# EXPLORING MICROPLASTICS IN WASTE DEPOSITS: DETECTION, DEVELOPMENT, AND HEALTH IMPACTS: A REVIEW

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## ABSTRACT

The ubiquitous presence of microplastics has raised concerns about their deleterious effects on environmental health, particularly in terrestrial ecosystems. However, research in this area remains very limited. A landfill or a dumping site can act as a potential hotspot for these tiny pollutants (MPs). This review's main aim is to provide an overview of recent studies on the presence of microplastics in dumps for municipal solid waste. This overview focuses on microplastic identification, quantification and distribution in dumps, and the health effect of MP exposure on the human body. Data from seven countries including five countries from the sub-continent have been investigated. Various types of MPs like PE, PVC, PS, PP, etc. of different sizes ranging from 20 µm to 5mm have been identified from different leachate samples. The possible risks to the human body based on recent findings are also presented. Additionally, different processes of microplastic removal are also analyzed and various critical viewpoints are suggested.

***Keywords:*** *Solid wastes, Microplastics, landfill, Removal, Health risks*

## 1. INTRODUCTION

In modern times, plastic is everywhere; it may be found in bottles, packaging, toys, and many regular items. Since the 1950s, plastic development has accelerated significantly (He et al., 2019). Global production of plastic reached 348 million tons in the year 2017. (PlasticEurope, 2018). Plastics can be divided into three sizes: macro, meso, and micro (Afrin el. at ,2020). According to Cole et al., 2011), MPs can be divided into primary and secondary MP categories. Microplastics are a diverse range of plastic particles with a length of less than 5 mm. MPs are now a prime example of human waste and a major source of pollution in the environment (Galloway et al., 2017). Microplastics are found in many different parts of the environment; reports of their presence in marine (Bergmann et al., 2015; Desforges et al., 2014; Law et al., 2014; Wieczorek et al., 2018; Woodall et al., 2014), water (Imhof et al., 2013; Yonkos et al., 2014; Zhang et al., 2017), soil (Nizzetto et al., 2016b; Zubris and Richards, 2005), atmosphere (Dris et al., 2016; Gasperi et al., 2018; Prata, 2017), and wastewater plants (Carr et al., 2016; Mahon et al., 2017; Murphy et al., 2016; Ziajahromi et al., 2017). The widespread and detrimental nature of microplastics has previously been demonstrated by the presence of microplastics in wastewater treatment plants and other artificial habitats (Xu et al., 2020). The complex nature of landfills may cause more serious environmental problems than others because of the interaction between highly concentrated contaminants and microplastics (Silva et al., 2021). The presence of microplastics may further enhance this frequency, potentially posing a threat to the public ( Zhang et al., 2022; Zhu et al., 2022). In order to comprehend and manage the human health risks posed by microplastics, it is essential to compile an overview of the distribution and occurrence of microplastics in municipal solid waste landfills.

This review examines recent advancements in landfill microplastic management to address the environmental risk and the primary sources and sinks of microplastics, aiming to establish a foundation for effective risk management. The study also investigates challenges in identifying microplastics in landfills, analyzes their distribution and concentration, discusses environmental risks, and suggests outlooks for managing MPs in landfills, ultimately guiding hazard management. Microplastics pose a severe threat to environmental health, especially in terrestrial ecosystems. While microplastic pollution in the aquatic environment has been extensively studied, terrestrial contamination remains under-researched, particularly in Bangladesh. This study aims to provide evidence of MP contamination, detection, and quantification in landfill areas throughout the world, shedding light on the fact that landfills act as potential reservoirs of MP contamination. It also focuses on the possible pathways of MP contamination, health risk assessment, and removal process of MPs.

## 2. REVIEW PROCESS

Research Papers about Microplastics waste deposits comprising field and lab research, were gathered and reviewed. Relevant research publications were found using bibliometric databases such as Scopus, Google Scholar, ScienceDirect, and ResearchGate. Publications from South Asian regions were chosen because they share socioeconomic and geographical similarities with Bangladesh. Also, papers from the United States and Canada were considered for quality evaluations. To establish the basis for scaling up microplastic risk management, this review focuses on current discoveries in landfill microplastics. First, the difficulties in recognizing microplastics in landfills are analyzed. The location and quantity of microplastics, which in landfills are then studied. Those papers were evaluated based on their shortcomings, strengths, findings, and theories. This review took into account around 82 articles from 2005 to 2023, covering journals and conference papers.

## 3. DISTRIBUTION

MPs in the leachate from landfills are primarily derived from two sources: solid debris or landfill and sewage treatment plant residuals, such as sludge and fat, oil, and grease (FOG), among other materials (Golwala, 2021). MPs can also come from a variety of primary sources and end up in landfills. Landfills can undergo multiple abrasive processes when plastic waste is disposed of, leading to the production of secondary microplastics. Microplastics are generally less prevalent in landfill leachates than in debris.

During the deterioration treatment, microplastics may release common chemicals like plasticizers and bisphenol A. Thus, to some extent, the quantity of these compounds may indicate the level of MP decomposition in a landfill. Plastic garbage from everyday use is dumped in large quantities in landfills. According to reports, up to 20% of all solid waste is made up of plastic components (Silva, 2021). Microplastics from the regular use of cosmetic and personal care products are also found in landfill waste (Shen, 2022). The landfill leachate may contain primary microplastics originating from waste generated by specialized industries and facilities handling these products (Kabir, 2023). Figure 1 shows a possible pathway of MP contamination from the landfill to the surroundings representing how MP gets access to our food chain (Golwala, 2021), and the source types and MPs types that are found in the environment are shown in Figure 2. (Lamichhane et al., 2022)

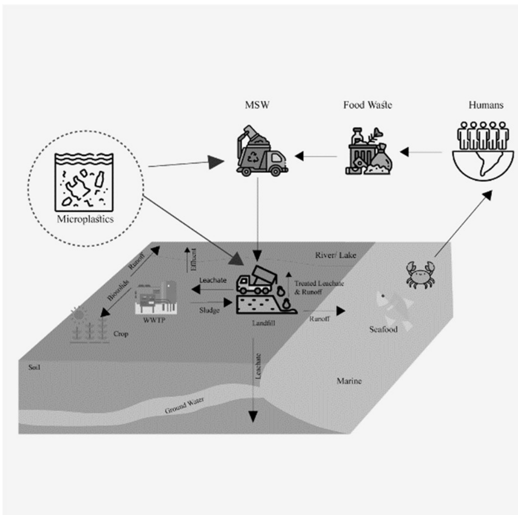


Figure 1: Sources MPs in the landfill (Golwala, 2021)

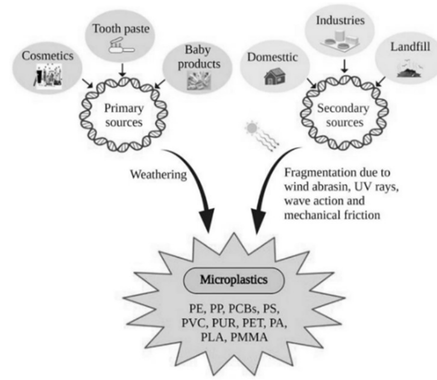


Figure 2: The sources and MPs types (Lamichhane et al., 2022)

When these materials reach the end of their useful lives, recycling is the best and most preferred course of action. Nevertheless, worldwide, only 15–25% of waste plastic can be recycled successfully using conventional methods; the remaining 21–42% is dumped in landfills (Nizzetto et al., 2016 & Burlakovs et al., 2019). Nowadays, biodegradable plastic products decompose slowly in landfills; full decomposition is only achievable when generated in industrial facilities built for the molecular breakdown of polymers (Brebu, 2020). All waste goes through a series of treatment steps in landfills, including the following: initial aerobic biodegradation, a change from aerobic to anaerobic conditions, hydrolysis and acid formation, methanogenesis to produce methane, and the final maturing and stabilization process. Every step generates secondary MPs and quickens the breakage of plastic (US EPA, 2006 & Hou et al., 2021).

Additionally, Wastewater is a major source of microplastics (Sun et al., 2019). An investigation found that there are 80–110 items/m3 of microplastics in getting rivers for leachate from landfills (Kilponen et al., 2016). Furthermore, a different study discovered that although the receiving water for the nearby wastewater treatment plant contained just 2.84 item/L of microplastic, the nearby marine habitat of a waste coastal landfill had roughly 6 item/L (Kazour et al., 2019). According to these studies, landfills were a significant route for microplastics to get into the environment and may have contributed more than wastewater treatment plant effluent in certain cases.

Despite the landfill being acknowledged as an enclosed system, certain microplastics have been found in the surrounding areas (Kilponen et al., 2016 & Kazour et al., 2019). Five different routes have been found to explain how microplastics move from landfills into the environment: 1) surface runoff or stormwater; 2) atmospheric transport; 3) leaked or initially discharged leachates; 4) organisms carried microplastics through ingestion and excretion; and 5) the consumption of treated leachates (Upadhyay et. al, 2021). It is necessary to give more attention to the microplastics in landfills on account of the above-migrated pathway.

## 4. HEALTH IMPACT

The environmental health professionals has become more concerned with the effects of microplastics (MPs) on human health since water, food, and air all contain these particles. The effects of MPs instantly as they enter the human body have not been thoroughly studied (Revel et al., 2018). According to some research, macrophages or blood vessel endothelial cells may be able to internalize MPs into their bodies (Yoo et al., 2011). Few studies have been done to confirm the distribution and metabolism of MPs in the body, even in the unlikely event that they enter the bloodstream (Revel et al., 2018). Stool samples from eight individuals from various countries contained up to nine distinct types of MPs (Parker, 2018; Quenqua, 2018). The existence of MPs at the final stage of the human digestive tract indicates the importance of the results, despite the small sample size in this pilot project, as these compounds existence found in the human digestive system. MPs have been in the ecosystem and are returning to us.

Most plastic products that we come into contact with on a daily basis, such as polypropylene (found in yogurt containers) and polyethylene (found in plastic bags), are considered inert and harmless (Revel et al., 2018; Rist et al., 2018). A substantial quantity of studies into plasticizing agent additives such as BPA and phthalates have revealed that they contain endocrine-disrupting chemicals that have the potential to harm fertility in humans and development, like carcinogenesis (Cole et al., 2011; Rist et al., 2018).

MPs' indirect impact on human health is also implicated in a recently identified phenomenon known as "the Plastisphere" (Keswani et al., 2016). Hard plastic surfaces are ideal for microbial colonization. As a result, the huge surface area-to-volume proportion and hydrophobic characteristics of MPs enable a suitable microenvironment that fosters favorable conditions for microorganism growth and replication (Cole et al., 2011). Colonies of bacteria can form biofilms by producing protein molecules that allow them to adhere to one another alongside living or nonliving surfaces, forming a protective niche that allows microbes to survive in hostile conditions (Keswani et al., 2016). In addition, biofilms allow plastics to become disease vectors by facilitating microbe dispersal and transport throughout air, water, and land (Keswani et al., 2016; Revel et al., 2018). As a result, MPs have inadvertently formed a promising vessel for pathogenic transmission.

### 4.1 Heavy Metals as Additives

Although heavy metals naturally exist in our environment (for example, in the atmosphere, the lithosphere the hydrosphere, or biosphere, their natural environment pollution and human exposure are primarily the result of anthropogenic activities (Godwill et al.,2019). One of their primary applications is as polymer additives (e.g., colorants, flame retardants, additives, and stabilizing agents) (Table 1) during the manufacturing process to improve the physical characteristics of plastics. The table shows the heavy metal additives and their health effects on human.

Table 1: The major use of heavy metals as polymer product additives and their impact on human health

| Heavy Metals | Additives | Polymer Types | Human Health Effects | Reference |
|---|---|---|---|---|
| **Arsenic (As)** | Biocides | PVC, LDPE and polyesters | Carcinogen: lung, skin, liver, bladder, kidneys; gastrointestinal damage; death. | Hahladakis et al.,2018; Hansen et al.,2013; Jan et al.,2015; |
| **Cadmium (Cd)** | Heat & UV stabilizers, inorganic pigments | PVC | Phosphorus and bone; osteomalacia and bone fractures in postmenopausal women; cellular apoptosis; DNA methylation | Hahladakis et al.,2018; Hansen et al.,2013; Godwill et al.,2019; Massos et al.,2017; Sharma et al.,2005; Jan et al.,2015; |

| | | | | |
|---|---|---|---|---|
| **Chromium (Cr)** | Inorganic pigments | PVC, PE, PP | Nasal septum ulcer; hematological, gastrointestinal, renal, hepatic, and neurological effects and possibly death. | Godwill et al.,2019; Massos et al.,2017; |
| **Lead (Pb)** | Heat & UV stabilizers, inorganic pigments | PVC | Anemia; hypertension; miscarriages; disruption of nervous Systems; brain damage; infertility; | Byrne et al.,2013; Hahladakis et al.,2018; Massos et al.,2017; Jan et al.,2015; |
| **Mercury (Hg)** | Biocides | PU | Mutagen or carcinogen; brain damage. | Cook et al.,2019; Hansen et al.,2013; Goyer et al., 2004; |

PVC= Poly Vinyl Chloride; LDPE= Low-density polyethylene; PE= Polyethylene; PP= Polypropylene; PU= Polyurethane

The above table shows the effect of heavy metals as polymer products and their impact on human health. Such as Arsenic and Mercury are carcinogens. Cadmium can affect bone and cause DNA methylation whereas the presence of Chromium in the human body is responsible for Nasal septum ulcer and many more gastrointestinal and neurological effects. Lead can cause anaemia, hypertension, miscarriage, brain damage etc. So, the deleterious effect of heavy metals on the human body is clearly seen here. With MP contamination and plastic intake these heavy metals get access to the human body and pose various health risks shown in here.

## 5. DETECTION OF MICROPLASTICS

Detecting microplastics (MPs) in landfill leachate typically involves three steps: collecting a sample, preparing it for analysis, and identifying and/or counting the MPs (Kabir et al., 2023). As MPs surfaced in various environmental parameters like soil, aquatic body, etc. it is highly unlikely to depend on a single analytical strategy to detect and quantify them. Methods that were used in the studies, were influenced by the researchers' goals, the resources they had available, and the characteristics of the samples. Most studies took quality control measures to prevent sample loss bias and the potential risk of contamination of the leachate samples. (Kabir et al., 2023; Shi et al., 2023b). Pre-treatment is the most important step that can affect the accuracy of microplastic (MP) detection.

To fully understand the microplastics (MPs) in landfill leachate, it is important to describe the physical attributes (color, size, and shape) and chemical characteristics (composition of polymers). But using a single identification technique to define MPs is a big challenge. The simplest and easiest approach to detect MP is with a visual identification process with MP range of 2-5mm (Heo et al., 2013). The most used tool in leachate analysis for counting and categorizing physical properties such as microplastic size, shape, color, and surface is the stereomicroscope. But this has also limitations when the sample contains organic matter and particle size decreases. Up to 70% error can be found if analysis is done only on the basis of stereomicroscope (Hidalgo-Ruz et al., 2012). With its keen eyes, SEM (Scanning electron microscopy) identifies microplastics lurking within complex environmental samples. (Cooper & Corcoran, 2010). This technique uses transparent and high-resolution images that can be magnified and help to characterize the surface morphology of microplastic and help to differentiate it from organic matter.

To elucidate the chemical structure of microplastic or analyze it chemically, Fourier Transform Infrared Spectroscopy (FTIR) is widely used. FTIR uses a coded polymer spectrum library to confirm the presence of plastic particles and detect the specific types of polymers present there. However, particle size can be an influential factor in determining the chemical composition. So, based on the sample size to be analyzed different FTIR techniques are applied. (Rolsky et al., 2020) used Micro-FTIR (m-FTIR) for analyzing MPs smaller than 1 mm and attenuated total reflectance (ATR) mode (ATR-FTIR) for analyzing MPs larger than 1 mm. Raman spectroscopy can provide better results for tinner samples. (Araújo et al., 2018). By examining the particle's chemical bond polarity, it determines the polymer composition of the sample. Micro-Raman spectroscopy can detect MPs smaller than 20 μm (Schymanski et al., 2018). So, it can be understood that different techniques are applied to the requirements of the research.

Table 2: The Location, content, composition, and detection methods of microplastics in landfills

| Country | Location of Site | MPs size | Method | Composition | Reference |
|---|---|---|---|---|---|
| **Bangladesh** | Sediment from Urban Lake | - | - | PC, CA, PP | (Mercy et al., 2022) |
| **China** | Vegetable Firm land | 0.2-5mm | ATR-FTIR, m.-FTIR | PS, PP | (Chen et al., 2020) |
| **India** | Groundwater | 1000-5000 μm | ATR-FTIR,SEM, stereomicroscope with camera | - | (Bharath et al., 2021) |
| **Indonesia** | Leachate Pond, Leachate Drain | 80-5000 μm | m-FTIR, microscope with camera | - | (Nurhasanah et al., 2021) |
| **Thailand** | Leachate Pond | - | FTIR, stereomicroscope | - | (Puthcharoen, 2019) |
| **Australia** | Industrial Area | 20-40 μm | FTIR | PVC, PE, PS | (Fuller & Gautam, 2016) |
| **USA** | Vegetable Wetland | <75 μm – 5mm | FTIR | PS, PE | (Helcoski et al., 2020) |

*PC= Polycarbonate; CA= Cellulose Acetate; PS= Polystyrene; PVC= Poly Vinyl Chloride; PE= Polye-thylene; PP= Polypropylene;

Table 2 shows the evidence of the presence of MP from different landfill leachates in seven different countries. The plastic composition varies from site to site. MPs ranging from 20 μm to 5mm have been detected using different methods suitable for that particular size.

## 6. REMOVAL OF MICROPLASTICS FROM THE ENVIRONMENT

Microplastics pose a major threat to ecosystems, wildlife, and human health, which is why it is imperative to eliminate them from the environment. They might collect toxic compounds, which could lead to bioaccumulation and biomagnification in food chains, eventually affecting humans and other larger animals. Eliminating microplastics from our surroundings lessens the possibility of ingestion by aquatic organisms. As a result, it lowers the ecological harm and helps maintain the delicate balance of our ecosystem benefiting both humans and wildlife. Removal of microplastics should be given priority as it is essential to preserve biodiversity and give future generations a cleaner, healthier environment.
A comparison of treatment techniques for eliminating microplastics from the environment is displayed in Table 3. The table summarizes the pros, cons, and efficiency of the removal projects used over the last few years. Practically speaking, the best ways to get rid of microplastics are with membrane-included technologies. On the other hand, it seems that the main goal of the ongoing initiatives is to identify appropriate substitutes for these approaches.

Table 3: Comparing multiple methods to the elimination of microplastics from the environment

| Method | Efficiency % | Advantages | Disadvantages | Reference |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **Filtration** | 100 | • Versatility<br>• Existing Infrastructure<br>• Physical Barrier | • Size Limitations<br>• Filter Clogging<br>• Cost and Energy Requirements | (Yuan et al.,2022) & (Akarsu et al.,2021) |
| **Sedimentation** | 80-100 | • Cost-Effective<br>• Simple Operation<br>• High Efficiency | • Time Consuming<br>• Space Requirements | (Ahmed et al.,2022) & (Saboor et al.,2022) |
| **Centrifugation** | | • Scalability<br>• High Efficiency<br>• Rapid Process<br>• Versatility | • Energy Consumption<br>• Potential Damage to Fragile Samples | (Sacco et al.,2023) |
| **Electro-coagulation** | >90 | • Wide Applicability<br>• Lower chemical use | • Energy Consumption<br>• Electrode Fouling | (Sacco et al.,2023) |
| **Adsorption on green microalgae** | 94.5 | • High affinity of the cut surfaces | • Nonrecyclable method | Lagarde et al. (2016) and Zhang et al. (2017) |
| **Dynamic membranes** | >90 | • Low filtration resistance<br>• Low trans-membrane pressure<br>• easy operation | • Energy Demand<br>• Sludge Accumulation | Li et al. (2018b) |
| **Membrane bioreactors** | >99 | • Combined Advanced Treatment | • Shape Dependency<br>• Membrane fouling | (Lares et al. (2018) |
| **Biological Treatment** | | • Environmentally Friendly<br>• Cost Effective | • Slow Treatment Rate<br>• Biological Interferences | (Sacco et al.,2023) |
| **Photocatalytic degradation** | | • Efficient Mineralization | • Lack of selectivity<br>• lower efficiency | Sekino et al. (2012), Tofa et al. (2019), Wang et al. (2019) |
| **Conventional activated sludge** | 98 | • Robust,<br>• Cost-effective<br>• Flexible | • Long retention times<br>• High-cost Energy | Gurung et al. (2016) |
| **Wastewater treatment plants** | >95 | • Low costs<br>• Simple operation | • Sludge aggregation<br>• Large mechanical devices | Leslie et al. (2017), Long et al. (2019) |

## 7. CONCLUSIONS

Weathering relentlessly grinds plastic into microplastics, these tiny invaders silently filtering into our environment, posing a growing threat. Microplastics, unleashed from decaying landfill plastic, pose a hidden danger to the delicate balance of our ecosystems. The detection of MPs depends on basically three steps sampling, pre-treatment, and quantification. To identify and quantify MPs, different approaches have been accepted depending on the target of the research and the objective of the work. The size of MPs is another important factor when choosing the appropriate method for quantification. The review shows that MPs have been identified in almost every landfill site throughout the world that had been investigated. This proves landfill sites as a potential hub of MP contamination. Microplastics could infiltrate the ecosystem by landfill liners leaking. More work should be done to identify the actual pathway of MP contamination. Though the direct impact of MP exposure on the human body is yet to be determined, but the indirect effect of MP on human health has been studied and identified. The use of heavy metals as additives in plastics poses deleterious effects on the human body. Depending on the efficiency, different methods can be adopted to remove microplastic from the ecosystem. Findings from this research can be implemented in a variety of fields in the context of Bangladesh. Comparison and analysis of microplastic pollution and its effects in Bangladesh with other Asian countries can easily be seen. It can be conveniently employed to minimize the potential cycles of MPs entering landfills. Health impacts due to the MPs can be specified. There are numerous low-cost and effective strategies for removing MPs from the food chain. By removing MPs, multiple diseases and human health hazards can be reduced. However, it’s wise to maintain better practices to stop MP contamination rather than removing it from our surrounding. More research work should be done to evaluate the direct impact of MP on the human body

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