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Microplastic and Their Impact on Food Chains

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A B S T R A C T

This contribution focuses on microplastics, their classification, and the sources or pathways through which they find their way into the ecosystem. The microplastics thus enter various food chains and pose a direct impact on biota including the benthos, corals, and avifauna. Indirectly they may also pose a threat to humans. Besides impacting the food chain, additives also play an important role in causing several diseases. This article further, enumerates some preventive steps taken by different countries to reduce or combat plastic pollution and on addressing the microplastic issue. A discussion on the future course of action through policy measures and/or economic principles promoting and helping reduce microplastic pollution, other eco-friendly alternatives, etc. is also discussed.

Keywords:

Microplastics, nanoplastics, trophic transfer, bioaccumulation, Bisphenol-A, phthalates

Introduction

Plastic is a human-engineered polymer that shows exceptional properties, such as, strength, durability, lightness, versatility, and transparency making it a unique material. It evidences its contribution in almost every sector, including food packaging, electrical and civil construction products, and even in pharmaceuticals and medical uses.[1] The properties of plastics make their degradation slow/least; once produced, they persist in the environment.[2] After disposal, these can enter the oceans as macroplastics; and due to the action of environmental factors, these degrade to form microplastics, nanoplastics, fibers, and fragments.[3] The size of microplastics varies from one micrometer to five millimeter in diameter. In the marine ecosystems, based on the source of emissions, these can be characterized as primary microplastics and secondary microplastics.

Primary microplastics- When the microplastics are intentionally engineered with a size below five millimeter for domestic or industrial purposes, they are termed primary microplastics (Fig. 1). Usually, the categories of plastics like polypropylene, polyethylene, and polystyrene are used in engineering

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primary microplastics.[2] Cosmetic industries involve microplastics in their products like face wash, sunscreen, shaving cream, toothpaste, body wash, scrubs, etc., to serve a variety of reasons, such as, to increase the volume of the product, control viscosity, helping the product to form a thick layer, and also in adding aesthetics.[13] Textile industries include microplastics to enhance the durability of cloth material. Microplastics are also generated by the printing industries and tyre industry in the production of synthetic tyres that are long-lasting. These are also produced from air blasting technology which involves blasting acrylic, melamine, or polyester. Primary microplastic scrubbers are also used in machinery and engines to remove rust and paint, and these scrubbers are used continuously till they diminish in size or lose their cutting capability. They often get contaminated by heavy metals too.[4]

Secondary microplastics- The macroplastics, and plastic bits when degraded by natural forces into smaller-sized particles, give rise to the secondary microplastics.[2] This degradation process can be mechanical (involving erosion, wave action, and abrasion), chemical (involving photo-oxidation, temperature-action, and corrosion), and biodegradation (Fig. 2). Another factor resulting in the fragmentation of macroplastics is solar ultraviolet (UV) rays via the process of solar UV ray-induced oxidation which gets accelerated by high temperatures[14]. The disintegration of plastics into microplastics is affected by their properties, such as size, density, and the presence of additives.[4]

Both primary and secondary microplastics are accompanied by some additives or chemicals to enhance their properties, such as, bisphenol-A (BPA), phthalates, brominated flame retardants, and organo-tin which are of more concern than the plastic itself.[14]

Sources and pathways of microplastic contamination in food chains

Microplastics can enter marine ecosystems on account of activities in terrestrial ecosystems, such as, wastewater treatment plant effluents, river discharges into oceans, groundwater leaching, or anthropogenic activities like illegal disposal or accidents during fishing or shipping, as well as from gas and oil exploration platforms. [(3,5)] Microplastics can also enter marine ecosystems through processes of natural degradation and from the atmosphere, such as, exhausts from textile or rubber industries, household dust, etc.

As microplastics share their resemblance with some of the planktons which are at the base of the marine food chain, they are captured and ingested by zooplankton. [(3,5)] According to a study, it took only three hours for microplastic particles to get transferred to macro-zooplanktons after being exposed to meso-zooplanktons.[10] After ingestion, microplastics are neither digested nor absorbed, these are instead egested or passed on through the cell membrane, and get accumulated within tissues (Fig. 3). These contaminated zooplanktons are further taken up by other animals of higher trophic levels leading to contamination throughout the food web and nutrient cycles.[5] Indirect transfer includes feeding on the microplastic particles present in the fecal matter of contaminated organisms, as observed in the coprophagous copepods. If microplastics are not excreted out, they will be transferred to organisms of other higher trophic level(s) via a carnivorous diet.[7] Other than benthic marine organisms, large aquatic animals, such as, seabirds and turtles are more prone to ingesting microplastics; they can directly consume microplastics floating on the water surface, or indirectly by consuming the already contaminated marine organisms.[8]

Impact on marine biota

When a microplastic is consumed by an organism, it tends to face some rejection for being digested, therefore, sometimes it is retained in the digestive tract giving the organism a feeling of fullness that decreases its hunger and ultimately its feeding urge. This can lower down the nutrient intake which leads to diminished body weight, growth inhibition, and decreased reproduction rate of the organism.[7]

Corals

They form a symbiotic association with algae to get energy, they also get nourishment by consuming phytoplankton, zooplankton, and small organisms like copepods and amphipods which are often contaminated with the microplastics. The microplastics cannot be digested by corals, and get accumulated within their digestive system leading to branching of hard coral species which gets fragmented later. It results in reduced habitat heterogeneity supporting macroalgal colonization.[8]

Plankton

In algae, besides several physical damage and oxidative stresses, microplastics can also cause gene expression alteration involved in certain pathways. In a few cases, a reduction in chlorophyll content has also been reported in the affected algal species.[11]

Ichthyofauna

Many species of fishes in the English Channel were found to have consumed microplastics consisting of polystyrene, polyamide, polyester, and low-density polyethylene. This contamination and accumulation in the gut cavity have led to starvation, malnutrition, and even the death of organisms. The life-span of the microplastics in the body of fish is decided by the size of microplastic, as the smaller microplastic pieces can be removed with natural excretion whereas larger particles tend to stay longer. The longer they stay the more they affect the fish in sub-lethal ways.[8]

Sea avifauna

Many birds feed on the sea surface, like, albatrosses, shearwaters, and petrels. On their quest for gathering food, they ingest microplastics that get accumulated in their stomach. In the Atlantic region, plastic pellets were observed in the digestive systems of sea birds, and some microplastics were also reported in their excreta. The presence of microplastics in their body is responsible for altered feeding habits which lead to starvation and lack of fitness.[8]

Chelonians

Approximately, 30 per cent of species of turtles are known to be contaminated with microplastics in their digestive tract as observed in Brazil, due to direct ingestion or via bioaccumulation. The ingestion of plastic particles results in clogging of the intestine and gut cavity, leading to starvation.[8]

Large mammals

Whales have a high content of fat and lipids in their body, which make them more potent to ingest and accumulate microplastics in their intestine or stomach. There are numerous reports of deaths of stranded whales that show the presence of microplastics in the litter present in their gut. Microplastics were also observed in the stomach of Hooker's sea lions and the scat of fur seals.[8]

Impact on Humans

Owing to their versatility, plastics have found a niche in almost all forms of human requirements. We remain in contact with plastics daily for various objects, starting from toothpaste containing microbeads to other personal-use products. Not only are we getting in contact with plastics but indirectly we have also started consuming them. Humans are at the apex of many food chains and consume a huge variety of both freshwater and marine organisms, making them vulnerable to biomagnified concentrations of microplastics.[9]

The ingestion of microplastics can alter chromosomes which can result in infertility, obesity, and various forms of cancer.[7] When nanoplastic particles are consumed with contaminated seafood, these obstruct the blood flow by getting aggregated.[14] Specifically, in women, few microplastics can mimic estrogen which can lead to breast cancer.[8] Microplastic additives (Table 1) like phthalates are known to cause birth defects.[14] Certain additives can result in early puberty in females, obesity, alteration in the functioning of reproductive organs, and cause a reduction in sperm count in males due to their hormone disruptive ability.[13] Flame retardants and phthalates are known to be carcinogenic and endocrine-disrupting compounds. Phthalates can also cause birth defects. Lead which is commonly used in PVC (Polyvinyl chloride) as heat or UV stabilizers, can lead to infertility or cell damage. Butyl benzyl phthalate (BPA) inhibits thyroid hormone-mediated transcription and alters pancreatic beta cell functioning. Tin which is also used in PVC can cause breast cancer, vomiting, and stomach complaints. The presence of Arsenic in ingested microplastics can damage kidneys, liver, and can also cause death.[17] As microplastics in water bodies travel along the long route, these tend to carry some harmful pathogens which increase the disease risk in aquatic animals as well as humans.

Overcoming the microplastic problem

In the Anthropocene era, the global community is posed with an issue "***Is future free from plastic pollution possible***?" Being highly persistent in the environment, microplastics are entering the food chains and food webs and getting trophically- transferred in different levels. The presence of microplastics in marine ecosystems directly or indirectly affects marine organisms.[6] Human population is increasing at an alarming rate which also increases the dependence of humans on marine organisms, but marine organisms contaminated with ingestion of microplastics are affecting food availability.[12]

Plastic pollution is the center of attraction globally, therefore, many countries have taken several steps to control it (Tables 2 and 3). Each year, 3rd July is now recognized as "***Plastic Bag-free Day***" as a part of the broader breadth of "***Free from Plastic Movement***". A complete ban on the usage of microplastics in the cosmetic industry was seen in the year 2017 in the US, in 2018 in Canada, followed by in the UK. Some countries, such as, Sweden, Iceland, Finland and Ireland are planning to ban rinse-off cosmetic products.[13] In Ireland, a noticeable reduction of usage of plastic bags has been observed because of Lowenthal's bill, which directs for a high tax on using plastic bags. Funds so collected, are used in conservation projects. California has banned single-use plastic bags under the Prop67 Bill.[8]

Microplastics are emerging pollutants, and their concerns have resulted in many guidelines and programmes. When the Expert Panel of the United Nations Environmental Programme (UNEP) noticed marine organisms consuming microplastics, the Panel set-up a programme engaging 120 countries creating awareness and educating people to reduce plastic use and promote recycling and use of alternatives. Several NGOs have also come up with many programmes of educating people about plastic pollution.[4] There are policies, such as, Extended Producers Responsibility (EPR) which makes the producers responsible for collecting their used products and getting them recycled instead of doing the same by the municipal authorities. It involves collecting waste or the used products, and converting them for use as raw materials; this also leads the way for a circular economy. These actions can lead to minimize waste and reduce the pollution emanating from them too.[16]

What can we do?

A combination of science and policy– **political ecology application** is called for to mitigate the microplastic-centric pollution in the environment.[14] Both policymakers and scientists have to work together to reduce microplastic pollution. As the governments have started banning the usage of microplastics in cosmetics, many international cosmetic companies came up with various alternatives, such as, beeswax and jojoba wax which are worth giving a try.[13] Microbeads in cosmetic products are one of the major sources of microplastic entering the water bodies. As producers, these industries must mention the ingredients in their products, and the consumers need to be made aware of what they are using, and its impact on the environment.

Plastic cannot be degraded completely but some bacteria could degrade the microplastic up to some extent; the list includes *Pseudomonas*, *Bacillus amyloliquefaciens*, *Moraxella* spp. and many more. Recently, scientists have developed biodegradable microbeads from cellulose, which can occupy the place of plastic microbeads in the coming years.[14] Health impacts of microplastics and even smaller nanoplastics are not known much to the common human mass. Taking charge of creating awareness and educating people by the product manufacturers and by government, will help drawing attention to problems posed by the microplastics.[4]

The scientific community also needs better funding to work into more aspects of these micro-pollutants and find ways for their replacement and degradation. At an individual level, as a consumer, we need to be well-versed with the products that are used and opted, for all-natural ingredients or environment-friendly alternatives. Instead of using single-use plastic products, reusable products usage should be encouraged. Food materials packed in plastic containers should be labeled strictly. Government incentives for the adoption of strategies like EPR by manufacturers can help in reducing waste collection costs and encourage a circular economy. Above all, we need to promote "***conscientious consumerism***" locally, regionally, and globally.

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Table 1: Impact of selected additives on human health

Additive	Impact on human health
BPA	Hormone disruption, alteration of liver and pancreatic beta cell functioning
Phthalates	Carcinogenic, endocrine disruptor
Flame-retardants	Carcinogenic, endocrine disruptor
Lead	Anaemia, hypertension, miscarriages, nervous system damage, infertility, oxidative stress, cell damage
Mercury	Mutagenic or carcinogenic, disturbs the molecular structure of DNA, brain damage
Tin	Breast cancer, skin rashes, stomach complaints, nausea, vomiting, diarrhoea, headache, potential clastogen
Arsenic	Congenital disabilities, carcinogenic, lung, skin, liver, bladder, kidney, gastro-intestinal damage and death

Table 2: Initiatives adopted by certain countries to overcome microplastics pollution

Country	Policy or Bill	Mitigation Measure
Ireland	Lowenthal's Bill	Ten per cent fine for shopkeepers on giving plastic bags to take away groceries, and four per cent if the bag is recyclable.
USA (California)	Prop67 Bill	A complete ban on single-use plastic bags
USA (California)	Assembly Bill 888	Strict action on using microbeads in domestic and cosmetic products; emphasized natural and eco-friendly alternatives
USA	Microbeads Free Waters Act, 2015	Set-up to minimize microbeads pollution in water
USA (Canada)	Canadian Protection Act	A complete ban on the usage of microbeads in cosmetics

Table 3: Institutional initiatives for safe collection of and disposal of plastic waste in India

Initiative	Measure Adopted
Plastic Waste Management (Amendment) Rules, 2018	• Expended the jurisdiction of applicability from the municipal area to rural area, as the plastic has reached to rural areas also. • Applicable to every waste generator, waste producer and manufacturer of plastic carry bags and multi-layered packaging material. • Increased minimum thickness of plastic carry bags from 40 to 50 microns to facilitate collection and recycling of plastic waste. • All producers, importers and brand-owners have to fulfill the Extended Producers Responsibility (EPR) and submit EPR Action Plan as per SOP evolved by Central Pollution Control Board (CPCB).
Guidelines for Handling, Treatment and Disposal of Waste	• Waste non-cotton masks and gloves in general households are to be kept for 72 h minimum prior to their disposal. • Discarded Personal Protective Equipment) PPEs are to be stored in a separate bin for three days, later dispose them after cutting/shredding.

generated during Treatment/ Diagnosis/ Quarantine of COVID-19 patients, 2020	• At material recovery facilities, discarded PPEs containing plastic, are to be shredded and send to the authorized plastic waste recyclers or disposed off at sanitary landfill only. • Healthcare staff to take back the PPEs for safe disposal.

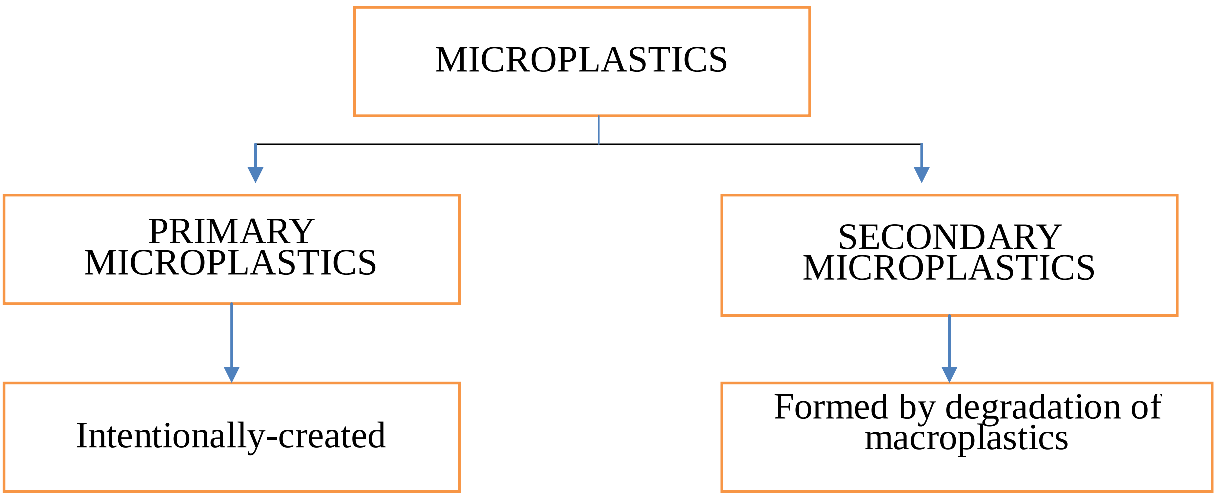

Figure 1:Categories of microplastics

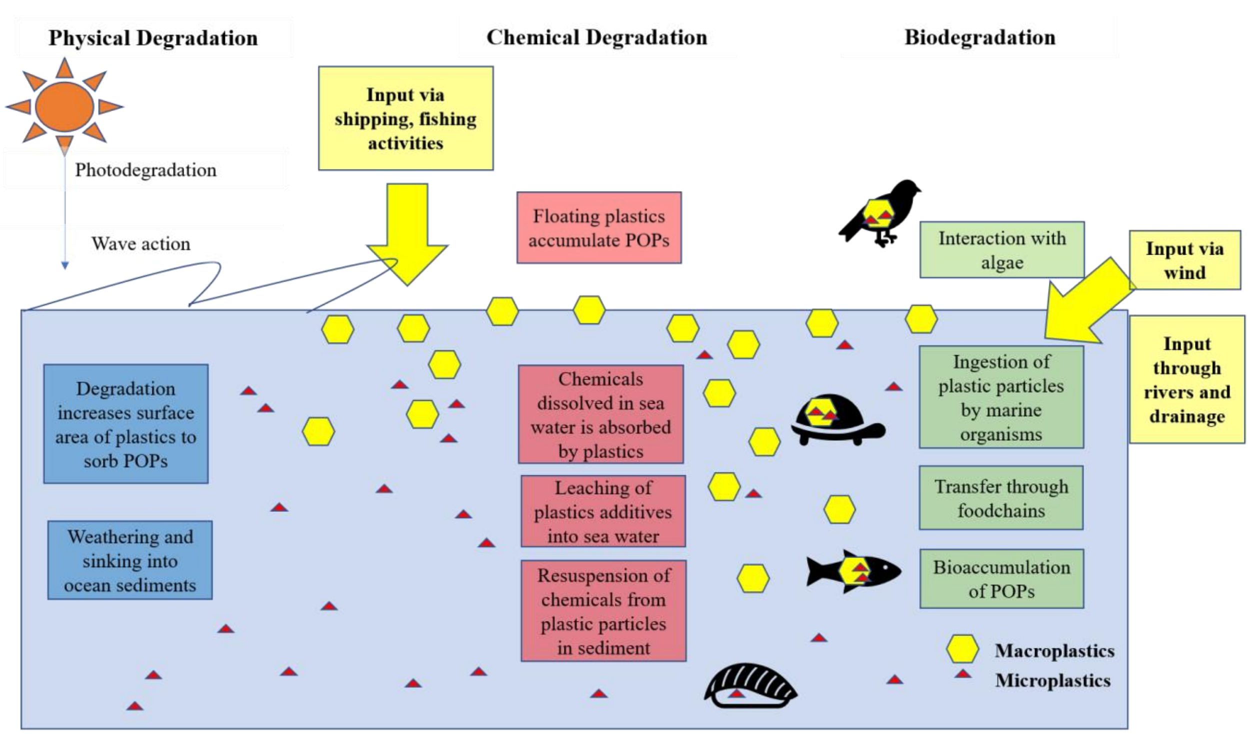

Figure 3: Sources of marine microplastics and the various physical, chemical, and biological processes affecting microplastics in the marine environment

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