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# Removal of Microplastic Pollution through Waste Water Treatment: A Review

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## ABSTRACT

**The presence of plastic materials in a water stream is a serious environmental concern because of their poor degradability characteristics. The enormous rise in the production of plastics causes a significant amount of plastic waste on the land to enter water bodies. If the particle size is small at the micro level (less than 5 mm in diameter), it has significant potential for blocking the fine pores of filtration and membrane systems. Their encroachment also poses a threat to human health in the food chain. Wastewater treatment plants (WWTPs) play an important role in removing a significant amount of microplastics; otherwise, they end up in the process of bioaccumulation. This study provides an idea about the characteristics of microplastics, removal efficiency, and the correlation between wastewater quality and microplastic concentrations from three different WWTPs that differ in the biological and advanced wastewater treatment techniques, which are believed to play an important role in microplastic removal. It also focuses on how waste treatment facilities affect the retention of microplastics and discusses issues with using sewage sludge laden with microplastic.**

***Keywords***- Microplastics, wastewater treatment, coagulation, food chain.

## I. INTRODUCTION

In addition to the atmosphere (Abbasi et al., 2019), soil (Guo et al., 2020), sea (Wang et al., 2020b), groundwater (Han et al., 2020), as well as the bottom of an Arctic body of ocean (Gonz' alez-Pleiter et al., 2020), microplastics are found in a wide variety of environments. Due to their small volume (particle debris size is typically smaller than 5 mm) and high specific surface area, they can adsorb pollutants such as polycyclic aromatic hydrocarbons (PAH) (Srensen et al., 2020), heavy metals (Foshtomi et al., 2019), polybrominated diphenyl ethers (Singla et al., 2020), pharmaceuticals, and personal care products (Liu et al., 2018). As a result of their buildup in organisms, microplastics inevitably result in chronic toxicity (Li et al., 2018). Plastic waste builds up in aquatic habitats, which is now a well-known issue. Researchers have found that there are a lot of tiny pieces of plastic in freshwater and marine environments. Municipal wastewater treatment plant effluents, also known as sewerage system pollutants, are a significant entry point for both primary and secondary microplastics into the aquatic environment. While there is currently no design or optimization for removing microplastics in WWTPs, certain research suggests that cutting-edge treatment methods can enhance the elimination of these materials. It may be concluded that the physiochemical characteristics of the target polymer and the treatment procedure will affect how well microplastics are removed in WWTPs (density, particle size, charge, hydrophobicity, etc.).

Domestic, commercial, industrial, and occasionally surface run-off wastewater are all sent to WWTPs. Effluent may be discharged into freshwater ecosystems, usually rivers, and then carried to the marine environment, depending on the nation and region. The sludge, occasionally processed and given to land for reuse in agriculture, may contain microplastics extracted from the sewage but not eliminated. Although several recent reviews on plastics in wastewater treatment have been published, none have calculated removal efficiencies for microplastics for pertinent treatment processes based on all the literature that has been produced or settling/floating velocities for polymers that are frequently found in wastewater. This study aimed to examine how microplastics behaved during the wastewater treatment process, including measuring how well they were removed using various techniques and concentrations in sewage sludge (Dris et al., 2015).

Previous investigations on the microplastic treatment methods in WWTPs found that these technologies did not completely remove microplastics from wastewater. For instance, the total abundance was reduced by 6%, 68%, 92%, and 96%, respectively, during the preliminary, primary, secondary, and tertiary treatment processes in a WWTP in the UK (Blair et al., 2019). About 99% of the microplastics entering a WWTP were removed by mechanical, chemical, and biological treatment methods (Ziajahromi et al., 2016). The removed microplastics were mostly transported to the sludge phase after treatment (Ngo et al., 2019).

Meta-analysis, a mathematical technique for the numerical examination of a number of separate properties of one item, has been used more frequently to examine wastewater issues in a better methodical way (Erni-Cassola et al., 2019). For example, meta-analysis findings showed that photocatalysts frequently obtain the greatest diazinon removal efficacy, with an average efficiency of 79.2% (95% confidence interval: 76.8%–81.5%) (Malakootian et al. 2020). Another meta-analysis study found that membrane bioreactor systems might exhibit the highest removal effectiveness of organic trace pollutants in wastewater (Melvin and Leusch, 2016). No qualitative meta-analysis evaluation of the removal of microplastics in WWTPs has been provided as of yet. A more precise assessment of the removal of microplastics in crucial wastewater treatment technologies and a better understanding of the properties of microplastics in WWTPs are expected to result from the meta-analysis technique.

## II. ORIGIN OF MICROPLASTICS (MPS)

The aquatic ecology is examined to detect the presence of plastic particles in the environment. The study evidenced that MPs are dispersed in the surroundings through multiple origins. Those microplastics are now pervasive in freshwater and marine ecosystems with varying particle sizes based on transport factors, including marine waves and air. The type of polymer that is readily available is thermoplastic. This way, heating, chilling, and shaping can be readily and regularly reused. After a single heating and moulding process, those irreparable cannot be remoulded, reheated, reused, or released into the environment (Galgani et al., 2013; Talvitie et al., 2017a, b). The main cause of plastic particles is the release of plastic waste from apparel, cosmetics, plastic manufacture, fishing, shipping, sewage treatment, car and truck tyres, and air blasting industries.

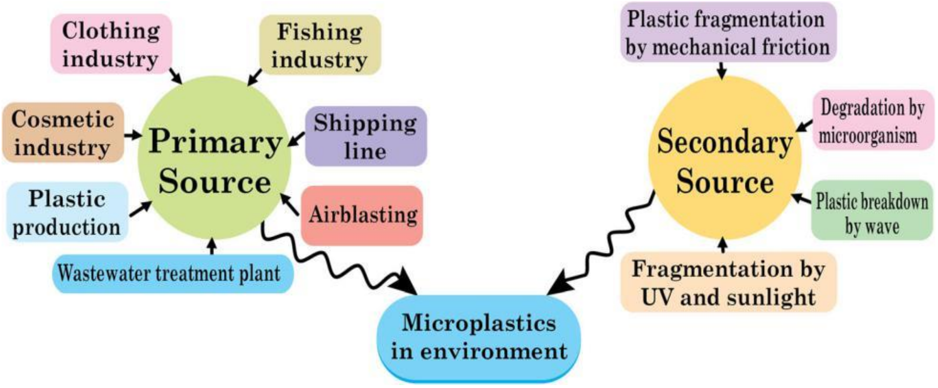


**Figure 1: Sources of Micro-plastics in the environment**

MP emissions from secondary sources, such as breaking big polymers into smaller ones under various environmental circumstances such as mechanical fracturing and UV light (Eriksen et al. 2014). The garment sector is a source of plastic particles because polystyrene, a less expensive substitute for cotton, generates about 100 fibres per litre of wash water (Browne et al., 2011), besides different artificial fibres, such as nylon. In general, washing 6 kg of garment loads can release more than 700,000 synthetic fibres into the environment (Napper and Thompson 2016). Due to the substitution of synthetic micro-exfoliates for natural exfoliants in the cosmetic industry, MPs have also decreased. A wide range of MPs, including nylon, and PET, are often utilised in personal care products. As a result, following usage, these plastic particles are immediately dumped into sewage treatment facilities (Zitko and Hanlon 1991). A normal water treatment facility may remove ninety-five to ninety-nine percent of MPs.

It is estimated that the water treatment plant releases 160 trillion litres of effluents per day into the aquatic ecosystem, containing 8 trillion plastic particles, while 808 trillion microbeads are released from household activities in a single day due to widespread personal use of cosmetics (Anderson et al. 2016). Since resin pellets and granules are used as raw materials in plastic manufacturing facilities, plastic waste is released. The majority of industrial locations are close to bodies of water. Plant effluents are thus released directly into the aquatic environment. For instance, Sweden's average number of plastic particles per cubic metre ranges from 150 to 2400. But the concentration of plastic is greater and is around 102,000 MPs per m3 close to the manufacturing facility. Therefore, it is reasonable to suppose that a significant amount of plastic garbage is being dumped in the environment without treatment (Cole et al., 2011). Additionally, improper handling of packing materials and inadvertent leaks during shipping might pollute water systems.

## III. COMPOSITION OF MICROPLASTICS

Polyvinyl chlorides (PC, 1), polyethenes (low density [LDPE], high density [HDPE], 2), polyamides (PA, 3), polypropylenes (PP, 4), polyurethanes (PU, 5), polystyrenes (PS, 6), and polyethene terephthalates (PET) (7) are among the many polymers that make up microplastics (Pitt et al., 2018). However, the European Union has identified more than 130 different polymers as microplastic parts (EC, 2017). According to Plastics Industries of Europe, the following materials make up the majority of the global production of plastics: PP (4, 23%, for packaging, food containers, and textiles); PE (2, 17% LDPE, 15% HDPE, for plastic bags, packaging, and microbeads); PS (6, 7%, for packaging); PET (7, 7%), for plastic bottles, synthetic fibres; and PA (3, 1%) for fibres. Additionally, polycarbonates (9, 1%) for plastic bottles, synthetic glass and poly(methyl)methacrylates (8, PMA, 1%) exist (Zang et al., 2018).

With an average density of up to 3.3 $\times 10^5$ plastic fragments/km$^2$ (in the North Pacific gyre) and 8 - 124 fibres per litre sediment on beaches, plastic particles, many of which are microplastics, have been found in ocean surface waters. On the other hand, freshwater bodies have concentrations ranging from $0.55\times10^5$ to 342 $\times10^5$ items/km$^2$. Microplastics have been discovered even in Arctic seas, just south and southwest of Svalbard, Norway, with a mean concentration of 0.32-0.34 particles per m$^3$ on the ocean surface (Lusher et al., 2015). Although denser microplastics are in the water column at various levels that can eventually be lodged in sediments, surface water includes microplastics. According to estimates, two-thirds of the microplastics end up as sediments on the ocean floor and one-sixth as seashore debris. There have been discoveries of terrestrial ecosystems with a mean content of 5 mg microplastic/kg soil (Scheurer and Bigalke, 2018).

## IV. ENVIRONMENTAL TOXICITY AND RISK OF MICROPLASTICS

Microplastics reach the soil and aquatic habitats by discharging sludge and wastewater. In addition to becoming emergent pollutants, they transport organic pollutants and heavy metals. Benthic creatures may consume microplastics that have heavy metals and polycyclic aromatic hydrocarbons adsorbed on them, which might cause bioaccumulation in marine food chains (Foshtomi et al., 2019). Microplastics alter soil metabolism and structure, impacting the soil's ability to retain water (Machado et al., 2018). The ability of terrestrial plants to absorb microplastics and other contaminants may be enhanced by certain characteristics (He et al., 2018).

The aquatic environment is where the microplastics in the effluent from WWTPs finally congregate (rivers and oceans). Secondary microplastics are created by physically, chemically, and biologically processing primary microplastics. Therefore, WWTPs are the primary contributors to secondary microplastics in the soil and aquatic habitats. One analysis from a WWTP in China found that although the amount of microplastics discharged into the water is less than 10 kg per day, the quantity of microplastic pieces is still substantial due to its low density and tiny volume (Liu et al., 2019). In other words, because of the high daily capacity of WWTPs, billions of microplastic particles are released into rivers daily. These microplastics probably harm aquatic species (Ma et al., 2020). Microplastics contaminating aquatic habitats should get more attention from developing nations and regions with inefficient wastewater treatment systems.

Sludge eventually retains the microplastics it contains in the soil environment. One of the most significant sources of microplastics in the soil environment is thought to be sludge. Each year, agricultural soils in Europe and North America received 43,000–63,000 and 30,000–44,000 tonnes of microplastics, respectively (Nizzetto et al., 2016). These microplastics take up to a thousand years to decompose. Microplastics increase soil contamination by absorbing hazardous substances. Studies on the souces, migration and toxicology of microplastics in soil were comprehensively studied by Guo et al., 2020. Further research is required to understand the ecological toxicity impact and danger of compound pollution caused by microplastics and other contaminants.

## V. IMPACT OF MICROPLASTICS ON AQUATIC ORGANISMS

Along with the growth in the human population, MP amplitude is also expanding. Although many other types of MPs exist in the environment, including lines, fragments, foam, sheets, and globules, aquatic ecosystems are home to the majority of fibre-shaped MPs. As a result, MPs are ingested directly by aquatic species and are also absorbed through their respiratory systems (Grossman 2015). More than 250 marine creatures are considered MP consumers, with vertebrates accounting for the bulk. Because of their impulsive nature and higher mortality rate, spectators see vertebrates more readily. It is thought that a new area for investigation is the effect of plastic particles on marine aquatic life. According to a study on biodiversity, half of all species of marine animals and one-fifth of all species of marine birds encounter plastic. The percentage of each waste product's influence also varies with the kind of material used.

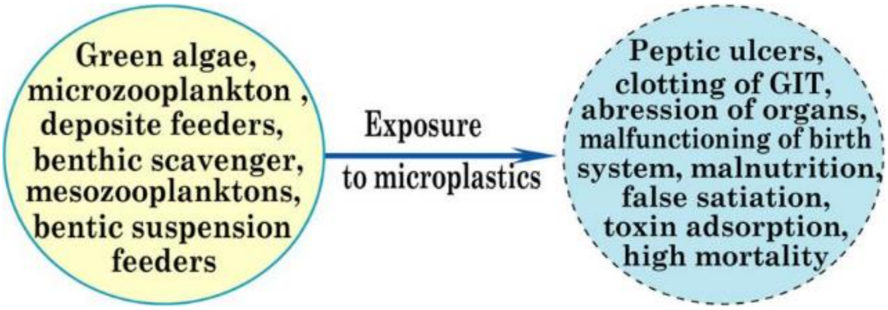
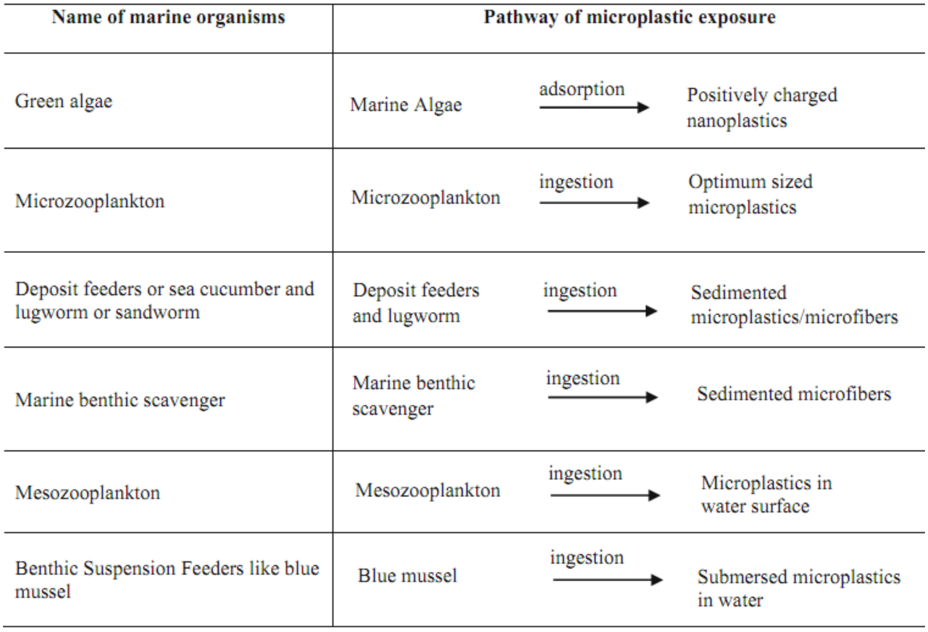


**Figure 2: Impact of microplastics on aquatic organisms**

For example, plastic trash accounts for 80% of the overall effect, whereas microplastics are responsible for 11%. In comparison, the combined amount of trash from paper (0.64%), glass (0.39%), and metal (0.39%) is around 1.5%. Additionally, MPs are found in a wide range of planktons, sediments, and marine animals. Planktivores, deposit feeders, detritivores, filter feeders, and low trophic suspensions may come into contact with these particles (Murray and Cowie 2011).

**Table: Microplastic-ingesting marine organisms and their pathways of exposure (Wright et al. 2013)**



| Name of marine organisms | Pathway of microplastic exposure | | |
|---|---|---|---|
| Green algae | Marine Algae | $\xrightarrow{\text{adsorption}}$ | Positively charged nanoplastics |
| Microzooplankton | Microzooplankton | $\xrightarrow{\text{ingestion}}$ | Optimum sized microplastics |
| Deposit feeders or sea cucumber and lugworm or sandworm | Deposit feeders and lugworm | $\xrightarrow{\text{ingestion}}$ | Sedimented microplastics/microfibers |
| Marine benthic scavenger | Marine benthic scavenger | $\xrightarrow{\text{ingestion}}$ | Sedimented microfibers |
| Mesozooplankton | Mesozooplankton | $\xrightarrow{\text{ingestion}}$ | Microplastics in water surface |
| Benthic Suspension Feeders like blue mussel | Blue mussel | $\xrightarrow{\text{ingestion}}$ | Submersed microplastics in water |

The usage of MPs by vertebrates has also been the subject of extensive investigation (Yamashita et al., 2011). As a result, MPs can build up in aquatic organisms and result in a variety of physical harms, including peptic ulcers, abrasion of internal or external organs, and GIT clotting (gastrointestinal tract). These harms include physical harm, malnutrition, false saturation, deterioration of the reproductive system, obstruction of the feeding tendency, and ingestion of toxic substances from marine environments. Numerous tiny marine animals, such as invertebrates, also experience the same issues. Ingestion of microplastics also results in further bodily harm, such as the suppression of enzyme secretion, toxin adsorption, malnutrition, and reproductive harm, which slows growth rate, reduces feed stimulation, lowers hormone levels, and delays egg generation from ovaries. Invertebrates' tissue surfaces are also prone to accumulate plastic particles, which can block the appendices that help the feeding mechanism (Derraik

2002). Additionally, a number of elements—including accumulation, translocation, form, and excretion of microplastics—are more likely to affect both the chemical and physical effects of plastics (Wright et al., 2013).

## VI. REMOVAL OF MICROPLASTICS BY MICROORGANISM

The biota species' microplastic concentrations were found rising quickly on the Portuguese coast (Neves et al., 2015). These plastic particles are pervasive even in the most remote regions of the earth, like the Antarctic Islands or the deep waters. Consequently, eliminating this plastic waste may be possible through MP biodegradation. The enzymes of living things play a crucial part in this process carried out by microorganisms. These organisms are more likely to degrade this plastic waste into biomass, methane, carbon dioxide, water, and numerous inorganic substances. Biological deterioration is also influenced by environmental factors such as temperature, humidity, sunshine, and UV radiation (Shah et al. 2008).

## VII. FUNGAL DEGRADATION

Synthetic plastics biodegrade over a very long period of time, influenced by environmental variables and the activity of microbial species found in the wild. Fungi play a crucial part in the biodegradation of plastics; they operate on plastics by secreting various degrading enzymes, such as cutinase, lipase, and proteases, lignocellulolytic enzymes, and they may also effectively degrade plastics in the presence of some pro-oxidant ions. The enzyme's oxidation or hydrolysis produces functional groups that increase the hydrophilicity of polymers, causing the high molecular weight polymer to break down into a low molecular weight polymer. Plastics begin to deteriorate as a result of a few days. Aspergillus nidulans, Aspergillus flavus, Aspergillus glaucus, Aspergillus oryzae, Aspergillus nomius, Penicillium griseofulvum, Bjerkandera adusta, Phanerochaete chrysosporium, Cladosporium cladosporioides, etc. are some well-known species that effectively degrade. According to several studies, the degradation of plastics was more efficient when photodegradation and thermo-oxidative mechanisms were linked with biodegradation at the same time (Srikanth et al., 2022).

For three months, Yamada-Onodera and colleagues conducted experiments to ascertain the fungus *Penicillium simplicissimum's* capability for polyethene (PE) degradation, which they measured as a rise in the percentage of fungal weight with a decrease in the percentage of plastic mass. Here, the plastic mass variation was 56.7% 2.9, the clearance was greater than 43%, and the biomass variance was 82.0% 2.1 (Paço et al. 2017). The research was also carried out in 2011 to examine the possibility of PUR MPs being degraded by endophytic fungi (*Pestalotiopsismicrospora*). Serine hydrolase was shown to be the catalyst for this polymer's breakdown in anaerobic settings (25 °C), despite PUR being considered a carbon source. However, because of the slower response rate, the period for plastic deterioration is longer. In order to start polymer deterioration before fungal degradation, pretreatment techniques such as solvolysis, ozonolysis, and photo-oxidation must be used.

## VIII. BACTERIAL DEGRADATION

Researchers are investigating the potential of different bacteria to degrade MPs into environmentally friendly monomers and could be an emerging alternative to remove plastic debris from the ecosystem. Experiments have been conducted to detect PET degrading whole-cell biocatalysts (Comamonas testosteroni) for the removal of MPs. Three types of media were considered: bacteria in neutral pH media (pH 7), bacteria in alkaline pH media (pH 12), and alkaline media without bacteria. Degradation of PET with bacteria was performed for 48 h, including a temperature of 37 °C and a stir-ring rate of 140 rpm. The mean PET particle diameter before treatment was 7.3 μm. After treatment, the particle size was 7.3, 2.63, and 1.58 μm for bacteria with no media, neutral pH media, and alkaline pH media, respectively. PET degradation rate with biocatalyst in higher pH is better than neutral media (Gong et al. 2018).

In 2016, research work was also carried out by Shosuke Yoshida and his team members (Yoshida et al. 2016) on the isolation of bacteria (Ideonella sakaiensis, 201-F6) capable of PET degradation into environmentally friendly monomers, TA (terephthalic acid), and ethylene glycol. This bacterium can secrete two enzymes (PETase and MHETase) to hydrolyze PET and use plastic waste as the primary source of carbon nutrients. The PET film degradation rate was 0.13 mg $cm^{-2}$ per day at a temperature of 30 °C, while 75% of the decomposed PET film was converted to carbon dioxide at 28 °C. At the same time, another research paper on PE film degradation via bacterium (*Bacillus subtilis*) was published, which showed that the biosurfactant secretion from this bacterium was responsible for degradation. Low-density polyethylene (LDPE) pretreatment with ultraviolet therapy increased degradation for 72 h due to increased plastic intake of isolated bacteria (*Bacillus subtilis*).

## IX. CONCLUSIONS AND FUTURE PERSPECTIVES

We can better understand the fate of microplastics in WWTPs thanks to meta-analysis. The maximum microplastic removal effectiveness was achieved by the filter-based treatment method. Fibres and microplastics with large particle sizes (0.5–5 mm) were easily separated by initial settling. PE and small-particle size microplastics (<0.5 mm) were easily retained in the activated sludge and by bacteria in the WWTPs. The interactions and removal processes between microplastics and essential treatment technologies were significantly varied. In flocculation technology, conventional flocculation interacts with microplastics via van der Waals interactions, hydrogen bonds, or electrostatic forces. The major methods by which the bioreactor system eliminated microplastics were microbe ingestion and aggregate sludge development. Advanced oxidation processes changed the physical and chemical characteristics of microplastics, disrupted the bonds that were already there, and created new bonds. Microplastics were easily adsorbed on the membrane surface in membrane filtering technology due to interactions between the microplastics and the membrane pores and surface. While some of the microplastics removed by the technologies mentioned above were eventually incorporated into the sludge, others discharged by the WWTPs caused toxicity and environmental damage.

A future study is needed to address a few issues that have come up in the investigations of the microplastics in WWTPs so far. Further study should concentrate on creating standardised sampling and analytical procedures to more accurately assess the fate of the microplastics in WWTPs or other environmental media. The study of particular microplastics should be given priority in future studies, particularly in industrial areas. An in-depth study is also needed on the parameters that affect how well microplastics are removed in WWTPs, such as hydraulic retention time, salinity, and dissolved organic matter. Additionally, there was little knowledge on how the current treatment procedure produced conventional pollutant removal, reaction intermediates, and their toxicity in the removal of microplastics. Technologies for microplastic-targeted remediation are also urgently required to prevent emissions into the soil and aquatic habitats. In future, it is also important to look at any potential effects that sludge use might have on the soil ecosystem. It is vital to study, in particular, how various polymers affect plant roots. This study offers crucial data for a thorough comprehension of the crucial microplastic removal methods and theoretical backing for creating microplastic-targeted technology.

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