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Microplastics: An Emerging Contaminant in Aquatic Ecosystems

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Abstract

Microplastics are a common contaminant that has been found in almost all aquatic environments, which poses a hazard to the aquatic ecosystem. Direct discharges of microplastics into the environment occur from a variety of sources and accumulate pollutants from the surrounding environment, which later affect living organisms mostly by ingestion. Biomagnification and trophic transfer are the two major possible ways for microplastics to enter humans. Microplastic pollution has gained attention in recent years, which has increased understanding of its impacts on living organisms. This article focuses on the sources, characteristics and impacts of microplastics on the aquatic ecosystem and also discusses mitigation measures for microplastic pollution.

Introduction

The variety and adaptability of plastics allow for the production of a huge variety of items where high and low-density polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) and terephthalate (PET) are the most widely used synthetic plastics. Some other types of plastics are nylon (NY), polyurethane (PU), polyamide (PA), rayan (RY), *etc*. Plastics are appropriate for use in a wide range of applications due to a number of factors, including resistance to corrosion, low thermal and electrical conductivity, durability, the capacity to carry other materials and affordable production costs. Microplastics (MPs) are a heterogeneous mixture of various materials, sizes, shapes, and colours. The consequences of microplastics (MPs), which are typically understood as plastic particles with sizes below 5 mm, are a subject of growing scientific and public concern. Nearly 200 nations, who recognized the significance of this issue, signed the UN draft Resolution on Marine Litter and Microplastic in Nairobi in December 2017 (Choudhury *et al.*, 2018). They admitted that if nothing is done, then by 2030 the volume of microplastics will shoot up to double and further double by 2050. Microplastics (MPs) have been quantified in various aquatic ecosystems, including riverine beaches, surface water and sediments of rivers, lakes and reservoirs. With regard to environmental health in general, prolonged exposure could result in bioaccumulation of these particles and damage to the aquatic biota.

Sources

MPs pollution in aquatic ecosystems is closely related to the terrestrial environment. The waste generated by industries, coastal tourism, fishing and the production of plastic products has a direct environmental impact on the seas and oceans. Today, primary MPs (< 5 mm in diameter) can be found in toothpaste, facial cleaning products, as well as cosmetics such as nail polish, foundation, eye shadow, blush powder and many other items. Plastics, along with other pollutants from land areas typically migrate to aquatic ecosystems and a high concentration of MPs can be found in various water bodies along industrialized cities. The diagrammatic representation of inflow of microplastics in aquatic ecosystem is given in figure 1. Large plastics have also been found in water dumped by nearby areas. Based on their density, plastics either float on the surface or deposit on the sea floor. Under the effect of both biotic and abiotic factors such as microorganisms, topography of the sea, water temperature, salinity, availability of sunlight, *etc*., large plastic particles are weathered into MPs, which are further called secondary MPs. The Indian plastics industry has tremendous growth potential and as its use increases daily, plastic waste is dumped into the environment, causing severe pollution.

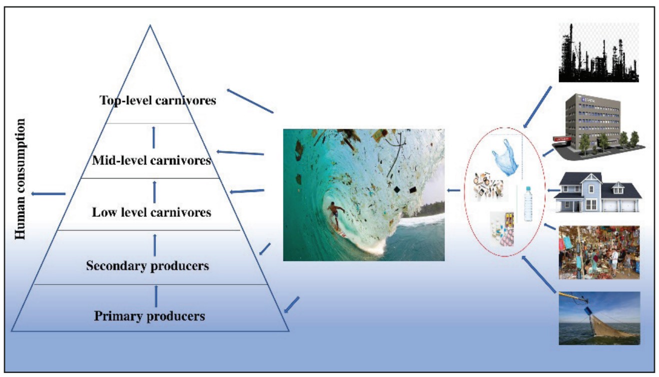

Figure 1: Diagrammatic representation of inflow of microplastics in aquatic ecosystem

Effect of MPs on Aquatic Ecosystem

Fish is a good source of protein and micro-nutrients for the human body. Previously ignored aquatic flora and fauna are also now considered food for humans to cope with population growth. However, the increased availability of microplastics in aquatic ecosystems has raised concerns about food safety and the potential impacts on aquatic biodiversity. These are also known for their potential to absorb chemical compounds. When compared to nearby water in the ocean, the quantity of hydrophobic contaminants on microplastics can be much higher. The most sophisticated and productive coral reef ecosystems, which support a wide variety of marine animals and offer ecosystem services to humans, have also been shown to contain a variety of chemical contaminants, including petroleum hydrocarbons, pesticides, trace metals, etc., which can synergistically act with increasing temperature and help in the bleaching of these gardens of the sea. Ingested microplastics are accumulated in different tissues and effect on digestion, tissue necrosis, energetics, trophic transfer, pollutant toxicity can be noticed.

Benthic species like barnacles, sea squirts, as well as bacteria that build biofilms on the sea bed, may use plastics as novel substrates. The buoyancy and sinking rates of microplastics may change due to biofouling, which may also protect them from UV radiation and influence the eating of microplastics by predatory organisms. Microplastics may be absorbed and consumed by species at the first trophic level, allowing a gateway into the food chain. A vector of microplastic contamination to deeper levels of the water column could be migratory zooplankton. In marine ecosystem(s), zooplankton serves as a food supply for a variety of different species and function as a link between higher trophic levels and primary producers like phytoplankton. MPs were demonstrated to have detrimental impacts on planktonic organisms' health, including decreased enzymatic activity, reduced reproductive success, decreased survival and growth, decreased fecundity and reproductive rates, etc. Modifications to filtering capacity, swimming activity, oxidative defence, energy production and feeding behaviours were other effects that indirectly affected zooplankton survival (Rodrigues *et al.*, 2021).

The most likely way that marine creatures and microplastics may interact is through ingestion. In some cases, an organism's feeding habits do not permit it to distinguish between prey and artificial objects. Microplastics are also likely to bioaccumulate in predatory animals due to the continual ingestion of vast quantities of MPs ingested by zooplanktons. Fish have evolved to deal with many undesirable gastrointestinal nonfood materials as a result of either intentional or unintentional ingestion of partially digestible or indigestible material; however, microplastics have some special properties that could have a variety of negative effects on fish. Microplastic accumulates in different organs of fish, such as gills, liver, brain, gastro-intestinal tract, *etc*. Microplastic absorption by the gill is mainly dependent on its size and the physical characteristics of its filament and causes stress to the host. MPs also have the potential to accumulate fat in the liver, disturb metabolic processes, oxidative stress and many more. The biological effects of MPs in some targeted fish species are given in table 1. The toxicological effects of microplastics act as both a source and a vector for a variety of pollutants. Higher trophic species can more readily absorb pollutants linked to microplastics. Humans may also absorb microplastic particles by drinking water, eating aquatic and terrestrial foods, *etc*. Very small particles of MPs can pass through cell membranes and may have effects on cell damage, oxidative stress, inflammation, *etc*., leading to serious health issues.

Mitigation of MPs Pollution

Macro-, micro- and nano-plastics have an adverse effect on the environment and living things due to their poisonous properties, release of sorbed pollutants and the leaching of their compounds. The greatest strategy for combating plastic pollution is to find a replacement. The ideal substitute for non-degradable plastics

Table 1: Biological effects of MPs in some targeted fish species

Sl. No.	Targeted species	Types of MPs	Concentration	Biological effect
1	Gold fish (*Carassius carassius*)	PA, PS, EVA	15-76 items fish^{-1} for 6 weeks	Reduced weight gain, damage buccal cavity.
2	African catfish (*Clarias gariepinus*)	PE	50-500 µg L^{-1} of water for 96 h	Decreased high-density lipoprotein in blood, increased albumin to globulin ratio.
3	Zebrafish (*Danio rerio*)	PS	20-2000 µg L^{-1} of water for 3 weeks	Increased superoxide dismutase and catalase activity; Necrosis and lipid droplets were observed in hepatocytes.
4	European sea bass (*Dicentrarchus labrax*)	PVC	0.1% MPs in diet for 90 days	Increase of goblet cells in distal intestine, shortening and swelling of villi, widening of the lamina propria, vacuolation of enterocytes.
5	Common goby (*Pomatoschistus microps*)	PE	100 items L^{-1} of water for 96 h	Reduced predatory performance
6	Silver barb (*Barbonymus gonionotus*)	PVC	0.2-1.0 mg L^{-1} of water for 96h	Increased mean thickness of distal and proximal intestine, increased trypsin and chymotrypsin activity.

(Source: Wang *et al*., 2020)

is the use of bio-plastics. These are made of biodegradable polymers such as starch, cellulose, pectin, *etc*. Degradable polymers are made up of polymers that degrade aerobically or anaerobically into carbon dioxide, water and organic matter, but they are twice as expensive as traditional plastics. The demand for environmentally friendly and naturally derived products is rising daily. These biopolymers are used widely in the food and pharmaceutical industries.

However, the two main methods to mitigate plastic pollution, aside from technical innovations, are controlling the source of plastic through awareness campaigns and cleanup programmes. It is possible to minimize plastic production by implementing appropriate legislation and restrictions on plastic use. Increasing awareness and proper education on the environmental and health impacts of microplastics or plastics is a long-term solution to reduce the use of plastics, which will direct people to use their alternatives. This will lead to the redesigning of plastic products into plastic-free products.

Conclusion

All oceans have been observed to be accumulating plastic, particularly microplastic particles. MP is also found in freshwater ecosystems such as rivers and wetlands. Sometimes these materials degrade to such an extent that they mix with sediment and become difficult to identify. Visual inspection with a microscope was typically the first step in the quantitative and qualitative assessment of MPs, which was then followed by spectroscopic analysis. It is essential to have a deeper understanding of microplastic pollution in the aquatic environment. To develop a microplastic-free environment, collaborative approaches must be taken between sociological, biological, engineering and technological sectors. To stop future aquatic contamination, technology or strategy must be implemented before MPs become nanoplastics.

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