Microplastics: Challenges, Solutions and Detection Techniques

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**ABSTRACT**

When plastics are recklessly dumped into water sources, small particles known as microplastics are created by splintered debris. The smaller size of microplastic makes it simpler for aquatic species to consume it, which leads to an accumulation of toxic wastes. Microplastics are widely available and have a strong potential to interact with the environment, which disturbs the flora and fauna of the biosphere. Microplastics can leach out compounds. Due to mechanical and photochemical reactions driven by waves and sunshine, respectively, plastics in the marine environment splinter to create microparticles. Depending on the type of polymers used, microplastics vary in color and density. Polyethylene makes up about 54.5% of the microplastics floating in the water, followed by polypropylene at 16.5%, and then polyvinyl chloride, polystyrene, polyester, and polyamides. Due to their lower density compared to marine water, polyethylene and polypropylene affect the ocean's surfaces by floating, whereas materials with a higher density sink and affect the seafloor. The pandemic (COVID-19) has also elevated the risks of microplastic pollution due to the extensive use of single-use plastic. In this chapter, the consequences of plastic debris in the water and aquatic systems from a variety of sources and the solutions to abate the threats by microplastics are discussed.

**Keywords-** microplastics; contaminant; pandemic; environment; toxic effect.

**I. INTRODUCTION**

Plastic spoilage in the marine and freshwater has been a problem for decades, mainly because of its accumulation of “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,so are calledmicroplastics**.** 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 microplastic is that they have tendency to move up in the food chain and which causes adverse effect 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. Research focused on this issue has been done more intensively since the early 2000s and microplastics are considered as an emerging contaminant [2]. The most used and manufactured plastic polymers are polyamide, polystyrene, polyvinylchloride, and polyethylene. The considerable percentage of the manufactured plastic accumulated in the aquatic environment is due to waste mismanagement, or accidental discharge[3]. World Health Organisation (WHO) established that there are inconclusive evidences about the harmful effect of the microplastic on human health therefore they have suggested to conduct extensive research on the impact of microscopic particles on human health.[4]

**II. SOURCES OF MICROPLASTICS**

Generally, microplastics comes from two sources, one is primary and the other is secondary source [5]. Primary microplastics are generated microscopically and are usually of about 0.25 mm in size. It is formed to be smaller in size like nurdles or powder and is mainly present in cosmetic products. These microplastic particles can enter in the environment from household waste or sewage system [6]. The wastewater treatment plants are also one of the major sources of microplastics. The majority of microplastics are present in the aquatic environment and it is formed due to the breaking up of larger particles and results in secondary microplastics [7]. Breakage of larger particles depends upon temperature or amount of UV radiations [8].

Once the microplastics are released or enter in the aquatic environment, it will undergo the transportation and fate process. Plastic material enters in the environment by diverse ways. For example, transportation of microplastic from land to river system will depend upon the weather conditions or distance between them. Now a day the collection of microplastics at road side was generally observed and these plastics enter into aquatic environment by overland runoff or by cutting action to roadside ditches [9]. Microplastics may have different rates of degradation as they will be transported in the environment as compared to larger plastics. Microplastics enter in the aquatic environment from different sources [10].

There is limited information available on the plastic degradation under environmental relevant conditions. Plastic formation rate is often not investigated because some polymer such as polyethylene do not readily depolymerize, they will decompose into smaller fragments and that smaller fragment further decompose into nano particle. Therefore, the prediction of plastic fragmentation rate is not a straightforward process. Once the plastic particle enters in the environment, they contaminant and accumulate in the food chain. Microplastic have tendency to move up in the food chain from one trophic level to another, for example, from zooplankton to birds and possibly to human [2][4].

**III. CLASIFICATION OF MICROPLASTICS**

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

**Figure 1: Classification of microplastics**

**A. Fragments**

Fragments are smaller pieces of plastic that are formed from breakdown of larger pieces of plastics. Common examples include pieces of cutlery, lids etc. Sun radiation (UV radiation) breakdowns these fragments into even smaller pieces.

**B. Fibers-**

Itis amajor constituent of the total microplastics. It comes from washing machine because when we wash synthetic clothes, the fibers detached from the clothes and go into the wastewater. Synthetic clothing composed of plastics like acrylic and polyester.

**C. Microbeads**

Microbeads are non-biodegradable plastic particles whose size is less than 1 millimeter in diameter. They found in facial cleanser, toothpaste, and exfoliating soaps because of their small size they can easily pass-through treatment plants and enter in the aquatic environment.

**D. Foams**

Like fragments, Styrofoam breaks down into smaller pieces*.* Styrofoam is usually white plastics used to make containers that prevent food and liquid from changing temperature. Chemicals from Styrofoam can leach into food and liquid and affect human health.

**E. Pellets**

Pellets are small plastics used to manufacture plastic goods. They are melted down by businesses to create molds for plastic goods like container lids. Due to their small size, they can easily enter the aquatic environment.

**IV. PROBLEMS CAUSED BY MICROPLASTICS**

Microplastic contamination poses damage to the ecosystem and to human health [11]. Mainly the problem with microplastics is that they don’t readily breakdown into harmless molecules but they can take thousands of year to decompose and in the meantime cause destruction on the environment [12]. The adverse effect on organisms that are exposed to microplastics can be separated into two categories**,** physical effect, and chemical effect. The physical effect of microplastics is influenced by their size, shape, and concentration, while the chemical effect is influenced by the potentially dangerous compounds that are linked to microplastics. Microplastics can contain two types of chemicals: one is additives and polymeric raw materials originating from the plastics and the second is chemical absorbed from the surrounding [11].

Microplastics have been detected in marine organism from planktons to whales, in commercial seafood and in drinking water. When microplastic binds with other harmful chemicals, they are ingested by microorganism [12]. Researcher 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. As a result, microplastic will further deplete zooplanktons populations than that they will transfer up the food chain to reach humans. If we knock out something like zooplanktons, the base of our marine food web, we had more worried about impacts on fish stocks and the abilities to feed the worlds populations [13]. Microplastic introduce harmful impact at the tissue and cellular level, reproductive success and cause adverse effect on biodiversity and environment. Plastic material contains toxic compounds that may be harmful to some organisms such as bacteria and fungi that plays an important role in ecosystem functioning [2].

Researchers have several theories about how plastics affect human health. If they are small enough to enter the cells or tissues, thin fibers of asbestos can inflame lung tissue and lead to cancer. There’s a potential parallel with air pollution like vehicle exhaust and forest fires called PM10 and PM2.5 (particulate matter measuring 10 micrometer and 2.5 micrometer across) are known to deposit in the airways and lungs and higher concentration can damage respiratory system. But PM10 levels are thousands of times higher than the concentration at which microplastic have been found in air. Microplastics are smaller in size and they can easily enter in the human body through inhalation (carried by the wind or from the agriculture depositions) this spread could leads to respiratory distress, cytotoxic and inflammatory effect and autoimmune disease in human body [13]. Microplastics can enter in the human body through skin contact (through water while washing or while using scrubs and cosmetics that contain microplastics.) and cause harm and influence the cytotoxicity of particles to cells and tissues [11]. Ingestion of contaminated food is one of the major microplastic entry point in the human system[9] [14]. From recent studies, 0.44 MPs/g microplastics were found in sugar, 0.11 MPs/g were found in salt, 0.03 MPs/g were found in alcohol, and 0.09 MPs/g were found in bottled water [15] [16]. 80 g of microplastics are consumed by people daily through fruits and vegetables that pick up MPs from contaminated soil [17] [18].

The larger microplastics are more likely to exert negative effects through chemical toxicity. Manufactures add compounds such as plasticizers, stabilizers, and pigments to plastics and many of these substances are hazardous. Plasticizers are complex chemical products that have low vapor pressure, insoluble in water but chemically stable and it insert in between the molecular chain to reduce the physical interaction and increase their mobility and workability. Bisphenol A (BPA) is a common plasticizer that is used in industry especially in polycarbonate plastics manufacturing processes and food packaging. But it has been proven to be endocrine disruptors that can damage human health if ingested or inhaled [11].

**V. SOLUTION OF PROBLEMS CAUSED BY MICROPLASTICS**

The amount of plastic waste we create has continued to increase exponentially because the demand of plastic used were increased day by day. Microplastics exist everywhere in our environment that they are in the air we breathe, the water we drink, the food we eat, and deep within our organ tissues. To control this exposure, we must use different approaches: -

* **Bans on** Single-use plastics and microplastics in personal care and cosmetic products like shaving foam, shower gel and toothpaste etc. It is already introduced in some countries.
* **Plastic microfiber filtration could help scoop up the problem at home**- People who wash their clothes contribute 35% of the microplastic that ends up in the ocean. Synthetic textiles like fleece and other plastic-based materials break off as they tumble through our [washing machines](https://www.greenmatters.com/p/are-front-loaders-or-top-loaders-better-for-the-environment) and end up as [plastic microfibers](https://www.greenmatters.com/p/what-are-microfibers), which then flow into the water system. The development of home-based filtering systems that can remove these microplastics may be the solution to this specific issue. If that works, such technology could be used to solve other "particulate" problems and be repurposed as a means to remove other types of microplastics from waterways the world over [19].
* **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 program was also initiated in 2011 under the joint declaration of the global plastic associations and it aims to reduce waste [20].
* **Mass cleanups may be our best solution.** The garbage patches are a big problem all its own, and we can only solve that problem by cleaning things up before it gets any worse. Cleaning up after that plastic after it turns into microplastic is next to impossible. Thus, removing plastic from the water before it even becomes micro could be the answer. The easiest approach to stop more microplastics from entering the waterways of our planet 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].
* **Protecting water bodies and the landscape** from microplastics is a major issue. 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. The safe management of sewage sludge and the treatment of runoff and wastewater are significant steps toward accomplishing these goals [21].
* **Invention of robot-fish** has provided us with another solution for tackling microplastics in water. The particles contain organic dyes, antibiotics, and heavy metals, which have strong electrostatic interactions with the fish’s materials. The microplastics will then cling to the surface of the fish, allowing it to collect and remove microplastics from the water. Though the robot-fish can now only work on water surfaces[20].
* **Recycling, reusing and rethinking** plastic products will be effective method if everybody participate effectively. Besides clean-up programs and technological innovation, individuals can also play a key role in reducing microplastic in water [22],[20].
* **Researchers have found enzymes and bacteria** that can break down the plastic, but they need to figure out how they are worked without any potential negative side effects, such as producing greenhouse gases [22].

**VI. IDENTIFICATION AND CHARACTERIZATION OF MICRPLASTICS**

Microplastic is everywhere in the marine ecosystem, and it cause adverse impact on biological life. And need to study about these particles and the effects caused in detail with respect to their size [23][24]. A good characterization would further help to understand, the nature of these particles, such as their shapes, colours, and its polymeric material. The most commonly reported identification methods were using an optical microscope, Fourier-Transform Infrared spectroscopy (FTIR), Raman spectroscopy, Scanning Electron Microscopy (SEM) and thermal analysis [25].

**A. Optical microscope**

This technique is commonly used to study the larger size particulate masses. This method allows the study of surface texture and enables the differentiation of microplastic from the contaminating ambiguous mass [26][27]. Even while most particles can be recognized under an optical microscope, some particles in the sub 100μm 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 fibres (such PES and cotton that has been dyed) also came up short. Studies have revealed that fibres make up the majority of the microplastics in samples of the ocean, water, soil, and living things [29].

**B.** **Scanning electron microscopic (SEM)**

Scanning electron microscopy (SEM), which shows the surface features of the particles [30]. This method uses a concentrated electron beam to scan a sample's surface in order to get high-resolution photographs of the object [31]. The distinction between particles is made possible by the exquisitely detailed sample images (> 0.5 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].

**C. Fourier transform infrared (FTIR) spectroscopy**

The use of FTIR (Fourier Transform Infra-Red) spectroscopy as a tool for microplastics characterisation has also proven to be quite beneficial. It provides information on the chemical functional groups that are present in a specific polymer. Every polymer creates a distinct set of spectroscopic band signatures that enable discrimination between plastics as well as between plastics and organic material [33]. An intelligently designed and extensive library of available standard spectroscopic data for the various plastic polymers makes polymer identification simple. The option of micro FTIR may be employed when samples with ridiculously small particle sizes are available. Prior to spectroscopic experiments in the FTIR, the initial studies are carried out by switching between the objective lens and the IR probe [34].

**D.** **Raman spectroscopy**

An advantage of Raman spectroscopy is its ability to detect Microplastics particles with sizes between 1 and 20 μm due to the smaller diameter of the laser beam as compared to the FTIR [35]. It is used to identify Microplastics among zooplankton samples, which is made possible by the confocal microscopic attachment seen in the Raman Spectroscopy [36]. For the identification of Microplastics, Raman spectroscopy is also frequently used in addition to FTIR [37]. The laser beam that was fired at the particles causes a specific pattern of backscatter based on the molecular structure of the atoms on the surface. In contrast to FTIR, which only permits the identification of the polymer, Raman spectroscopy will reveal a composition of the polymers in addition to identifying the plastic. Additionally, keeping in mind the high cost of the equipment, Raman's spectroscopy provides us with an identification tool that is similar to the FTIR in addition to the non-destructive approaches of chemical analysis and microscopy [38].

**E. Thermal analysis**

The thermo-analytical method, which is used to examine changes in the physiochemical properties of the plastic with respect to its thermal stability, is the most recent tool to make its debut among those used to identify Microplastics [39]. Differential Scanning Calorimetry (DSC), which investigates the thermal characteristics of unidentified polymer microparticles, is one such technology. With this method, a specific microplastic sample must be identified and matched using reference materials. 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 found that this could aid in differentiating between PP(Polypropylene) and PE (polyethylene) polymers. 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 combined with solid phase extraction (SPE) and when connected to a thermal desorption gas chromatography mass spectrophotometry (TDS-GC-MS). 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 on March 11, 2020, the usage of plastic-based special protection accessories as a method to reduce infection has increased considerably. 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 single-use plastics while encouraging more online food services.

The COVID-19 epidemic has raised concerns about pollution from personal protective equipment (PPE), as wearing masks was recommended globally to stop the spread of the corona virus from person to person 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. Since PPEs are primarily 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 gets worsen, possibly causing an increase in the amount of plastic pollution present in marine habitats [46]. More research on biodegradable PPEs is required to stop a future microplastics pandemic, as there is a strong need for environmentally friendly solutions given the involvement of the COVID-19 pandemic in microplastic pollutions.

**VIII. CONCLUSION**

Microplastic 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 few methods to control these materials, however, there is still a need to explore more alternate ways to prevent their harmful effects. Although less research has been done on freshwater system, this issue has recently gained significant attention. Freshwater Microplastic is particularly crucial to contamination buildup due to its proximity to sources and accessibility to more pollutants. As a result, freshwater species may be exposed to increased levels of contaminants, especially near industrial and heavily populated areas where levels of microplastics and hydrophobic toxins may be higher. To control the exposure of microplastic we have need to instigate studies to better understand how the microplastic interact with environment. Also, more research is required to understand how microplastic cause adverse effect on aquatic environment, human health. Apart from that more techniques are required for identification and characterisation of microplastic so that these could be identified and controlled at early stage.

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