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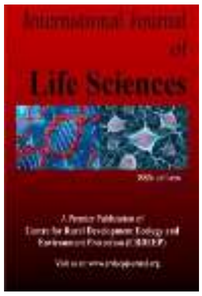

Full Length Research Paper

A Review on Emerging Microplastics Pollution in the Marine Environment: A Threat to Seafood Security and Human Health

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ABSTRACT

In the present Era, plastic is a critical raw material, particularly in the last 30 years, as production and use have steadily increased. The rise in plastic discharge into the marine environment drew a lot of research, media, and public attention to assessing their environmental impact in terms of plastics classification, sources, and effects. This significantly affects marine biodiversity, public safety, and the spread of infectious diseases among aquatic and human species. The detection of Microplastics (MPs) in biotic and abiotic matrices is critical for determining how these pollutants affect marine ecosystems and put them at risk of losing functionality and biological diversity. MPs are considered accessible to species throughout the food web due to their microscopic size. Direct and indirect impacts of MPs in the fish population can lead to human nutritional deficiencies since fish contribute 20% of total animal protein intake .8To better focus future research in this area and fill knowledge gaps, we conducted a review of some of the literature on microplastic exposure, pathways, and their potential risk to fishes and human beings.

Introduction

Plastic is a critical raw material in today's world, particularly in the last 30 years, as production and use have steadily increased. They are highly flexible materials that have benefited society greatly. They are low-cost to manufacture, lightweight, and adaptable which makes them useful in a wide range of applications, including food packaging, consumer goods, and medical devices. Primarily, the durability of plastic, which makes it such a desirable material to use, also makes it very resistant to deterioration, making it difficult to dispose of plastic garbage (Nemat *et al*.,2022), While some plastic waste is recycled, the majority of it ends up in landfills, where decomposition can take centuries. Plastics that reach the maritime environment due to indiscriminate disposal are of particular concern (Abedin *et al*.,2022). Plastics that enter the marine environment can persist for hundreds and thousands of years before being broken by mechanical and photochemical processes, culminating in the production of microplastics (less than 5 mm) or nano plastics (less than 1 m). Even though plastics are a globally recognized pollutant with legislation to reduce the number of plastic debris in the ocean (Horton *et al*.,2022). (Thompson 2006) estimates that up to 10% of plastics produced end up in the oceans, where they may persist and accumulate.

MPs, which include small plastic granules used as scrubbers in cosmetics and air-blasting, as well as small plastic fragments derived from macroplastic breakdown, have become a growing source of environmental concern (Kacprzak and Tijing, 2022). Small plastic fragments were first discovered in the open ocean in the 1970s (Carpenter and Smith, 1972), and a renewed scientific interest in MPs over the last decade has revealed that these contaminants are widespread and ubiquitous in the marine environment, with the potential to harm biota. MPs are considered accessible to species throughout the food web due to their microscopic size. Fish is one of the readily available sources of food, and it is rich in vitamins, proteins, and minerals which are essential for the proper growth and maintenance of body functions.it is also an excellent source of amino acids and which are easily digestible proteins.

These days fish demand is increasing because of its high nutritional qualities. Micronutrients are abundant in most small fish. It plays a crucial role in human nutrition (Koehn *et al*.,2022). major constituents in the muscle portion are water, protein, lipid, and minerals. The most dangerous chemical constituents present in MPs are translocated to the tissues of fishes and affect human health and food security. Direct and indirect impacts of MPs in the fish population can lead to human nutritional deficiencies since fish contribute 20% of total animal protein intake. The detection of MPs in biotic and abiotic matrices is critical for determining how these pollutants affect marine ecosystems and put them at risk of losing functionality and biological diversity.

Review methodology

This study made use of a review of academic articles, internet materials, bulletins and conference papers on microplastics and its impacts from Elsevier, Springer, Wiley, Tailor and Francis. This led to the compilation of various researchers' work on combined or individual consequences of both these menaces and strategies.

Microplastics

Microplastics are a common pollutant in the marine environment that poses a health risk. They are produced either directly for commercial purposes or indirectly as a result of the decomposition of bigger polymers. Microplastics have a wide range of physio-chemical characteristics and toxicological behavior, making determining a toxicological profile difficult. Other factors to consider in their potential toxicity include polymer type, size, form, and color, in addition to their concentration (Meaza *et al*.,2021). (Thompson *et al*., 2004) coined the term "MPs" to describe micro-sized plastic particles in sediments and water. MPs can be found in the environment as primary or secondary MPs. Primary MPs are purposefully made to be that size, while secondary MPs are bits of plastic that break down from larger pieces. MPs are found in different forms like Pellets, fragments, fibers, films, foams, beads, and many other shapes. Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyethylene Terephthalate (PET), Polyvinyl Chloride (PVC), Nylon, and Rayon are some of the most common MP polymers found around the world (Thompson *et al*., 2009a). Globally, these polymers contribute to over 85% of plastic polymers synthesized. Approximately, 90% of plastic polymers fall under one of these 2 categories such as HDPE (high-density polyethylene), or LDPE (low-density polyethylene) (Andrady and Neal, 2009).

Primary Microplastics

Primary MPs are plastics that are made to be microscopic. These plastics are commonly found in facial cleansers and cosmetics (Batool *et al*.,2022), as well as air-blasting media (Nabi *et al*.,2022), and their use in medicine as drug vectors is becoming more common (Patel *et al*., 2009). Virgin plastic production pellets (typically 2–5 mm in diameter) can be considered primary MPs under the broader definitions of a microplastic (Andrady, 2011; Costa *et al*., 2010). Air blasting technology has also been developed using primary MPs (Nabi *et al*.,2022). This method involves blasting machinery, engines, and boat hulls with acrylic, melamine, or polyester microplastic scrubbers to remove rust and paint (Browne *et al*., 2007).

Secondary Microplastics

Secondary MPs are small plastic fragments that result from the breakdown of larger plastic debris when exposed to natural phenomena like sunlight, wind, water, and other environmental stress (Padha *et al*.,2022). Exposure to sunlight for long periods can cause photodegradation of plastics; UV radiation causes oxidation of the polymer matrix, which leads to bond cleavage (Andrady, 2011; Browne *et al*., 2007; Moore, 2008). As a result of this degradation, additives designed to improve durability and corrosion resistance may leach out of the plastics (Talsness *et al*., 2009). The total amount of secondary MPs discharged into the marine environment is estimated to be between 68,500 and 275,000 tons per year (Plastics Europe, 2016)

Sources of Microplastics

The indiscriminate disposal of waste products that are either directly or indirectly transmitted to our seas and oceans leads to marine litter (Kacprzak and Tijing;2022). Plastic is a synthetic material that owns numerous special properties such as soundness, resilience, lightness, etc (Li *et al*., 2019). And due to its numerous unique properties, it has been widely used by various industries. However, improper treatment of plastic disposes-off methods has contributed largely to the accumulation of this non-degradable synthetic material into several water bodies. (Daniel *et al*.,2022) his study revealed that the 2018 flood had an impact on the input and distribution of MPs in surface water, bottom sediments, and beach sediments along the Cochin coast in Kerala, India. In all of the months analyzed, MP pollution was identified in all three environmental compartments, albeit the number and variety of MPs rose dramatically after the flood. There was a three-fold rise in MP abundance in coastal waters and a 1.5-fold increase in beach sediments as a result of the flood, but no substantial increase in MP abundance in bottom sediments. The degradation behavior of plastics, when discarded in the environment, is a crucial parameter to investigate. However, the majority of bioplastic degradation studies haven't taken into account the formation of microplastics (Miri *et al*.,2022). Some microplastics will remain pristine (as made) when released into the environment, whereas those originating from water or wastewater treatment plants will have undergone some weathering before being released. Even while these methods can remove up to 95% of microplastics, these facilities' biosolids streams (i.e., dewatered or stabilized sludge) might still wind up in the environment (Alimi *et al*.,2022).

Plastic garbage has been identified in numerous environmental mediums as a result of the increased production and abuse of plastics inland. The classification, sources, impacts, characterization, and quantification of MPs and NPs were addressed in this overview, even though MPs and NPs research is extremely broad and renewable (Aprol *et al*.,2021). Microfibres are microscopic synthetic fibers used in a variety of materials for various sorts of garments. They have been utilized in place of cotton and leather in several products. MPs accumulate in the environment as a result of inappropriate disposal of these items from frequent use. According to a recent study (Ross *et al*. 2021), the Arctic is heavily contaminated by MP fibers, which could have come from clothing laundering. Microfiber aggregation will grow more intense as a result of increased textile manufacturing and the lack of microfiber breakdown (Liu *et al*. 2021). (M. A. Browne *et al*.,2011) noted that experiments that sampled wastewater from domestic washing machines revealed that a single garment could produce greater than 1900 fibers per wash. This shows that domestic and commercial wastewater is one of the principal causes of MPs collecting in natural water bodies. Microbeads are solid plastic particles that are less than 0.5 millimeters in size. They are made up of polyethylene but can also be manufactured from other polymers plastics such as polypropylene and polystyrene. The common uses of these materials are in the production of biomedical and personal care products. Sewage treatment facilities cannot filter these minute particles completely. This is especially true for facilities in developing and underdeveloped countries, where methods are less advanced than in developed countries. Samples collected from sewage sludge disposal sites on the coasts of six continents revealed that there was an average of one particle of MPs per liter of sludge (Browne *et al* .2011).

Coastal tourism, recreational and commercial fishing, marine boats, and marine businesses (e.g., aquaculture, oil rigs) are these sources of plastic that can enter the marine environment directly, posing a risk to biota as macroplastics and secondary MPs after long-term derogation. Tourism and recreational activities are the major responsibility for a variety of plastics being abandoned along beaches and coastal resorts (Derraik, 2002). One of the most commonly noticed plastic trash items having a maritime provenance is fishing gear. Discarded or lost fishing gear, such as plastic monofilament line and nylon netting, is usually neutrally buoyant and thus findable. (Xu *et al*.,2022) in their study sampling and analysis methods, occurrence, source analysis, and health risk of AMPs (Atmospheric Microplastics) were summarized and discussed. Global data on the composition characteristics of MPs in soil and freshwater was compiled, revealing that the fragment MPs in soil and freshwater were higher than in the atmosphere. PP and PE were the most common polymers in soil and fresh water, while PET was the most common AMP in the atmosphere. Once inhaled, AMPs can constitute a health risk, and the amount consumed varies by age, with adults having a lower consumption than children (Yuan *et al*.,2022). A recent major source of MPs pollution is the PPE (Personal Protective Equipment). (Abedin *et al*.,2022) analyzed PPE generated during the 3rd wave of COVID-19 was maximum. They have also mentioned the impact of PPE waste contamination on terrestrial and aquatic ecosystems. The widespread source of PPE is the major source of MPs pollution. They have revealed that PPE waste increase with the increase of infected patients. Overuse of personal protective equipment (PPE) during a pandemic exacerbates plastic waste in the seas, as all sources of deterioration eventually end up in the water. As the outbreak progresses, the situation will worsen, potentially leading to an increase in already existing plastic pollution in marine areas. The manufacture of plastic items that utilize granules and small resin pellets, known as 'nibs,' as their raw material is another noteworthy source of plastic trash (Ateia *et al*.,2022). Production increased from 2.9 million pellets in 1960 to 21.7 million pellets in 1987 in the United States alone (Pruter, 1987). These raw materials can infiltrate aquatic ecosystems by unintentional spills during transportation, both on land and at sea, inappropriate use as packaging materials, and direct out-flow from processing plants. Polymers like polyvinyl chloride (PVC), polypropylene (PP), and polystyrene (PS) can persist in the environment for a long time and affect all organisms. MPs have been concerned about a global issue. Studies revealed that sediments are the long-term sink for MPs. logically high-density plastics sink in sediment and low-density one floats on the surface. due to these benthic organisms consuming these plastics adsorbed in the sediments (Van *et al*., 2015). Pollution associated with MNPs should be controlled through source reduction, incorporation of plastics into the circular economy, and efficient waste management (Sarkar *et al*.,2022).

Table:1 Specific densities of different polymer type

Categories	**Common applications**	**Density (g/cm^3)**	**Reference**
Polyethylene (PE)	Plastic bags, squeeze bottles, detergent bottles	0.917- 0.965	*Zhang et al.,2019*
Polypropylene (PP)	Stoppers, sanitary goods, diaper, sterile wrap, jars	0.9 – 0.91	*Esterhuisen et al.,2022*
Polystyrene (PS)	Disposable cutlery, test tubes, Petri dishes, CD and DVD cases	1.04 - 1.1	*Dong et al., 2019*
Polyvinyl chloride (PVC)	Some bags and liners, blood bags, pipes, adhesive tapes, electric cables	1.16 – 1.58	*Hidalgo Ruz et al., 2012*
Polyamide or nylon (PA)	Production of combs, toys, bangles, decorative gift articles, ball pen, tooth brush	1.02 – 1.05	*Zhao et al., 2020a*
Polyethylene terephthalate (PET)	Water bottle, liquid hand soap, mouth wash	1.37 – 1.45	*You et al., 2020*
Polyester	Clothing fabrics, home furnishing materials such as blankets, curtain, bedsheet etc, manufacture of mouse pads	1.24 – 2.3	*Cai et al., 2020*
Acrylic	Sole of shoes, paint, air craft wind shields, glass roofs, exterior wall designs etc	1.09 – 1.20	*Hidalgo Ruz et al., 2012*

Microplastics in the marine environment

Marine sediment

Plastics are one of the fastest-growing marine contaminants (Zhu *et al*., 2018), they are abundant in marine sediments because they end up in the marine environment (Hassan *et al*., 2022). MPs enter the marine environment through several pathways such as rivers, estuaries, beach littering, aquaculture, fisheries, and shipping/boating activities. According to (Sambandam *et al*.,2022) major input source of MPs are rivers and the dominant polymers are polyethylene and polypropylene. Plastics are dispersed through all zones of the marine environment from the surface water to the sediment floor. Positively buoyant plastics that float on the water's top will only be there for a short time before being fouled and ending up in the benthic zone. Surface fouling on sinking plastics can be briefly re-floated by grazing, resulting in a cyclic floating and sinking pattern until they eventually settle in the depths of the oceans (Alimi *et al*. 2021). (Maghsodian *et al*.,2022) reviewed the contamination of sediments and organisms in mangrove forests with microplastic particles. Sediments and roots of mangrove forests can act as livestock and cause the accumulation of pollutants. The study aimed to compare the average content of microplastic particles in mangrove forest sediments around the world, evaluation of the effect of sediment tissue on the abundance of microplastic particles in the mangrove forests, investigate the relationship between sediments pH and abundance of microplastic particles in mangrove forests, and exploration of microplastic content in studied organisms in the mangroves forest around the world.

MPs have been found in marine sediments all over the world, according to numerous studies (Jiang *et al*.,2022). (Liang *et al*.,2022) assessed MPs in 12 remote lakes on the Tibetan plateau, China. Up to 2644 items of MPs were found per kg of dried sediment collected from Tibetan lakes. When compared with other lakes worldwide these values are considered high. The common type of polymers identified was Polyamide and polyethylene terephthalate.

Microscopic plastic particles are resistant to biodegradation and could persist in the marine environment for hundreds of years, posing a threat to the environment and biology (Zhou *et al*., 2021). The rate of disintegration of plastics is unknown. (Neelavannan *et al*.,2022) assessed the magnitude, type, and source of MPs in bottom sediments from freshwater Anchar lake, Kashmir valley. The study revealed that 606 ± 360 MPs were present per kg of the dried sample, dominated by fibers, pellets, and fragment forms. Polyamide was the dominant polymer followed by Polyethylene terephthalate, polyvinyl chloride, polystyrene, and polypropylene. They concluded that the complex source of MPs is from the automobile industry, textiles, and packaging industries.

The plastics can affect a wide range of organisms such as zooplankton, benthic invertebrates, bivalves, fish, and seabirds which contributes to several biological and metabolic complications in the aquatic organisms (Zhang *et al*., 2022) There have been reports of negative effects on the growth, reproduction, and survival of the marine organisms, as well as oxidative stress and neurotoxicity (Prata *et al*., 2019). (Way *et al*.,2022) was the first one to show indication for the underestimation of microplastics in the environment of approximately 14% across the studies they reviewed. They found that sediment was the most studied medium and the saline solutions were the most used reagent, and polyethylene and polypropylene are the most common polymers in the environment.

Marine water

9.4 million tonnes of plastic waste are produced each year, India's plastic industry is one of the country's fastest-growing industries (Lawale and Jelkie, 2017). Out of this, only 60% of plastic wastes are recycled and reused while the remaining is disposed into landfills or aquatic environments (Ministry of Housing and Urban Affairs, 2019). The vertical and horizontal movement of plastics in the water is caused by a combination of plastic trash characteristics and local environmental conditions. The vertical movement of plastics in water, or sedimentation rate, is influenced by three factors: density, polymer surface area, and particle size (Domercq *et al*., 2022). A polymer's density might be higher or lower than that of water (ocean density 1.02–1.04 g cm1 vs. freshwater density 1.00 g cm1). Several polymers float in water, while others sink, and a third group falls somewhere in between. Rivers are a key entry point for MPs into the marine realm. River discharges transport MPs from land-based to maritime environments (Sambandam *et al*., 2022). A systematic approach on a seasonal basis is necessary to understand the holistic pattern of MPs distribution into the oceans through the rivers. MPs make an entry into the oceans through several pathways which include household and industrial sewage, garbage dumping, wastewater treatment plant (WWTP) discharges, agricultural pollution, textile industry, and cosmetics. The annual input of MPs into the oceans from riverine sources varies between 1.15 and 2.41 million tonnes, with Asia contributing the most (Lebreton *et al*., 2017). MPs account for about 80% of all debris discharged from the terrestrial to the aquatic environment (Wan *et al*., 2022).

Marine biota

The most likely interaction between marine creatures and MPs is ingestion. Because of their small size, MPs have the potential to be consumed by a diverse spectrum of biota in both benthic and pelagic habitats. (Nikki *et al*.,2021) his study indicates that the gut content of *Etroplus spp* was dominated by 99% of organic matter and some sand grains. His finding was, that fishes are consuming plastics intentionally or non-intentionally when they cannot differentiate plastics from prey or organic matter. A vast range of creatures, including birds, fish, turtles, mammals, and invertebrates' mistake MPs for food. Despite the worries about MPs ingestion, little research has specifically addressed the presence of MPs in wild, insitu populations because assessing MPs ingestion in the field is methodologically problematic. Fishes of higher trophic status are exposed to MPs directly from the environment as well as bioaccumulation from lower organisms. (Daniel *et al*., 2021) in his study reported the detection of microplastics in edible tissues of squid species. The findings revealed that shellfish consumers absorb around 13± 58 microplastic particles each year, which can vary depending on the species, quantity, and extent of gut clearance of the seafood consumed. Some of the polymers such as PVC and PS may have carcinogenic effects on marine organisms when consumed (Kumar *et al*., 2022). MPs could also pose serious health threats like mutagens and carcinogens for marine animals causing death (Alprol *et al*.,2021). The endemic barb *Sahyadria chalakkudiensis,* which lives in the Western Ghats of South India, has thriving aquarium commerce and is known to live in the upstream portions of these rivers. Microplastics were found in the stomachs of 730 fish in coordinated research of their feeding biology, suggesting to substantial plastic pollution harming riverine ecosystems. As evidenced by the percentage index of relative indices of various prey items such as animal matter (62 percent), filamentous algae (26 percent), sand particles (4 percent), and other matter, this fish exhibits an omnivorous feeding behavior (8 percent). Microplastic fibers were regularly found in 86 intestines, among other things (Anju *et al*.,2021). (Gundogdu *et al*.,2020) showed the presence of MPs in the stomachs and digestive tracts of 243 individuals of leaping mullet, red mullet, surmullet, Mediterranean horse mackerel, and Sand steenbras collected, and the contents of their guts were examined using a microscope and μ-Raman analysis. A total of 283 MPs were extracted. The most frequently detected polymers were polypropylene (25%), polyethylene (21.9%), polyethylene terephthalate/polyester (8.3%), and cellulose (7.5%).

Many studies have reported the occurrence of MPs in live fishes however few studies are conducted on dried shellfishes from markets. (Li *et al*.,2022) investigated characteristics of microplastics in six kinds of dried shellfish following different cooking treatments. Microplastics were detected in all the uncooked, dried shellfish products, ranging from 0.3 to 4.2 items/g. The polymer types included polyethylene terephthalate, rayon, polyester, nylon, polypropylene, cellophane, and polyester. Frying was suggested for cooking mussels, boiling for clams and winkles, and steaming for scallops.

Biomagnification of Microplastics

Plastic debris accumulates in the marine environment and may affect ecological characteristics (Sivadas *et al*., 2022). As a result, plastic litter is a significant threat to aquatic biodiversity. In ecological risk assessments, bioaccumulation and biomagnification are two key concepts for determining the extent of pollutant transport within food webs. The serious concept of bioaccumulation and biomagnification usually refers to dissolved chemical contamination although the terminology has been readily adopted by the MP literature (Dawson *et al*.,2018). Generally, bioaccumulation (or body burden) is defined as the net uptake of a contaminant from the environment through all possible routes like contact, ingestion, and respiration from any source. bioaccumulation occurs when the uptake of a contaminant is greater than the ability of an organism to digest a contaminant. The biomagnification of contaminants at higher trophic levels may result from bioaccumulation and further trophic transfer of contaminants. Biomagnification across a food web is thus defined as the increase in the concentration of a contaminant in one organism compared to the concentration in its prey. Quantification of MPs in field-collected organisms and their natural predators, as well as controlled feeding studies attempting to simulate MP trophic transfer through artificial food chains, provide evidence for MP trophic transfer (Yusuf *et al*.,2022).

Polystyrene nanoparticles (24 nm) were fed to goldfish *(Carassius carassius)* via a freshwater food chain that included algae *(Scenedesmus sp.)* and zooplankton *(Daphnia Magna)* (Cedervall *et al*., 2012). When compared to control fish, exposed fish took twice as long to ingest the same number of zooplankton. Weight reduction, variations in the triglycerides: cholesterol ratio of blood serum, and cholesterol distribution between muscle and liver were all described as metabolic effects. The transfer of MPs and pollutants in a maritime environment could have serious consequences. MPs were discovered in planktivorous fish, which led to larger predatory feeding on fish (Aytan *et al*.,2022). Low-density MPs are expelled as pseudo feces, and the majority of them remain in the gastrointestinal tract (Capone *et al*.,2020).

Human exposure to Microplastics

The presence of MPs in seafood poses a serious health risk to humans. Seafood is an important part of the human diet. Consequently, MPs contamination in sea-derived products along with human health and safety has gained attention in recent times (Karami *et al*., 2017). Humans consuming seafood which are contaminated with intoxicated MPs may be subjected to serious health impacts (Kumar *et al*., 2022). Apart from seafood, MPs have been observed in foodstuffs such as table salts, beer, sugar, and bottled drinking water which is commonly consumed by humans (Kosuth *et al*., 2018). Therefore, humans are also affected due to consumption. The serious risk of MPs spreading to other organs of the body is demonstrated by the contamination of the intestinal system. (Leslie *et al*.,2022) reported exposure to plastic particles in human blood. They developed a sensitive sampling and analytical method with double-shot pyrolysis - gas chromatography/mass spectrometry and measured plastic particles ≥700 nm in human whole blood from 22 healthy volunteers. The most common polymers found were polyethylene terephthalate, polyethylene, and polymers of styrene, followed by poly methyl methacrylate. Polypropylene was investigated; however, the results were not quantifiable. The mean of the sum measurable concentration of plastic particles in blood was 1.6 g/ml in this investigation of a small group of donors, indicating the first measurement of the mass concentration of the polymeric component of plastic in human blood. Plastic particles are accessible for uptake into the human bloodstream, according to this ground-breaking human biomonitoring study. The most common way humans consume MPs and nano plastics is through ingestion, according to exposure and toxicity studies. Humans may consume 0.1–5 g of microplastics per week on average through diverse exposure paths around the world (Senathirajah *et al*.,2021). The basic human diet consists of fruits and vegetables, meat, fish, cereals, and legumes, with water serving as the primary hydration source. The number of particles consumed with fruits and vegetables has been determined (Conti *et al*.,2020). MPs were found in a mean level of 132 740 p/g (particles/gram) in five commonly consumed fruits and vegetables (apples, pears, broccoli, lettuce, and carrots) from various grocery stores. (Domenech and Marcos,2021) estimated that the total burden of human exposure to Micro and Nano Plastics s is 2.93 1010 p/year, from recent data available.

The second most method of human exposure is inhalation. Our environment contains airborne plastic particles primarily from synthetic textiles leading to unintended inhalation. Recent studies on the human inhalation of plastic particles have indicated that atmospheric fallout in urban areas is a significant cause of the particles. Although people are most exposed to MPs through inhalation and ingestion, alternative exposure pathways such as dermal contact should not be overlooked. However, the scarcity of research in this area stands out. Furthermore, all exposure quantification studies are carried out in a specific setting, examining a specific exposure pathway. As a result, estimating total global human exposure is impossible.

Impacts of Microplastics

Marine biota

Table 2: Impacts of various fishes upon MP exposure

Species	Health effects	Reference
Danio rerio	Delay in hatching, oxidative stress, cellular detoxification	Marco *et al*.,2022
Oryzias melastigma	Hypoxia, cardiac development, delayed hatching	(Xia *et al.*,2022).
(PVC PMP) Primary microplastics	Shortened hatching time, teratogenic effects	
PVC (SMP) Secondary microplastics		
Sparus aurata		
MP diet	Higher mortality rate, increased abundance of several brain and liver primary metabolites, hepatic and intestinal histological defects, higher assimilation of an essential element (Zn), and lower assimilation of a non- essential element (Ag)	Jacob *et al.*, 2021
Control diet	Lower mortality rate	
Barcodes gonionotus	Intestinal mucosal epithelium thickened	Romano *et al.*,2018
Dicentrarchus labrax, Trachurus trucharus *Scomber colias*	lipid oxidative damage in the gills, muscle, and brain and increased brain AChE activities	Barboza *et al.*, 2020
Pimephales promelas		Bucci *et al*.,2021
polyethylene and polypropylene preproduced pellets	lower survival, length and weight	
polyethylene and polypropylene from environment	a greater rise in length and weight	

The impact of MPs on the environment and biota is well known. aquatic organisms ingest the MPs adsorbed by pollutants and lead to the contamination of the food web. MPs can also absorb the pollutants like hydrophobic pollutants, persistent organic pollutants, heavy metals, and pathogenic microbes, and all these contaminants along with MPs are accumulated in organisms. MPs' ability to be encountered or ingested by marine species is mostly due to two fundamental characteristics of the particles: size and density. The smaller sizes of MPs make the marine organisms accidentally consume them thereby causing blockages of digestive and intestinal tracts resulting even in death.

Zebrafish *(Danio rerio)* prominent model of the organism and many studies have been conducted by biological researchers. to elucidate the impact of MPs, a fish embryo toxicity test was performed on Zebrafish. it has been exposed to 10 μm Polystyrene MPs 200 particles/mL for 120 hpf (hours post-fertilization). After exposure, the number of MPs accumulated in the larvae was quantified, survival, hatching, and larvae growth were tracked, and oxidant/antioxidant reactions and cellular detoxification were assessed. There was no effect on the survival of growing zebrafish, but there was a considerable delay in hatching. Also increased level of gene transcription is involved in oxidative stress and cellular detoxification (De Marco *et al*.,2022). (Xia *et al*.,2022) investigated the embryotoxicity of polyvinyl chloride SMP (Secondary MP) and PMP (Primary MP) to the marine *Oryzias melastigma*. the study determined the physical impacts of MPs and the underlying mechanism of physical toxicity. According to the study SMP is more toxic. It shortened hatching time and induced higher teratogenic effects. Their study highlighted the negative effects of environment-relevant SMP on the marine environment. (Jacob *et al.*, 2021) exposed juvenile seabreams *(Sparus aurata)* for 35 days to control diet and MP diet. To control diet, they have prepared glass beakers filled with seawater and phytoplankton and aerated with an air pump. For MP diet same procedure with 20 mg of polyethylene primary MP particles and they have examined biological, physiological, and histological markers to evaluate the impact of MP in fish. Fish exposed to MP shows more aggressive behaviour than control, and it also shows severe toxicity. *Barcodes gonionotus* were exposed to polyvinyl chloride at various concentrations of 0.2, 0.5, and 1.0 mg/L for 96 h. for which the whole-body histological evaluation and analysis of digestive enzymes trypsin and chymotrypsin were performed. With the increase in PVC exposure, trypsin and chymotrypsin activities are increased. Tissue damage was not evident in any of the organs or gills (Romano *et al*.,2018). (Barboza *et al*., 2020) his study investigated MP contamination and effect biomarkers in three commercially important fishes *(Dicentrachus labrax, Trachurus trachurus, and Scomber colias)* from the North-East Atlantic Ocean. A total of 368 microplastic items were recovered from 50 specimens of each species. AChE, CHE activities, and LPO levels are determined using the brain and dorsal muscles of the fish. Fish with microplastics had significantly higher brain AChE activity and increased LPO levels in the brain, muscle, and gills than fish without microplastic. No significant differences in muscle ChE activity between fish with and without microplastics were found in any of the species. (Bucci *et al*.,2021) demonstrated the impacts of polyethylene and polypropylene microplastics acquired as preproduction pellets (referred to as "preconsumer"), as well as a mixture of polyethylene and polypropylene gathered from the environment, were explored. For 14 days, embryo-stage fathead minnows *(Pimephales promelas*) were exposed to either physical plastic particles and associated leachates or chemical leachates alone at a concentration that was either environmentally relevant (280 particles/L) or high (2800 particles/L). Larvae exposed to preconsumer polyethylene had, lower survival, length, and weight, whereas those exposed to preconsumer polypropylene gained weight. Environmental microplastics produced a greater rise in length and weight, as well as nearly six times the number of malformations as pre-consumer microplastics. Although preconsumer microplastics only had effects when species were exposed to both particles and chemical leachates, environmental microplastics had effects when organisms were just exposed to chemical leachates, implying that the mechanism of impacts is context-dependent. (Korez *et al*., 2022) demonstrated that *Crangon Crangon* was exposed to MPs of different sizes, shapes, and origins. The shrimp ingested microplastics along with food. however, these species do not show any oxidative stress. Microplastics are retained by the pyloric filter in the stomach which prevents the entry of MPs into the midgut gland. (Nikki *et al*.,2021) showed that the gut content of all the fishes that they analyzed was almost full. Partially digested phytoplankton, animal parts, sand grains, and microplastics constituted the bulk of gut content of *Etroplus spp*. From 30 fish samples, overall, 438 microplastics were identified.

Mugil cephalus is a demersal fish with benthic organisms as their diet hence are prone to microplastic contamination from the sediments. Despite accounting for 2.7 percent of global marine catch (Mondal *et al*., 2015*), Mugil cephalus* consumes high levels of MPs, potentially lowering its market value. (Kılıç, E., and Yücel, N. 2022) in their study 4 different commercial fishes *(Mullus barbatus, Mullus surmuletus, Mugil cephalus, Saurida undosquamis)* were used as a bioindicator to assess the MPs pollution in the north-eastern Mediterranean. the majority of extracted microplastics were fiber, black in color, and less than 1 mm in size, and the Highest microplastic ingestion rate was observed in the *Mugil Cephalus*. These MPs tend to be bio-accumulated to higher organisms since many birds and carnivorous fishes consume them. Since *Mugil cephalus* is a preferred delicacy of humans, microplastic contamination of these fishes may raise human health concerns. Regarding various studies considering the environment, the relevant concentration of microplastic results may vary depending on species, and polymer characteristics

Human health

According to a recent study by (Sarkar *et al*.,2022) the widespread presence of MPs in the environment has raised concerns about MP exposure and health effects. One of the most common ways for nano and MPs to enter the human system is through contaminated food (Kumar *et al*.,2022). Sugar has 0.44 MPs/g of nano and MPs, salt has 0.11 MPs/g, alcohol has 0.03 MPs/g, and bottled water has 0.09 MPs/g, according to (Ebere *et al*.,2019). Plants (fruits and vegetables) that absorb MPs from polluted soil may expose humans to up to 80 grams of MPs per day. Several in vitro and in vivo investigations have revealed that MPs can induce physical stress and damage, as well as apoptosis, necrosis, inflammation, oxidative stress, and immunological responses in humans. (Kumar *et al*.,2022) had conducted laboratory experiments. For example, amine-modified polystyrene nanoparticles were found to strongly interact and aggregate with mucin, causing mucin- and non-mucin-secreting intestinal epithelial cells to die.

(Stock *et al*.,2019) his study analyzed the uptake and effects of microplastic particles in human in vitro systems and in rodents in vivo. After oral exposure to a mixture of MPs, mice's liver, duodenum, ileum, jejunum, large intestine, testes, lungs, heart, spleen, and kidneys showed no signs of severe toxicity. According to other research, oral exposure (via oral gavage or drinking water) causes liver inflammation, neurotoxic responses, reduced body and liver weight, decreased mucin excretion in the colon, altered amino acid, and bile acid metabolism, and altered microbiota composition (Lu *et al*.,2018). Some of the consequences of MPs exposure, such as impaired lipid metabolism, were also seen in the mice's pups (Luo *et al*.,2019).

MPs can be transported through gastrointestinal tracts of the lymph and circulatory system, to unborn foetuses through the placenta. (Ragusa *et al*.,2022) in their study, six human placentas were evaluated using Raman Micro spectroscopy to determine the presence of microplastics. The placentas were acquired from consenting mothers with normal pregnancies. In all, 12 microplastic pieces with spheric or irregular shapes were identified in 4 placentas (5 on the foetal side, 4 on the maternal side, and 3 in the chorioamnionitis membranes); all microplastic particles were classified in terms of morphology and chemical composition. All of them were pigmented; three of them were identified as stained polypropylene, a thermoplastic polymer, while the remaining nine could only be identified by their pigments, and they were all used in man-made coatings, paints, adhesives, plasters, finger paints, polymers, cosmetics, and personal care products.

Weber *et al*.,2022 investigated that Nano plastics exposure induces inflammatory processes in primary human monocytes. so, they exposed monocyte-derived dendritic cells in vitro to nanoparticles of different sizes, shapes, and polymer types using concentrations of 30–300 particles. According to their findings, irregular PVC particles cause the most cytokine release of these Nano plastics. When compared to spherical Nano plastics, irregular polystyrene elicited a considerably stronger pro-inflammatory response. Chemicals leached from the particles made a tiny contribution. The effects were dose-dependent, but they differed significantly between cell donors. They infer that Nano plastics can cause human immune cells to release cytokines, which are important inflammatory mediators. MPs can directly influence metabolism by altering metabolic enzymes or by upsetting the energy equilibrium. MPs have the potential to alter the human immunological system. They are reported to cause systemic or local immune responses after being in an exposure. Ingestion of MPs in higher organisms or human leads to the alteration of chromosomes which leads to cancer, infertility, cardiovascular issues, etc. (Prata *et al*.,2020) and showed in their studies that prolonged inflammation and irritation caused by MP s may induce cancer by causing DNA damage.

Using -FTIR, (Chen *et al*.,2022) discovered 65 microfibers in 100 human lung tissues, including 24 microplastics (> 20 m). Microfibers were detected in 58 percent of tumours, compared to 46 percent in normal tissue, and two-thirds of microplastics were discovered in tumours. With time, the number of microfibers in lung tissue grew. Furthermore, patients with a greater microfiber exposure risk history had a considerably higher tumour detection rate than those with a lower risk history, suggesting that microfiber inhalation may be linked to the development of GGN (Ground Glass Nodules). Furthermore, the significantly worn surface of microfibers extracted from lung tissue suggested that surface roughness could be linked to disease progression. (Zhang *et al*.,2021) determined the concentration of Polyethylene terephthalate) and polycarbonate MPs in 3 Meconium, 6 infant, and 10 adult faeces. PET and PC MPs were found in some meconium (concentration ranges lower than the limit) and all infant stool specimens. They are also found in almost adult stools but lower than infant stool specimens. Hence their study suggests that infants are more exposed to MPs than adults. Human absorption models of nanomaterials produced by various industrial manufacturing methods are still being used to investigate the interactions of MPs/nanoparticles with other human organs.

Conclusion

Mismanagement, inappropriate use, and abuse of plastics have resulted in MPs pollution on every edge of the aquatic system, from the highest pelagic layer to seafloor sedimentary rocks in today's world. Because MPs are abundant in watery habitats, fish species have easy access to them. MPs are hazardous to a wide spectrum of fish and human beings according to growing studies. Following ingestion, MPs can gather in the gastrointestinal system of fish before dispersing to other body parts. MPs can put fish's health at risk in a variety of ways. Humans are exposed to plastic particles in several ways like ingestion via contaminated plastic-tainted seafood or trophic transmission, inhalation, or skin contact. As a result, several chronic sickness epidemics emerge, with people suffering the consequences. The fate and impact of the MPs' ingestion of human and fish bodies are still debated and unknown. Due to a lack of data, the effects of MPs on humans and fish are unknown; however, effects could be caused by physical properties (size, shape, and length), chemical properties (polymer type), concentration, or microbial biofilm growth. As a result, reducing MPs contamination in the aquatic environment is critical. Implementing effective waste management strategies such as bioremediation, photodegradation, and increasing awareness can significantly reduce litter input into ecosystems, allowing the aquatic ecology to recover.

Recommendations

Microplastic monitoring techniques along the food chain should be the focus of future research. There is a research gap and scarcity of information on how microplastic contamination affects food security. Finally, plastic waste management and microplastic legislation must be improved. We hope that, in the future, environmental and financial incentives provided by environmental agencies will help to close the knowledge gaps that still exist about MPs.

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