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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 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 (“Microplastics”[Mesh])) AND (((“Solid 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

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 mechanical-biological 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

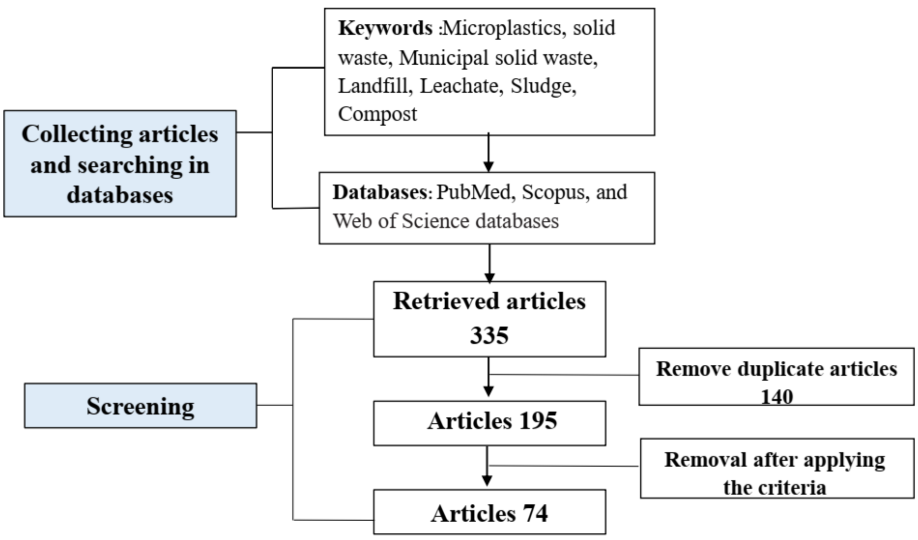

Figure 1. Schematic representation of the articles’ selection and screening processes for this review

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

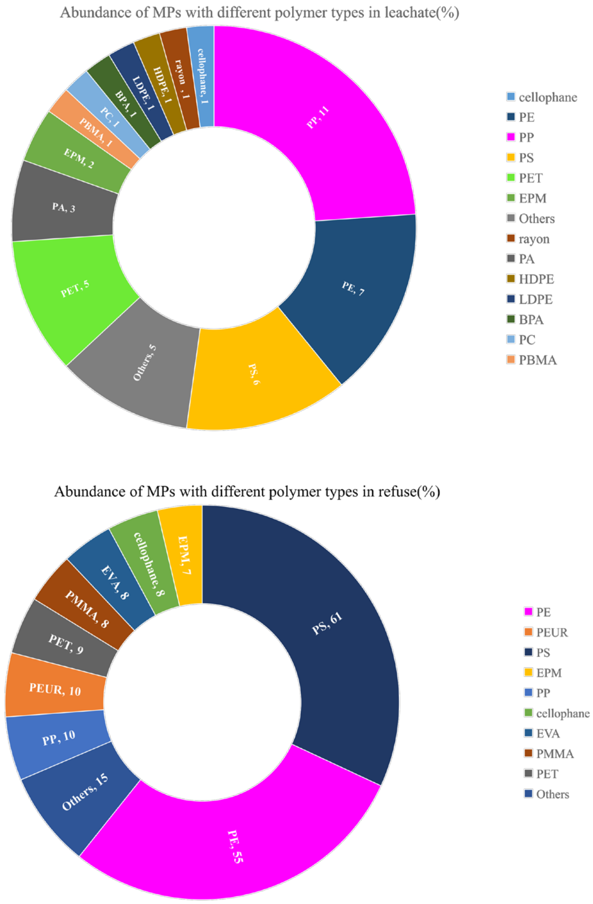

Figure 2. The abundance of MPs with different polymer types in leachate and landfills, as presented in Table 1

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
Sludge	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)
	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)

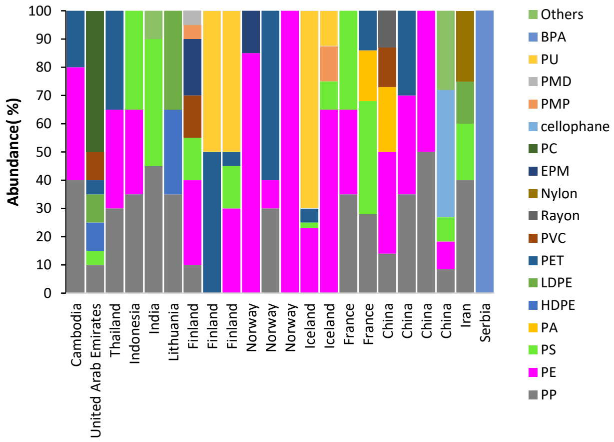

Figure 3. Polymer composition in landfills worldwide, as presented in Table 1

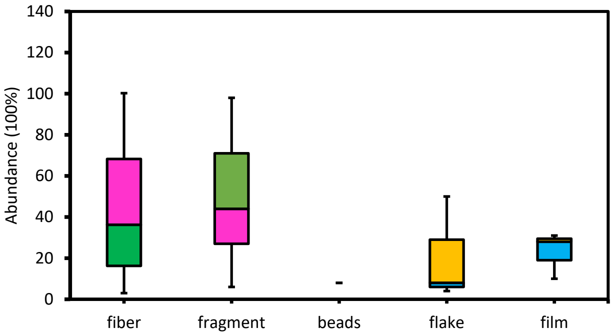

Figure 4. Shapes of MPs in landfills worldwide, as presented in Table 1

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.

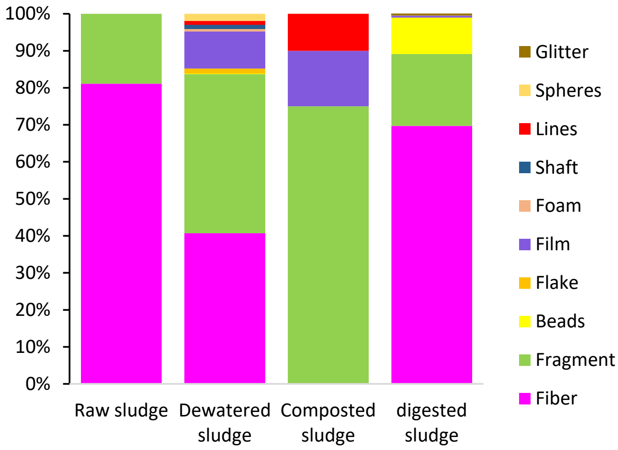

Figure 5. Major shapes of MP particles in different types of sludge (from 19 papers)

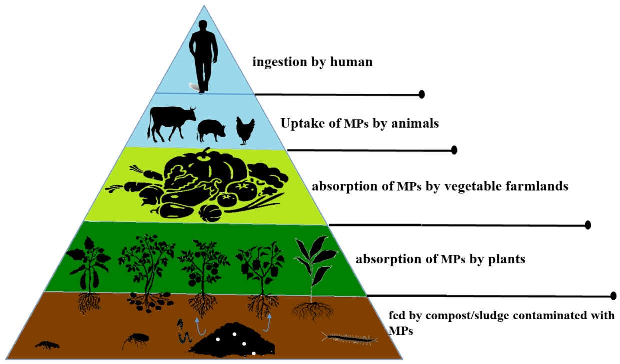

Figure 6. Microplastics in the food chain

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).

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 30 000 items per kilogram with a size of less than 3 mm (97). In 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.

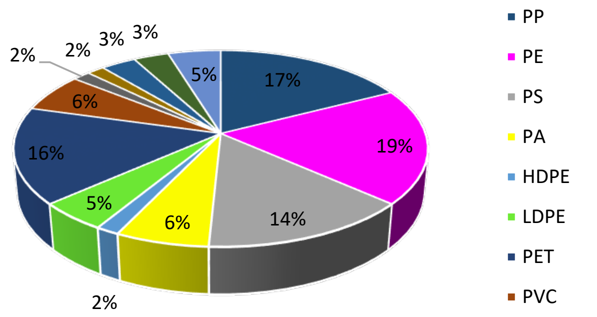

Figure 7. The abundance of MPs with different polymer types in food waste, as shown in Table 2

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)

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, polyethylene-co-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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References

1. Schrama GJ. The internalization of environmental management at GE plastics Europe. In: Environmental Management in European Companies. CRC Press; 1998. p. 219-38.
2. Brahney J, Hallerud M, Heim E, Hahnenberger M, Sukumaran S. Plastic rain in protected areas of the United States. Science. 2020;368(6496):1257-60. doi: 10.1126/science.aaz5819.
3. Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, John AW, et al. Lost at sea: where is all the plastic? Science. 2004;304(5672):838. doi: 10.1126/science.1094559.
4. Cole M, Lindeque P, Halsband C, Galloway TS. Microplastics as contaminants in the marine environment: a review. Mar Pollut Bull. 2011;62(12):2588-97. doi: 10.1016/j.marpolbul.2011.09.025.
5. Horton AA, Walton A, Spurgeon DJ, Lahive E, Svendsen C. Microplastics in freshwater and terrestrial environments: evaluating the current understanding to

identify the knowledge gaps and future research priorities. Sci Total Environ. 2017;586:127-41. doi: 10.1016/j.scitotenv.2017.01.190.
6. Barnes DK, Galgani F, Thompson RC, Barlaz M. Accumulation and fragmentation of plastic debris in global environments. Philos Trans R Soc Lond B Biol Sci. 2009;364(1526):1985-98. doi: 10.1098/rstb.2008.0205.
7. Ryan PG, Moore CJ, van Franeker JA, Moloney CL. Monitoring the abundance of plastic debris in the marine environment. Philos Trans R Soc Lond B Biol Sci. 2009;364(1526):1999-2012. doi: 10.1098/rstb.2008.0207.
8. Su L, Sharp SM, Pettigrove VJ, Craig NJ, Nan B, Du F, et al. Superimposed microplastic pollution in a coastal metropolis. Water Res. 2020;168:115140. doi: 10.1016/j.watres.2019.115140.
9. Jahedi F, Jaafarzadeh Haghighi Fard N, Ahmadi M, Takdastan A, Haddadzadeh Shoushtari M, Dehbandi R, et al. Microplastics in urine, sputum and lung lavage fluid from patients with respiratory illnesses. Environ Res. 2025;274:121278. doi: 10.1016/j.envres.2025.121278.
10. Alimi OS, Farner Budarz J, Hernandez LM, Tufenkji N. Microplastics and nanoplastics in aquatic environments: aggregation, deposition, and enhanced contaminant transport. Environ Sci Technol. 2018;52(4):1704-24. doi: 10.1021/acs.est.7b05559.
11. Klingelhöfer D, Braun M, Quarcoo D, Brüggmann D, Groneberg DA. Research landscape of a global environmental challenge: microplastics. Water Res. 2020;170:115358. doi: 10.1016/j.watres.2019.115358.
12. He P, Chen L, Shao L, Zhang H, Lü F. Municipal solid waste (MSW) landfill: a source of microplastics? -Evidence of microplastics in landfill leachate. Water Res. 2019;159:38-45. doi: 10.1016/j.watres.2019.04.060.
13. Yurtsever M. Glitters as a source of primary microplastics: an approach to environmental responsibility and ethics. J Agric Environ Ethics. 2019;32(3):459-78. doi: 10.1007/s10806-019-09785-0.
14. Yadav V, Sherly MA, Ranjan P, Tinoco RO, Boldrin A, Damgaard A, et al. Framework for quantifying environmental losses of plastics from landfills. Resour Conserv Recycl. 2020;161:104914. doi: 10.1016/j.resconrec.2020.104914.
15. Rist S, Carney Almroth B, Hartmann NB, Karlsson TM. A critical perspective on early communications concerning human health aspects of microplastics. Sci Total Environ. 2018;626:720-6. doi: 10.1016/j.scitotenv.2018.01.092.
16. Wright SL, Kelly FJ. Plastic and human health: a micro issue? Environ Sci Technol. 2017;51(12):6634-47. doi: 10.1021/acs.est.7b00423.
17. Sussarellu R, Suquet M, Thomas Y, Lambert C, Fabioux C, Pernet ME, et al. Oyster reproduction is affected by exposure to polystyrene microplastics. Proc Natl Acad Sci U S A. 2016;113(9):2430-5. doi: 10.1073/pnas.1519019113.
18. Wang F, Wong CS, Chen D, Lu X, Wang F, Zeng EY. Interaction of toxic chemicals with microplastics: a critical review. Water Res. 2018;139:208-19. doi: 10.1016/j.watres.2018.04.003.
19. Karbalaei S, Hanachi P, Walker TR, Cole M. Occurrence, sources, human health impacts and mitigation of microplastic pollution. Environ Sci Pollut Res Int. 2018;25(36):36046-63. doi: 10.1007/s11356-018-3508-7.
20. Prata JC, da Costa JP, Lopes I, Duarte AC, Rocha-Santos T. Environmental exposure to microplastics: an overview on possible human health effects. Sci Total Environ. 2020;702:134455. doi: 10.1016/j.scitotenv.2019.134455.
21. Braun M, Mail M, Heyse R, Amelung W. Plastic in compost: prevalence and potential input into agricultural and horticultural soils. Sci Total Environ. 2021;760:143335. doi: 10.1016/j.scitotenv.2020.143335.
22. Yang Z, Lü F, Zhang H, Wang W, Shao L, Ye J, et al. Is incineration the terminator of plastics and microplastics? J Hazard Mater. 2021;401:123429. doi: 10.1016/j.jhazmat.2020.123429.
23. Hu T, He P, Yang Z, Wang W, Zhang H, Shao L, et al. Emission of airborne microplastics from municipal solid waste transfer stations in downtown. Sci Total Environ. 2022;828:154400. doi: 10.1016/j.scitotenv.2022.154400.
24. Sholokhova A, Denafas G, Mykhaylenko V. Microplastics generation and concentration during mechanical-biological treatment of mixed municipal solid waste. Environ Res. 2022;214(Pt 1):113815. doi: 10.1016/j.envres.2022.113815.
25. Suzuki G, Uchida N, Tuyen LH, Tanaka K, Matsukami H, Kunisue T, et al. Mechanical recycling of plastic waste as a point source of microplastic pollution. Environ Pollut. 2022;303:119114. doi: 10.1016/j.envpol.2022.119114.
26. Gao M, Liu Y, Song Z. Effects of polyethylene microplastic on the phytotoxicity of di-n-butyl phthalate in lettuce (*Lactuca sativa* L. var. *ramosa* Hort). Chemosphere. 2019;237:124482. doi: 10.1016/j.chemosphere.2019.124482.
27. Loppi S, Roblin B, Paoli L, Aherne J. Accumulation of airborne microplastics in lichens from a landfill dumping site (Italy). Sci Rep. 2021;11(1):4564. doi: 10.1038/s41598-021-84251-4.
28. Nika MC, Ntaiou K, Elytis K, Thomaidi VS, Gatidou G, Kalantzi OI, et al. Wide-scope target analysis of emerging contaminants in landfill leachates and risk assessment using risk quotient methodology. J Hazard Mater. 2020;394:122493. doi: 10.1016/j.jhazmat.2020.122493.
29. Propp VR, De Silva AO, Spencer C, Brown SJ, Catingan SD, Smith JE, et al. Organic contaminants of emerging concern in leachate of historic municipal landfills. Environ Pollut. 2021;276:116474. doi: 10.1016/j.envpol.2021.116474.
30. Xu Z, Sui Q, Li A, Sun M, Zhang L, Lyu S, et al. How to detect small microplastics (20-100 μm) in freshwater, municipal wastewaters and landfill leachates? A trial from sampling to identification. Sci Total Environ. 2020;733:139218. doi: 10.1016/j.scitotenv.2020.139218.
31. Su Y, Zhang Z, Wu D, Zhan L, Shi H, Xie B. Occurrence of microplastics in landfill systems and their fate with landfill age. Water Res. 2019;164:114968. doi: 10.1016/j.watres.2019.114968.
32. Nizzetto L, Futter M, Langaas S. Are agricultural soils dumps for microplastics of urban origin? Environ Sci Technol. 2016;50(20):10777-9. doi: 10.1021/acs.est.6b04140.
33. Kilponen J. Microplastics and Harmful Substances in Urban Runoffs and Landfill Leachates: Possible Emission Sources to Marine Environment. Lahti University of Applied Sciences; 2016.
34. Tun TZ, Kunisue T, Tanabe S, Prudente M, Subramanian A, Sudaryanto A, et al. Microplastics in dumping site soils from six Asian countries as a source of plastic additives. Sci Total Environ. 2022;806(Pt 4):150912. doi: 10.1016/j.scitotenv.2021.150912.
35. Kabir MS, Wang H, Luster-Teasley S, Zhang L, Zhao R. Microplastics in landfill leachate: Sources, detection, occurrence, and removal. Environ Sci Ecotechnol.

2023;16:100256. doi: 10.1016/j.ese.2023.100256.

36. Xu Q, Gao Y, Xu L, Shi W, Wang F, LeBlanc GA, et al. Investigation of the microplastics profile in sludge from China's largest water reclamation plant using a feasible isolation device. J Hazard Mater. 2020;388:122067. doi: 10.1016/j.jhazmat.2020.122067.
37. Mahon AM, O'Connell B, Healy MG, O'Connor I, Officer R, Nash R, et al. Microplastics in sewage sludge: effects of treatment. Environ Sci Technol. 2017;51(2):810-8. doi: 10.1021/acs.est.6b04048.
38. Magni S, Binelli A, Pittura L, Avio CG, Della Torre C, Parenti CC, et al. The fate of microplastics in an Italian wastewater treatment plant. Sci Total Environ. 2019;652:602-10. doi: 10.1016/j.scitotenv.2018.10.269.
39. Corradini F, Meza P, Eguiluz R, Casado F, Huerta-Lwanga E, Geissen V. Evidence of microplastic accumulation in agricultural soils from sewage sludge disposal. Sci Total Environ. 2019;671:411-20. doi: 10.1016/j.scitotenv.2019.03.368.
40. Magnusson K, Norén F. Screening of Microplastic Particles in and Down-Stream a Wastewater Treatment Plant. Swedish Environmental Research Institute; 2014.
41. Zhang J, Wang L, Halden RU, Kannan K. Polyethylene terephthalate and polycarbonate microplastics in sewage sludge collected from the United States. Environ Sci Technol Lett. 2019;6(11):650-5. doi: 10.1021/acs.estlett.9b00601.
42. Zhang L, Liu J, Xie Y, Zhong S, Gao P. Occurrence and removal of microplastics from wastewater treatment plants in a typical tourist city in China. J Clean Prod. 2021;291:125968. doi: 10.1016/j.jclepro.2021.125968.
43. Li X, Chen L, Mei Q, Dong B, Dai X, Ding G, et al. Microplastics in sewage sludge from the wastewater treatment plants in China. Water Res. 2018;142:75-85. doi: 10.1016/j.watres.2018.05.034.
44. Yang L, Li K, Cui S, Kang Y, An L, Lei K. Removal of microplastics in municipal sewage from China's largest water reclamation plant. Water Res. 2019;155:175-81. doi: 10.1016/j.watres.2019.02.046.
45. Liu X, Yuan W, Di M, Li Z, Wang J. Transfer and fate of microplastics during the conventional activated sludge process in one wastewater treatment plant of China. Chem Eng J. 2019;362:176-82. doi: 10.1016/j.cej.2019.01.033.
46. Wiśniowska E, Moraczewska-Majkut K, Nocoń W. Efficiency of microplastics removal in selected wastewater treatment plants–preliminary studies. Desalin Water Treat. 2018;134:316-23. doi: 10.5004/dwt.2018.23418.
47. Carr SA, Liu J, Tesoro AG. Transport and fate of microplastic particles in wastewater treatment plants. Water Res. 2016;91:174-82. doi: 10.1016/j.watres.2016.01.002.
48. Gies EA, LeNoble JL, Noël M, Etemadifar A, Bishay F, Hall ER, et al. Retention of microplastics in a major secondary wastewater treatment plant in Vancouver, Canada. Mar Pollut Bull. 2018;133:553-61. doi: 10.1016/j.marpolbul.2018.06.006.
49. Mintenig SM, Int-Veen I, Löder MGJ, Primpke S, Gerdts G. Identification of microplastic in effluents of waste water treatment plants using focal plane array-based micro-Fourier-transform infrared imaging. Water Res. 2017;108:365-72. doi: 10.1016/j.watres.2016.11.015.
50. Lares M, Ncibi MC, Sillanpää M, Sillanpää M. Occurrence, identification and removal of microplastic particles and fibers in conventional activated sludge process and advanced MBR technology. Water Res. 2018;133:236-46. doi: 10.1016/j.watres.2018.01.049.
51. Wei Z, Shen W, Feng K, Feng Y, He Z, Li Y, et al. Organic fertilizer potentiates the transfer of typical antibiotic resistance gene among special bacterial species. J Hazard Mater. 2022;435:128985. doi: 10.1016/j.jhazmat.2022.128985.
52. Yuan F, Zhao H, Sun H, Sun Y, Zhao J, Xia T. Investigation of microplastics in sludge from five wastewater treatment plants in Nanjing, China. J Environ Manage. 2022;301:113793. doi: 10.1016/j.jenvman.2021.113793.
53. Wan X, Huang H, Liao Z, He H, Yue Q, Zhao F, et al. The distribution and risk of microplastics discharged from sewage treatment plants in terrestrial and aquatic compartment. J Environ Manage. 2022;314:115067. doi: 10.1016/j.jenvman.2022.115067.
54. Li L, Geng S, Li Z, Song K. Effect of microplastic on anaerobic digestion of wasted activated sludge. Chemosphere. 2020;247:125874. doi: 10.1016/j.chemosphere.2020.125874.
55. Pittura L, Foglia A, Akyol Ç, Cipolletta G, Benedetti M, Regoli F, et al. Microplastics in real wastewater treatment schemes: comparative assessment and relevant inhibition effects on anaerobic processes. Chemosphere. 2021;262:128415. doi: 10.1016/j.chemosphere.2020.128415.
56. Ziajahromi S, Neale PA, Telles Silveira I, Chua A, Leusch FD. An audit of microplastic abundance throughout three Australian wastewater treatment plants. Chemosphere. 2021;263:128294. doi: 10.1016/j.chemosphere.2020.128294.
57. Lee H, Kim Y. Treatment characteristics of microplastics at biological sewage treatment facilities in Korea. Mar Pollut Bull. 2018;137:1-8. doi: 10.1016/j.marpolbul.2018.09.050.
58. Murphy F, Ewins C, Carbonnier F, Quinn B. Wastewater treatment works (WwTW) as a source of microplastics in the aquatic environment. Environ Sci Technol. 2016;50(11):5800-8. doi: 10.1021/acs.est.5b05416.
59. Edo C, Fernández-Piñas F, Rosal R. Microplastics identification and quantification in the composted organic fraction of municipal solid waste. Sci Total Environ. 2022;813:151902. doi: 10.1016/j.scitotenv.2021.151902.
60. Gajšt T, Bizjak T, Palatinus A, Liubartseva S, Kržan A. Sea surface microplastics in Slovenian part of the Northern Adriatic. Mar Pollut Bull. 2016;113(1-2):392-9. doi: 10.1016/j.marpolbul.2016.10.031.
61. Zhang J, Wang X, Xue W, Xu L, Ding W, Zhao M, et al. Microplastics pollution in soil increases dramatically with long-term application of organic composts in a wheat–maize rotation. J Clean Prod. 2022;356:131889. doi: 10.1016/j.jclepro.2022.131889.
62. Vithanage M, Ramanayaka S, Hasinthara S, Navaratne A. Compost as a carrier for microplastics and plastic-bound toxic metals into agroecosystems. Curr Opin Environ Sci Health. 2021;24:100297. doi: 10.1016/j.coesh.2021.100297.
63. Cui G, Lü F, Hu T, Zhang H, Shao L, He P. Vermicomposting leads to more abundant microplastics in the municipal excess sludge. Chemosphere. 2022;307(Pt 3):136042. doi: 10.1016/j.chemosphere.2022.136042.
64. Zhang S, Li Y, Chen X, Jiang X, Li J, Yang L, et al. Occurrence and distribution of microplastics in organic fertilizers in China. Sci Total Environ. 2022;844:157061. doi: 10.1016/j.scitotenv.2022.157061.
65. Gui J, Sun Y, Wang J, Chen X, Zhang S, Wu D. Microplastics in composting of rural domestic waste: abundance, characteristics, and release from the surface of macroplastics. Environ Pollut. 2021;274:116553. doi:

10.1016/j.envpol.2021.116553.
66. Fakour H, Lo SL, Yoashi NT, Massao AM, Lema NN, Mkhontfo FB, et al. Quantification and analysis of microplastics in farmland soils: characterization, sources, and pathways. Agriculture. 2021;11(4):330. doi: 10.3390/agriculture11040330.
67. Wu RT, Cai YF, Chen YX, Yang YW, Xing SC, Liao XD. Occurrence of microplastic in livestock and poultry manure in South China. Environ Pollut. 2021;277:116790. doi: 10.1016/j.envpol.2021.116790.
68. Yang J, Li L, Li R, Xu L, Shen Y, Li S, et al. Microplastics in an agricultural soil following repeated application of three types of sewage sludge: a field study. Environ Pollut. 2021;289:117943. doi: 10.1016/j.envpol.2021.117943.
69. Huerta Lwanga E, Mendoza Vega J, Ku Quej V, de Los Angeles Chi J, Sanchez Del Cid L, Chi C, et al. Field evidence for transfer of plastic debris along a terrestrial food chain. Sci Rep. 2017;7(1):14071. doi: 10.1038/s41598-017-14588-2 .
70. Scopetani C, Chelazzi D, Cincinelli A, Martellini T, Leiniö V, Pellinen J. Hazardous contaminants in plastics contained in compost and agricultural soil. Chemosphere. 2022;293:133645. doi: 10.1016/j.chemosphere.2022.133645.
71. Schwinghammer L, Krause S, Schaum C. Determination of large microplastics: wet-sieving of dewatered digested sludge, co-substrates, and compost. Water Sci Technol. 2021;84(2):384-92. doi: 10.2166/wst.2020.582.
72. van Schothorst B, Beriot N, Huerta Lwanga E, Geissen V. Sources of light density microplastic related to two agricultural practices: the use of compost and plastic mulch. Environments. 2021;8(4):36. doi: 10.3390/environments8040036.
73. Wan Y, Chen X, Liu Q, Hu H, Wu C, Xue Q. Informal landfill contributes to the pollution of microplastics in the surrounding environment. Environ Pollut. 2022;293:118586. doi: 10.1016/j.envpol.2021.118586.
74. Kazour M, Jemaa S, Issa C, Khalaf G, Amara R. Microplastics pollution along the Lebanese coast (Eastern Mediterranean Basin): occurrence in surface water, sediments and biota samples. Sci Total Environ. 2019;696:133933. doi: 10.1016/j.scitotenv.2019.133933.
75. Mortula MM, Atabay S, Fattah KP, Madbuly A. Leachability of microplastic from different plastic materials. J Environ Manage. 2021;294:112995. doi: 10.1016/j.jenvman.2021.112995.
76. Puthcharoen A, Leungprasert S. Determination of microplastics in soil and leachate from the landfills. Thai Environ Eng J. 2019;33(3):39-46.
77. Narevski AC, Novaković MI, Petrović MZ, Mihajlović IJ, Maoduš NB, Vujić GV. Occurrence of bisphenol A and microplastics in landfill leachate: lessons from South East Europe. Environ Sci Pollut Res Int. 2021;28(31):42196-203. doi: 10.1007/s11356-021-13705-z.
78. Nurhasanah, Cordova MR, Riani E. Micro- and mesoplastics release from the Indonesian municipal solid waste landfill leachate to the aquatic environment: case study in Galuga landfill area, Indonesia. Mar Pollut Bull. 2021;163:111986. doi: 10.1016/j.marpolbul.2021.111986.
79. Mohammadi A, Malakootian M, Dobaradaran S, Hashemi M, Jaafarzadeh N. Occurrence, seasonal distribution, and ecological risk assessment of microplastics and phthalate esters in leachates of a landfill site located near the marine environment: Bushehr port, Iran as a case. Sci Total Environ. 2022;842:156838. doi: 10.1016/j.scitotenv.2022.156838.
80. Ghorbaninejad Fard Shirazi MM, Shekoohiyan S, Moussavi G, Heidari M. Microplastics and mesoplastics as emerging contaminants in Tehran landfill soils: the distribution and induced-ecological risk. Environ Pollut. 2023;324:121368. doi: 10.1016/j.envpol.2023.121368.
81. Sun J, Zhu ZR, Li WH, Yan X, Wang LK, Zhang L, et al. Revisiting microplastics in landfill leachate: unnoticed tiny microplastics and their fate in treatment works. Water Res. 2021;190:116784. doi: 10.1016/j.watres.2020.116784.
82. Zhang Z, Su Y, Zhu J, Shi J, Huang H, Xie B. Distribution and removal characteristics of microplastics in different processes of the leachate treatment system. Waste Manag. 2021;120:240-7. doi: 10.1016/j.wasman.2020.11.025.
83. Manikanda Bharath K, Natesan U, Vaikunth R, Praveen Kumar R, Ruthra R, Srinivasalu S. Spatial distribution of microplastic concentration around landfill sites and its potential risk on groundwater. Chemosphere. 2021;277:130263. doi: 10.1016/j.chemosphere.2021.130263.
84. Kazour M, Terki S, Rabhi K, Jemaa S, Khalaf G, Amara R. Sources of microplastics pollution in the marine environment: importance of wastewater treatment plant and coastal landfill. Mar Pollut Bull. 2019;146:608-18. doi: 10.1016/j.marpolbul.2019.06.066.
85. Sholokhova A, Ceponkus J, Sablinskas V, Denafas G. Abundance and characteristics of microplastics in treated organic wastes of Kaunas and Alytus regional waste management centres, Lithuania. Environ Sci Pollut Res Int. 2022;29(14):20665-74. doi: 10.1007/s11356-021-17378-6.
86. Ziajahromi S, Neale PA, Rintoul L, Leusch FD. Wastewater treatment plants as a pathway for microplastics: development of a new approach to sample wastewater-based microplastics. Water Res. 2017;112:93-9. doi: 10.1016/j.watres.2017.01.042.
87. Ziajahromi S, Neale PA, Leusch FD. Wastewater treatment plant effluent as a source of microplastics: review of the fate, chemical interactions and potential risks to aquatic organisms. Water Sci Technol. 2016;74(10):2253-69. doi: 10.2166/wst.2016.414.
88. Sun B, Hu Y, Cheng H, Tao S. Releases of brominated flame retardants (BFRs) from microplastics in aqueous medium: Kinetics and molecular-size dependence of diffusion. Water Res. 2019;151:215-25. doi: 10.1016/j.watres.2018.12.017.
89. Zhang GS, Zhang FX, Li XT. Effects of polyester microfibers on soil physical properties: perception from a field and a pot experiment. Sci Total Environ. 2019;670:1-7. doi: 10.1016/j.scitotenv.2019.03.149.
90. Kabir A, Sekine M, Imai T, Yamamoto K, Kanno A, Higuchi T. Microplastics in the sediments of small-scale Japanese rivers: abundance and distribution, characterization, sources-to-sink, and ecological risks. Sci Total Environ. 2022;812:152590. doi: 10.1016/j.scitotenv.2021.152590.
91. Stenger KS, Wikmark OG, Bezuidenhout CC, Molale-Tom LG. Microplastics pollution in the ocean: potential carrier of resistant bacteria and resistance genes. Environ Pollut. 2021;291:118130. doi: 10.1016/j.envpol.2021.118130.
92. He D, Zhang Y, Gao W. Micro(nano)plastic contaminations from soils to plants: human food risks. Curr Opin Food Sci. 2021;41:116-21. doi: 10.1016/j.cofs.2021.04.001.
93. Li Z, Li R, Li Q, Zhou J, Wang G. Physiological response of cucumber (*Cucumis sativus* L.) leaves to polystyrene nanoplastics pollution. Chemosphere. 2020;255:127041. doi: 10.1016/j.chemosphere.2020.127041.

94. Huang Y, Liu Q, Jia W, Yan C, Wang J. Agricultural plastic mulching as a source of microplastics in the terrestrial environment. Environ Pollut. 2020;260:114096. doi: 10.1016/j.envpol.2020.114096.
95. de Souza Machado AA, Lau CW, Kloas W, Bergmann J, Bachelier JB, Faltin E, et al. Microplastics can change soil properties and affect plant performance. Environ Sci Technol. 2019;53(10):6044-52. doi: 10.1021/acs.est.9b01339.
96. Liu M, Lu S, Song Y, Lei L, Hu J, Lv W, et al. Microplastic and mesoplastic pollution in farmland soils in suburbs of Shanghai, China. Environ Pollut. 2018;242(Pt A):855-62. doi: 10.1016/j.envpol.2018.07.051.
97. Sun Y, Ren X, Rene ER, Wang Z, Zhou L, Zhang Z, et al. The degradation performance of different microplastics and their effect on microbial community during composting process. Bioresour Technol. 2021;332:125133. doi: 10.1016/j.biortech.2021.125133.
98. Hu HW, Chen QL, He JZ. The end of hunger: fertilizers, microbes and plant productivity. Microb Biotechnol. 2022;15(4):1050-4. doi: 10.1111/1751-7915.13973.
99. Paul-Pont I, Lacroix C, González Fernández C, Hégaret H, Lambert C, Le Goïc N, et al. Exposure of marine mussels Mytilus spp. to polystyrene microplastics: toxicity and influence on fluoranthene bioaccumulation. Environ Pollut. 2016;216:724-37. doi: 10.1016/j.envpol.2016.06.039.
100. Green DS. Effects of microplastics on European flat oysters, *Ostrea edulis* and their associated benthic communities. Environ Pollut. 2016;216:95-103. doi: 10.1016/j.envpol.2016.05.043.
101. Arossa S, Martin C, Rossbach S, Duarte CM. Microplastic removal by Red Sea giant clam (*Tridacna maxima*). Environ Pollut. 2019;252(Pt B):1257-66. doi: 10.1016/j.envpol.2019.05.149.
102. Brennecke D, Ferreira EC, Costa TM, Appel D, da Gama BA, Lenz M. Ingested microplastics (>100 μm) are translocated to organs of the tropical fiddler crab *Uca rapax*. Mar Pollut Bull. 2015;96(1-2):491-5. doi: 10.1016/j.marpolbul.2015.05.001.
103. Watts AJ, Urbina MA, Goodhead R, Moger J, Lewis C, Galloway TS. Effect of microplastic on the gills of the shore crab *Carcinus maenas*. Environ Sci Technol. 2016;50(10):5364-9. doi: 10.1021/acs.est.6b01187.
104. Oliveri Conti G, Ferrante M, Banni M, Favara C, Nicolosi I, Cristaldi A, et al. Micro- and nano-plastics in edible fruit and vegetables. The first diet risks assessment for the general population. Environ Res. 2020;187:109677. doi: 10.1016/j.envres.2020.109677.
105. Hosseinpour A, Chamani A, Mirzaei R, Mohebbi-Nozar SL. Occurrence, abundance and characteristics of microplastics in some commercial fish of northern coasts of the Persian Gulf. Marine Pollution Bulletin. 2021;171:112693. doi:10.1016/j.marpolbul.2021.112693.
106. Li J, Qu X, Su L, Zhang W, Yang D, Kolandhasa.my P, et al. Microplastics in mussels along the coastal waters of China. Environ Pollut. 2016;214:177-84. doi: 10.1016/j.envpol.2016.04.012.
107. De Witte B, Devriese L, Bekaert K, Hoffman S, Vandermeersch G, Cooreman K, et al. Quality assessment of the blue mussel (*Mytilus edulis*): comparison between commercial and wild types. Mar Pollut Bull. 2014;85(1):146-55. doi: 10.1016/j.marpolbul.2014.06.006.
108. Van Cauwenberghe L, Janssen CR. Microplastics in bivalves cultured for human consumption. Environ Pollut. 2014;193:65-70. doi: 10.1016/j.envpol.2014.06.010.
109. Al Hammadi M, Knuteson S, Kanan S, Samara F. Microplastic pollution in oyster bed ecosystems: an assessment of the northern shores of the United Arab Emirates. Environ Adv. 2022;8:100214. doi: 10.1016/j.envadv.2022.100214.
110. Joshy A, Krupesha Sharma SR, Mini KG. Microplastic contamination in commercially important bivalves from the southwest coast of India. Environ Pollut. 2022;305:119250. doi: 10.1016/j.envpol.2022.119250.
111. Vieira Dantas Filho J, Perez Pedroti V, Temponi Santos BL, de Lima Pinheiro MM, Bezerra de Mira Á, Carlos da Silva F, et al. First evidence of microplastics in freshwater from fish farms in Rondônia state, Brazil. Heliyon. 2023;9(4):e15066. doi: 10.1016/j.heliyon.2023.e15066.
112. Su L, Cai H, Kolandhasamy P, Wu C, Rochman CM, Shi H. Using the Asian clam as an indicator of microplastic pollution in freshwater ecosystems. Environ Pollut. 2018;234:347-55. doi: 10.1016/j.envpol.2017.11.075.
113. Avio CG, Gorbi S, Milan M, Benedetti M, Fattorini D, d'Errico G, et al. Pollutants bioavailability and toxicological risk from microplastics to marine mussels. Environ Pollut. 2015;198:211-22. doi: 10.1016/j.envpol.2014.12.021.
114. Mühlschlegel P, Hauk A, Walter U, Sieber R. Lack of evidence for microplastic contamination in honey. Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 2017;34(11):1982-9. doi: 10.1080/19440049.2017.1347281.
115. Kedzierski M, Lechat B, Sire O, Le Maguer G, Le Tilly V, Bruzaud S. Microplastic contamination of packaged meat: occurrence and associated risks. Food Packag Shelf Life. 2020;24:100489. doi: 10.1016/j.fpsl.2020.100489.
116. Daniel DB, Ashraf PM, Thomas SN. Abundance, characteristics and seasonal variation of microplastics in Indian white shrimps (*Fenneropenaeus indicus*) from coastal waters off Cochin, Kerala, India. Sci Total Environ. 2020;737:139839. doi: 10.1016/j.scitotenv.2020.139839.
117. Akhbarizadeh R, Dobaradaran S, Nabipour I, Tajbakhsh S, Darabi AH, Spitz J. Abundance, composition, and potential intake of microplastics in canned fish. Mar Pollut Bull. 2020;160:111633. doi: 10.1016/j.marpolbul.2020.111633.
118. Halstead JE, Smith JA, Carter EA, Lay PA, Johnston EL. Assessment tools for microplastics and natural fibres ingested by fish in an urbanised estuary. Environ Pollut. 2018;234:552-61. doi: 10.1016/j.envpol.2017.11.085.
119. Bessa F, Barría P, Neto JM, Frias J, Otero V, Sobral P, et al. Occurrence of microplastics in commercial fish from a natural estuarine environment. Mar Pollut Bull. 2018;128:575-84. doi: 10.1016/j.marpolbul.2018.01.044.
120. Lusher AL, McHugh M, Thompson RC. Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Mar Pollut Bull. 2013;67(1-2):94-9. doi: 10.1016/j.marpolbul.2012.11.028.
121. Karami A, Golieskardi A, Ho YB, Larat V, Salamatinia B. Microplastics in eviscerated flesh and excised organs of dried fish. Sci Rep. 2017;7(1):5473. doi: 10.1038/s41598-017-05828-6.
122. Rummel CD, Löder MG, Fricke NF, Lang T, Griebeler EM, Janke M, et al. Plastic ingestion by pelagic and demersal fish from the North Sea and Baltic Sea. Mar Pollut Bull. 2016;102(1):134-41. doi: 10.1016/j.marpolbul.2015.11.043.
123. Baalkhuyur FM, Bin Dohaish EA, Elhalwagy ME, Alikunhi NM, AlSuwailem AM, Røstad A, et al. Microplastic in the gastrointestinal tract of fishes along the Saudi Arabian Red

Sea coast. Mar Pollut Bull. 2018;131(Pt A):407-15. doi: 10.1016/j.marpolbul.2018.04.040.
124. Tanaka K, Takada H. Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. Sci Rep. 2016;6:34351. doi: 10.1038/srep34351.
125. Compa M, Ventero A, Iglesias M, Deudero S. Ingestion of microplastics and natural fibres in *Sardina pilchardus* (Walbaum, 1792) and *Engraulis encrasicolus* (Linnaeus, 1758) along the Spanish Mediterranean coast. Mar Pollut Bull. 2018;128:89-96. doi: 10.1016/j.marpolbul.2018.01.009.
126. Campbell SH, Williamson PR, Hall BD. Microplastics in the gastrointestinal tracts of fish and the water from an urban prairie creek. Facets. 2017;2(1):395-409. doi: 10.1139/facets-2017-0008.
127. Li HX, Ma LS, Lin L, Ni ZX, Xu XR, Shi HH, et al. Microplastics in oysters *Saccostrea cucullata* along the Pearl River estuary, China. Environ Pollut. 2018;236:619-25. doi: 10.1016/j.envpol.2018.01.083.
128. Iñiguez ME, Conesa JA, Fullana A. Microplastics in Spanish table salt. Sci Rep. 2017;7(1):8620. doi: 10.1038/s41598-017-09128-x.
129. Fadare OO, Okoffo ED, Olasehinde EF. Microparticles and microplastics contamination in African table salts. Mar Pollut Bull. 2021;164:112006. doi: 10.1016/j.marpolbul.2021.112006.
130. Karami A, Golieskardi A, Keong Choo C, Larat V, Galloway TS, Salamatinia B. The presence of microplastics in commercial salts from different countries. Sci Rep. 2017;7:46173. doi: 10.1038/srep46173.
131. Abelouah MR, Romdhani I, Ben-Haddad M, Hajji S, De-la-Torre GE, Gaaied S, et al. Binational survey using *Mytilus galloprovincialis* as a bioindicator of microplastic pollution: insights into chemical analysis and potential risk on humans. Sci Total Environ. 2023;870:161894. doi: 10.1016/j.scitotenv.2023.161894.
132. Espiritu EQ, Rodolfo RS, Evangelista SM, Feliciano JJG, Sumaway AM, Pauco JLR, et al. Microplastics contamination in the fishes of selected sites in Pasig River and Marikina River in the Philippines. Mar Pollut Bull. 2023;187:114573. doi: 10.1016/j.marpolbul.2023.114573.
133. Lo HS, Wong LC, Lai KP, Cheung SG. The influences of spatial-temporal variability and ecological drivers on microplastic in marine fish in Hong Kong. Environ Pollut. 2023;327:121527. doi: 10.1016/j.envpol.2023.121527.
134. Ribeiro VV, Nobre CR, Moreno BB, Semensatto D, Sanz-Lazaro C, Moreira LB, et al. Oysters and mussels as equivalent sentinels of microplastics and natural particles in coastal environments. Sci Total Environ. 2023;874:162468. doi: 10.1016/j.scitotenv.2023.162468.
135. Rukmangada R, Naidu BC, Nayak BB, Balange A, Chouksey MK, Xavier KA. Microplastic contamination in salted and sun-dried fish and implications for food security - a study on the effect of location, style and constituents of dried fish on microplastics load. Mar Pollut Bull. 2023;191:114909. doi: 10.1016/j.marpolbul.2023.114909.
136. Mehmood T, Gaurav GK, Cheng L, Klemeš JJ, Usman M, Bokhari A, et al. A review on plant-microbial interactions, functions, mechanisms and emerging trends in bioretention system to improve multi-contaminated stormwater treatment. J Environ Manage. 2021;294:113108. doi: 10.1016/j.jenvman.2021.113108.
137. Delacuvellerie A, Cyriaque V, Gobert S, Benali S, Wattiez R. The plastisphere in marine ecosystem hosts potential specific microbial degraders including *Alcanivorax borkumensis* as a key player for the low-density polyethylene degradation. J Hazard Mater. 2019;380:120899. doi: 10.1016/j.jhazmat.2019.120899.
138. Singh L, Wahid ZA. Methods for enhancing bio-hydrogen production from biological process: a review. J Ind Eng Chem. 2015;21:70-80. doi: 10.1016/j.jiec.2014.05.035.
139. Taniguchi I, Yoshida S, Hiraga K, Miyamoto K, Kimura Y, Oda K. Biodegradation of PET: current status and application aspects. ACS Catal. 2019;9(5):4089-105. doi: 10.1021/acscatal.8b05171.
140. Zhang Y, Kang S, Allen S, Allen D, Gao T, Sillanpää M. Atmospheric microplastics: a review on current status and perspectives. Earth Sci Rev. 2020;203:103118. doi: 10.1016/j.earscirev.2020.103118.
141. Matjašič T, Simčič T, Medvešček N, Bajt O, Dreo T, Mori N. Critical evaluation of biodegradation studies on synthetic plastics through a systematic literature review. Sci Total Environ. 2021;752:141959. doi: 10.1016/j.scitotenv.2020.141959.
142. Kim HR, Lee HM, Yu HC, Jeon E, Lee S, Li J, et al. Biodegradation of polystyrene by *Pseudomonas* sp. isolated from the gut of superworms (Larvae of *Zophobas atratus*). Environ Sci Technol. 2020;54(11):6987-96. doi: 10.1021/acs.est.0c01495.
143. Jaafarzadeh Haghighi Fard N, Jahedi F, Dehdarirad H. The possibility of microplastic removal by earthworms and comparing with conventional chemical removal methods (a global and deeply systematic review). J Polym Environ. 2023;31(12):5050-64. doi: 10.1007/s10924-023-02954-3.
144. Auta HS, Emenike CU, Jayanthi B, Fauziah SH. Growth kinetics and biodeterioration of polypropylene microplastics by *Bacillus* sp. and *Rhodococcus* sp. isolated from mangrove sediment. Mar Pollut Bull. 2018;127:15-21. doi: 10.1016/j.marpolbul.2017.11.036.
145. Peng BY, Chen Z, Chen J, Yu H, Zhou X, Criddle CS, et al. Biodegradation of polyvinyl chloride (PVC) in *Tenebrio molitor* (Coleoptera: Tenebrionidae) larvae. Environ Int. 2020;145:106106. doi: 10.1016/j.envint.2020.106106.
146. Song Y, Qiu R, Hu J, Li X, Zhang X, Chen Y, et al. Biodegradation and disintegration of expanded polystyrene by land snails *Achatina fulica*. Sci Total Environ. 2020;746:141289. doi: 10.1016/j.scitotenv.2020.141289.
147. Ibrahim S, Gupta RK, War AR, Hussain B, Kumar A, Sofi T, et al. Degradation of chlorpyriphos and polyethylene by endosymbiotic bacteria from citrus mealybug. Saudi J Biol Sci. 2021;28(6):3214-24. doi: 10.1016/j.sjbs.2021.03.058.
148. Paço A, Duarte K, da Costa JP, Santos PS, Pereira R, Pereira ME, et al. Biodegradation of polyethylene microplastics by the marine fungus *Zalerion maritimum*. Sci Total Environ. 2017;586:10-5. doi: 10.1016/j.scitotenv.2017.02.017.
149. Sánchez C. Fungal potential for the degradation of petroleum-based polymers: an overview of macro- and microplastics biodegradation. Biotechnol Adv. 2020;40:107501. doi: 10.1016/j.biotechadv.2019.107501.
150. Chia WY, Ying Tang DY, Khoo KS, Kay Lup AN, Chew KW. Nature's fight against plastic pollution: algae for plastic biodegradation and bioplastics production. Environ Sci Ecotechnol. 2020;4:100065. doi: 10.1016/j.ese.2020.100065.
151. Tang DY, Khoo KS, Chew KW, Tao Y, Ho SH, Show PL. Potential utilization of bioproducts from microalgae for the quality enhancement of natural products. Bioresour Technol.

2020;304:122997. doi: 10.1016/j.biortech.2020.122997.
152. Sarmah P, Rout J. Efficient biodegradation of low-density polyethylene by cyanobacteria isolated from submerged polyethylene surface in domestic sewage water. Environ Sci Pollut Res Int. 2018;25(33):33508-20. doi: 10.1007/s11356-018-3079-7.
153. Khoironi A, Anggoro S, Sudarno. Evaluation of the interaction among microalgae *Spirulina* sp, plastics polyethylene terephthalate and polypropylene in freshwater environment. J Ecol Eng. 2019;20(6):161-73. doi: 10.12911/22998993/108637.