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Review

Microplastics as an Emerging Threat to the Global Environment and Human Health

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Abstract: In recent years, there has been mounting concern about the bearing of microplastics on human health and the comprehensive natural environment. These particles come from a variety of sources, such as soaps, personal care products, and the rundown of bigger plastic items. The impacts of microplastics on marine life and other ecosystems are substantial, including ingestion by marine animals, interference with their reproductive systems, and even death. The economic implications of microplastics are also significant, with industries, such as fishing and tourism being affected by the presence of microplastics in the environment. Exposure to microplastics can also pose potential health risks to humans, including respiratory and digestive problems, as well as disrupt sleep, contribute to obesity, and increase the risk of diabetes. To address this issue, policies and initiatives have been put in place to reduce microplastic pollution, but there are challenges that need to be overcome, such as lack of awareness, limited resources, and ineffective regulations. Further research is also needed to fully understand the impacts of microplastics on our health and to develop effective strategies to mitigate the problem. In this article, we have discussed the requirement of a multifaceted approach including reducing plastic use, promoting proper disposal and recycling of plastic waste, developing innovative technologies for capturing and removing microplastics from the environment, raising public awareness, and implementing effective regulations and policies. It is only through concerted efforts and collaboration between individuals, industries, and governments that the threat of microplastics can be tackled.

Keywords: microbeads; microfibers; public health; biohazards; pollution; mitigation; ecosystem

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1. Introduction

In the last decade, microplastics have become a major environmental and health concern worldwide. They are small plastic particles that come from various sources, such as discarded plastics, textiles, and personal care products including face wash and soaps. These particles are so tiny that they can route through water filtration techniques and easily become pervasive in our environment [1].

These tiny particles can have a significant impact on marine life [2,3]. Marine animals, such as fish, sea turtles, and seabirds, mistake microplastics for food, which causes serious harm to their lives or death [4,5]. Plastics that accumulate on beaches undergo weathering degradation, which causes surface embrittlement and microcracking, resulting in the formation of microparticles. These particles can be carried into the water by wind or waves. One of the major concerns with microplastics is that they tend to attract and concentrate persistent organic pollutants from the surrounding water due to partition, in contrast to inorganic fines present in seawater [6–8]. This accumulation of pollutants on the

surface of microplastics can pose a significant threat to marine ecosystems and the health of organisms that ingest them [7]. Microplastics can also interfere with the reproductive systems of marine animals, leading to a decline in population numbers.

Microplastics have truly emerged as a significant environmental concern due to their widespread distribution and persistent nature. As we know, these minuscule particles, originating from various sources including plastics fragmentation and degradation, pose significant negative impacts on ecosystems. When microplastics enter aquatic environments, they can be consumed by a diverse variety of creatures, including plankton, and marine mammals, such as fish, leading to adverse effects on their physiology and behavior [5,9]. Microplastics can cause physical harm, such as internal blockages and tissue damage, as well as chemical harm by acting as carriers of pollutants and toxins. Furthermore, microplastics can disrupt food webs, alter nutrient cycling, and contribute to the decline of biodiversity [10–12]. The detrimental consequences of microplastic pollution highlight the urgent need for effective mitigation strategies to safeguard the health and resilience of ecosystems.

Microplastics are a major environmental concern due to their potential impact on marine ecosystems (Figure 1). Studies have shown that these tiny plastic particles can interfere with the reproductive systems of marine animals, leading to a decline in population numbers [13,14]. Microplastics can act as endocrine disruptors, altering hormonal signaling pathways that are essential for the proper functioning of reproductive systems. They can also cause physical damage to reproductive tissues, such as the ovaries and testes, through their abrasive nature. In addition, microplastics can be ingested by marine organisms, causing blockages in their digestive tracts, malnutrition, and ultimately, death. The reproductive health of marine animals is critical to maintaining the biodiversity and balance of marine ecosystems, and the impact of microplastics on this aspect of animal physiology represents a significant hazard to the well-being of these systems. Therefore, there is a pressing requirement to foster effective strategies for preventing and reducing the release of microplastics into the environment.

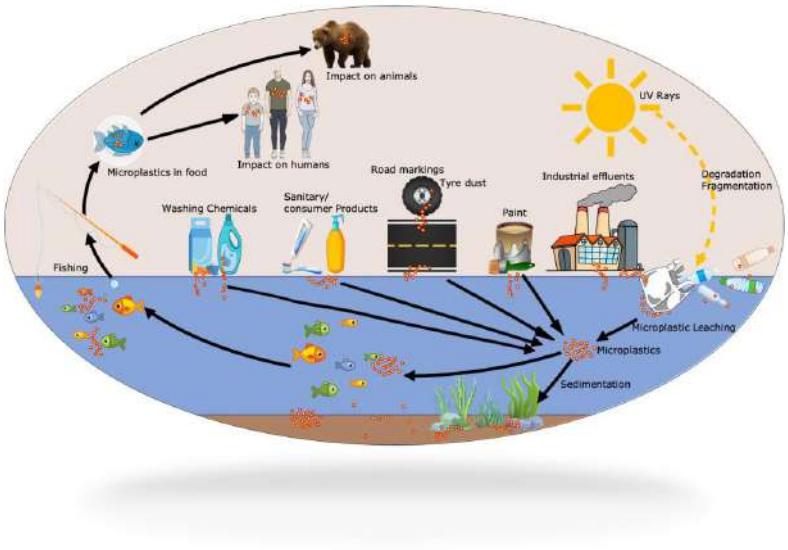

Figure 1. Microplastics generation, transportation and ingestion in the environment effecting the whole ecosystem. Various processes that are part of our daily life contribute to microplastic leaching due to littering and erroneous disposal systems. These microplastics can assimilate inside various forms of food items at different levels of food chain and get consumed by animals or humans. Microplastic leaching can be contributed by various forms of plastic fragmentation, that might be from degradation of plastic debris, industrial effluents, paint tubs, road markings, tire dust, and also from our face wash and toothpastes.

Furthermore, microplastics can also have an impact on human health [15–17]. Studies have found that microplastics can enter our body through food, water, and even the air we

breathe (Table 1). Research has found microplastics in tap water, bottled water, seafood, and air [15]. Once microplastics enter our body, they trigger inflammation, which can lead to various health issues [18]. They can also release toxic chemicals into the body, leading to a range of health problems, including cancer [19], reproductive problems, and developmental issues [20]. Moreover, microplastics have also been found to contribute to the growth of antibiotic resistance [14,21]. This is because microplastics can serve as a proliferation field for bacteria, which can become resistant to antibiotics over time. This could have serious implications for human health, as antibiotic resistance is already a major global health concern. In this article, we have discussed the factors that impact the global environment together with human health. Further, current efforts and future directions have been highlighted to improve the situation of microplastic menace.

Table 1. The various types of plastics, their size ranges, environmental impacts, and potential health effects. Each plastic type listed represents a distinct material composition. The environmental impact highlights the specific effects of each plastic type on the environment. The health impacts sheds light on the potential risks associated with each plastic type. Making informed decisions regarding plastic usage, promoting environmental conservation efforts, and raising awareness about potential health risks is required. By considering the size ranges, environmental impacts, and health effects of different plastic types, individuals and organizations can make more sustainable choices and contribute to mitigating the negative consequences associated with plastic materials.

S. No.	Plastic Type	Size Range	Environmental Impact	Health Impacts	References
1	Polyethylene	0.06 to 11.06 µm	Contributes to marine pollution, harms marine life	Potential ingestion through contaminated seafood, respiratory issues	[22–25]
2	Terephthalate	Less than 4 µm to greater than 100 µm	Contaminates water bodies, affects aquatic organisms	Disruption of hormone regulation, respiratory problems	[26–30]
3	Polystyrene	33 to 190 µm	Persists in the environment, accumulates in marine organisms	Respiratory issues, potential hormone disruption, adverse neurological effects	[31–36]
4	Polypropylene	120 to 220 µm	Poses risks to wildlife	Gastrointestinal problems, respiratory issues, potential immune system effects	[37–43]
5	Polyvinyl Chloride (PVC)	Less than 10 nm and as much as 20 µm	Releases toxic chemicals, hazardous to aquatic ecosystems	Respiratory problems, potential reproductive and developmental issues	[44–47]
6	Polycarbonate	5–200 nm	Contributes to marine pollution, affects marine organisms	Hormone disruption, potential adverse effects on neurological development	[48–50]
7	Polyethylene Terephthalate (PET)	Microfiber dimensions: 12 to 18 µm in thickness Length: shorter than 1 mm	Contaminates water bodies, harms marine animals	Ingestion through contaminated seafood, potential respiratory issues	[51–53]
8	Polyurethane	Less than 5 mm	Pollutes land and water, poses risks to terrestrial ecosystems	Respiratory problems, potential skin irritation, potential effects on immune and nervous systems	[54–58]
9	Polyvinylidene Fluoride (PVDF)	Less than 5 mm	Persists in the environment, accumulates in marine organisms	Prolonged inhalation or skin contact with PVDF particles can cause irritation or sensitization in some individuals.	[59–61]
10	Acrylic copolymer	80 to 110 nm	Negatively impacting aquatic ecosystems and potentially entering the food chain	Develop allergic reactions or sensitization to acrylic, leading to dermatitis or respiratory issues upon exposure.	[62–64]

2. Background Information on Microplastics

The small particles of plastic, known as microplastics, usually under 5 mm of size, have become a substantial environmental and health concern in recent years. They can be found in various environments, including the ocean, freshwater bodies, soil, and even in the air we breathe [13,65]. One of the most common sources of microplastics is discarded plastic products, such as bags, bottles, and packaging materials. When these plastics break down, they release small particles that can end up in the soil and water. Additionally, microplastics can also come from synthetic fibers in clothing that shed during washing and drying processes [66].

Microplastics are generated by the fragmentation, weathering, and degradation of the larger plastic objects, as well as through the release of synthetic fibers from textiles and other sources. Microplastics are prevalent in various environments, including ocean, freshwater bodies, soil, and air. Their effects on ecosystems and human health are a growing concern. There are two primary types of microplastics: primary and secondary. Primary microplastics are deliberately produced to be small, such as the microbeads used in cosmetics and personal care commodities, while secondary microplastics are materialized by the rundown of bigger plastic articles. Secondary microplastics are the most common type of microplastics found in the environment [67].

There are diverse sources of microplastics ranging from large industrial products to everyday household items (Figure 1). Some of the most common sources of microplastics include:

1. Textiles: Synthetic fabrics, such as nylon, acrylic, and polyester, shed microfibers when they are washed, leading to the release of microplastics into the environment [68–73].
2. Synthetic paints and tire dust: Multiple sources of synthetic polymers (including paints, abrasion of aquaculture gears, tire dust, and discarded fishing equipment and ropes) after wear and tear produces the highest level of microplastics in oceans [74]. The erosion and chafing of the road markings also significantly impact microplastic pollution [75].
3. Plastics in the ocean: Plastic debris makes up a substantial source for generation of microplastics in the ocean [76]. This includes substances, such as bottles and bags made of plastic, and wrapping provisions that break down over time due to sunlight exposure and additional environmental factors [77].
4. Personal care products: Microbeads, which are tiny plastic beads used in exfoliating scrubs, toothpaste, and other products used for personal care [67], can enter the environment via treatment plants for wastewater and transpire in marine as well as freshwater ecosystems.
5. Industrial products: Many industrial products, such as plastic pellets used in the manufacture of plastic products, are also a source of microplastics [77,78].

The prevalence of microplastics in various environments differs as per the source and the settings of the environment (Table 2). In the ocean, microplastics are widespread and can be found at all depths, from the surface to the seafloor. In fact, some estimates suggest that plastic particles amounts to five trillion or more in all of our oceans, with microplastics accounting for a significant portion of this total [79]. Microplastics have also been found in freshwater bodies, such as rivers and lakes, where they can accumulate in sediment and in the tissues of aquatic organisms. Studies have shown that microplastics are present in tap water and bottled water, as well as in food products, such as seafood and salt [80]. Microplastics are also prevalent in soil, where they can enter the environment through the application of plastic mulch films and other plastic-based agricultural products [81,82]. They can also be introduced to soil through the use of biosolids, which are treated wastewater sludges that are applied to agricultural land as fertilizer.

Table 2. Overview of the various sources of microplastics, which are minuscule plastic particles known to pose threats to both the environment and human health. The table encompasses sources, such as cosmetics, personal care products, synthetic textiles, plastic packaging and containers, industrial processes, tire wear, and paints and coatings. Each source is accompanied by a concise description detailing how microplastics are generated or released into the environment, along with their potential ecological and human health implications. This valuable information can assist in the development of effective strategies aimed at preventing or minimizing the release of microplastics into the environment [83–103].

Sources	Mode of Microplastic Generation and Release in Environment
Cosmetics and personal care products	Microbeads and other microplastics are often used as exfoliants or abrasives in products like facial scrubs, toothpaste, and body wash. Such tiny particles end up in waterways and seas because they are miniscule products which simply get filtered out by wastewater treatment plants and other contemporary procedures. Some countries have banned or highly regulated microbeads usage in the manufacturing of personal care and other products due to their serious environmental impact.
Synthetic textiles	Synthetic fabrics like polyester, nylon, and acrylic shed microfibers when washed or worn. These fibers can end up in waterways and oceans, where they can be ingested by marine life. Studies have found that microfibers are one of the most common types of microplastics found in the ocean. Some companies are developing solutions to reduce microfiber shedding from clothing, such as special washing bags or coatings for fabrics.
Plastic packaging and containers	Single-use plastics like water bottles, food containers, and plastic bags can break down into smaller pieces over time due to exposure to sunlight and other environmental factors. These smaller pieces can eventually become microplastics that are difficult to remove from the environment. Some countries have regulated and implemented policies that help in reducing plastic litter and misuse, for instance prohibiting one-use plastics or requiring manufacturers to use more sustainable materials for packaging.
Industrial processes	Microplastics can be generated during manufacturing processes, such as plastic production or cutting/grinding of plastic materials. These particles can end up in the air or water near industrial facilities, potentially impacting nearby ecosystems or human health. Some companies are exploring ways to reduce microplastic pollution from industrial processes, such as using closed-loop systems for plastic production or implementing filtration systems for wastewater discharge.
Tire wear	As tires wear down on roads, they release tiny particles of rubber that can contain microplastics. These particles can be washed into waterways or become airborne, potentially impacting human health and the environment. Some researchers are studying ways to reduce tire wear and develop more sustainable tire materials.
Paints and coatings	Some paints and coatings contain microplastics that can be released into the environment during application or removal. These particles can end up in waterways or soil, potentially impacting nearby ecosystems. Some companies are developing alternatives to traditional paints and coatings that do not contain microplastics.

Moreover, microplastics have also been found in the atmosphere, with studies suggesting that they may be present in indoor and outdoor air as a result of the rundown of goods made of plastic, and the flaking and sloughing of synthetic fibers from different types of textiles [104]. It is easily understandable that microplastics are a substantial ecosystem and health concern due to their extensive prevalence in various environments [105,106]. The sources of microplastics are diverse, ranging from large industrial products to everyday household items, and their impacts on ecosystems and human health are still being studied [107,108]. Knowing the types of microplastics, their sources and impacts on environment and human health would be an essential first step in developing effective strategies for preventing and reducing the discharge and expulsion of microplastics into the natural world.

3. Impacts of Microplastics on the Environment

Microplastics have significant impacts on marine life and other ecosystems, from the smallest organisms to larger marine animals. Microplastics are mistaken for food by marine animals, leading to ingestion and accumulation in their bodies. This causes physical harm to marine life, including blockages in the digestive tract and damage to internal organs. Additionally, ingesting microplastics also causes malnutrition by filling up the stomachs of marine animals without providing any nutritional value. These microplastics also interfere with the reproductive systems of marine animals, leading to a decline in population numbers. Studies also show that microplastics can disturb the behavior and physiology of marine animals, such as reducing their swimming ability and increasing their susceptibility to predators [109–111].

In addition to marine life, microplastics can also have adverse effects on other ecosystems. Microplastics in soil are known to alter the soil properties by reducing water retention and affecting nutrient cycling [112,113]. In freshwater ecosystems, microplastics can disrupt the food web and negatively impact the health of aquatic organisms. Additionally, microplastics can also pose a threat to human health, as they can enter the food chain and potentially cause harm to those who consume contaminated seafood or water [66,114]. Microplastics may also have adverse effects on air quality [115], although more research is needed in this area. Predominantly, the effects of microplastics on oceanic life and other ecologies are becoming more severe, and more efforts are required to moderate the discharge of microplastics into the ecosystem and to develop effective strategies for their removal.

Dismally, the microplastics' presence in marine environments has significant economic implications on industries, such as fish catching and tourism. The microplastics are able to accumulate in the tissues of fish and shellfish, leading to a reduction in their quality and market value [114,116,117]. The existence of microplastics in seafood can also result in consumer concerns about food safety [114,118], which can further affect the economic viability of the fishing industry. In addition to the fishing industry, tourism can also be impacted by microplastics. Coastal tourism relies heavily on the natural beauty and health of marine ecosystems, and the presence of microplastics can detract from the overall aesthetic and ecological value of these areas [6,119]. Beaches contaminated with microplastics can deter tourists and reduce the revenue generated by tourism in affected areas. There is an urgent need for more efforts to reduce the impact of microplastics on these industries and the environment as a whole. For example, initiatives to reduce plastic waste and improve waste management practices can help to avert the discharge of microplastics into the environment. Additionally, technologies for removing microplastics from water are being developed, which could help to mitigate the economic impact of microplastic contamination. The economic implications of microplastics on industries, such as fishing and tourism are significant and this highlights the importance of addressing this issue in a comprehensive and proactive manner.

4. Impacts of Microplastics on Our Health

We understand very well now that microplastics can enter our body via different routes, comprising inhalation, ingestion, and dermal exposure (Figure 2). Out of these, ingestion is the most common pathway for microplastic exposure in humans [66,107,120]. Microplastics can be present in contaminated seafood and drinking water, as well as in food packaging and utensils made of plastic. Once ingested, microplastics can potentially accumulate in the digestive tract and other organs [66,107]. Inhalation is another pathway for microplastic exposure, particularly for individuals who work in industries that involve the production or handling of plastic materials [120]. Microplastics can be present in the air as a result of their release during manufacturing processes, transportation, and disposal. On the other hand, dermal exposure to microplastics can occur via the use of merchandises used in personal care that contain microbeads, for example facial scrubs and body washes [121,122]. Microplastics can also be present in clothing and textiles made of synthetic materials, which can shed microfibers during use and washing [123].

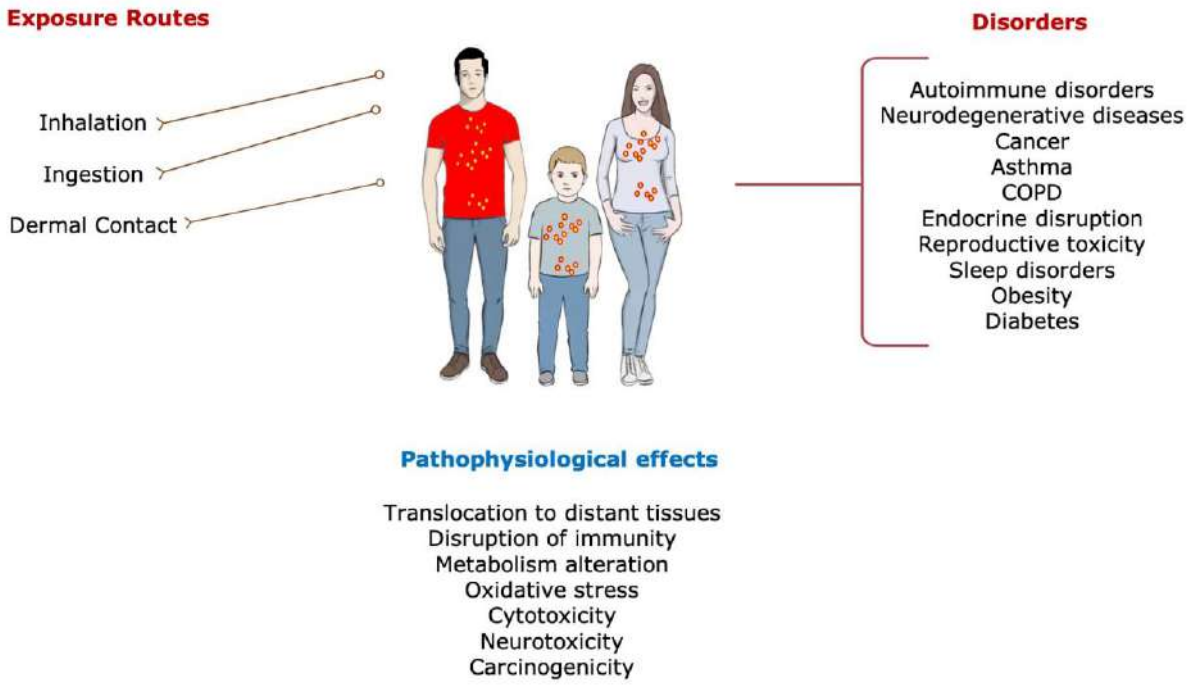

Figure 2. Microplastics severely impact human health. Through multiple routes microplastics can invade the human body and cause multiple changes via a downstream cascade of events that cause the body to experience pathophysiological effects, which can lead to a multitude of disorders including sleep disorders, obesity, cancer, Parkinson's disease, and others.

While the health effects of microplastic exposure in humans are still being studied, there is evidence to suggest that it has numerous negative impacts on our health. Various studies show that microplastics potentially trigger inflammation [124], cellular impairment [125], and genotoxicity in human cells [126]. Therefore, it is important to minimize exposure to microplastics and reduce their release into the environment in order to protect both human health [127] and the ecosystems (Figure 2).

Although the prospective health hazards correlated with contact to microplastics are still being investigated using in vivo, in vitro and in silico studies, there is a growing concern about their potential impact on human health. Studies show that the ingestion of microplastics cause damage to the intestinal wall, which can lead to inflammation, oxidative stress, and changes in gut microbiota [128–131]. This would possibly cause unwanted health effects, such as autoimmune disorders, cancer, and neurodegenerative diseases. Inhalation of microplastics can cause respiratory irritation and damage, and may contribute to the development of respiratory illnesses like chronic-obstructive pulmonary disease (COPD) and asthma [115,132]. Dermal exposure to microplastics has been linked to skin irritation and inflammation, and may potentially cause other health conditions, such as endocrine disruption [107] and reproductive toxicity [133]. In addition to these direct health risks, microplastics can also carry and concentrate harmful chemicals and pollutants [107,134]. Microplastics in our surroundings can adsorb persistent organic pollutants (POPs) [135], which can build up in the tissues of marine animals and potentially be transferred to human beings through the ingestion of contaminated seafood [136]. While the full extent of the health threats concerned with contact to microplastics like mental health and socio-behavioral implications are being investigated, there is enough evidence to suggest that microplastics may have negative impacts on human health (Figure 2). Hence, it is important to reduce our use of plastic products and to take steps to minimize the release of microplastics into our environment.

Multiple studies have found that microplastics in the environment can disrupt circadian rhythms and melatonin production [137,138], potentially leading to sleep disturbances and a higher risk of sleep disorders [107,139]. In terms of obesity, some studies have

shown that exposure to microplastics may disrupt hormone regulation and metabolism, potentially contributing to weight gain and obesity [140–143]. Additionally, exposure to microplastics may be linked to an increased risk of diabetes [141]. Microplastics have been shown to cause oxidative stress and inflammation [124,144], which are known risk factors for diabetes. Therefore, it is clear that microplastics can have negative impacts on both the environment and human health.

5. Current Efforts to Address the Issue

There are several policies and initiatives at the national and international levels that are aimed at reducing microplastic pollution. At the international level, the United Nations has taken action to address microplastic pollution through its Clean Seas campaign that targets to remove foremost sources of oceanic plastic and microplastic pollution [145]. The campaign focuses on promoting the reduction and elimination of single-use plastics, improving waste management, and increasing public awareness [145,146]. In Europe, the European Union has implemented a ban on microplastics in personal care products, such as toothpaste and face wash [147,148]. The EU has also proposed a ban on single-use plastics, including products such as straws and cutlery [149]. Multiple nations, like Canada and the United States, have also proposed or implemented bans on microbeads in personal care products [150].

In addition to these policy initiatives, there are also several private sector initiatives aimed at reducing microplastic pollution. For example, many companies have committed to reducing their use of single-use plastics, and some have implemented recycling programs to reduce plastic waste [150]. While these policies and initiatives are a step in the right direction, much work still needs to be done to reduce the amount of microplastic pollution in our environment. It is important for governments, businesses, and individuals to take action to reduce their use of plastic products and to properly dispose plastic waste in order to protect our ecosystems and human health.

Addressing the issue of microplastic pollution presents several challenges that need to be overcome in order to effectively inhibit pollution. One of the foremost challenges is the scarcity of public cognizance and understanding of this issue. Many people are still not aware of the extent of microplastic pollution and its influence on the environment and our health. Awareness about the impact that ranges from our mental health to the whole ecosystem needs to be inculcated among the global citizens, specially students from developing as well as developed nations [151]. In the long run, the lack of awareness can lead to a lack of political will to address the issue. Another challenge is the complexity of the problem. Microplastic pollution is a multifaceted issue that requires a multifaceted solution. It requires collaboration between various stakeholders, including governments, industries, and individuals, and requires changes in behavior, production, and consumption patterns. Additionally, there are technical challenges to identifying and measuring microplastic pollution, as the particles are often too small to be seen with the naked eye and are difficult to measure accurately. There is also a requirement for more investigations for an enhanced comprehension of the long-term influences of microplastic pollution on both the environment and our health.

Microplastic removal and elimination methods encompass a range of approaches to deal with the issue of microplastic contamination [152]. Wastewater treatment plays a crucial role in capturing and removing microplastics from wastewater before it is discharged into the water bodies. Advanced treatment processes like activated sludge systems and membrane filtration are employed for this purpose [152]. Filtration systems, including mesh screens, sand filters, and activated carbon filters, are also utilized to capture larger microplastic particles from water sources. Bioremediation strategies using specific microorganisms or enzymes are being explored as potential methods for microplastic degradation. In areas with high microplastic concentrations, floating boom systems can be deployed to contain and collect floating plastic debris, including microplastics. Manual removal of visible plastic debris from rivers, shorelines, and beaches through clean-up initiatives is

another widely practiced method. Additionally, innovative technologies, such as magnetic nano-adsorbents, electrocoagulation, and ultrasonic treatment are being researched to enhance microplastic removal efficiency [153]. It is important to recognize that these methods are still evolving, and a comprehensive approach involving source reduction, improved waste management, and targeted removal strategies is needed to effectively tackle microplastic pollution.

In order to effectively address the matter of microplastic pollution, it is crucial to prioritize research and collaboration efforts. Continued scientific studies are required to better comprehend the sources, pathways, and impacts of microplastics on ecosystems and human health [107,154]. This includes studying the long-term effects of exposure to microplastics, identifying emerging sources of microplastic pollution, and developing improved methods for detecting and quantifying microplastics in different environmental matrices. Collaboration between scientists, policymakers, industries, and civil society organizations is vital for the development and enactment of effective approaches. Sharing knowledge, data, as well as best practices can help identify innovative solutions and promote the adoption of sustainable practices across sectors. International collaborations and partnerships can facilitate the exchange of information and resources, enabling a more comprehensive and coordinated response to the global challenge of microplastic pollution [155]. Furthermore, education and awareness-raising initiatives play a pivotal role in addressing the issue. Public engagement programs, especially targeted towards students and young individuals, can promote behavioral changes and encourage responsible consumption and waste management practices. By fostering a sense of environmental stewardship and empowering individuals to take action, we can collectively work towards reducing the generation of microplastics and minimizing their release into the environment [156,157]. By enhancing research efforts, fostering collaboration, and promoting awareness, we can advance our understanding of microplastic pollution and develop effective strategies to mitigate its adverse effects. It is through collective action and a shared commitment to sustainable practices that we can safeguard ecosystems and protect human health from the detrimental impacts of microplastics [156].

Finally, since microplastic pollution is a global problem, or a transboundary issue that affects all countries, it requires a concerted and coordinated effort from all international stakeholders, as well as a commitment to innovation and ongoing research to identify effective solutions.

6. Future Directions

While there is comparably an increasing awareness of the effects of microplastics on the ecosystem and especially our health, there is still a demand for further research to fully understand the extent of the problem and its implications. One area where more studies are required is in understanding the pathways of microplastic contact to humans. While it is known that microplastics can easily enter our body (Figure 2) by the routes of ingestion, inhalation, and dermal contact, the health risks associated with each pathway are still not well understood. There is also a need for more research and development studies to find and comprehend the longstanding and enduring consequences of the exposure to microplastics on our brain as well as mental health, pre- and post-natal developmental effects, various neurological disorders like Alzheimer's disease [158], epilepsy [159], and other neuropsychological conditions [160–162]. While studies have shown potential risks such as inflammation, oxidative stress, and damage to organs, there is still much to be learned about the cumulative effects of exposure over time.

In addition, more studies are required to comprehend and identify the ecological impacts of the pollution caused by microplastics in both marine and terrestrial ecosystems. While it is known that microplastics can harm marine organisms and disrupt food webs, there is still a need for more research on how these effects may cascade through ecosystems. Finally, there is a need for standardized methods of measuring and quantifying microplastic pollution [163]. Currently, there is no universal method for measuring microplastics in various environmental

matrices, which can make comparisons across studies difficult [164,165]. To sum up, extensive research is crucial in developing effective solutions to address the problem of pollution caused by microplastics and mitigate its influences on our environment in totality. There are several individual actions that can be taken to reduce microplastic pollution. Here are some examples:

1. Minimize the use of single-use plastics: Opt for reusable and recyclable substitutes, such as water bottles made of stainless-steel and copper shopping bags made of jute or cloth, and reusable food boxes to reduce plastic waste.
2. Avoid products with microbeads: Check the ingredients of personal care products like face scrubs, toothpaste, and body wash to ensure they are microbead-free. Look for natural exfoliants like oatmeal or sugar instead.
3. Choose natural fibers over synthetic textiles: When purchasing clothing or textiles, opt for natural fibers like cotton, hemp, or linen, as they shed fewer microfibers compared to synthetic materials like polyester or acrylic.
4. Properly dispose of plastic waste: Ensure that plastic waste is disposed of in designated recycling bins. This helps prevent plastics from ending up in waterways and ultimately breaking down into microplastics.
5. Avoid excessive use of household plastics: We must significantly reduce the usage of plastic bags and wraps, and disposable cutlery. Rather we should opt for reusable alternatives like beeswax wraps, reusable bags, and stainless-steel utensils.
6. Support initiatives and policies addressing microplastic pollution: Stay informed about local initiatives and support organizations working towards reducing microplastic pollution. This can include advocating for policies that promote sustainable practices and responsible plastic waste management.
7. Participate in beach and river clean-ups: Join or organize clean-up activities in your community to help remove plastic debris, including microplastics, from natural environments.

Importantly, we must remember that even individual small actions can contribute to a significant reduction in microplastic pollution when adopted collectively.

7. Conclusions

Microplastics, originating from sources, such as cosmetics and personal care products, and found in various environments including the ocean, freshwater bodies, soil, and even air, pose a serious hazard to the ecosystem as well as our own health. The influences of microplastics on oceanic life and other ecosystems are significant, including ingestion by marine animals, interference with their reproductive systems, and even death. Not to ignore, the economic implications of microplastics are also significant, with industries, such as fish and tourism, being influenced by the presence of microplastics in our surrounding ecosystem. There are also impending health hazards linked to the exposure of microplastics, including respiratory and digestive problems, sleep disruption, obesity, and increased risk of diabetes.

To address microplastics pollution, there are policies and initiatives in place. However, there are also challenges that need to be overcome, such as lack of awareness, limited resources, and ineffective regulations. There is an urgent need for action to tackle the impending threats posed by microplastics to the whole ecosystem and our health too. This would require a multidimensional approach, that would cover reducing the usage of plastic, promoting its proper disposal and recycling of plastic waste, developing innovative technologies for capturing and removing microplastics from the environment, raising public awareness, and implementing effective regulations and policies. In addition, further research and development studies are needed to better associate, connect and understand the microplastics' impact on our ecosystem as well as human health. This would also help in the implementation and enhancement of the different strategies to mitigate the problems associated with microplastics. It is only through concerted efforts and collaboration between individuals, industries, and governments that we can successfully address the urgent threat of microplastics and protect our planet for future generations.

The pervasive presence of microplastics across various environments presents a substantial and multifaceted danger to ecosystems and human well-being. The detrimental

impacts on marine life, including ingestion and reproductive disruptions, highlight the urgent need for action. Additionally, the economic implications and potential health hazards concerned with the exposure of microplastic underscore the severity of the issue. While policies and initiatives exist to tackle microplastic pollution, challenges such as limited awareness and resources, as well as ineffective regulations, persist. To effectively address this urgent threat, a comprehensive approach is required, encompassing reducing plastic consumption, improving waste management, developing innovative removal technologies, raising public awareness, and implementing robust regulations. Continued research is also essential to better comprehend various microplastics' influences and evaluate the effectiveness of mitigation strategies. Through collective efforts and collaboration, we can safeguard our planet and create a sustainable future for generations to come.

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