

MICROPLASTICS: CHALLENGES, SOLUTIONS AND DETECTION TECHNIQUES

Abstract

Microplastics are tiny particles that are produced from the splintered waste of plastics dumped into water. Microplastics are easier to absorb by aquatic organisms, because of their smaller particle size and contribute to harmful waste. Due to their widespread availability and high potential for environmental interaction, microplastics damage the biosphere's flora and animals. Microparticles are created when plastics on the water's surface break down mechanically and photochemically due to waves and sunshine, respectively. Microplastics come in a variety of colors and densities depending on the type of polymers utilized. Water with floating microplastics is primarily made of polyethylene, which accounts for 54.5% of them. The other compounds are polypropylene, polystyrene, polyamide, polyvinyl chloride, and polyester. Polyethylene and polypropylene have an impact on the ocean's surfaces by floating because of their lower density relative to marine water, whereas materials with a higher density sink and have an impact on the seafloor. The pandemic (COVID-19) has also elevated the risks of microplastic pollution due to extensive single-use plastic usage. In this chapter, the effects of microplastic waste on waterways and aquatic environments from various sources along with the ways to reduce the risks due to them are discussed in detail.

Keywords: Microplastics; contaminant; pandemic; environment; toxic effect.

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I. INTRODUCTION

Plastic spoilage in the marine and freshwater has been a problem for decades, mainly because it accumulated 'litter' on beaches and the seafloor. Polymeric material plastics are not biodegradable they degrade through other weathering processes which makes them form smaller plastic particles and, therefore are called microplastics. The microscopic plastic particle size is less than 5mm and these particles found in the aquatic environment have recently drawn a lot of attention [1]. One of the major problems with microplastics is that they tend to move up in the food chain which causes adverse effects on human health. The chemicals present in the microplastic (plasticizers and flame retardants) may cause toxicological effects. The awareness of microplastics in the environment and their tendency to cause environmental damage is a recent development, which is now attracting an increasing amount of attention. More intense research focused on this issue has been done since the early 2000s, and microplastics are considered emerging contaminants [2]. The most used and manufactured plastic polymers are polyamide, polystyrene, polyvinyl chloride, and polyethylene. The significant portion of manufactured plastic that remains in waterways is the result of improper waste management or unintentional discharge [3]. According to the World Health Organization (WHO), there is conflicting evidence regarding the negative effects of microplastic on the well-being of humans, therefore they have suggested conducting extensive research on the impact of microscopic particles on human health [4].

II. SOURCES OF MICROPLASTICS

There are two sources of microplastics, one is primary and the other is a secondary source [5]. Primary microplastics are produced under a microscope and are usually about 0.25 mm in size. It is made to have a tiny size, like powder or nurdles, and is mainly present in cosmetic products. These microplastic particles can enter in the environment from household waste or sewage systems [6]. The wastewater treatment facilities are a key source of microplastics. Aquatic environments are where most microplastics are found and it originates from the fragmentation of bigger particles and produces secondary microplastics. [7]. The breakage of larger particles depends upon the temperature or amount of UV radiation [8].

Microplastics may have varying rates of deterioration while being carried in the environment as compared to larger plastics. They undergo transportation and fate processes once they are introduced into the aquatic ecosystem [9]. Microplastics enter the environment through diverse ways and their transportation from land to river system will rely on the climate or the distance between them. Nowadays the collection of microplastics at the roadside is generally observed, and these plastics enter aquatic environment by overland runoff or by cutting action to roadside ditches. Multiple sources contribute to the presence of microplastics in waterways [10].

Information on the decomposition of plastic in environmental circumstances is limited. Plastic formation rate is often not investigated because some polymers such as polyethylene do not readily depolymerize, they will break down into smaller pieces, and smaller fragments further decompose into nanoparticles. Therefore, predicting the rate of plastic fragmentation is not an easy task. Once the plastic particle enters the environment, they contaminate and accumulate in the food chain. Microplastics tend to move up in the food

chain from one trophic level to another, for example, from zooplankton to birds and possibly to humans [2][4].

III. CLASIFICATION OF MICROPLASTICS

Based on sources, microplastics can be divided into two groups, primary microplastics and secondary plastics. Primary microplastics represent the directly manufactured microplastics. These are used in the cosmetics, facewashes, and toothpaste. Secondary microplastics are fragmented product formed from larger plastics that breaks due to physical stress or photo-oxidation process[3] based on shape, microplastics are classified into five categories, fragments, fibers, microbeads, foams, pellets (Figure1)



Figure 1: Different types of microplastics

- 1. Fragments:** Smaller plastic particles known as fragments are created when bigger plastic parts break down. Examples that are frequently used are silverware, lids, etc. These fragments are broken down into even smaller pieces by solar radiation (UV radiation).
- 2. Fibres:** It is a major constituent of total microplastics. It comes from washing machines because when we wash synthetic clothes, the fibers detach from the clothes and go into the wastewater. Synthetic clothing is composed of plastics like acrylic and polyester.
- 3. Microbeads:** Microbeads are plastic granules with a diameter of less than 1 millimeter that are not biodegradable. They can easily pass through treatment facilities and reach the aquatic environment due to their small size, which is why they are used in toothpaste, exfoliating soaps, and facial cleansers.
- 4. Foams:** Styrofoam disintegrates into tiny pieces like fragments. To manufacture containers that stop food and drink from altering temperature, Styrofoam is often made of white plastic. Styrofoam contains chemicals that can seep into food and liquids and harm people.
- 5. Pellets:** Small plastic pieces called pellets are used to make plastic items. Businesses melt them down to make mold for plastic products like container lids. They may easily infiltrate the aquatic environment because of their diminutive size.

IV. HARMFUL EFFECTS OF MICROPLASTICS

Microplastic contamination poses damage to the ecosystem and human health [11]. Mainly the problem with microplastics is that they don't readily break down into harmless molecules but they can take thousands of years to decompose and in the meantime cause destruction to the environment [12]. There are two types of harmful effects on organisms exposed to microplastics: physical effects and chemical effects. The amount, shape, and concentration of microplastics have an impact on their physical effects, whilst the chemicals

associated with microplastics have an impact on their chemical effects. In addition to additives and polymeric basic materials derived from plastics, microplastics may also contain substances absorbed from the environment. [11].

Microplastics have been found in commercial seafood, drinking water, and marine life including plankton to whales. When microplastic binds with other harmful chemicals, they are ingested by microorganisms [12]. Researchers have done a lot of work on microplastic risks to marine organisms. The smallest sea animals, zooplanktons, grow more slowly and reproduce less when exposed to microplastics. Microplastic will therefore further reduce the numbers of zooplankton before moving up into the food chain to affect humans. We were more concerned about the effects on the quantity of fish and the ability to feed the world's population if we eliminated anything like zooplankton, the foundation of our marine food web [13]. Microplastics introduce harmful impacts at the tissue and cellular level, on reproductive success, and cause adverse effects on biodiversity and the environment. Plastic material contains toxic compounds and it could be lethal to some creatures, such as bacteria and fungi, which are vital to the health of an ecosystem [2].

Researchers have several theories about how plastics affect human health. If thin asbestos fibers become tiny enough to get inside the cells or tissues, they may damage lung tissue and cause cancer. Vehicular exhaust and forest fires contain tiny particles known as PM10 and PM2.5 (particulate matter measuring 10 μm and 2.5 μm , respectively) that can accumulate in the airways and lungs, and the larger concentrations can harm the respiratory system. Due to the smaller size and ease of entry into the body through inhalation, microplastics may cause autoimmune diseases, cytotoxic and inflammatory effects, and respiratory discomfort in humans [13]. Microplastics can injure cells and tissues and affect the toxicity of particles when they come in contact with skin via water while using cleansers or cosmetics that include microplastics [11]. One of the main ways that microplastic enters the human system is through contaminated food [14]. According to recent studies, sugar include 0.44 MPs/g of microplastics, salt had 0.11 MPs/g, alcohol contained 0.03 MPs/g, and bottled water contained 0.09 MPs/g [15] [16]. 80 g of microplastics are consumed by people every day through fruits and vegetables that pick up MPs from contaminated soil [17] [18].

The larger plastic particles have a greater probability of being chemically harmful. Plastics are manufactured using additives including plasticizers, stabilizers, and colors, many of which are hazardous. Plasticizers are complex chemical substances that are inserted between the chains of molecules to reduce physical contact and promote mobility and workability. They are chemically stable, have moderate vapor pressure, and are insoluble in water. A common plasticizer used in industry, particularly in the production of polycarbonate plastics and food packaging, is bisphenol A (BPA), and it has been reported to contain endocrine disruptors which can harm human health when consumed or inhaled [11].

V. WAYS TO REDUCE HARMFUL EFFECTS OF MICROPLASTICS

The consumption of plastic garbage has been significantly increasing day by day. Microplastics exist in every aspect of our environment, including the food we consume, the water that we drink, the air we inhale, and the tissues deep inside our organs. To control this exposure, we must use different approaches: -

- Restrictions on the use of single-usage plastics as well as microplastics in cosmetic and personal care items like shaving foam, shower gel toothpaste, etc. This practice has already been introduced in some countries.
- Plastic microfiber filtration could help eliminate the problem at home. People who wash their clothes contribute 35% of the microplastic that ends up in the ocean. When synthetic textiles such as wool and other materials made from plastic go through our washing machines, the fibers break off and become plastic microfibers, which subsequently enter the water supply. The development of home-based filtering systems that can remove these microplastics may be the solution to this specific issue. [19]. If it succeeds, similar technology might be applied to address other particulate issues and repurposed as a technique to eliminate other kinds of plastic particles from waterways around the world.
- Different programs have been carried out to raise awareness of the issue. The United Nations Environmental Programme (UNEP) has been encouraging recycling, advocating for decreased plastic use, and assessing disposal options. Another initiative to reduce waste was also started in 2011 as part of the common declaration of the International Plastic Associations [20].
- Mass cleanups could be the greatest option for us. The garbage areas are a significant issue on their own, and the only way to address that issue is to clean up the area while it gets worse. It is quite impossible to remove the plastic once it has become microplastic. So, the solution might be to remove plastic from the water's surface before it ever becomes tiny. The easiest approach to stop more microplastics from entering the waterways is through ocean cleanups. Numerous tons of trash have already been cleared from our oceans by the ocean cleanup project and other organizations, and they've even disclosed some intriguing new technology developments that could make the cleanup even simpler [19].
- Preventing microplastics from contaminating waterways and the environment is a severe problem. To safeguard water bodies from pollutant loads, limit the export of microplastics from cities and the environment, and repair harmed water ecosystems, we must develop and implement solutions and minimize exposure to populations at risk. Significant steps toward achieving these goals include the treatment and disposal of drainage and wastewater as well as the secure handling of sewage sludge. [21].
- The invention of robot fish has given us yet another way to deal with water microplastics. Organic colours, antimicrobial agents, and heavy metals are among the particles' contents, and they interact strongly electrostatically with the fish's tissues. The fish can then gather and eliminate plastic particles from the water because the microplastics will stick to its surface. The robot fish can currently operate only on the water's surface [20].
- Recycling, reusing, and rethinking plastic products will be an effective method if everybody participates efficiently. In addition to clean-up initiatives and technical advancement, people can significantly contribute to the reduction of microplastic production by recycling and reusing the plastics and reducing the generation of plastic waste [22],[20].
- Scientists have discovered enzymes and microorganisms that may degrade plastic, but they must determine how to employ them without causing any negative consequences, such as the production of greenhouse gases [22].

VI. IDENTIFICATION AND CHARACTERIZATION OF MICROPLASTICS

The marine ecology is filled with microplastic, which has a negative influence on biological life. Moreover, it is necessary to thoroughly research these particles' impacts on their sizes [23][24]. An accurate description could help in understanding the nature of these particles, including the way they look, shades, and polymeric composition. The optical microscope, Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy, scanning electron microscopy (SEM), and thermal analysis were the most often reported identification techniques [25].

- 1. Optical Microscope:** This method is commonly used for determining particle mass of larger size. This technique makes it possible to examine the surface texture and separate microplastic from the contaminated ambiguous bulk [26][27]. Even while most particles can be recognized under an optical microscope, some particles in the sub 100 μm range may be particularly challenging to recognize because, in addition to their size restriction, they may also lack a defined shape or colour [28]. The ability of microscopic technologies to differentiate between natural and synthetic fibers (such as PES and cotton that has been dyed) also came up short. Studies have revealed that fibers make up the majority of the microplastics in samples of the ocean, water, soil, and living things [29].
- 2. Scanning Electron Microscopic (SEM):** This technique scans a sample's surface with a focused electron beam to produce high-resolution images of the object and gives the idea about its surface properties [30][31]. The distinction between particles is made possible by the exquisitely detailed sample images ($> 0.5 \text{ nm}$). SEM, however, is unable to reveal the polymer's chemical makeup [32]. The samples also need to be specially prepared, which includes washing, drying, coating them with conductive material, and mounting them on a stub using conductive tape [30].
- 3. Fourier Transform Infrared (FTIR) Spectroscopy:** The use of FTIR (Fourier Transform Infra-Red) spectroscopy as a tool for microplastic characterization has also proved to be highly beneficial. It provides information on the chemical functional groups that are present in a specific polymer. The ability to distinguish between plastics and organic material is possible by the fact that each polymer produces its own unique set of spectroscopic band signatures [33]. Polymer identification is made easier by a wide and cleverly designed library of available standard spectroscopic data for the major plastic polymers. The option of micro FTIR may be employed when samples with ridiculously small particle sizes are available. The initial studies are carried out by changing between the objective lens and the IR probe before spectroscopic measurements in the FTIR [34].
- 4. Raman Spectroscopy:** Raman spectroscopy has the benefit of being able to identify microplastics particles having the diameters range from 1 to 20 μm [35]. The Raman Spectroscopy's confocal microscopic attachment allows it to be utilized to detect microplastics in zooplankton samples.[36]. For the identification of microplastics, Raman spectroscopy is also frequently used in addition to FTIR [37]. Based on the chemical structure of the atoms on the surface, the laser beam that was shot at the particles creates a certain pattern of backscatter. Raman spectroscopy will show the composition of the polymers in addition to identifying the plastic, in contrast to FTIR, which only allows the identification of the polymer. Along with the non-destructive methods of chemical

analysis and microscopy and keeping in mind the high cost of the equipment, Raman's spectroscopy offers us an identification tool similar to FTIR [38].

- 5. Thermal Analysis:** The thermo-analytical method is the most recent tool to identify microplastics, which is used to investigate changes in the physiochemical properties of the plastic with respect to its thermal stability [39]. Differential Scanning Calorimetry (DSC), a technique that examines the thermal properties of unknown polymer microparticles, is one such technology. With this method, a specific microplastic sample is identified using reference material. As a result, this method is frequently used to identify primary polymers, which are easily referenced using materials like tiny beads of PE. The idea of coupling thermogravimetric analysis (TGA) to dynamic scanning calorimetry (DSC) was tested, and it was discovered that this could help distinguish between the polymers PE and PP (polypropylene). However, the method encountered the issue of phase transition overlap and as a result, it was unable to identify a small number of significant polymers, such as PVC, PES, PA and PET [41]. TGA offers the user several benefits when coupled with a thermal desorption gas chromatography-mass spectrometer (TDS-GC-MS) and solid phase extraction (SPE). In comparison to a Py-GC/MS (Pyrolysis-gas chromatography-mass spectrometry), it permits higher sampling sizes, and in comparison, to a DSC, it offers better resolution. To validate this method, it was discovered that TGA-SPE TDS-GCMS was successful in identifying and quantifying PE from a sample of soil and mussels. Comparable results were also obtained for PP, PS, and mixed polymers [42].

VII. COVID-19 AND MICROPLASTICS

The global COVID-19 outbreak, which affected millions of people, began in 2019 and was originally documented in Wuhan, China [43]. Since the COVID-19 epidemic was deemed a global epidemic by the World Health Organization (WHO) on March 11, 2020, the utilization of plastic-based special protective equipment as a means of infection prevention has grown significantly. We were not only approaching a new epidemic but also a surge in single-use plastics. Italy forbade infected persons from organizing their garbage [44]. Trading companies that previously permitted customers to bring their own bags have rethought the plastic bag prohibition and progressively switched to reducing single-use plastics and promoting more online meal delivery services.

The COVID-19 epidemic has raised concerns about pollution from personal protective equipment (PPE), as wearing masks was recommended globally to stop the transfer of the Coronavirus from one person to another. and is now a common sight in places all over the world [45]. Personal protection equipment (PPE) is frequently made using nanofiber electrospinning, which suggests that PPE could serve as a source for microfibers because PPEs are the primary composites made of several nondegrading polymers. Various polymer materials, such as polyethylene, PAN, polypropylene, polyester, etc., are used to make surgical masks [46]. Overuse of PPE during an epidemic worsens plastic waste in the ocean because the ocean is the ultimate destination of all forms of deterioration. As the epidemic spreads, the issue worsens and potentially increases the amount of plastic waste in marine ecosystems [46]. More research on biodegradable PPEs is required to stop a future microplastic pandemic, as there is a strong need for environmentally friendly solutions given the involvement of the COVID-19 pandemic in microplastic pollution.

VIII. CONCLUSION

Microplastics cause adverse effects on the aquatic environment and human health. Controlling the adverse effects of microplastic is a big challenge in front of scientists. Though we have discussed a few methods to control these materials, however, there is still a need to explore more alternative ways to prevent their harmful effects. Although less research has been done on freshwater systems, this issue has recently gained significant attention. Freshwater microplastic is particularly crucial due to its accessibility to additional pollutants and proximity to sources of pollution, contamination can accumulate. Freshwater animals may therefore be subjected to higher amounts of pollution, particularly close to industrial and densely populated areas where microplastics and hydrophobic poisons may be more commonly found. To control the exposure of microplastic we need to instigate studies to better understand how the microplastic interacts with the environment. Also, more research is required to understand how microplastics cause adverse effects on the aquatic environment and human health. Apart from that more techniques are required for the identification and characterization of microplastics so that these can be identified and controlled at an early stage.

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