutting-edge technology, including microbes capable of breaking down plastic in sewage effluent and other polluted settings. The rapid adoption of new materials and technologies in a country can promote further study and development in the pertinent areas and result in advancements.

Conclusions

MPs have a high capacity for contamination, both in water and terrestrial environments, and negatively affect the quality of life of the biota with adverse effects that can result in serious damage to animals, which leads to obstruction and blockage of the intestine.

When MPs are in the water, the main way they interact with organisms is by eating plastic debris that is floating in the water or that has been gathered from contaminated food. This causes these animals to grow and develop more slowly. In the terrestrial environment, the soil contains a higher concentration of MPs and mainly has an impact on animals. Animals that live on land mostly interact with micropollutants by breathing them in. These micropollutants then hurt living things by causing inflammation, intestinal blockages, and respiratory and cardiovascular diseases.

In this way, it is clear that the research focused on the impacts of MPs on terrestrial organisms was less successful when compared to the studies with animals from marine and freshwater environments. From this perspective, there is a need for the development of future work focused on the ecotoxicological effects of these MPs on animals in the terrestrial ecosystem, such as humans.

An analysis of 419 chemicals used in foam, soft, and hard plastic toys for children showed that 126 of them had the potential to cause cancer or other health problems in children. As parents and other caregivers, we must be aware of the potential risks associated with microplastics. Currently, MP intake rates account for around 20% by mass of the total food ingested every day, generally due to the lack of data on other foods. Most living things accidentally consume MPs with their food sources in an ecosystem. Similarly, MPs may also enter the human body through the food chain.

Two additional variables contributed to the spike in plastic usage after the COVID-19 outbreak: the suspension of plastic use laws owing to concerns about increased virus transmission and the decline in petroleum prices as a result of decreased global oil demand.

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