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Review Article



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Microplastic contamination and accumulation in municipal solid waste: A global review of sources, pathways, and impacts

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Abstract

Background: One of the most serious environmental challenges is pollution caused by microplastics. They are found in many parts of the environment, but most research has focused on aquatic environments. Municipal solid waste is the main source of microplastics on land, which has been largely ignored. The sources of microplastics in solid waste can be landfills, sludge, compost, and food waste. Landfills pose a threat to soil and groundwater pollution. Addition of sludge or compost to the soil for fertility poses a threat to the entry of microplastics into the human food chain. Therefore, it is essential to comprehend the behavior of microplastics in various types of solid waste.

Methods: We conducted a literature search, screened the articles, and selected the relevant articles. The search was performed in 3 main databases: PubMed, Scopus, and Web of Science. This study evaluated the characteristics of microplastics in landfills, sewage sludge, compost, and food waste, their fate, and their entry into the human body. Finally, methods of biological removal are mentioned.

Results: A total of 335 articles were retrieved from three databases; after removing duplicates, 195 articles remained. By screening and removing reviews, notes, books, and irrelevant articles, we identified 74 articles focused on microplastics in municipal solid waste.

Conclusion: Municipal solid waste is a source of microplastics, which includes landfill waste, sludge, compost, and food waste. The results of this study will pave the way for future researchers to gain a deeper understanding of the behavior of this pollutant in solid waste.

Keywords: Microplastics, Solid waste, Composting, Refuse disposal, Sewage

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Introduction

Plastic is a vital material in modern life, but it also poses one of the biggest challenges for humanity in this century (1). In 2015, the world produced 4.9 billion tons of plastic waste, and this amount is expected to reach 12 billion tons annually in 2050 (2). Microplastic particles (MPs) are small pieces of plastic that are less than 5 mm in size (3) and come from two main sources (4,5). The first source is primary MPs, which are mainly used in medical and cosmetic products, including polystyrene (PS), polyethylene (PE), and polypropylene (PP) particles (5). The next source is secondary MPs, which are created from the crushing of larger plastics due to chemical, biological, and physical processes (6,7). MPs can have diverse shapes, such as fibers, fragments, foams, rods, and flakes (8), with fibers being the most common type (9). MPs are found everywhere: in the air, wastewater treatment plants, landfills, lakes, oceans, rivers, sediments, and estuaries (10,11). The exposure and health effects of MPs in solid waste are less well understood than those in marine environments,

although municipal solid waste is an important source of MPs in the environment. Landfills, one of the most common methods of solid waste management, can be a significant source of MPs (12,13). Several factors, such as rain and wind, can transport MPs from landfills to nearby environments (14). Moreover, since plastics are widely used in food production factories, if municipal solid waste is not managed correctly, it can be expected that this pollutant will be seen in various foods (15,16). MPs are a growing concern in aquatic environments because they can harm living organisms, and they can also accumulate and magnify in the food chain. MPs cause disturbances in the reproduction and feeding systems of aquatic animals (17). They also release harmful substances, additives, and monomers that can cause cancer (18). Moreover, exposure to MPs can lead to damage to the lungs and liver (19,20). Therefore, understanding the role of MPs and their impact is essential to ensure that the health of humans, animals, and aquatic life is not compromised. To increase the knowledge about MPs and their control, it is

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*Correspondence to: Faezeh Jahedi, Email: Jahedi.f@ajums.ac.ir necessary to know all their sources. Although solid waste is one of the important sources of increasing MPs in the environment, there is a lack of information in this field, and this important source has been largely ignored. Here, we documented the main types of solid waste that cause MPs pollution.

Materials and Methods

We searched, screened, and selected the relevant papers, as shown in Figure 1. The words used to search the database are as follows:

- PubMed: ((Microplast*[Title/Abstract]) OR ((("Solid ("Microplastics" [Mesh])) AND Waste"[Mesh]) OR "Composting" [Mesh]) OR (Solid waste*[Title/Abstract] OR Municipal solid waste*[Title/Abstract] OR landfill*[Title/Abstract] OR Leachate*[Title/Abstract] OR Sludge*[Title/ Abstract] OR Biodegradat*[Title/Abstract] OR Compost*[Title/Abstract] OR Food waste*[Title/ Abstract] OR Sea food*[Title/Abstract]))
- Web of Science: (TS = Microplast*) AND (TS = ("Solid waste*" OR "Municipal solid waste*" OR landfill* OR Leachate* OR Sludge* OR Biodegradat* OR Compost* OR "Food waste*" OR Seafood*))
- Scopus: TITLE-ABS-KEY (microplast*) AND TITLE-ABS-KEY ("Solid waste*" OR "Municipal solid waste*" OR landfill* OR leachate* OR sludge* OR biodegradat* OR compost* OR "Food waste*" OR seafood*

Results

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In the screening stage, EndNote software was used. The authors first screened all abstracts and titles from the search based on the inclusion and exclusion criteria, then excluded completely irrelevant studies. A total of 335 articles were retrieved from three databases; after removing duplicates, 195 articles remained. By screening and removing reviews, notes, conferences, books, and irrelevant articles, we reached a total of 74 articles that focused on MPs' contamination and accumulation in municipal solid waste. Finally, 74 articles were reviewed. This review aimed to present the major types of solid waste that produce MPs pollution and give an overview of the amounts of MPs in solid waste, and suggest future research directions.

Discussion

Solid waste as a source of MPs

A landfill, the most common method of waste disposal, can be a source of MPs production in the environment. It should be noted that compost can be an important source of MPs released into agricultural soils and, consequently, agricultural products. Another part related to municipal solid waste is the burning of waste by incinerators. The ash from incinerators can contain MPs. In this regard, Bern et al. identified MPs in incinerator ash (21,22). Municipal solid waste transfer stations can also be a source of releasing MPs into the air and pose a risk of inhaling these pollutants. In this regard, Hu et al conducted research, and the presence of MPs in the air around municipal solid waste transfer stations with a diameter of 400 micrometers has been proven (23). He et al also mentioned that treatment processes can produce MPs (12). Organic matter from the mechanicalbiological treatment of municipal solid waste can be a source of increasing MPs in the environment, which is still not well understood (24). The plastic recycling industry can be a source of MPs production. Suzuki et al reported that, considering the trend of increasing plastic use and its importance in the economic cycle, more MPs emissions can be expected (25). Gao et al reported that the recycling of PET bottles created MPs (26). In the following section, we discuss the studies conducted in the field of MPs in landfills, sludge, compost, and





food waste.

Microplastics in landfills

Landfills can account for about 40% of the share of MPs released into the environment (27). Plastics in landfills are of a secondary type because they are created by degradation and crushing (28). Researchers have reported that the amount of MPs in landfills is much higher than the amount in soil and sludge (29). Additionally, the identification of MPs in aquatic organisms, such as mussels, can be attributed to the proximity of the landfill to these water resources (30). The age of the landfill is a crucial factor in the release of MPs. Some studies have examined MPs in landfills of different ages (31). The leachate is a strong wastewater with a high concentration of contaminants. Recent studies have proven the presence of MPs in the landfill leachate (32). Some studies conducted in this field are presented in Table 1. Kilponen (33) investigated the concentration of MPs in leachate, and the results showed that the concentration of MPs was 1.1 MPs/L. The size of these MPs was often more than 1 mm. Another study in China identified 500-1000 MPs in landfill waste. In this study, the predominant form of MPs was fibrous, and their color was clear. The predominant composition also included PE, PP, and polyethylene terephthalate (PET) (34). Kabir investigated the presence of MPs in landfill leachate and reported an average MPs concentration of 0-2.7 per liter of leachate, and the predominant composition was PE and PP (35). Polymer compositions of MPs in refuse and leachate landfills are shown in Figure 2. Knowing the type of composition of MPs gives us the possibility to determine the type of plastic used most frequently and to implement effective plastic control and minimization programs. In the landfill, the dominant polymers are as follows: PE, PP, PS, expanded polystyrene (EPM), and polyether urethane (PEUR) (31). Figure 2 illustrates the abundance of MPs with different polymer types in leachate and landfills, as shown in Table 1. Moreover, in Figure 3, we compared the types of polymers present in landfills across different countries, as listed in Table 1. As seen in Figures 3 and 4, polyethylene, PP, and fibers and fragments have been the most abundant materials in landfills across various countries worldwide.

Microplastics in sludge

Sludge in wastewater treatment plants, as solid waste, can be a source of releasing MPs into the environment. Studies on the efficiency of removing MPs in treatment plants indicate that MPs are still present in the treated sludge. The risk of their release into the environment depends on the method of sludge management (47,58,86,87). The researchers stated that the concentration of MPs in the primary sludge was higher than in the secondary sludge, which could be attributed to the percentage of MPs removed in the secondary treatment. Corradini et al Abundance of MPs with different polymer types in leachate(%)



Abundance of MPs with different polymer types in refuse(%)



Figure 2. The abundance of MPs with different polymer types in leachate and landfills, as presented in Table 1

in Chile reported that The average number of MPs in 1 g of sludge was 34 particles, and the predominant shape was fiber (39). Xu et al collected samples from the largest sewage treatment plant in China and investigated the MPs in this sludge. The results showed that the concentration was approximately 4000 particles per kilogram of sludge, and 25 compounds of MPs were also identified, with PBA being the dominant compound (36). Li et al, in a study, reported that the concentration of particles in the sampled sludge ranged from 1.60 to 56.4 particles per kilogram of sludge. The predominant color and shape identified were white and fiber, respectively (43). Fibers and fragments occupy a large proportion of the MPs found in both raw and treated sludge (Figure 5). The size of MPs in sludge depends on the type of method used in the wastewater treatment process (88). One of the methods of reuse is the use of sludge in the soil, which is being implemented worldwide. However, if the sludge is used in the soil for a long time, it leads to the release of MPs into the soil and, consequently, into the human food chain (89). MPs in sludge can react with other toxic elements to form hazardous compounds (90). In a study conducted by Yang, the number of MPs in a sludge (which had been used for years) was approximately 149.2-68.6 particles Table 1. Reviewing the literature on the abundance of MPs in sludge, compost, landfill, and leachate

	Country	Concentration	Composition	Size	Shape	Color	Identification device	Ref
	China	4044±1359 particles/kg	Rayon, PE, PET, PP, PP/PE, and PS, ABS	0.19-0.13 mm	Pellets, fragments, films, and microfibers	-	FTIR	(36)
	Ireland	4196–15,385 items/kg	PA, PP, PET	0.25–4 mm	Fiber, fragment, film, sphere	-	SEM	(37)
	Italy	56000–170000 items/kg	PES, PA	0.5–0.1 mm	Fiber, fragment	-	µFT-IR	(38)
	Chile	18000 to 41000 particles kg ⁻¹	Acrylic, Nylon, PS	0.04-2.7 mm	Fiber, fragment	-	-	(39)
	Russia	15000-627000 particles kg ⁻¹	-	-	-	-	-	(40)
	United States	0–12 g/kg	PET, PC	-	-	-	-	(41)
	China	234.7-6908.3 items/kg	PP, PE, PP, PET, PAN	0.5-5 mm	Fiber, fragment, and film	-	Optical microscope	(42)
	China	1565–271,700 items/kg	PA, PP, PE, polyolefin, acrylic	0.025–5 mm	Fiber, fragment	-	-	(43-45)
	Poland	6700–62600 items/kg	-	-	-	-	-	(46)
	United States	800–4000 items/kg	-	<5 mm	Fiber	Red, blue, green, violet, and yellow	-	(47)
	Canada	Secondary sludge: 1500–7300 items/kg	-	-	Fiber, fragment	-	FTIR	(48)
	Germany	1000–24000 items/kg	PE	<5 mm	-	-	μFTIR	(49)
Sludge	Finland	8.2-301.4 items/kg	-	<1 mm	-	-	FTIR	(50)
-	China	44.4–750 items/kg	PP, PE, PS, PVC, PET, Nylon	> 1 mm	Fiber	Green, Translucent, white	Microscope, FTIR	(51)
	China	13.06 × 10 ³ - 29.66 × 10 ³ items/kg	PE, PP, PET	-	Fragments, film, fibrous, granular	Transparent, black, white, red, green, blue, yellow	Microscope, FTIR	(52)
	China	5583 items/kg	PP, PE, PS, PA, PET, PVC	<300 µm	Fragment fiber	Transparent, gray, blue, black, red, pale brown, green	Microscope, Roman	(53)
	China	5524 items/kg	PP, PE, PS, PET, PA, PVC	-	Fibers, films, fragments, microbeads	White, transparent, black, blue, green, yellow, pink	SEM-EDS, FTIR	(54)
	Italy	4740 items/kg	PE and PP	0.1–0.5 mm	Film, fragments, lines, glitters	-	Stereomicroscope, μ-FTIR	(55)
	Australia	15900 - 56500 items/kg	PET, PP, PE, Nylon	>25 µm	Fiber and fragment	Black, green, yellow, white and transparent	µFTIR, ATR FTIR	(56)
	Korea	14900 items/kg	-	>106	Fibers, fragments	Red, blue, black, green, yellow, brown	µFTIR, ATR FTIR	(57)
	England	2000 items/kg	-	1.34–1.62 mm	-	-	-	(58)

Table 1. Continued.

	Country	Concentration	Composition	Size	Shape	Color	Identification device	Ref
Compost	Spain	5–20 particles/g	PE, PS, PP, PVC, acrylic		Fragments and fibers	-	FTIR	(59)
	Poland	1200 mg plastic kg-1	-	-	-	-	NIR	(60)
	China	11,640±3565 items kg−1	PP and PE	1.35±1.00 mm	Fibers-Fragment	Different color	FTIR	(61)
	Sri Lanka	10–2800 item kg-1	-	-	-	-	-	(62)
	China	104 particles ⋅kg−1	PE	0.05–0.5 mm	Fragment	-	µFTIR- SEM	(63)
	China	386 items/kg	-	1–3 mm	Film	White-transparent	-	(64)
	China	2533±457 item kg−1	PS, PE, PP	0.05–5.0mm	-	-	µFTIR- SEM	(65)
	Taiwan	53 ± 34 item m ²	PE, PP, PS	1.0–5.0	Fragment- fibers	White-transparent	FTIR- SEM	(66)
	China	3780 items/kg	PP, PR, PE, PET	-	Fragment- fibers	White, red, blue	µFTIR- SEM	(67)
	China	1250 items/kg	Rayon	1–3 mm	Fragment, film	Transparent, white, green, purple	µFTIR, ATR FTIR	(68)
	Mexico	129800 items/kg	-	0.1-1mm	-	-	Stereomicroscope	(69)
	Finnish	6.6±1.5 items/kg	PET, PE, acrylates, ABS, PP, PS, PU	-	-	-	SEM- FTIR	(70)
	Germany	12±8-46±8	-	-	Fibers and fragments	-	Microscope	(21)
	Germany	39–102	PVC, PE, PET, PS, PES	1.0–5.0 mm	Fragment and film, fiber, sphere		Stereomicroscope, ATR-FTIR	(71)
	Netherlands	2800±616 item kg ⁻¹	PE and PP	0.03-2mm	-	-	SEM- FTIR	(72)

Table 1. Continued.

	Country	Concentration	Composition	Size	Shape	Color	Identification device	Ref
Landfill & leachate	China	291±91 particles/L in leachate	PP, PA, rayon, PE	20–100 µm	Film, floc, flake, strip, and fragments	Translucent, light yellow, dark yellow, and blue	FTIR	(30)
	China	landfill refuse: 590 to 103,080 items/kg landfill leachate: 3 to 25 items/L	PE, PP, PET	-	-	-	FTIR	(73)
	Cambodia	218,182 pieces/kg dumping site	PE and PP	-	-	-	FTIR- SEM	(34)
	France	Surface water: 6 items/L Sediments: 50–1110 items/kg	PS, PP, PET	0.02–0.08 mm	Fragment, fiber, film, sphere	Black, blue, red, white, transparent, and green	micro-Raman	(74)
	United Arab Emirates	43.1 mg/L- 19868 items/L in leachate	PET, PP, PVC, LDPE, HDPE, PS, PC	0.0005 mm	-	-	SEM-EDX and FTIR	(75)
	China	0.42 to 24.58 items/L in leachate	PE, PP	0.1-1 mm	Fragment	-	FTIR- µFT-IR	(12)
	Thailand	Landfill leachate: 13.5–27.5 items/l	PE, PP, PET		Fiber, film, granule, irregular, sphere	-	FTIR	(76)
	China	Landfill refuse: 20000–91000 items/kg landfill leachate: 0.4–24.6 items/L	PE, PP, PEUR, PS, EPM, Cellophane	0.07–1 mm	Fragment, fiber, flake, granule	-	µFT-IR	(12,31)
	Serbia	Leachate: 0.64 - 2.16 mg L ⁻¹	BPA	-	-	-	-	(77)
	Indonesia	Leachate: 80640±604.80 particles	PP-PE-PS	-	Cellophane	-	FTIR, µFTIR	(78)
	Iran	Leachate: 79.16 items/L	nylon	<25 µm	Fibers	Black	µRaman	(79)
	Iran	Landfill: 25±138 particles/kg	LDPE, PP, and PS	0.5–1.0 cm	Film	Black and withe	FTIR-ATR	(80)
	China	Leachate: 235.4±17.1 item/L	PA, PVA, PVB, PMP, PAA, PBMA	<50 µm	Fiber, film, fragment, Beads	-	µRaman	(81)
	China	Leachate: 1.2±0.57 items/L	PE, PS, PES, PP, PA, EPM, PVAC	-	fiber	-	µFTIR, ATR FTIR, SEM	(82)
	India	Leachate: 2–80 items/L	PP, PS	-	Nylon, Pellets, foam, fragments, fibers	White, black, green, red, blue, yellow	ATR-FTIR, SEM-EDX	(83)
	France	244 items/L	PS-PA-PET-PP	-	Films, fragments, microbeads, fibers	Dark, red, yellow, blue, white or green	µRaman	(84)
	Finland Norway Iceland	2.36 μg/L 1.17 μg/L 0.71 μg/L	 PE, PS, PET, PU PET, PMMA PE, PS, PET, PU 	>500 µm	-	-	µFTIR ATR-FTIR	(35)
	Lithuania	Autumn: 17407 ± 1739 particles kg ⁻¹ in and winter: 15400 ± 1217 particles kg ⁻¹ in	PP- LDPE-HDPE	-	Fragments-Film	-	FTIR	(85)



Figure 3. Polymer composition in landfills worldwide, as presented in Table 1



per kilogram of dry sludge, as reported (68). Additionally, MPs can serve as a platform for transporting pollutants, including heavy metals and pathogenic microorganisms (91). Therefore, extensive studies on MPs in sludge and the management of the application of sludge in soil are necessary.

Microplastics in compost

One of the resources considered a non-renewable resource for human life is soil. Therefore, investing in and preserving this resource is vital. Much news is reported about the daily release of plastics into marine ecosystems (92). However, in the meantime, there is another environmental damage and danger that has received very little attention but has a high-risk potential, and that is agricultural pollution caused by plastic. The use of plastic in agriculture can lead to the penetration of plastics into the soil, and subsequently, they often enter the food chain (Figure 6). Studies reveal a high presence of MPs in agricultural soils and vegetable farmlands. Some studies have reported the absorption of plastic particles by the roots of lettuce, wheat, and cucumbers (93). The possibility of absorption of MPs particles by plants is high (94). Especially when crops are fed by compost contaminated with MPs, or grown in soils contaminated with sludge or sewage (95). An excessive number of MPs in compost has been reported in the literature, which creates concern in the agricultural industry in recent years (96).



Figure 5. Major shapes of MP particles in different types of sludge (from 19 papers)



Figure 6. Microplastics in the food chain

A study in China reveals that the concentration of MPs in the compost obtained from municipal solid waste ranged from approximately 140 to 316 items per kilogram, with MPs measuring approximately 1 mm in size (61). Another research in Taiwan investigated MPs in compost, and the results showed that the amount of MPs is 53 per square meter of compost with a size of 1-5 mm (66). Similar results are found in the Dutch and Sri Lankan compost, which indicate a number of MPs of approximately 2800 per kilogram, with a particle size of 0.03 mm. Examining the studies, we find that the common components in compost are polyester, PP, and polyethylene. Moreover, the dominant shape is fibers, pieces, shafts, and fine grains (62). These results were conducted in Spain on MPs in compost and reported the amount of 5-20 particles per gram of dry weight, which was the predominant form of fibers (59). Fertilizer refers to any material that is generally added to the agricultural soil to strengthen it due to the positive effects of the valuable elements in it. To address the deficiency in soil nutrients required for plant growth, the use of fertilizer will be highly beneficial. However, the presence of MPs in fertilizers has also been reported (65). The amount of MPs in organic fertilizers depends on the biological method used in the preparation of the fertilizer. According to the studies, this amount is about 30000 items per kilogram with a size of less than 3 mm (97). In

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past studies, little attention has been paid to the presence of MPs in fertilizers and their effects on the health of animals, plants, and humans. Other pollutants (such as heavy metals, etc.) were the main target of studies in organic fertilizers and compost, so in future research, it is necessary to concentrate more MPs and provide a solution to reduce the abundance of MPs in fertilizers (98).

Microplastics in food waste

In recent years, attention to packaging in food production has increased. Almost all the food prepared, mainly processed types, comes with packaging. Unfortunately, most of the packaging we see around us is disposable, and they are usually thrown away after consumption. These plastics enter the human food cycle through terrestrial and marine food sources and are ultimately discarded as food waste. Extensive studies have been conducted on the presence of MPs in aquatic animals and invertebrates. MPs have been detected in the body tissue of mussels (99), oysters (100), clams (100,101), and crabs (102,103). Li et al examined Chinese mussels (Mytilus edulis) for the presence of MPs and found that the most common form was fibers and fragments (104). Oliveri Conti et al. showed in a study that fruits have more MPs (size 10 micrometers) than vegetables (104). Hosseinpour et al examined 14 species of fish in the Persian Gulf for the presence of MPs in their tissue and reported the dominant shape, color, and size as fiber, black, and less than 75 micrometers, respectively (105). Other studies have reported the presence of MPs in drinking water, salt, fish, and honey. Some of these studies are given in the table (56-80). According to the studies, it can be concluded that the dominant composition of MPs in food and food waste is as follows: (PU) < (PVC) < (PS) < (CP) < (RY) < (PA) < (PEST) < (PE)(106-108). By comparing the amount of MPs in seafood, we find that the amount of MPs in mussels is higher than in other organisms. A study conducted in Italy reported this amount in mussel oysters ranging from 0 to 1.5 items per kilogram of muscle body tissue. The size of these particles was in the range of 0.01-5 mm (109). A similar study in India evaluated the types of bivalves in five locations in terms of the presence of MPs. The highest frequency of MPs was 163 items per liter, with the most common shape being fibers, and the size of MPs was often below 2 mm. The most common polymers identified are PP and high-density polyethylene (110). In a study conducted in Brazil, MPs were found in farmed fish for the first time. The results of this study showed that MPs with fiber shapes and red, blue, and transparent colors were the most observed MPs. The abundance of MPs in two rainy and dry seasons was reported as 286 items and 58 items per liter, respectively. The water from the fishponds by the rivers is supplied. Therefore, water pollution with waste and wastewater containing MPs can also be a reason for fish pollution (111). Figure 7 shows the abundance of MPs (with different polymer types) in food waste based on Table 2.

Degradation of MPs in solid waste

Polymer degradation refers to any change in the physical or chemical properties of plastic materials that occurs as a result of exposure to specific environmental factors, such as light, heat, moisture, or biological activity. Specifically, these types of polymer degradation methods are referred to as optical degradation, thermal-oxidative degradation, and biodegradation, respectively. Biodegradation enables microorganisms, such as bacteria, fungi, and algae, to break down polymer materials through their metabolic activity. They rely on this form of biodegradation, which does not require thermal energy and can be carried out under either aerobic or anaerobic conditions. For example, aerobic biodegradation yields the production of carbon dioxide and water in the soil, whereas anaerobic decomposition typically results in the production of carbon dioxide, water, and methane. In general, the biodegradation of polymers is a very complex process that depends on several factors, including substrate availability, surface characteristics, morphology, and polymer molecular weight (136-140). Recently, researchers have discovered bacteria that can eat plastic, and it has been reported that these bacteria originate from landfills, specifically from the species of the phyla Proteobacteria, Actinobacteria, and Firmicutes (141). Some earthworms and insect larvae are also capable of decomposing plastic. The reason why worms can decompose MPs is the presence of Pseudomonas aeruginosa bacteria in their intestines, which easily decompose polystyrene MPs (142,143). Also, Bacillus strains showed high degradation of PP within 40 days (144). The larvae of the yellow ardalo worm are capable of decomposing polyvinyl chloride (145). The microbial population located in the gut of Achatina fulica (snails) was able to degrade PS significantly (146). Likewise, Tribolium castaneum larvae harbor Acinetobacter bacteria and decompose PS, while citrus mealybugs possess endosymbiotic bacteria that enable them to break down polyethylene (147). Fungi also have the potential to decompose MPs. They can do this by using enzymes.



Figure 7. The abundance of MPs with different polymer types in food waste, as shown in Table 2

Table 2. Reviewing the literature on the abundance of MPs in food waste

Food Products	Country	Concentration	Composition	Size	Shape	Color	Identification device	Ref
Clam (Corbicula fluminea)	China	0.3-4.9 items/g	PS-PP-PE	0.021-4.83 mm	fibers	Blue and transparent	μFTIR	(112)
Mussel (Mytilus galloprovincialis)	Italy	0-1.5±0.58	PE, PP, PS, PVC, PET, PA, EVA, PI, PEST, PU, epoxy resin, PBT, poly terpene rubber, PVOH, silicone, poly acrylate, copoly (EVA/ PA), copoly (PVC/PVOH/PE)	0.01-5 mm	Fibers	-	-	(113)
Honey	Switzerland	0–8.3	PET-PS	50 µm	Fibers	Black, white, transparent	FTIR-ATR	(114)
Chicken gizzard	Mexico	45.82±42.6 per gizzard	PE-PS	1-5 mm	Fiber	-	-	(69)
Packaged chicken breasts, packaged turkey escalopes (Extruded PS tray)	franc	4.0 to 18.7	EPS, PS	0.3-0.4 mm	Fibers, fragment	-	FTIR	(115)
Shrimp	India	0.39±0.6	PA, PE, PP	157 – 2785 μm	Fibers, fragments, sheets	Red, Blue, Black, Transpare and Green	FTIR	(116)
Canned fish	Iran	25.60±0.87	PET, PS, PP, PA, PVC, LDPE	0.1-5 mm	Fibers	black -blue -green -red -transparent	SEM-EDX- µ-Raman	(117)
Mussel	China	0.9 to 4.6 items/g	CP, PET, and PES	0.25-1 mm	Fibers-Fragment- sphere- flake	-	μ–FTIR SEM	(105)
Fish	Sydney	0.2 to 4.6 items/fish	PET, PS, and rayon	0.13–5 mm	Fiber,	-	ATR-FTIR μ-Raman	(118- 125)
Fish	Creek	0.5-70 items/fish	LDPE, PPH, PVC, HDPE	0.32-1.4 mm	Fibers, fragments, beads	-	FTIR	(126)
Oysters	China	1.5 to 7.2 items/g	PET, PE, PES, CPVC, PA	0.02-5 mm	Fibers	Transparent, white, green, yellow, blue, brown, black, and red	μ FTIR	(127)
Salt	Spain	50–280 MPs/kg	PET, PE, PP,	30 µm to 3.5 mm	Fiber, fragment, pellet	Black, red, blue, white, and transparent	FTIR	(128)
African table salts	Africa	(0–1.333 MP/kg)	PVA, PP, PE	-	Fiber	-	FTIR SEM	(129)
Salt	Iran-France- Malaysia-south Africa	1–10 items/kg	PE, PET, PS, poly acrylonitrile	0.16–0.98 mm	Fragment, filament, film		µ-Raman	(130)
Bivalves	India	Digestive gland: 22.8-5.6 gill: 29.6-8.5	PP, PE	less than 2 mm	Fibers		Raman	(109)
Oyster	United Arab Emirates	101.2±93.8 MP/Kg found in oysters	-	1.0-2.0 mm	Fibers- fragments	Transparent, black, blue, red, pink, white, and green	ATR-FTIR	(108)
Mussels	Moroccan - Tunisian	Morocco (gills: 1.88 MPs/g ww ⁻¹ ; digestive glands: 0.92 MPs/g ww ⁻¹) Tunisia (gills: 1.47 MPs g^{-1} ; digestive glands: 0.79 MPs g^{-1})	PET, PP, and PE	1000 µm	Fibers	-	ATR-FTIR SEM-EDX	(131)
Fish farming	Brazil	rainy season (286 items mL⁻¹ dry season (58 items mL⁻¹)	-	-	Fibers	Blue- Transparent-red-	Stereoscopic microscope	(110)
Fish	Philippines	0.08 to 2.0 MP/fish	PP-PE- PET	1.6 mm	Fragments	-	Raman	(132)
Fish	Hong Kong	44.0 items	Nylon 66, PE, PP, PS, PE, PMMA		Fibers- fragments		FTIR	(133)
Oysters and mussels	Brazil	44.1 particles⋅g⁻¹	Cellulose-PMMA	1000 µm	Fibers	Transparent-white- black, blue, green, red	FTIR	(134)
Dry fish	Indian	99±18.91 MPs/g	LDPE, PP	<100 µm	Fragments	-	FTIR	(135)

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Numerous studies confirm this statement. For example, in a study conducted on a species of marine mushroom, it was found that the mushroom used polyethylene to grow and reduced its amount. In another study, the Aspergillus flavus PEDX3-degrading fungus was investigated from the intestine of a worm, and within 4 weeks, the fungus was able to degrade HDPE (96,148,149). Limited algae can decompose MPs, although biodegradation by algae is not very effective. However, some algae can decompose lignin and extracellular polysaccharides. Species can decompose blue-green algae, green algae, diatoms, Navicula pular and *Scenedesmus dimorphus*. The future has a promising perspective on plastic degradation by algae (150-153).

Conclusion

This study examined municipal solid waste as a source of MPs emission, which includes landfill waste, sludge, compost, and food waste. Due to the increasing use of plastic in the food packaging industry and factories, there is a possibility of transferring MPs to the environment through the disposal of plastic containers. If these containers are disposed of in landfills, they contribute to the production of MPs in landfills. Landfills can introduce MPs into the environment through leachate. Sludge used in agricultural soils, fertilizers, and compost is another source of MPs release. Sludge, compost, and fertilizer can release MPs into the environment through the soil and food chain, ultimately entering the human body. This systematic review reveals that polyethylene, PP, and fibers and fragments are the most abundant materials in landfills across various countries worldwide.

In addition, MPs are like sponges, absorbing all the toxic substances around them. It can provide a surface for the absorption of toxic metals. Fish and other animals, plants, and agricultural products uptake them and return them right to your dinner plate. However, only limited research has been conducted on MP in solid waste. Therefore, it is necessary to conduct further research and inform the public about this emerging pollutant. There are gaps in these studies; for example, there is no standard for leachate sampling, especially for smaller-sized microplastics. In addition, it is essential to pay attention to the role of microplastics as a carrier of pollutants and a cause of disease in future studies.

Abbreviations

EVA, ethylene vinyl acetate copolymer; HPPE, high-density polyethylene; PAN, polyacrylonitrile; PE, polyethylene; PP, polypropylene; PES, polyester; PET, polyethylene terephthalate; PUR, polyurethane; PS, polystyrene; PVC, Polyvinyl chloride; PMMA, Polymethyl methacrylate; PTFE, polytetrafluoroethylene; PVB, polyvinyl butyral; LDPE, low-density polyethylene; PEAA, polyethyleneco-acrylic acid; PSAN, polystyrene-co-acrylonitrile; PVA, polyvinyl alcohol; PC, polycarbonate.

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Competing interests

The authors declare that they have no conflict of interest.

Ethical issues

There were no ethical issues in writing this article. All authors certify that all data collected during the study are as stated in the manuscript and no data from the study have been or will be published separately elsewhere.

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