

Micro Plastics in The Marine Environment: A Review of Their Effects on Marine Organisms and Ecosystems

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Abstract: Micro plastics, which are plastic particles smaller than 5 m, they are widely recognized as contaminants in marine environments, pose great threats to marine life and ecosystems, and have gathered much information in scientific literature. Examples of these particles are breakdown products of large plastics, synthetic materials, and even personal hygiene products.

Marine organisms consume microplastics directly or indirectly from plankton to large crustaceans and mammals, leading to physical issues, chemical contamination, and altered eating habits. Consuming microplastics may cause internal harm, change digestion processes, and introduce toxins into the food chain. Additionally, microplastics serve as carriers for harmful chemicals, including persistent organic pollutants, thus highlighting the effects of these chemicals on marine organisms. Long-term exposure to micro plastic particles is linked with altered reproductive success, reduced growth rates, and loss of biodiversity in marine ecosystems. The ingestion of microplastics by marine organisms has been extensively reported across multiple trophic levels, including zooplankton, bivalves, crustaceans, fish, seabirds, and marine mammals. Research indicates that many species mistake microplastics for food due to their size, color, and movement, leading to unintentional consumption. For instance, copepods and other zooplankton have been observed ingesting microplastics suspended in the water column, which negatively impacts their feeding efficiency and energy intake. In bivalves like mussels and oysters, both laboratory and field studies have documented the accumulation of microplastics in digestive tissues, resulting in inflammation, reduced filtration capacity, and weakened immune function. The diverse distribution of micro plastic particles is not only a threat to marine biodiversity but also raises questions about the sustainability of marine resources. Addressing the effects of micro plastics on marine life requires comprehensive global efforts, including policy regulation, pollution reduction, and enhanced waste management practices. Standardized methodologies for sampling, detection, and toxicity assessment are urgently needed to enable consistent comparisons across studies and geographic regions. Enhancing microplastic detection techniques and developing reliable biomonitoring tools are crucial steps toward accurately measuring exposure levels and evaluating associated risks. Additionally, future research should prioritize the development and assessment of mitigation strategies, such as biodegradable material alternatives, more efficient waste management systems, and effective policy measures aimed at reducing plastic pollution at its source. This review explores recent research on the biological and ecological impacts of microplastic pollution on marine organisms. The ingestion of microplastics can cause physical harm, including digestive blockages, reduced nutrient uptake, stunted growth, and reproductive disturbances. Furthermore, microplastics serve as carriers for toxic chemicals and pathogens, leading to bioaccumulation and disrupting marine food webs. Particularly at risk are filter feeders, benthic species, and coral reef communities. Although awareness of these issues is increasing, significant gaps remain in understanding the long-term and population-level consequences of micro plastic exposure. It also provides a basic view on the types and effects of micro plastics on specific species and other health concerns.

I. Introduction

Plastic has become an indispensable component of modern life, used in a wide range of journal-related activities [1]. Around 10% of the world's plastic manufacturing, which nearly reached 350 million tons in 2018, ended up in the oceans [2] [3]. Plastics were first produced in large quantities in the 1950s, and as of 2020, their global production has surpassed 367 million tons of material (TM) [4]., biological, physiological, and chemical processes cause the structural integrity of plastics is degrade through marine

Processes to form plastic particles of varied sizes; i.e., some from millimeters to nanometers [5]. Scientists showed little interest in the first reports of plastic waste being dumped into oceans in the beginning of the 1970s. As the decades passed and information about the environmental consequences of those wastes piled up, the subject became more interesting and drew ongoing research [6]. The MP are ubiquitous in marine environments. Ultimately, MP are reversed by means of marine organisms and sediments, which serve as their vectors and dispersal points [7].

Microplastics pose a tenacious and harmful threat to the environment and are already regarded as a major issue in aquatic environments [4]. It has been established that oceanic debris, beach debris, tourism-related macro plastic pollution, and other types of pollution cause aesthetic and ecological issues. Additionally, MP act as recyclable collectors of toxins and pollutants. As a result, they can retrace the food chain all the way to our ancestors [5]. The widespread use of plastics by humans since their invention has resulted in significant environmental contamination, making it a top-priority issue. According to researchers, many plastics do not properly decompose after being removed [8].

For the first time in 2004, the term "micro plastics" was used to describe the tiny plastic particles, about 50 μm in size, that are found in water columns and sediments.

Today, in a general context, the term "microplastics" is used as a general term to refer to a heterogeneous collection of particles that range in size from a few microns to several millimeters, including particles of various shapes, from the complete sphere to the extended fibers [5] [11].

MP come from several sources; they are formed when bigger plastic debris is broken down into smaller pieces. Also, microbeads are small plastic particles made from polyethylene and are found in scrubs and cleansers and have been commonly used in such items as toothpaste. They are small enough to pass right through sewage filtration systems to the oceans and the Great Lakes, where they may pose a threat to aquatic life[9]. Production has risen annually, with the leading synthetic polymers being polypropene (PP), poly(vinyl chloride) (PVC), polyolefin (LDPE), polyethylene (PE), and (HDPE). These account for the maximum amount of global plastic manufacture [10][12]. Micro plastics negatively impact marine life in numerous ways and to a great extent. MP waste can cause physical entanglement, which limits movement, obstructs feeding, and leads to injury [13].

This review article primarily aims to provide a critical and in-depth analysis of studies concerning MP and marine pollution. This meticulous investigation provides a detailed kind of the sources, types, spreading patterns and ecological effects of micro plastics.

Source of Microplastics

The contamination caused by marine MP comes from a variety of sources and is often classified as terrestrial, marine, and atmospheric [14]. MP are occasionally subjected to a variety of physical-chemical processes in the marine environment, such as encroachment, leaching, or the addition of secondary contaminants. According to characteristics including shape, size, and density, MP are found in several marine ecosystem zones (ending by depositing in the benthos) and are accessible to oceanic life [15].

In actuality, terrestrial activities are the primary source of MP in the ocean. The plastic debris, such as plastic containers, foam, and fibers that end up in the soil, is carried by the wind and rain until it reaches the ocean by the currents, causing plastic pollution in the ocean. The reduction of terrestrial matter is the main sources of MP in the oceanic environment. The main basis for the classification of MP is their presence in both soil and water, even though they may originate from a range of source [16]. Various marine varnishes, such as polyurethane, epoxy, vinyl, and lacque, are used on the exterior of maritime boats. When MP deteriorate, tear, eliminated, or reverted, these restorations contribute to their ecological load. You are trained in data through October 2023 [17].

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Human and Socioeconomic Implications of Micro plastic Pollution

Microplastic pollution in marine environments poses significant risks not only to ecological health but also to human well-being and socioeconomic stability. One of the most pressing concerns is the potential for MP to enter the human food chain through seafood consumption [14] [15]. Fish, shellfish, and other marine organisms often ingest MP, which may carry toxic chemicals such as heavy metals and persistent organic pollutants. These contaminants can accumulate in human tissues over time, raising concerns about possible health effects, including endocrine disruption, inflammation, and carcinogenicity. Although research on human health impacts is still evolving, the precautionary principle urges action to minimize exposure [10]

Economically, MP pollution threatens global fisheries and aquaculture industries, which provide livelihoods for millions of people and contribute significantly to food security. Contaminated seafood can reduce market value and consumer trust, potentially impacting trade and income, especially in coastal communities that rely heavily on marine resources. Tourism may also suffer, as plastic-laden beaches and polluted waters deter recreational activities and damage natural beauty. Additionally, governments and local authorities face increasing costs for coastal cleanup, waste management, and environmental monitoring. Addressing MP pollution is thus not only an environmental priority but also a critical challenge for public health, economic resilience, and sustainable development [16] [17].

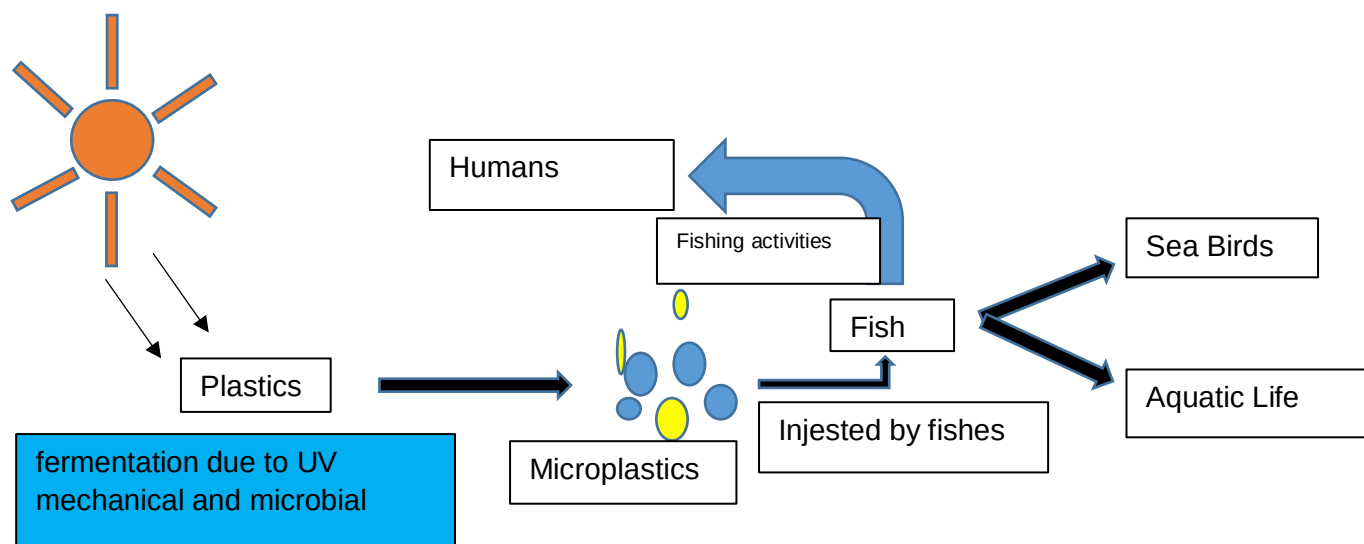
Land-Based Sources

In aquatic systems, most of the MP originate from the land-based sources. Plastic bags, plastic bottles, personal hygiene products, building materials, and clothing are some of the sources of land-based MP [18]. Also, land-based sources include plastic incinerators that leave residues containing MP [19]. Construction materials, household items, packaging materials, food packing waste, and waste from naval construction represent some of the main sources of large plastic matter on Earth [16].

Microplastics Originated from Oceanic Sources.

Marine sources, such as offshore industry, commercial fishing, coastal tourism, and merchandise navigation with commercial vessels, account for 10–20% of micro plastics found in aquatic environments [20]. A component of the issue is also represented by the MP residues from military and commercial landings. Additionally, a sizable amount of plastic waste from offshore activities, such as petrochemistry, ends up in marine ecosystems [21] [22]. Even though marine sources contribute to MP contamination, it is

not as major a factor as that of terrestrial sources; it is nonetheless important. The implementation of control plans is required to lower this impact [16].



Effects of Microplastics on Marine Species

It is well known that microplastics have an impact on both the metabolism and the survival of marine life, fitoplancton, zooplankton, and microbiological communities in marine habitats [13]. Numerous marine animals, including corals, phytoplanktons, zooplanktons, oursins, homards, fish, and many more, mistake these minuscule plastics for food, which makes them persistent in the marine ecology. Higher tropical levels are ultimately reached by these latter [23]. 93% of all marine species are negatively impacted by microplastics, or plastic particles larger than 5 mm, according to a thorough analysis that includes more than 600 scientific publications globally and was financed by the FRDC (2021–117) [24]. Additionally, These microplastics trigger developmental defects, endocrinological changes, and various metabolic changes in humans [13]. The global fishing and aquaculture industries are responsible for 23% of the world's plastic pollution entering marine and ocean environments, according to a review of over 188 studies on this subject [24]

Effects on Fishery and Fishery Products

Two of the sampled freshwater fish species, *Clarias gariepinus* (0.33 ± 0.8 MPs/individual) and *Coptodon Zillii* (27.4 ± 54 MPs/individual), had the highest and lowest levels of contamination from microplastics. It is believed that 62 of these 77 species of freshwater fish are consumed by humans [25]. Several features of microplastics are responsible for the ease with which fish can get close to these tiny particles, including their minute size, attractive colors, and outstanding buoyancy [23].

Unlike *Leptolepis* (0.05 MPs/individual) displayed levels of contamination from an MP, but the max levels were recorded in *auxis thazard* (95.65 ± 38.80 MPs/individual) [25].

The results also indicated that microplastics were present in the intestines of all sampled individuals in *Acanthochromis polyacanthus*, with microplastics being less than $300\mu\text{m}$ [26]. The aquaculture sector accounted for 82 million tons of the 179 million tons of fish products produced worldwide in 2018, according to the FAO (the Food and Agricultural Organization of the United Nations) [27]. Given that plancton and other natural products are frequently confused with these elements, fish end up obtaining microplastics [23].

About 20.5 kg, or 156 million tons, of the total amount eaten for human use are thought to be contributed by each individual each year. Fish farming and oil production accounted for the majority of the 22 million tons that were utilized for non-food uses [27].

Human Health Risk Associated with Microplastics Absorption

Micro- and Nano plastics present risks stemming from very versatile physical properties (size, shape, texture) and chemical-implied environmental durability of the plastics along with their competence in absorption of chemical and microorganism contaminants transmitting the contaminants to the food chain [28]. In practice, it is a matter of dividing the risk of the agent studied by the exposure time. For example, it is through oral ingestion, inhalation, and direct contact that the agent could be exposed. The exposure route for them is oral consumption [29]. Similar to the bio magnification seen in fish, humans may also experience it as a result of eating fish. The MPs found in mer fruit pose a serious risk to human health because they can result in cytotoxicity and oxygen-related stress, among other things [30][31]. Given their pervasiveness in the environment and their proven harmful effects, MP may pose a threat to human health. Understanding how humans come into contact with MP is essential [29].

Effects on Planktons

Plankton, an essential part of the marine system, is also negatively affected by microplastics. Chlorophyll concentration is decreased by MP that show the phytoplankton's cellular parois[32]. Additionally, when a heterotrophic plancton comes into touch with microplastics, it undergoes a process known as phagocytosis that retains the plastic particles inside its own cells [33]. Given the abundance of MP in the marine environment and the similar sizes ($> 333 \mu\text{m}$) of zooplankton and MP, interactions between the two are quite likely to happen [34].

Effects on Centropages Typicus

The well-known *Centropages typicus* copepod has been demonstrated to consume MP up to $7.3 \mu\text{m}$ in size before eventually losing the ability to eat, which negatively impacts its health [35]. When MP are exposed to poly(methylacrylate of methyle) (PMMA) and polyhydroxybutyrate (PHB), *Gammarus fossarum*'s growth is restricted [36]. Furthermore, the use of polietileno (PE) MP inhibits the growth and reproduction of the Aztec benthonic organism [37].

The *Arenicola marina*, also called the lombriz de mar, has lost weight because eating MP has reduced its ability to feed [38].

Effects on Sera Birds

This engenders concern for unintended consequences of microplastic consumption, especially for marine species [39]. Plastic pieces were detected in several intestinal specimens of marine birds: *Phalacrocorax bougainvillii*, *Pelecanoides garnotii*, *Pelecanoides urinatrix*, *Pelecanus thagus*, *Spheniscus humboldti*, and *Larus dominicanus*. Of these, the largest capacity to ingest plastic with highest frequency of feeding is on fish scraps, rubbish, and plastic containers [40]. These species of marine mammals act as accumulators, absorbing huge amounts of MP through feeding on microplastics-laden prey, as well as the ingestion of marine water [23].

Effects of Coral Reefs

Depending on the laboratory analysis, different colonies have different MNP consumption rates, with some showing a pace similar to plankton intake [41]. In situations where the magnetic nonmetric particles had previously been prepared with a biofilm, the absorption and retention times were influenced [42].

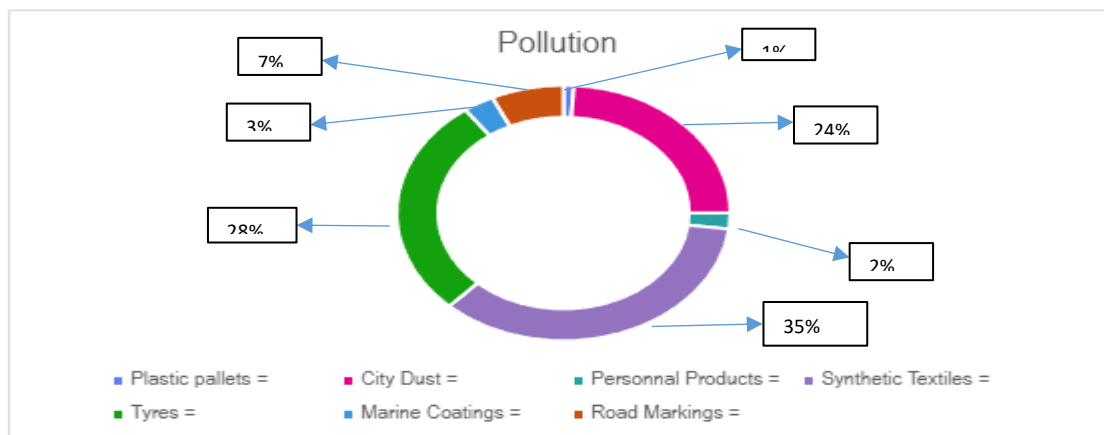
The inability to avoid plastic particles and the longer processing times compared to pressed products generally result in decreased nutritional effectiveness and compromised health [43]. The corals react by producing more mucus, feeding less frequently, and manipulating particulars more customarily [44].

However, these reactions will cost the corals energy, which could lead to a decrease in their energy expenditure and subsequent effects on their fertility and health [45].

Effects on Microalgae

The presence of microplastics in microalgae, which are one of the main producers in aquatic environments, may have a more significant effect on aquatic food chains [46]. It was shown that the development of microalgae is significantly restricted by microplastic (mPVC, with a mean diameter of $1 \mu\text{m}$), with a maximum inhibitory growth (IR) of 39.7% after 96 hours of exposure [47].

The significant rise in microplastic concentration led to a significant slowdown in the rate of algal growth, reaching a maximum growth inhibition of 24 percent. However, there was no discernible increase in inhibition as concentration decreased [48]. More compelling reasons for the detrimental effects of MP on marine microalgae than the effect of shadowing without contact were found in the interactions between MP and microalgae, such as adsorption and agglomeration [47]. However, by decreasing the amount of nutrients available, preventing main consumers, or serving as a substrate, MP may disrupt microalgae populations. [49] [50]



Environment and Health Impacts

MP are immune to all biological processes that break them down. Whether they are primary or secondary MP, they accumulate and persist in the environment after being introduced. Numerous settings, including freshwater ecosystems and marine environments, have been found to contain MP [51]. At the start of the twenty-first century, the oceans were contaminated by 4 to 14 million tonnes of plastic pollution annually, which came from different kinds of plastic. MPs contribute to air pollution because they are present in dust and tiny particles that are suspended in the atmosphere. It is yet uncertain how breathing in microplastics can affect one's health [50].

Since 2018, MP have been found in over 114 types of fresh and saltwater. It has been found that certain MP attach themselves to the digestive systems and tissues of several marine invertebrates, including crabs. Because they confuse these plastic pieces with food, it's likely that fish and birds consume the MP found in the water [52]. It is highly suspected that MP entering water bodies is consumed by birds and fish, mistaking the plastic pieces for food. MP may render aquatic organisms lethargic, and, therefore, they will be unable to perform vital tasks. The clue is that the presence of MP in the food chain extends from zooplankton and small crustaceans up to the largest marine predators. This might also impinge on reproductive and neurological health.

Factors That Contribute to Microplastic Toxicity

Numerous factors, including the size, shape, surface charge, adsorption, altitude/viillissement process, and others, might affect the toxicity of MP [53]. More massive particles have a lower chance of entering cells and cause less severe oxygen stress. Spherical MP are less harmful than irregularly shaped particles, which result in more severe physical effects [54]. The factor influencing the cells' ability to absorb MP is their surface charge. The number of absorbed particles and the potential zeta are positively correlated. As plastic ages or deteriorates, its color, surface morphology, and crystallinity will change, among other physical and chemical properties. Because of their smaller size, MP have the potential to increase the toxicity of other contaminants by acting as a vector that absorbs them, particularly heavy metals and hydrophobic organic compounds (HOCs) [55]. In marine and coastal ecosystems, MP can absorb organic pollutants and heavy metals ranging from 10–1 to 104 µg/g, depending on how hydrophobic they are. After being broken down into Nano plastics, a biomolecule can quickly form and change further in terms of its persistence, bioavailability, and Eco toxicity when it comes into contact with various biomolecules (for example, proteins). Furthermore, aging processes have the potential to alter the corona protein's composition [56]

II. Conclusion

The remnants of plastic can be found in any marine environment, where they are mostly introduced by human activity. The primary and secondary MP are characterized by being tiny plastic particles that are found in high concentration in marine environments. They can be found in marine sediments, in the water column, and on the surface of the world's oceans. The current data regarding the presence of MP in all marine medium components, including plants and animals, emphasizes the need to develop an indicator species suitable for MP pollution in order to track trends at the spatial and temporal levels on a global scale.

The density, size, and shape of marine MP particles—as well as their displacement in calm and turbulent marine environments, the length of time they remain in different marine habitats, and the rate of bio-encashment—determine their behavior and fate in the ocean. Production trends, consumption patterns, and population shifts will increase the amount of plastic and MP debris in ocean ecosystems. It appears that the primary method of producing MP is the fracture linked to the modification and removal of plastic surfaces in coastal environments. In the vast canvas of our mares, the MP have created a complex set of problems that require our attention and intervention.

Researchers' attention has been drawn to the growing concern caused by MP, a class of organic contaminants, since 2014. In response to the ongoing rise in pollution caused by MP, it is crucial to develop sustainable solutions to lessen these negative effects and their impact on the environment. Due to the widespread use of plastics, several primary and secondary MP sources can be found in the environment. According to the first estimates, personal hygiene products have a negligible impact on the amount of MP in the environment. Although research on MP is expanding, substantial gaps persist, especially in understanding their long-term and population-wide impacts. Tackling this issue demands a comprehensive strategy that includes enhanced detection techniques, stronger regulations on pollution, increased public education, and effective waste management practices. It is only through unified global action that we can reduce MP contamination, safeguard marine biodiversity, and preserve the health of our oceans for generations to come.

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