Chapter

# The Risks of Microplastic Pollution in the Aquatic Ecosystem

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## Abstract

Microplastic pollution is a global issue that has a detrimental effect on the food chain in the marine ecosystem. They are found in their highest concentrations along coastal lines and within mid-ocean gyres. In marine environments, microplastics are a threat to marine organisms, as they are often in the same size range as prey and are mistaken as food. When ingested can have a deleterious range of effects on marine organisms, a process which may facilitate the transfer of chemical additives or hydrophobic waterborne pollutants to aquatic lives. In this chapter, we looked at the risk of microplastic pollution and its impact on marine organisms and humankind. The study shows that consumption of microplastics has led to ingestion of chemical toxins in aquatic fish, which leads to damage of digestive organs, choking of marine organisms, channel for the spread of microbes, and a reduction in growth and reproductive output. These threats increase the risk to aquatic fishes and human survival. Hence, the need to educate the public on the dangers of using products that pose an immediate and long-term threat to the marine ecosystem and the health of its organism, and the food we eat by marine scientists.


**Keywords:** microplastic pollution, marine ecosystem, food chain, aquatic, microbeads, cosmetics

## 1. Introduction

Plastics are synthetic polymers that are pliable (flexible) in nature and may be molded into various shapes [1]. Plastic is made up of long chains of polymers made up of carbon, oxygen, hydrogen, silicon, and chloride, which are derived from natural gas, oil, and coal [2]. Polyethylene (PE), polyamide (PA), polypropylene (PP), polyester (PES) polyurethane (PU), acrylic (AC), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC), high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyimide (PI), poly-methyl methacrylate (PMMA), polytetrafluoroethylene (PFE), polyvinyl chloride (PVC), and high-density polyethylene (HDPE) are the most common synthetic polymers, accounting for 90% of global plastic manufacturing [3, 4]. Materials made from plastics are cheap. And because of its low production cost, simplicity, durability, strength, corrosion resistance, good thermal and electrical conductivity, and physiochemical properties, plastic has become an essential and general material in all aspects of our lives.

The mass production of plastics began in the 1940s, and thereafter microplastic pollution of the marine ecosystem has been a growing problem [5]. Global plastic production has nearly tripled in the last three decades, and it is expected to reach 33 billion tons by 2050 [6–8]. Despite rising knowledge of plastic pollution and measures to reduce it, annual plastic output continues to rise. Research conducted by [4] has revealed that over 280 million metric tons of plastics wastes are generated by the manufacturing industrial sector yearly. An estimated amount of 275 million metric tons of territory plastic garbage from 192 coastal countries entered the marine, resulting in 4.8–12.7 million metric tons [9]. The percentage of worldwide aquatic plastic pollutants entering into the marine ecosystem [10] based on data published recently has been shown in **Figure 1**. The majority of the world's largest polluting water bodies are in Asia, with a few in Africa as well.

Microplastics are microscopic plastic pieces with diameters of 5 mm found in marine environments [11]. These microscopic plastics can be ingested by a variety of marine living organisms, including corals, planktons, marine invertebrates, fish, and whales, and are then passed through the food chain. These biodegradable plastics directly endanger marine species and have an indirect influence on the ecosystem by decontaminating other marine pollutants. Microplastics accumulate hydrophobic contaminants from the aquatic environment due to their huge surface area-to-volume ratio [12]. Thus, microplastic contamination is becoming a source of concern due to its negative impact, particularly on marine life.

## 2. Microplastics

Microplastics are pieces of plastic that are between a millimeter and a nanometer in size and are invisible to the human eye. The term "microplastics" has been defined differently by various researchers (see [13–16]), including a workshop on the topic. Microplastics are defined as being in the size range <5 mm [17] (recognizing 333

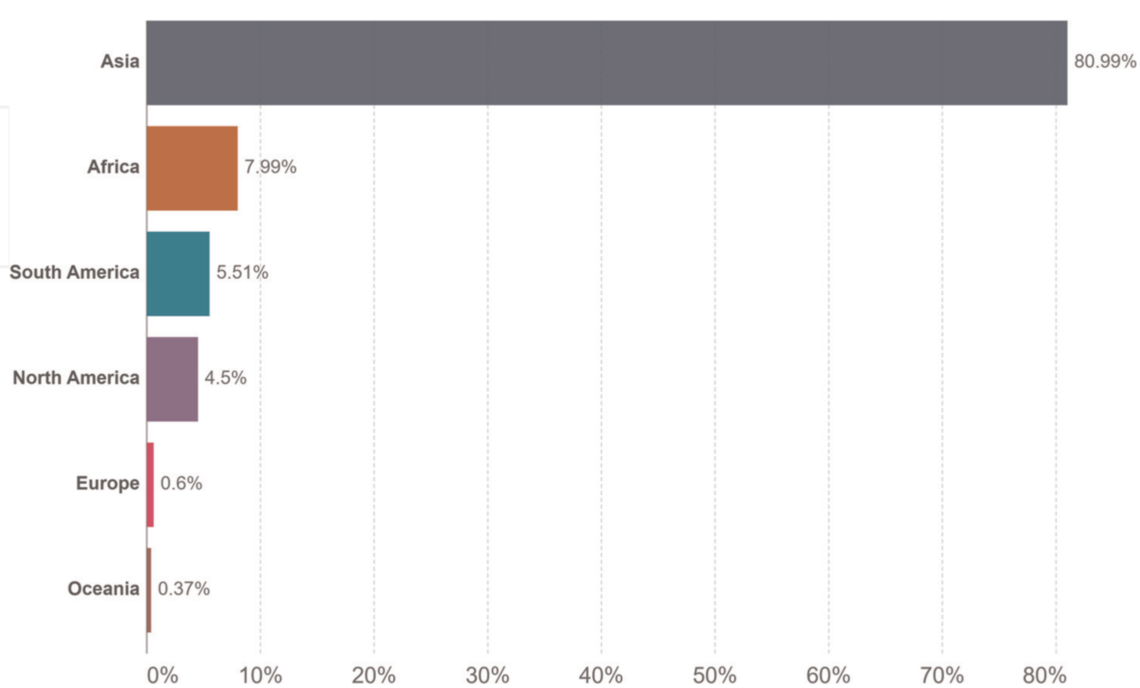


**Figure 1.**
*Over 1000 rivers are accountable for 80% of worldwide aquatic plastic pollution in the ocean.*

nanometers as a practical lower limit when neuston nets are used for sampling). Particles of plastics of sizes ranging from a few nanometers to 500 nanometers (5 mm) are commonly present in marine waters [18, 19]. For better understanding, the size range stated above is referred to as "microplastics" here. Other larger particles such as virgin resin pellets are referred to as "mesoplastics" [14].

Also, microplastics are tiny plastic granules used as scrubbers in cosmetics and air-blasting, and small plastic fragments are derived from the breakdown of macroplastics [20–22]. The presence of small plastic fragments in the open ocean was first highlighted in the 1970s [23], and a renewed scientific interest in microplastics over the past decade has revealed that these contaminants are widespread and ubiquitous within the marine environment, with the potential to cause harm to aquatic lives [24, 25]. Typically, these are the smaller pieces of bigger plastic objects, which are introduced into the marine ecosystem by a variety of mechanisms, such as industrial processes, human clothes (microfibers), and cosmetics (small beaded plastic). Due to their microscopic nature, they gradually make their way through the water systems where they are not cleaned out before being pumped back into the drainage channels. Persistent organic pollutants (POPs) that occur globally in marine waters at very low concentrations are picked up by these meso-microplastics via partitioning. The hydrophobicity of POPs facilitates their concentration in the meso-microplastic litters at a level higher than that in the marine ecosystem [26]. These contaminated plastics when ingested by aquatic organisms pose a serious problem by which the POPs can enter the marine food web. Unlike macroplastics, microplastics are not readily visible to the naked eye; even resin-pellets (mesoplastics) mixed with sand are not easily discernible. Net sampling does not of course collect the smaller microplastics and no acceptable standard procedure is presently available for their enumeration in water or sand [26].

### 2.1 Types of microplastics

Microplastics are classified into two groups based on their origin: primary and secondary microplastics [27].

#### *2.1.1 Primary microplastics*

Primary microplastics are micro-sized synthetic polymers that are directly introduced into the environment as minute particles. They are utilized as exfoliates in a variety of operations, such as chemical compositions, abrasive media, chemical and petrochemical cleaning, and synthetic clothing manufacturing. They can be added voluntarily to items like cleaning agents in hygiene and cosmetics (e.g., shower gels). They can also be caused by the abrasion of big plastic objects during manufacturing, usage, or maintenance, such as tyre erosion, while driving or the abrasion of synthetic textiles during washing [28]. Microbeads are a form of primary plastic (size 2 mm) that is made up of polyethylene (PE), polypropylene (PP), and polystyrene (PS) beads and are used in cosmetic and health care goods [12].

#### *2.1.2 Secondary microplastics*

Secondary microplastics are microplastics that result from the decomposition of larger plastic products into microscopic plastic pieces in the marine ecosystem. This occurs as a result of ecological changes, such as microbial degradation, photocatalysis,

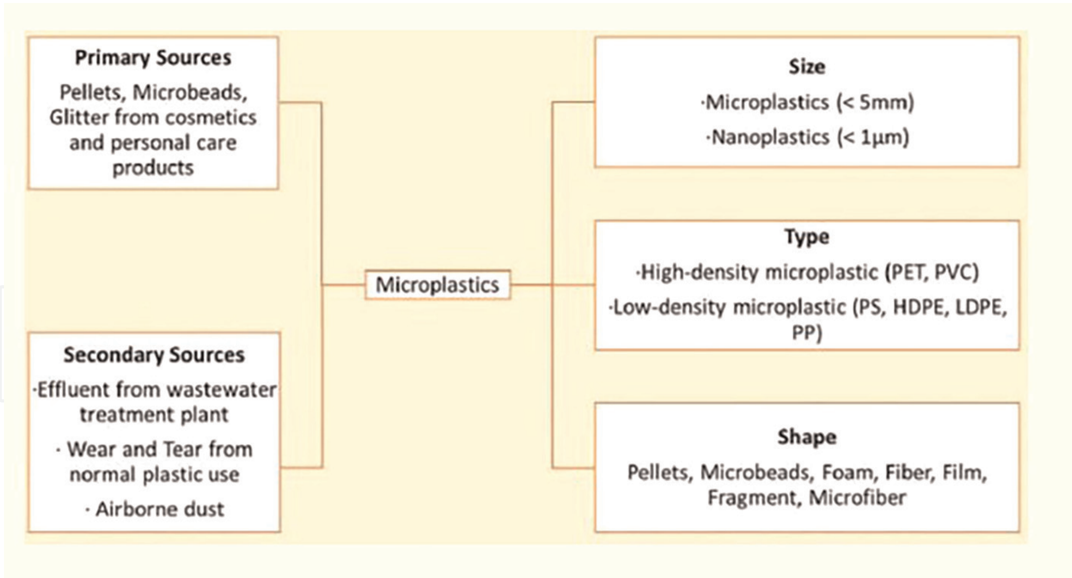


**Figure 2.**
*Classification of microplastic based on sources, size, type, and shape [29].*

high-temperature degradation, thermal decomposition, hydrolysis, and other weathering processes of indiscriminate dumping, such as abandoned plastic bags or unexpected losses, such as fishing gear. Microplastics in the waters can either circulate or sink. Microplastics that are lighter than seawater, such as polypropylene, will flow and spread across the oceans. They subsequently congregate in gyres formed by tidal currents (**Figure 2**) [28].

## 3. Sources of microplastics emission into the marine ecosystem

General littering, plastic waste mismanagement, tires, synthetic textiles, marine coatings, road markings, personal care products, plastic pellets, city dust, and release of wastewater from sewage treatment plants have been the main sources of microplastic pollution in the marine ecosystem [30]. Marine litter results from the indiscriminate disposal of refuses that are either directly or indirectly transferred to our seas and oceans [22, 31]. Whilst the emphasis of this study is on microplastics, in this section, we also consider the indiscriminate disposal of macroplastics, as with time, they eventually degrade into mesoplastics and microplastics. Plastic litter from land [terrestrial] sources contributes 80% of the plastics found in marine litter [26]. Such plastics include primary microplastics used in cosmetics and air-blasting, improperly disposed "user" plastics, and plastic leachates from refuse sites. With approximately half the world's population residing within 50 miles away from the coast, these kinds of plastic have a high likelihood of entering the marine ecosystem via rivers and wastewater systems, or by being blown off-shore [16, 32]. Plastic microbeads are utilized as components in cosmetic and personal care products for a range of functions, including an adsorptive state for active substance distribution, exfoliating, and viscosity control. Some products carry quite so much plastic as ingredients in which they are packaged [33]. These account for up to 10% of the product weight and thousands of microbeads per gram of product [34]. Microplastics used both in these cosmetics and as air-blasting media can easily enter waterways through domestic or industrial drainage systems [21]. The traditional use of products for

**Figure 3.**
*Microplastic and garbage pollution present in the ocean [35].*

personal care culminates in the direct input of microplastic into industrial wastewater from homes, hotels, hospitals, and sports facilities, such as beaches. Cosmetic microbeads have been detected in field investigations conducted in many parts of the world (**Figure 3**) [36].

Tourism and recreational activities had contributed to the discarded plastics left along beaches and coastal resorts [21], as well as those from marine debris, observed on beaches arising from the beaching of materials carried on in-shore and ocean currents [32]. Whilst wastewater treatment plants will trap macroplastics and some small plastic debris within sewage sludge, a greater percentage of microplastics will pass through such filtration systems [13, 37, 38]. Plastics that enter river systems—either directly or indirectly—will then be transported out into the ocean. A couple of studies conducted have shown how the high single-directional flow of freshwater systems drives the movement of plastic debris into the oceans [39, 40]. Another common marine source of plastic debris is fishing gear [26]. Discarded or lost fishing gear, including plastic monofilament line and nylon netting, which is typically buoyant and can therefore drift at variable depths within the oceans. This is particularly problematic due to its inherent capacity for causing entanglement of marine organisms, known as "ghost fishing" [31]. Historically, marine materials have been a great contributor to marine litter, with estimates indicating that during the 1970s the global commercial fishing fleet dumped over 23,000 tons of plastic packaging materials in the ocean [41]. Additionally, the manufacture of plastic products that use granules and small resin pellets, known as "nibs," as their raw material is another source of plastic debris [microplastics] [41–43]. Many plastics are introduced into the marine as pellets (usually 2–5 mm in diameter) or powders. Pellets are discharged into the marine environment through little or big occurrences along the entire plastic value chain during manufacturing, processing, transport, and recycling [44]. In the US alone, production rose from 2.9 million pellets in 1960 to 21.7 million pellets by 1987 [41].

## 4. Distribution of microplastics in the marine environment

Plastic contamination and microplastics have spread throughout the world's aquatic ecosystems [21, 22, 31]. Plastic pollution and microplastics can be transported over long distances by ocean currents, winds, river outflow, and drift [19, 45, 46],

| Shape of microplastic | Type of marine ecosystem | Type of microplastic | Source of transport | References |
|---|---|---|---|---|
| microfiber | Deep sea Atlantic ocean | PS, PA, AC, acetate | Sewage treatment plants | [48] |
| Microplastic fragments | Tamar estuary | PVC, PES, PA | Wind, wave, and tides | [49, 50] |
| Microfibers | Shorelines | PES, AC fibers | Sewage treatment plants | [50] |
| Fibers or fragments | Irish continental shelf | PP, PET, PA, AC | Sewage treatment plants | [51] |
| Fibers | Deep sea and southern ocean | PVC, PES, PA | Wind, seabird | [45] |
| Resin pellets | North Atlantic ocean and Caribbean sea | HDPE, LDPE, PP, PE | Wind, plankton | [52] |
| Fragments, sheets, pellets, foam | Cape cod, Massachusetts to the Caribbean sea | PP, HDPP, LDPP PVC, PS, PET | Wind, dust, wave | [53] |
| Fragments, fishing net, pellet, fibers | Northeast Pacific ocean | HDPP, LDPP, PP PVC, PS, PET | Wind, wave, wear and tear | [54] |
| Fishing gear, vinyl, rubber | East China sea and South sea of Korea | PA, PP, PES, PE, PVC | Wear and tear, fishing operation | [55] |
| microfibers | mid-Atlantic, south-western Indian Ocean | PP, PES, AC, viscose | Deep sea organisms | [56] |

**Table 1.**
*Classification of microplastic, source of transport, and type of marine environment found.*

including mid-ocean islands [42], poles[47], and ocean depths [31]. Pellets are lost during loading and transit, both on land and at sea, as well as during processing at plastic molding plants. Because of their lightness and durability, lost pellets can travel long miles in the ocean before being stranded, either temporarily or permanently [42]. While plastic litter can be found across the whole of the marine ecosystem, the distribution of this debris and microplastics varies in type and nature [16, 46]. Beached litter descriptions frequently mention a variety of plastic manufacture pellets (**Table 1**) [57].

## 5. Risks of microplastic pollution in the aquatic ecosystem

Plastics have really been recognized as a substantial component of marine plastic pollution for centuries, but their biological and environmental implications on marine ecosystems have only recently been emphasized and appreciated [16, 21]. Microplastics pose a great risk to aquatic life, as their small size makes them readily available to a wide range of marine organisms, and it is of increasing scientific concern (**Figure 4**) [13, 19–21, 34, 45].

Chemical toxins, indigestibility, choking dangers, and a channel for the spread of microbes are just a few of the potential risks that microplastics provide to organisms. These threats increase the risk to aquatic fish and human survival. In this section, we discussed the various risks microplastic pollution posed to the marine ecosystem.

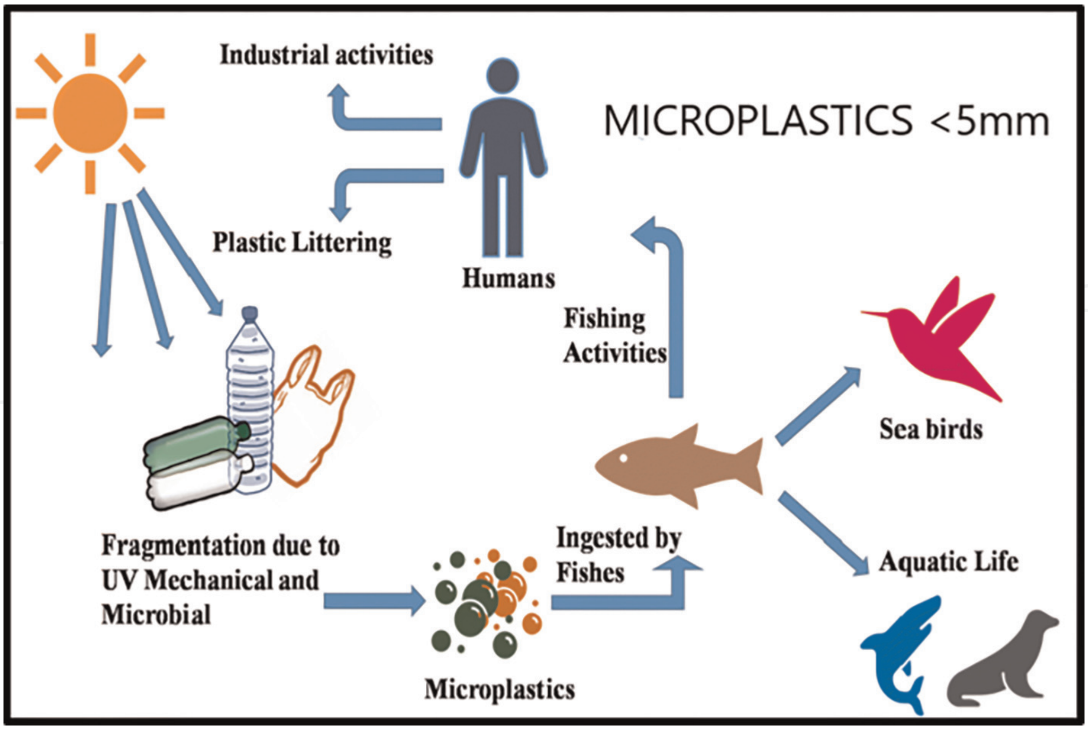


**Figure 4.**
*The effect of microplastic pollution on marine ecosystem [58].*

### 5.1 Chemical toxins

Plastic's durability and corrosion resistance make it an appealing and preferable material to employ, but it also makes it very resistant to deterioration, making the dumping of plastic litter troublesome [45]. The composition of this plastic waste, as well as the enormous surface area of microplastics, makes them vulnerable to attaching watery organic contaminants and hazardous plasticizer leaching. Ingestion of microplastics may thus introduce toxins to the bottom of the food chain in the marine ecosystem, where toxic chemical buildup in the tissues of aquatic living species is possible [59].

Perhaps because plastics are commonly considered to be biochemically inert [59, 60], plastic additives, also known as "plasticizers," may be fully integrated into plastics during manufacturing and injection molding to improve their properties or extend their life by providing resistance to heat (e.g., polybrominated diphenyl ethers), oxidative damage (e.g., nonylphenol), and antimicrobials (triclosan) [37, 61]. These additives are harmful to the environment and the marine ecosystem. Because they both prolong the decomposition time-frames of plastic and may seep out potentially hazardous chemicals into marine aquatic life [45, 62, 63].

A few of these chemicals can move away from the synthetic matrix of plastic due to inadequate polymerization of polymers during manufacture. The extent to which these additives leak from polymers is determined by the pore size of the polymer matrix, which varies by polymer, the additive's size and characteristics, and environmental circumstances, such as weathering [16, 19, 59]. Because microplastics have a high surface-area-to-volume ratio, live species in the marine ecosystem may be directly exposed to leached additives after ingesting microplastics. These chemicals and monomers have the potential to disrupt biologically vital processes, perhaps leading to endocrine disruption, which can have an impact on movement, reproduction and development, and carcinogenesis [45, 62, 64].

Polybrominated diphenyl ethers, phthalates, and the component monomer bisphenol A are well-known endocrine disruptors because they can mimic, compete with, or alter the synthesis of natural hormones [63]. Chemical imbalance can result in temporary or permanent morphological changes in aquatic creatures during their formative phases, as well as sexual disruption in adults. In aquatic invertebrates and fish, phthalates have been related to a variety of molecular and whole-organism consequences, including genotoxic damage (micronuclei and death in mussel hemocytes), restricted motility in invertebrates, and intersex abnormalities in fish [65].

### 5.2 Indigestibility

While larger forms of garbage are easier to remove from a beach, microplastics are more challenging to eliminate but appear less apparent. Microplastics, due to their microscopic size, have the potential to be consumed by a variety of marine biota [15, 66]. Microplastic consumption in the wild is difficult to observe methodologically [67], however, an increasing number of studies are reporting microplastic ingestion across the food chain. The marine ecological danger associated with microplastics is the increased likelihood of ingestion by animals, such as birds, fish, and invertebrates, resulting in diminished foraging capacity and feeding stimulation, nutritional loss, and gastrointestinal issues [22, 68].

Microplastics pose a significant risk to aquatic life due to their small size, which makes them easily accessible to a wide range of marine creatures, and it is a growing scientific concern [13, 18–21, 31]. In addition to the possible negative effects of swallowing microplastics, toxic responses could emerge from endogenous pollutants leaking from the microplastics and external pollutants adhering to and trying to disassociate from the microplastics. Moreover, utilizing fluorescent nanospheres, phagocytic uptake of nanoplastics in a heterotrophic ciliate was observed. These lower-trophic level creatures are especially susceptible to swallowing microplastics since many of them are indiscriminate feeders with poor ability to distinguish between plastic particles and food particles [16]. As a result, microplastics will be widely and easily available to a wide range of planktonic creatures, including the larval stages of a number of industrially useful species found in the euphotic zone [13, 38]. This interaction between plankton and microplastics is theoretically amplified in gyres, where plankton numbers are low and microplastic intakes are high due to plastic deposition by ocean currents [16].

Microplastics can be consumed by a variety of marine living animals, including seabirds, crustaceans, and fish [69, 70]. Microplastics were found in the intestines of 35% of the planktivorous mesopelagic fish dissected in the north Pacific central gyre [71]. Plastic fibers, pieces, and coatings were also discovered in 13 of 141 mesopelagic fish captured in the north Pacific gyre [72]. In total, 83% of Nephrops sp. sampled in the Clyde sea (Scotland) had consumed pollutants. This economically useful, omnivorous, benthic crustacean primarily ate portions of monofilament line, and plastic bag shards [73].

Plastic fibers in the ecosystem can be as small as one nanometer in diameter and 15 nanometers in length, making them easily accessible to minute planktonic species [74]. Such fibers may be particularly hazardous as they may clump and knot, potentially preventing egestion [73]. In all of the preceding situations, the marine species may have consumed the microplastics intentionally, mistaking them for prey or food. It is yet to be determined whether the consumption of non-polluted microplastics has any substantial detrimental health impacts on biota, such as sickness, death, or reproductive success [75]. Once eaten, microplastics may pose a mechanical hazard to tiny animals, comparable to the consequences reported with macroplastics and bigger species [13, 45].

### 5.3 Channels for the spread of microbes and adhered pollutants

Marine plastic pollutants, particularly microplastics, are vulnerable to contamination from a variety of waterborne contaminants, including aqueous metals [15, 27], produce harmful chemicals [19], and persistent organic pollutants (POPs), also known as hydrophobic organic contaminants (HOCs) [57]. Such compounds are typically found in the highest quantities in the sea-surface microlayer, which also contains the largest concentrations of low-density microplastics [19, 57, 59].

Under optimal circumstances, phenanthrene was more likely to stick to plastics than to sediments. However, if heavily polluted microplastics come into interaction with non-contaminated sediments, the deposition differential would allow phenanthrene desorption to organic materials in the sediment [5]. A variety of contaminants, including PCBs, PAHs, DDTs and their metabolites, PBDEs, and bisphenol A, were found adhering to the surface of plastic pieces (less than 10 mm) tested from pelagic and neritic stations [76].

Microplastic waste containing POPs may be carried across seas, damaging marine ecosystems [77], or swallowed by marine creatures, transmitting poisons from the environment to aquatic life (i.e., a "Trojan horse" effect) [20, 38]. Many POPs are hazardous, causing endothelial dysfunction, mutagenesis, and/or cancer, and have the potential to biomagnify in higher-trophic organisms [5]. Ref. [78] came to a similar conclusion when they discovered that ingestion of plastic particles hampered the accumulation of fat deposits in migratory red phalaropes (Phalaropus fulicarius), affecting long-distance migration and possibly their reproductive effort on breeding places.

### 5.4 Choking effect

Plastic pieces and microplastics may also obstruct feeding tentacles and/or impede food transit through the digestive tract [70] or produce pseudo-satiation [the feeling of being full], resulting in reduced food consumption [21, 32]. However, [26, 32] argue that numerous marine organisms have the ability to eliminate foreign particles, such as sediment, natural decaying organic matter, and particulates from their bodies without harm, as illustrated by polychaete worms, which ingested microplastics from their surrounding sediment and then egested them in their fecal contamination casts [20].

Ingestion of plastics may cause blocking of stomach enzyme secretion, decreased eating stimulation, decreased steroid hormone balance, prolonged ovulation, and fertility problems in several marine animals [79]. Ingestion of plastic waste by small fish and seabirds, for example, can limit food intake, induce internal damage, and death due to intestinal infection [22, 23, 80]. Nonetheless, the magnitude of the injury will differ between species. Because of their inability to excrete ingested plastic material, Procellariiformes, for example, are more vulnerable [79, 81].

## 6. The role of microbes in removal of micro-plastic from marine ecosystem

The environmental problems caused by microplastics in the marine ecosystem are continuously growing [82]. The most common microplastics, also known as synthetic polymers, that are found in the marine ecosystem include PE, PA, PP, PS, PES, AC, PU, HDPP, LDPP, PI, PMMA, PFE, PVC and PVDC [4]. Nevertheless, many conventional plastics, such as PE, PP, PS, PVC, and PET, are not biodegradable, and their increasing accumulation in the ecosystem has posed a danger to the environment [83]. To contend with this man-made challenge, contemporary wastewater treatment facilities need to necessitate fresh technologies [84]. Modern technology provides methods for limiting the availability of microplastics in an aquatic environment. However, such technologies seem to be either inadequate or prohibitively expensive, in addition to being time-consuming in both circumstances. Despite the fact that several microplastic products are considered structural pollutants that do not readily biodegradable or deteriorate at an extremely slow rate, microbial degradation is still a prevalent remediation technique because it is inexpensive and environmentally friendly nature [84, 85].

Microbial degradation can be achieved by using single or connected bio-cultures, including bacteria, algae, and fungi, which have been demonstrated to consume these polymeric materials and generate them into environmentally sustainable carbon compounds. In essence, no microbial techniques can eliminate microplastics from the ecosystem entirely and in an acceptable amount of time [84]. According to research, saturated synthetic polymer chains do not favor microbe degradation, whereas biodegradable polymers incorporate heteroatoms inside the hydrocarbon chains and hence degrade quickly when exposed to favorable weather conditions [86].

The removal rate of microplastic is determined by its creation and the circumstances under which it is exposed, which can range from abiotic factors (wind, waves, heat, and humidity) to microorganism assimilation, such as bacteria, algae, and fungi [87]. As a result, polymer degradation can be categorized as either abiotic or biotic [88]. Abiotic degradation refers to decomposition characterized by factors in the environment, such as temperature, UV irradiation, wind, and waves. Biotic degradation, on the other hand, is defined as the degradation process triggered by the actions of microorganisms that transform and ingest the polymer, modifying its qualities [89].

### 6.1 Mechanism of biodegradation of microplastics by microbes

The adherence of the microorganism to the surface of the polymer, preceded by the colonization of the external surface, growth of the microbial, use of the polymer as a source of carbon and energy, and final degradation of the polymer is the primary mechanism for microbial degradation [88, 90]. Microorganisms can stick to the surface of a polymer if it is hydrophilic. Once anchored to the surface, the organism can grow by utilizing the polymer as a source of carbon and energy. Polymer biodegradation happens by hydrolysis after colonization; first, the enzyme catalyzes the substrate material and then facilitates the hydrolysis reaction. Polymers degrade into small molecular weight oligomers, dimers, and monomers before finally mineralization to $CO_2$ and $H_2O$ [83]. The surface composition can quantify the scope of colonization on the polymer, as hydrophilic areas are much more conveniently colonized by microbes. This is a restriction since the polymer's water-repellent surface contradicts the porous structure of the microorganisms (**Figure 5**) [89].

### 6.2 Biotic degradation

Microplastic biodegrades as a consequence of degradation by microbes in the marine environment. However, because of their size, macroplastics (larger plastic debris) do not make the optimum source of nutrients for biotic degrading agents;

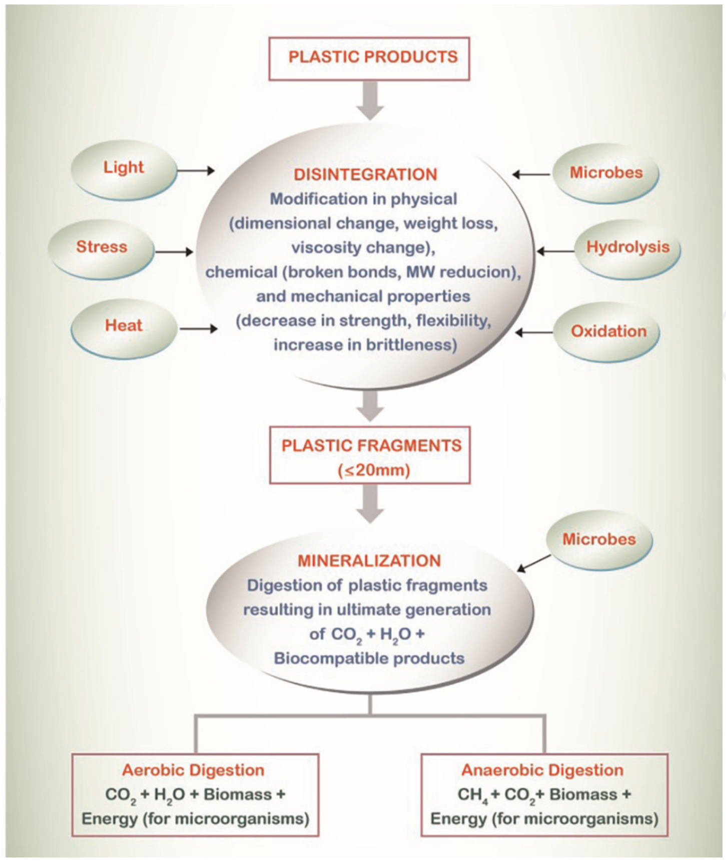


**Figure 5.**
*Mechanism of microbial degradation of microplastic [91].*

either the enzymes secreted by the microbes are insufficient to denature the macroplastics, or they contain not easily and quickly biodegradable for biological cell uptake [29]. Synthetic polymer plastics must first be changed into carbon molecules prior to being mineralized by microbial pathogens during the degradation reaction. Plastics' (polymers') organic molecules' size is bigger than the particle sizes of a microorganism's cellular membrane. As a result, they must be metabolized into tiny pieces before being assimilated and biodegraded within microbial cells. As a result, finer particles of plastic created as the result of environmental factors degradation are of sufficient size to be broken down even more by microbial cells [92]. Bacteria, fungi, and algae are the most common microorganisms found in marine ecosystems.

Microbial enzymes are responsible for biotic degradation. Chemical compounds are converted into simplified chemical compounds, metabolized, and deposited in primary-level cycles, such as carbon, nitrogen, and sulfur through microbial degradation. Carbon dioxide, methane, and microbial extracellular matrix components are among the by-products of this system [93, 94]. Microbial character traits, such as microbe form, propagation, developmental stage (temperature, pH, availability of oxygen, essential minerals, etc.), and enzymatic categories (intracellular and/or extracellular enzymes contributing to exo or endo polymer cleaving). Surface conditions (size, water-soluble, and hydrophilicity properties), first-order frameworks (chemical composition, molecular mass, and molecular dissemination), and relatively high structures (thermodynamic stability, melting temperature, fracture toughness, crystalline structure, and degree of crystallinity) are among the chemical and physical properties of polymers [83].

#### 6.2.1 Biodegradation by bacteria

Many bacteria genera that are commonly found in the marine environment like Bacillus species (e.g., Bacillus subtilis and Bacillus cereus, and Bacillus megaterium), Brevibacillus, Streptomyces, Amycolatopsis, Clostridium, Methanosarcina barkei, Schlegelella, Pseudomonas aeruginosa, Azotobacter spp., Alcanivorax, Hyphomonas, and Cycloclasticus species, Rhodococcus ruber, Serratia marcescens, Staphylococcus aureus, and Streptococcus pyogenes, and other bacterial strains also lead to the microbial degradation of plastics [29, 95–102]. The Bacillus species were discovered to secrete extracellular hydrolytic enzymes, such as lipase, xylanase, keratinase, chitinase, and protease, which resulted in the biodegradation of microplastics [103]. Methanosarcina barkei bacteria strain can degrade the most commonly used plastic polymer, PVC. They can stick to the surface of PVC surfaces and discharge exopolymeric compounds to produce a biofilm, preceded by the discharge of enzymes to breakdown the plastic through enzymatic hydrolysis of the synthetic polymer bonds which resulted in the biodegradation of PVC [104, 105]. Likewise, Rhodococcus ruber will also degrade PE by producing an enzyme laccase, which ultimately resulted in PE degradation [106]. Azotobacter spp., which releases hydroquinone peroxidase, could also degrade PS. PET can also be degraded by Alcanivorax, Hyphomonas, and Cycloclasticus species, which could also alter the physiochemical properties through the use of ester bond hydrolysis [107].

#### 6.2.2 Biodegradation by fungi

Many fungal genera, such as Acremonium, Zalerion maritimum, o Curvularia sp., Cladosporium, Debaryomyces, Emericellopsis, Eupenicillium, Fusarium, Mucor, Paecilomyces, Pullularia, Rhodosporidium, Verticillium, Aspergillus sp., Aureobasidium, Chaetomium, Cryptococcus, Fusarium, Rhizopus arrhizus, Trichoderma, Penicillium sp., Thermoascus, Tritirachium album, Humicola insolens, Rhodotorula aurantiaca, and Kluyveromyces sp. [83, 108–112] also contribute to the microbial degradation of plastics. It has been demonstrated that Aspergillus clavatus can biodegrade LDPE [113]. Zalerion maritimum, the ocean's dominant fungal species, could also degrade PE [114]. The main mechanism of plastic degradation by fungi, such as bacteria, involves fungi adhering to the polymer surface, in which they grow to create a biofilm and produce enzymes that degrade the carbon-carbon bonds occurring in the plastic. The above enzymes have the potential to accelerate the oxidation process as well as degrade plastic into tiny pieces (e.g., oligomers, dimers, and monomers). For example, fungi found in marine habitats, such as Penicillium citrinum and Fusarium oxysporum, breakdown PET, and Trichoderma harzianum release manganese peroxidase, lignin peroxidase, and laccase that breakdown PE and PU [114].

#### 6.2.3 Biodegradation by algae

Algae are frequently used throughout tested microorganisms for investigating the harmful effects of microplastics. However, various algae, both photorespiration and heterotrophic, have been extensively researched for their key responsibilities in the microbial degradation of microplastics [84, 85]. They are capable of removing both inorganic and organic contaminants from a diverse range of environments by soaking up, removing impurities, or metabolizing them into healthy and safe levels [115, 116].

They colonize the outer layer of microplastics by secreting extracellular polymeric compounds, and this colonization could well result in effectual deterioration. The existence of polymeric materials, as well as plastic wastes, encourages the generation of extracellular polymeric compounds [117]. Several algal species are effective at microbial degradation of microplastics. These include Phormidium lucidum, Oscillatoria subbrevis, Scenedesmus dimorphus, diatom Navicula pupula, Chlorella, Spirogyra, Nostoc, Spirulina sp., Anabaena spiroides, and Navicula pupula [118–120]. Bioactive compounds produced by some algae have been found to biodegrade microplastics. Phormidium lucidum and Oscillatoria subbrevis, for example, can break down easily PE and LDPE [121]. Discostella spp., Navicula spp., Amphora spp., and Fragilaria spp. algal biofilms have been discovered to deplete LDPE, PP, and PET in the marine ecosystem [122]. After forming a biofilm on the plastic surface, algae use the carbon available on the plastic as a feed ingredient, softening and lessening the plastic. Furthermore, species can produce extracellular polymeric compounds and enzymes, such as PETase, which degrade PET [123]. Plastic degradation by algae remains in its early stages and requires more research.

## 7. Conclusion and recommendation

### 7.1 Conclusion

Plastic pollution in the marine ecosystem is a growing concern due to the negative effects it has on aquatic habitats. Microplastic pollution has become a serious global issue that has a detrimental effect on the food chain in the marine ecosystem. The main sources of microplastic pollution in the marine ecosystem have been identified to result from general littering, plastic waste mismanagement, fishing gears, synthetic textiles, marine coatings, personal care products, plastic pellets, city dust, and release of wastewater from sewage treatment plants. This is the outcome of indiscriminate waste dumping, which is either directly or indirectly transmitted to our seas and oceans. Because microplastics are the same size as prey and are mistaken for food, they pose a threat to many marine organisms. When swallowed, it has a negative impact on marine organisms, facilitating the transmission of artificial chemicals or hydrophobic watery toxins to aquatic life. Microplastic pollution has contaminated various drinking sources, salt water, and other regularly consumed foods. Chemical toxication, indigestibility, choking of marine ecosystems, and a pathway for microbial propagation are all negative effects of microplastic contamination on the marine environment. Furthermore, the effects of microplastic pollution vary from the molecular level of an organism to its physiological mechanisms and include bad organism health and poor economic services. These threats increase the risk to aquatic fish's and human survival. Significant awareness about the harmful effects of microplastics has prompted some regions of the world, including the United Kingdom, the United States, and Canada, to take action. These initiatives have focused almost entirely on prohibiting the use of microbeads in various items, such as personal care and skincare products.

### 7.2 Recommendation

Microplastics have been found to be consumed by a variety of marine organisms in laboratory and field research. More research is needed to determine whether microplastic consumption alone causes unfavorable health impacts, such as mortality, morbidity, and reproductive success, or whether such a contaminant can be consistently transferred up the food chain in the marine ecosystem. Toxic chemical transfer to biota via microplastic intake is a major concern. However, just a few studies have reported on toxicity investigations, including microplastic vectors. More quantitative research should be conducted to investigate the toxins [toxic chemicals] transfer of microplastics to marine species, as well as any possible dangers of transfer from consumable marine organisms to people.

The most pressing need in this subject is to raise public understanding about the inert impacts of microplastics. This would encourage numerous inventions aimed at reducing the use and consumption of plastic and its byproducts. The most essential way to reduce plastic entry into the ecosystem is to gather and reuse plastic particles. To avert future threats, the best answer is to discontinue production and seek alternatives to plastic items.

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