

Transport of Microplastics from Municipal Solid Waste Landfills to Aquatic system: An Overview

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ABSTRACT

Microplastics possess a significant threat to water resources as well as aquatic life and present a challenge in overall water resource management. Among a wide variety of entry routes available for microplastics from land to water bodies, municipal solid waste (MSW) landfills are suspected to be one of the important land-based sources (entry point) of microplastics affecting water quality. Few studies reported the presence of microplastic in the leachate obtained from municipal solid waste landfills corroborating that MSW landfills not only act as a sink of microplastic pollution but also act as a source. Microplastics from these leachates move to the soil system thereby affecting its quality and further migrate to aquatic systems. This movement of microplastic from leachate to aquatic system not only deteriorate the water quality but also highlights the importance of land-based sources of microplastic. In this review, we focused on the role of landfills as a pathway for microplastics to water bodies. The main aims of this review the abundance and characteristics of microplastics in landfills and discuss the role of landfill age. Polyethylene in fragmented and fibrous form remains the predominant type and shape of microplastic in leachates. The shape, size, and abundance of microplastics in leachates vary with landfill age. Landfills also provide a favorable environment for microplastic degradation thereby turning macroplastics into tiny plastic pieces. The major type of degradation is oxidative degradation. Our review confirms that MSW landfills are indeed a source of microplastic and contribute to microplastic pollution in soil and aquatic systems.

Keywords: Municipal Solid Waste, Landfills, Microplastics, Plastic waste

1 Introduction

The management of municipal solid waste has long been a matter of scientific studies and public discussion. Traditional solid waste management strategy which consists of collection and disposal of waste (open dumpsites, open trenches, illegal dumping, and landfills is known to pollute adjoining aquatic sources (Hoorweg et al., 2012; Mor et al., 2012; Esakku et al., 2003; Aluko et al., 2003). The toxic chemicals (heavy metals and plasticizers) present in leachate and refuse from open solid waste dumps (or landfills) migrate either through subsurface soil or direct discharge in drains, to the surface water and groundwater sources, where they deteriorate the quality of these water bodies and puts human and animal health at risk (Baun & Christensen 2004; Samadder et al., 2017; Rajkumar et al., 2010).

Municipal solid waste dumping sites (landfill or open dumps) generate leachate, which if escapes to the environment, affects the surface and groundwater bodies as the leachate consists of high concentrations of heavy metals, organic compounds, and toxic contents. Recently, several studies have reported pollution of aquatic sources due to municipal solid waste leachates around the world and in India (Rajkumar et al., 2010; Sharma & Ganguly 2016; Lardjane & Belhaneche-Bensemra 2009; Nicholson et al., 1983; Naveen et al., 2018).



Global plastic production and consumption have increased significantly since 1950 with production increasing from 300 million tons in 2014 to 360 million tons in 2018. The future projection for an increase in plastic production is expected to double in the next 20 years with the current growth rate (Lebreton & Andrady, 2019). The environmental problems associated with plastics due to adaptive physio-chemical properties, high degradation rate, vast consumption, and inefficient plastic waste management practices have raised global alarming concerns, resulting in various mitigating and preventive measures in form of various laws and statutes to curb plastic pollution. The majority of the emphasis has been put on large plastic particles known as macroplastics (Size > 5 mm) while only in this decade the scientific community starts acknowledging smaller plastic particles known as microplastics (size- 1 micron to 5000 microns) an emerging threat of global concern. The increasing consumption of plastic material in our daily life is generating an enormous amount of plastic waste which ends up being part of municipal solid waste (do Nascimento Filho et al., 2013; Mølgaard 1995; Geyer et al., 2017; GESAMP 2015). Given the increase in urban population, expansion of municipalities, an increase in living standards, it's very likely that consumption of material resources will keep increasing. The increased consumption of heavy metals and plastics, if not disposed of properly, can significantly damage the environment and human health.

The body of knowledge available on microplastics abundance, characteristics in landfill is very limited and only five studies discussed this issue till August 2020 (Praagh et al., 2018; He et al., 2019; Kazour et al., 2019; Su et al., 2019; Puthcharoen & Suchat 2019). Here we reviewed papers discussing microplastics pollution in landfills to assess the abundance and characteristics of microplastics in landfills. We further highlighted the role of landfills in the generation of secondary microplastics. Lastly, we conclude that landfills are indeed a source and sink of microplastics pollutant, and their abundance in leachate highlights that microplastics can migrate from landfills and find their way to the aquatic environment.

2 Microplastics from landfills to aquatic environment

Microplastics are small pieces of man-made polymer particles with an upper size limit of 5 mm and a lower limit of 1 μm (Rochman 2015). They are a heterogeneous, complex group of different polymers, sizes, colors, shapes, and additives, which are ubiquitous in the environment, and their presence, have been reported in all environmental matrices (marine water, freshwater, soil, atmospheric fallouts, wastewater, and municipal solid waste) around the globe. Microplastics can be categorized as primary microplastics and secondary microplastics. Primary microplastics are those microplastics that are intentionally made in that size range to serve a specific purpose, mainly in personal care products, medicines, and feed material for the plastic industry. Secondary microplastics are derivative of macroplastics, when plastics are released in the environment, they come in contact with various environmental forces and undergo physical, chemical, and biological degradation, which results in fragmentation. These processes change the size and surface properties of macroplastics, thereby generating microplastics with high specific surface area enabling them to interact with toxic chemicals already present in the environment. Microplastics are loaded with various toxic chemicals used during their synthesis (known as plasticizers) to enhance their properties (Van Sebille et al., 2015; Rochman 2019; Hidalgo-Ruz et al., 2012; Hartmann et al., 2019; Ivleva et al., 2017; Hui et al., 2020; Koelmans et al., 2016; Horton et al., 2017). Microplastics, either intentionally made primary microplastics or secondary microplastics (resulting from fragmentation of macroplastics) are environmental stressors capable of trans-boundary migration which negatively affects our eco-system in a plethora of ways. The microplastics loaded with toxic chemicals get consumed by all types of life-forms including humans, where they start bioaccumulation in the host body or in

the environment. Our understanding of the eco-toxicological effect of microplastics on the biotic and abiotic environment is very limited though it is well established that microplastics act as a vector for toxic chemicals and pathogens and their transference occurs in all trophic levels (Green et al., 2016; Galloway et al., 2017; Carbery et al., 2018; Au et al., 2017).

The fate of microplastics in the environment depends mainly on their characteristics and surrounding environmental forces. As soon as microplastics enter the environment, they start trans-boundary migration across all matrices. Hence it is very important to identify various aquatic and terrestrial sources to propose mitigation measures. Microplastics originating from land-based sources utilize various pathways and end up in surrounding aquatic bodies. Among these sources and pathways, landfills have been identified to contribute microplastics to aquatic sources. Besides primary microplastics already present in the solid waste, MSW dumps create secondary microplastics due to the substantial amount of plastic waste buried in landfills and providing favorable environmental conditions for progressive and continuous degradation of macroplastics to microplastics.

Though waste management sectors have already been identified as one of the major sources of microplastics in an urban environment, the majority of our understanding is mainly based on wastewater management and only a few studies are available on microplastic release via solid waste management (Ziajahromi et al., 2016). Landfills have now been identified as releasing microplastics through the pathway of MSW dump leachate emitted to aquatic sources. Leaching of various contaminants from landfills, including plastic additives, is well known and documented. Additionally, the pollutants originating from MSW dumpsites are capable of trans-boundary migration where they move from a terrestrial environment to surrounding aquatic environment. These polluted local aquatic sources are utilized to supply water for drinking purposes to the public. Hence it is of paramount importance to identify the transport pathways through which pollutants are escaping from MSW dumpsites to prevent their migration, which safeguards the local aquatic sources from further pollution and also reduce the burden on water treatment facilities, saving valuable resources and public health (Aluko et al., 2003; Baun & Christensen 2004; Rajkumar et al., 2010; Sharma & Ganguly 2016; Lardjane & Belhaneche-Bensemra 2009)

Neither the information on the microplastic abundance in open solid waste dumps leachate nor on the potential impact of microplastic interaction with toxic chemicals already present in leachate has been available throughout the world, except one study originating from Thailand. Additionally, the decommissioned landfills have been found to generate toxic leachate (including heavy metals and microplastics) even after the landfill activities have stopped receiving solid waste. Hence, it becomes pertinent to keep assessing the pollution potential of decommissioned solid waste dumping sites (Praagh et al., 2018; He et al., 2019; Kazour et al., 2019; Su et al., 2019; Puthcharoen & Suchat 2019).

3 Abundance of microplastics in landfill leachates

Total 5 studies have reported the abundance of microplastics in leachate and refuse samples obtained from 31 landfills across the globe. Results from total of 31 landfills that were examined in five studies portray that number of microplastics varies significantly with almost none to 25 particles per liter. The maximum average microplastics abundance was reported to be 4 -13 particles/L of leachate from landfill at Laogang, Shanghai, China. The average abundance of microplastics in leachates of 12 landfills of Iceland, Norway and Finland are reported to be 4.51 particle/L, 18.38 particle/L, 24.58 particle/L respectively, 1.17 particle/L in 3 landfills of Sanghai, 0.96 particle/L in 1 landfill of Wuxi, 2.96 particle/L in Suzhou, 3.58 particle/L in Changzhou in china,

4 to 13 items/L Laogang landfill of Shanghai in China, 0.002 and 0.017 particle/L landfill around Tali, Helsinki, and 12 landfill sites of Thailand (Praagh et al., 2018; He et al., 2019; Kazour et al., 2019; Su et al., 2019; Puthcharoen & Suchat 2019).

The microplastics abundance is found to be varying from country to country. This can be attributed to varying living standards, plastic consumption, and plastic waste management being practiced in a given country. Leachate loaded with microplastics originating from landfills migrate to the aquatic environment either through seepage where they persist for a long duration. Landfills act as a biological reactor where various physical and biological processes interact with solid wastes. Under the influence of these forces, waste products start degrading. The plastics fraction of the waste starts degrading and fragmenting and generates secondary microplastics. Hence landfills not only store the microplastics being disposed of there, they simultaneously generate secondary microplastics, thereby serving as both source and sink. The abundance of microplastics in landfills mainly depends upon these two facts discussed above.

4 Characteristics of microplastics in landfill leachates

Characteristics such as density, shape and size of microplastics plays crucial role in fate of microplastics in environment. Polymer having high density than liquid medium will sink while polymer having lower density will float. Only 3 studies reported the size classification with microplastics size ranging between 5000 and 50 μm . The size classification of microplastics reported in studies is function of sampling and analytical techniques used in studies. Results reveals that average size of microplastics in leachate are much smaller than refuse. This is due to fact that smaller microplastics seeps with waste and ends up in leachate, while larger microplastics resulting from fragments remains trapped in refuse. These trapped microplastics are continually fragmenting and in time will end up being part of leachate.

The shape of microplastics is another important characteristic of microplastics which reveals crucial information relating to source and type of microplastics. In environment microplastics persist mainly in form of beads, foam, films, fibers and fragments. As discussed earlier, primary microplastics are intentionally made in specific size and shape resulting in abundance of beads and films. Secondary microplastics generally tend to be in shape of fragments. Majority of microplastics found in landfill leachate and refuse appears to be fragments and fibers, confirming that secondary microplastics are major source of microplastics in landfills.

Microplastics are made up of various types of polymers with varying properties. These properties influence the consumption of plastic products. Polyethylene remains not only most popular choice of polymer but it's also represents the highest fraction of microplastics found in leachate samples.

5 Role of landfill age in generation of secondary microplastics

Studies have shown that composition, chemical and biological properties of leachate changes with change in age of landfill when landfills start stabilizing (Kjeldsen et al., 2002; Kulikowska & Klimiuk, 2008). The age of landfill has been reported to influence the abundance and characteristics of microplastics in leachate and refuse. Landfills are a complex environmental system where many environmental factors significantly influence the degradation of landfill. With time the volume of plastic waste increases in the landfill; concurrently with time the degradative processes in landfills accelerate. This provides a favorable degradative environment in landfills which accelerates the generation of secondary microplastics.

With increasing consumption of plastic material and subsequent plastic waste generation, the plastic composition in municipal solid waste has increased drastically in the last 4 decades. The majority of this plastic

waste ends up in landfills where they go through fragmentation and degradation. The younger landfills are abundant with primary microplastics as these landfills receive primary microplastics originating from the community. However, older landfills generate secondary microplastics due to the continuous degradation of macroplastics being buried in landfills.

6 Conclusion

Our review elucidates that microplastics are abundant in landfill leachates throughout the globe. The composition, characteristics, and abundance vary geographically suggesting that the composition of plastic waste managed by the landfills governs these parameters. The generation of secondary microplastics due to degradative processes occurring in landfills is a major issue that requires detailed studies. Landfill leachate systems are capable of significantly reducing the microplastics concentration in leachates, however, given the amount of leachate being generated across the globe and the unavailability of such treatment facilities in developing countries, it is likely that landfills can be considered as a significant source of microplastics pollution. This review summarises the available knowledge in concise form and can serve as the baseline for future studies in the field.

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