Microplastics: Pollution of the Modern World

Milad Sheydaei *

Department of Chemical Engineering, Faculty of Engineering, University of Garmsar, Garmsar, Iran

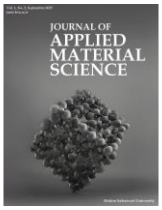
Editor's note: Microplastics, due to their small size and lightweight nature, have raised significant health concerns in recent years. They can influence our lives both directly and indirectly, making responsible management of plastic waste more important than ever. In this invited mini-review, Sheydaei discusses microplastic pollution and its sources, as well as the effects of microplastics on marine organisms.

doi: 10.22034/jams.2025.210143

How to cite: M. Sheydaei. *Journal of Applied Material Science*, **2025**, *1*, 210143.

JOURNAL OF
APPLIED
MATERIAL
SCIENCE
jams.hsu.ac.ir

Journal of Applied Material Science **2025**, *1*, 210143
How to cite: M. Sheydaei, *Journal of Applied Material Science*, **2025**, *1*, 210143.
Journal homepage: **jams.hsu.ac.ir**



Invited Review

Microplastics: Pollution of the Modern World

Milad Sheydaei *

Department of Chemical Engineering, Faculty of Engineering, University of Garmsar, Garmsar, Iran

Abstract

With the progress of industry and economy in societies, unfortunately, we are witnessing more pollution of the environment every day. It is believed that the progress of science and industry will bring comfort to the inhabitants of the Earth, but in reality, we are witnessing increasing pollution in many areas. Among all the pollutants, for several decades, humans have been causing a new pollution, and that is microplastics. Simply put, plastic particles smaller than 5 mm are called microplastics. They can be found everywhere, and, unfortunately, they have a long shelf life and high stability, so they slowly degrade. They have a high potential for fragmentation, which is why they are constantly decreasing in size, and this increases the scope of pollution. Also, they absorb many pollutants and can be considered as carriers of other pollutants. Microplastics easily accumulate in many organisms through ingestion and breathing, leading to physical damage. However, many of them contain chemical additives and can cause toxic effects. This review paper discusses microplastic pollution and its sources. The effects of microplastics on marine organisms are also addressed.

Keywords: Environmental pollution; Removal method; Marine organisms.

1. Introduction

The progress of industry and society has brought prosperity and comfort to humans, but on the other hand, it has caused great damage to the environment, which ultimately endangers the health of humans and other creatures living on earth [1-3]. Climate change, deforestation, and pollution of water resources and soil can be considered examples of this disaster [4-6]. Meanwhile, plastics are a group of polymers that are of great interest due to their unique properties, such as flexibility, cheapness, and easy molding [7, 8]. For this reason, in contemporary society, plastics can be seen in most applications. It has been reported in the literature that the annual production of plastic goods has increased from 1.5 million tons in the 1950s to 450 million tons in 2024 [9]. It can be said that the most common plastics produced are polystyrene (PS), polypropylene, polyamide (PA), polyethylene terephthalate (PET), polyethylene (PE), and polyvinyl chloride (PVC) [10]. Plastic waste pollution is of great importance because they have a long lifespan and many of them contain harmful substances such as bisphenol A [11]. Figure 1 shows the global cumulative disposal of inadequately managed plastic waste from 1950 to 2060.

Meanwhile, an uninvited guest has been a serious concern for all people on Earth for years: micro- and nano-scale plastic waste. They can be considered a new

---

* Corresponding author.
Email addresses: md.sheydaei@fmgarmsar.ac.ir, m.sheydaei@yahoo.com (M. Sheydaei)

Received 4 June 2025
Revised 28 June 2025
Accepted 28 June 2025

https://doi.org/10.22034/jams.2025.210143

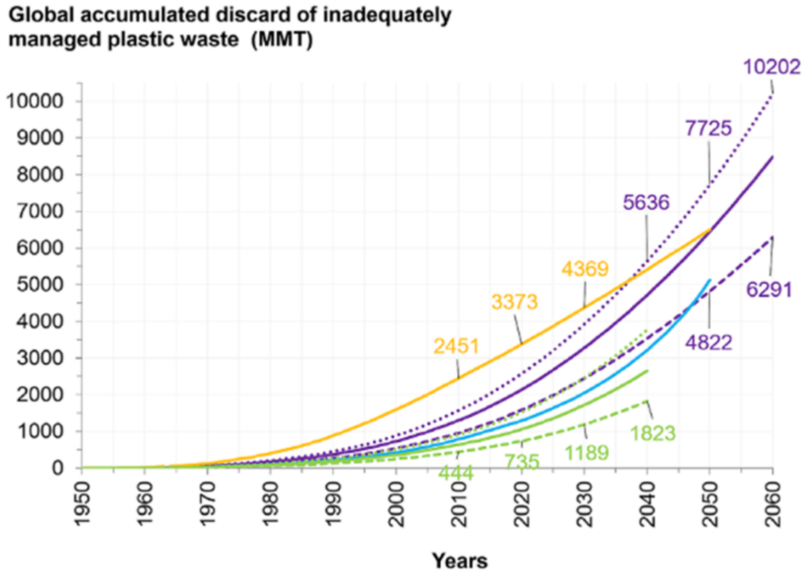


Figure 1. Global cumulative discard of plastic waste inadequately managed over 1950–2060 – The Business-As-Usual (BAU) scenario (MMT: million metric tons). Reprinted with permission from [9]. 2024, Cambridge University Press.

problem arising from plastic pollution. Due to their size, they can unfortunately easily enter the bodies of humans and fauna (see Figure 2). Due to their lightweight nature, microplastics are easily transported and can contaminate locations far from where they were produced [12]. Microplastics readily contaminate soil and water, and in recent years, their presence in the oceans has significantly increased, with concentrations reported to reach up to 100,000 particles per cubic meter [13]. The National Oceanic and Atmospheric Administration

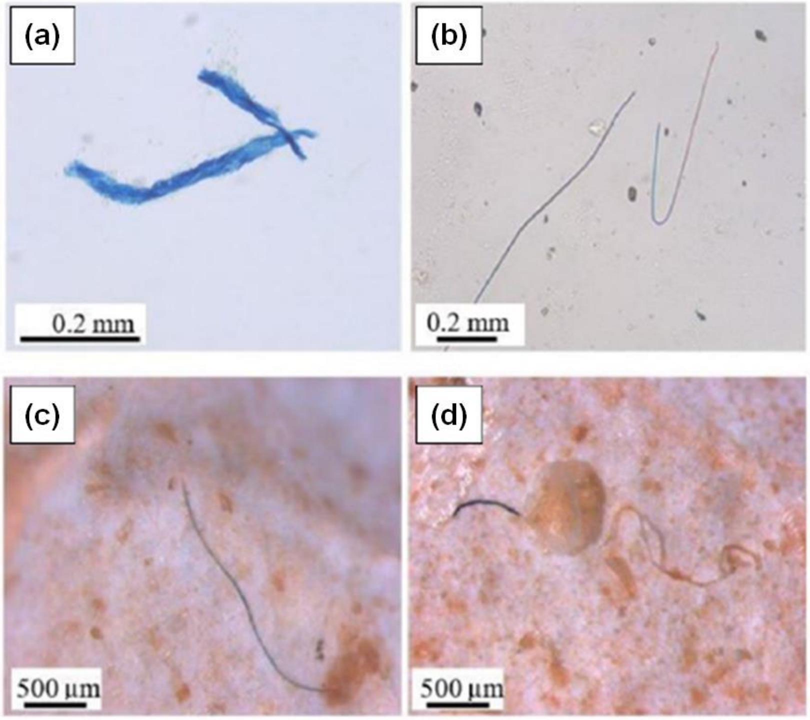


Figure 2. Microplastic fibers and filaments in the gastrointestinal tracts of myctophid fish (a-d). Reprinted with permission from [12]. 2023, MDPI.

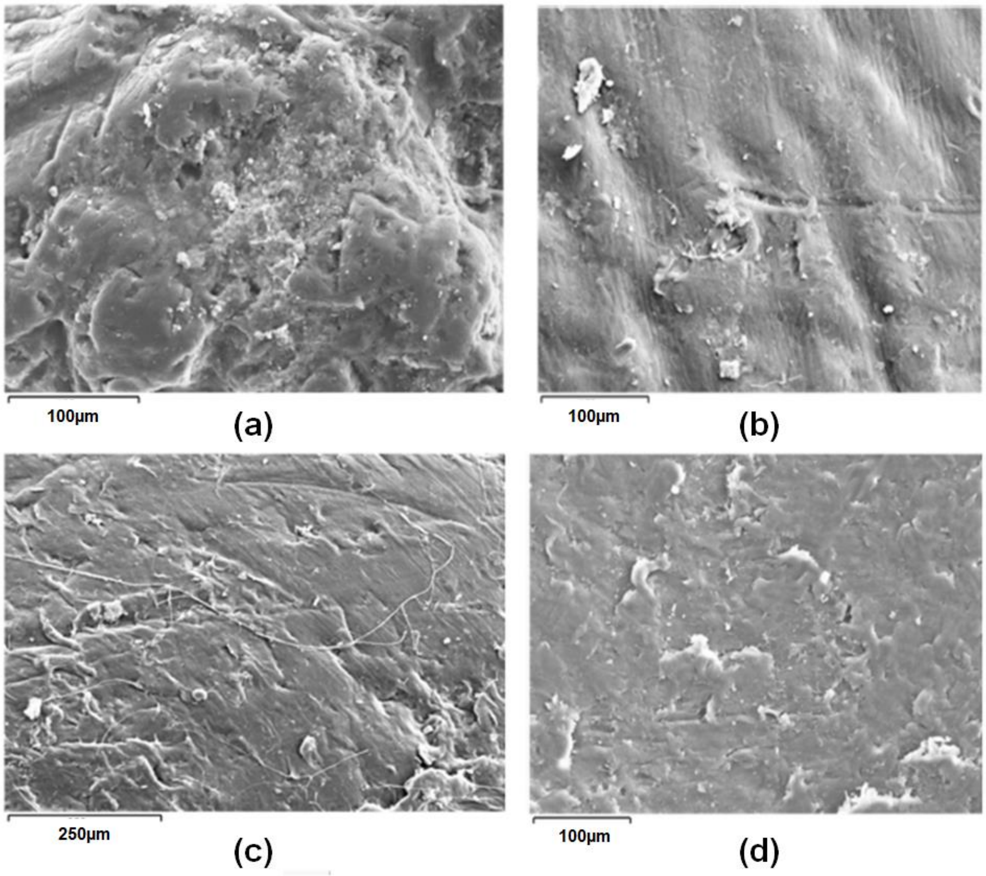


Figure 3. SEM images of pellets: (a) Before clean-up, (b) After the spill, (c) 5 months after the spill, and (d) 6 months after the spill. Reprinted with permission from [15]. 2022, MDPI.

defines microplastics as particles smaller than 5 mm in size [14].

Microplastics can be the result of the fragmentation of larger items, or they can be particles that are purposefully manufactured to a microscopic size. In October 2018, a storm in the Durban harbour (South Africa) resulted in the spillage of about 2,000 tons of polyethylene pellets, raising environmental concerns, and Mofokeng and Glassom [15] investigated this contamination.

Scanning electron microscopy (SEM) results (see Figures 3 and 4) showed that the old pellets had cracks while the newer pellets were smooth with little abrasion. After five and six months in the environment, the pellets showed signs of surface abrasion and deterioration, respectively. Bacterial and fungal growth was also observed on the surface of the old pellets after two months. Also, no heavy metal contamination was observed in the pellets over time.

In recent years, the use of alternatives to plastics, including glass and biodegradable packaging, has increased, but this approach requires a global agreement [16]. However, raising public awareness and reducing the use of plastic products and their release into the environment is far more valuable than plastic alternatives. This paper addresses microplastics and their negative effects on marine organisms and the research conducted in this field.

2. Microplastic sources

The reports show that the production of plastics derived from fossil fuels is increasing yearly, and plastic waste has become a global problem due to poor management. Microplastics pose a threat to many aquatic species, especially planktonic and invertebrate organisms, as they easily accumulate in their bodies (see

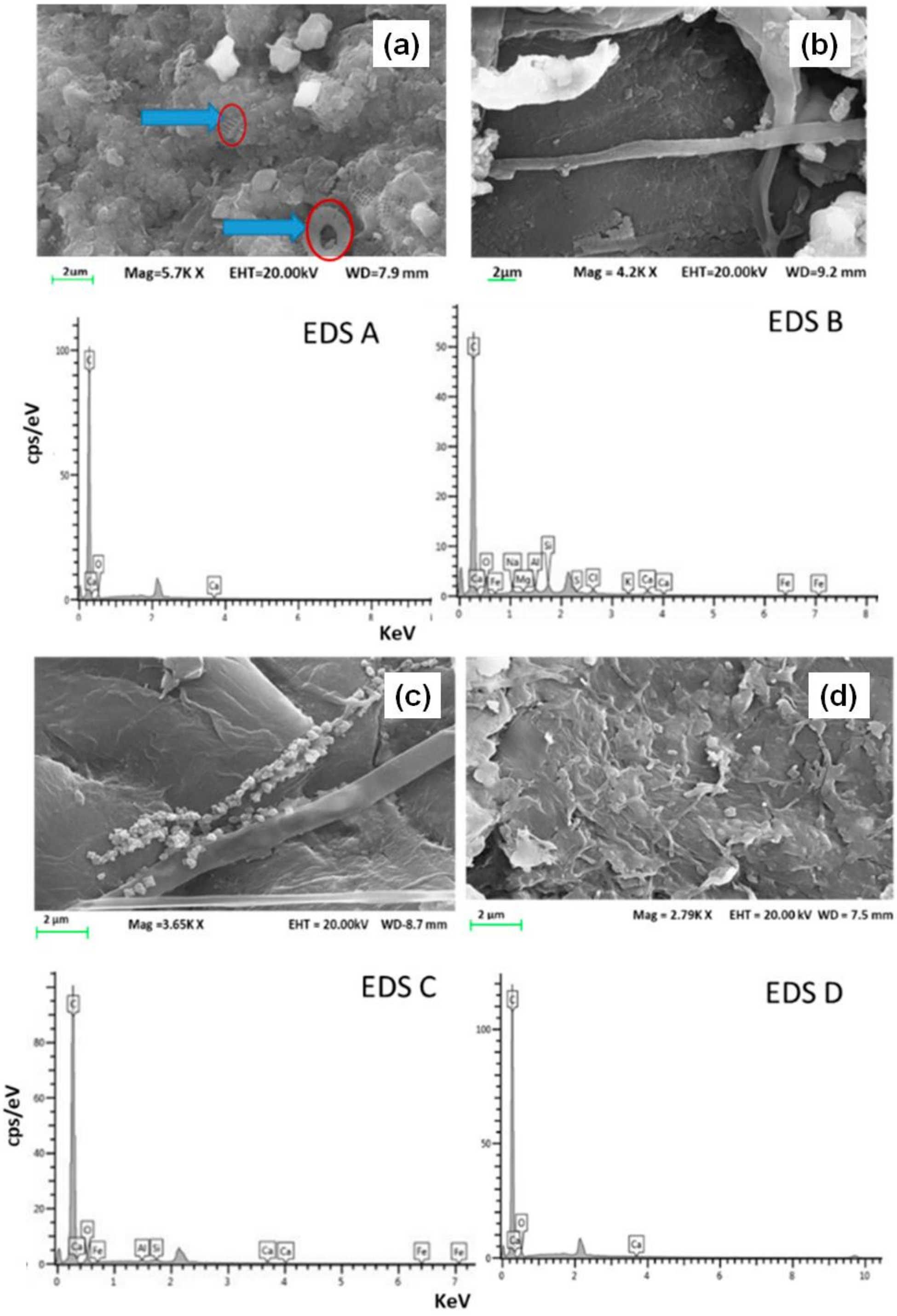


Figure 4. SEM images of pellets collected show surface metal concentrations. (a) Before clean-up (C, Ca, O, Ca), (b) after two months of exposure (C, Ca, O, Fe, Mg, Al, Si, S, Cl, K, Ca, Ca, Fe, Fe), (c) after three months of exposure (C, Ca, Fe, Al, Si, Ca, Ca), and (d) after six months of exposure (C, Ca, O, Ca). The red circles indicate the presence of diatoms on pellets. Reprinted with permission from [15]. 2022, MDPI.

Figure 5) [17, 18]. Many reports suggest that microplastics have the potential to cause chronic toxicity [19, 20]. Law et al. [21] investigated the effects of PS microplastics on marine filter-feeding fish, and the

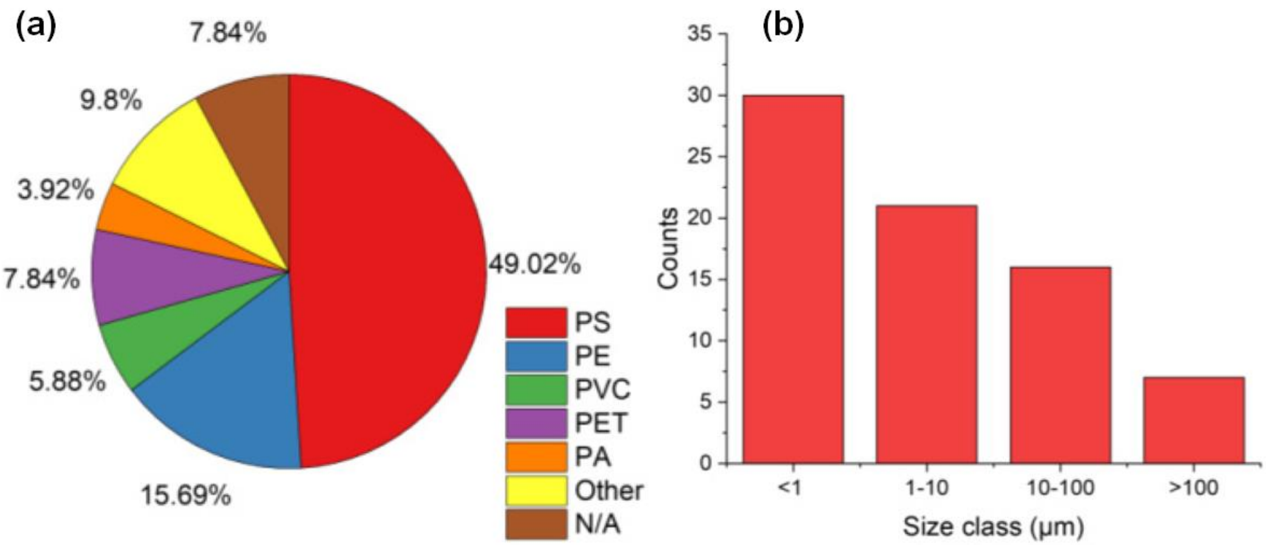


Figure 5. (a) Polymers used in different ecotoxicological tests to expose zooplankton species. (b) Average size distribution of the microplastics used. Reprinted with permission from [18]. 2023, MDPI. (Note: N/A: Studies that did not specify the type of polymer.)

results showed that PS microplastics can be transmitted through the blood and cause reproductive disorders.

The toxicity of microplastics is related to many factors, such as unreacted monomers, oligomers, and additives. These factors are leached under the influence of various factors such as UV light, long rubbing, solvents, and even ocean water [17]. For this reason, food packaging is of great importance because monomers and oligomers can easily migrate into food.

Many additives, such as plasticizers, fillers, inhibitors, and antioxidants, are toxic [17, 22-24]. Some phthalates used in baby bottles have been reported to release in the range of 50–150 μg/kg after a 120 min contact time at 70 °C [25]. This relatively easy release can be attributed to the lack of chemical reaction with the plastic structure, as most of these additives are not chemically bound to plastic structures [17, 26]. In addition to being toxic, plastics unfortunately also have the ability to absorb hydrophobic pollution from water [27]. We can say that they play the role of a Trojan horse.

Primary sources of microplastics include household and industrial sewage and feedstocks used to produce plastics (whether plastic products or granules and powders) [28]. However, secondary sources of microplastics can be identified through mechanical degradation and exposure to solvents and UV light [29]. Many wastewater treatment plants remove large plastic particles, but microplastics can pass through treatment units and enter the aquatic environment [30, 31].

Household sewage contains polymer particles from cosmetics, cleaning, and fibers (mainly polyester, acrylic, and PA) [17, 26]. It has been reported in the literature that bottled water can also contain microplastics [26]. Many foods and beverages should not be served in plastic containers, such as alcoholic beverages, as alcohol can release unreacted monomers and oligomers.

3. Effects of microplastics on marine organisms

The high production of plastics, most of which are designed for single use, has led to environmental pollution. Plastic waste is entering the environment at an uncontrollable rate, with the greatest impact on marine and freshwater ecosystems [14, 32]. They reach the oceans through wind and rivers, causing pollution [14]. One of the most important problems with plastics once they enter the environment is that they are continuously broken down into smaller particles, making them easier to transport [32]. Unfortunately, today microplastics are present even in the most remote marine environments, but gyres can be considered the main place for their accumulation [14, 33]. Brown et al. [34] evaluated the presence of microplastics on eighteen beaches on six continents, and the results showed that microplastics

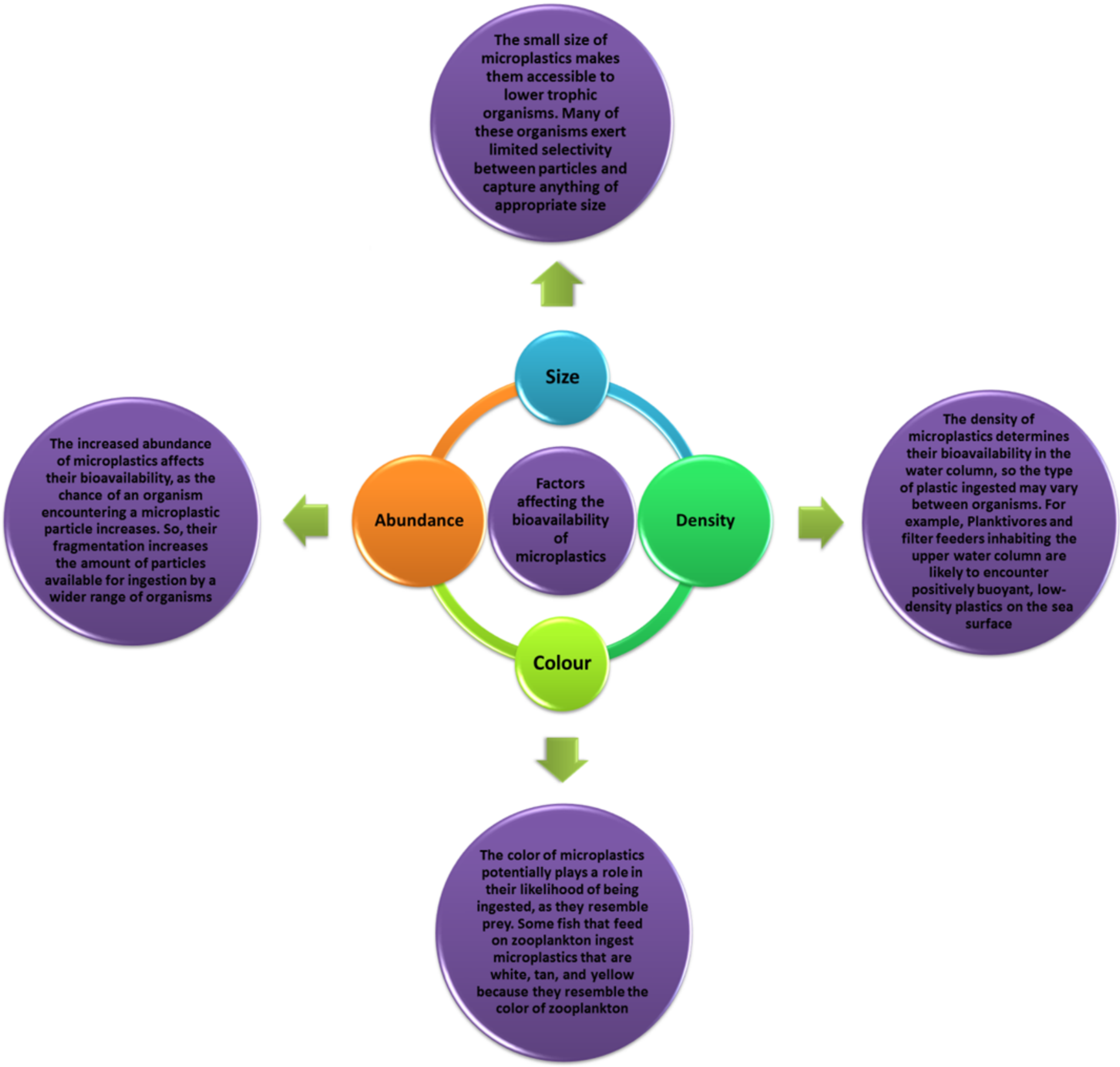


Figure 6. Factors affecting the bioavailability of microplastics.

were present in fibrous forms, with a maximum concentration of 124 fibers per liter. According to reports, microplastics are believed to be a serious threat to more than 250 marine species [14]. Figure 6 shows the factors affecting the bioavailability of microplastics in aquatic ecosystems.

In addition to freshwater, soils are also a site of accumulation of microplastic fibers [35]. They persist for a long time in layers of about 25 cm of agricultural soils treated with sewage sludge (as fertilizer). This indicates a gradual transfer in the solid media and then accumulation at depth [17]. Considering this fact, it can be said that agricultural soils have a higher probability of retaining microplastics compared to other areas [36].

Hunter et al. [37] assessed the presence of pre-production pellets (see Figure 7) in the Avon–Heathcote Estuary/Ihutai (Aotearoa–New Zealand). The results showed seven aggregation points, and a total of 3,819 pellets were identified. They were predominantly transparent (86%), 3 mm in size (54%), cylindrical (62%),

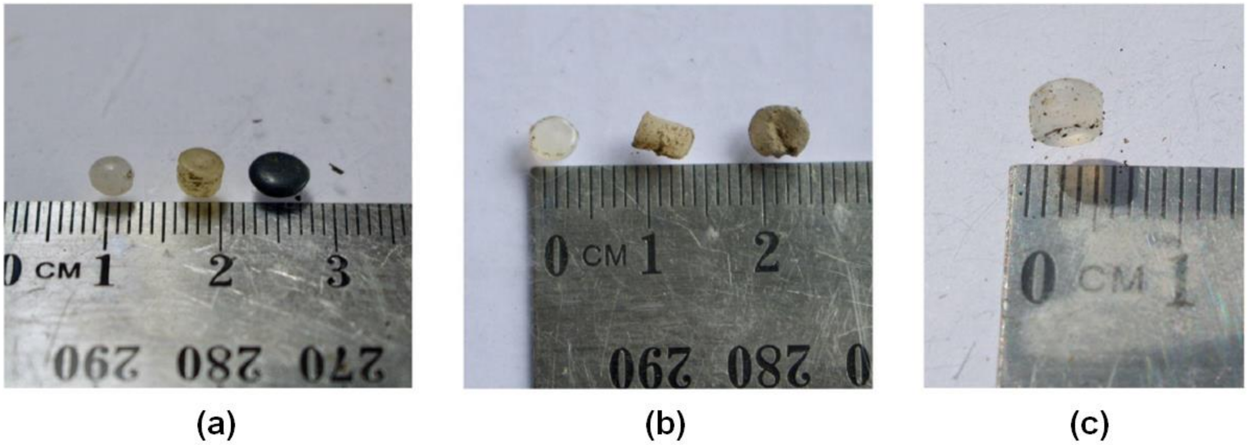


Figure 7. Pellet classification: (a) by shape, from left to right—spherical, cylindrical, lentil, (b) by weathering, from left to right—category "1" no yellowing or cracking, category "2" yellowing only, category "3" yellowing and cracking visible; (c) an exemplar pellet classified as 4 mm size, cylindrical and category "1" weathering. Reprinted with permission from [37]. 2022, MDPI.

moderately weathered (41%), and made of low-density PE (53%). The accumulation and abundance are likely influenced by the river flows along which the plastic producers are located, weather conditions, and proximity to stormwater outlets.

Rivers carry a high volume of microplastics, and in places where the energy of the river flow is low, microplastics settle together with sediments in the riverbed [38]. Riverbed sediments can always be considered an alarm for pollution because they always contain all the pollutants, such as microplastics and heavy metals, and by evaluating the sediments, the level of environmental pollution can be measured [3, 4, 38]. As shown in Figure 6, size and density are very important, as it has been reported that larger sizes with irregular shapes and jagged geometry and sharp ends and higher density of plastic lead to easy sinking in water and presence in sediment, while spherical particles tend to remain on the water surface [39-43]. Therefore, sediments in areas close to factories, densely populated cities, and densely populated coastal regions are highly polluted. Sediment-dwelling organisms such as benthic holothurians *Thyonella gemmate*, and lugworm *Arenicola marina* are always vulnerable to damage from microplastics because they generally have a non-selective feeding strategy and ingest large volumes of sediment, thus also ingesting microplastics or heavy metals [3, 4, 14]. Table 1 reports some marine organisms that are susceptible to ingesting microplastics, as well as their exposure routes to microplastics. Among aquatic organisms, mussels are filter feeders and process a high volume of water, so if the water is contaminated with pollutants, they will accumulate them [23]. They are almost sessile creatures that do not migrate, so they will be very damaged if their living environment is polluted [17, 33]. Table 2 also reports microplastics in some mussel and fish species.

Table 1. Some marine organisms and their exposure routes to microplastics (Data from [14, 33])

Species	Exposure routes
Amphipods	They directly mistake microplastics for a natural food source.
The marine polychaete A. *marina*	Selection is based on size, with smaller particles adhering and being retained by the mucous-lined proboscis papillae.
Plankton eaters	Due to the similarity in specific gravity of plastic microspheres with algae, they are mistakenly ingested by plankton eaters.
Echinoderm larvae	They ingest polymer microspheres based on their size (smaller than 3 mm).
Marine algae	Adsorbs nanoplastics, especially when positively charged.
Grazing microzooplankton	Size-based selectivity indicates the potential to ingest microplastics of appropriate size.

Table 2. Microplastics in some species of mussel and fish

Species	Region	Polymers observed	Shape	Size (mm)	Reference
Mytilus edulis	French Atlantic coast	PE, Polypropylene (PP)	Fragment	0.05–0.1	[53]
Mytilus spp.	Norwegian coastal waters	Cellophane, Ethylene-vinyl acetate (EVA), PET, PP, PE, PA	Fiber, Fragment	0.07–3.87	[54]
Mytilus Galloprovincialis	Adriatic Sea	PE, PP, PET, PS, PVC	Fiber, Fragment	0.02–0.3	[55]
Mytilus Galloprovincialis	Turkish coasts	PET, PP, PE	Fragment, Fiber, Film	0.5–2.0	[56]
Mytilus Galloprovincialis	N Ionian Sea	PE, PP, Polytetrafluoroethylene (PTFE)	Fiber, Fragment	0.04–0.74	[57]
Mytilus edulis, Perna viridis	Coastal waters China	PET, PVC, PE, PP, Rayon	Fiber, Fragment, Bead	0.25–1.0	[58]
Sardinia pilchardus	Adriatic Sea	PP, PVC, PTFE, PA	Fragment, Fiber	0.12–0.59	[59]
Sardina pilchardus	Gulf of Lyon, France	PET, PE, PA, PP	Fiber	1.77	[60]
Solea solea	Adriatic Sea	PVC, PP, PE, PA, Polyester	Fragment, Fiber	0.1–0.5	[61]
Boops boops	Mediterranean Sea	PE, PP, PS, PVC	Fiber	0.05–4.75	[62]
Boops boops	Catalan coast, Spain	PP, PE, PS	Fragment, Fiber	< 0.1–5	[63]
Mugil cephalus	E Hong Kong	PP, PE, Polyester	Fragment, Fiber	1.21	[64]

There are many reports of the effects of microplastic ingestion in organisms, such as internal abrasions and blockages of the digestive tract. Figure 8 shows the factors affecting the physical impacts of microplastics.

Among aquatic organisms, the Red Sea giant clam (*Tridacna maxima*) can remove microplastics [17]. Arossa et al. [44] evaluated the removal of polyethylene microplastics (53 to 500 µm in size) by *Tridacna maxima*. The results showed that clams' shells played a major role in removing microplastics (through sorption on the surface, microplastics attach to the clams' shells) and resulted in a 66.03% removal from wastewater. Researchers have proposed many methods for removing microplastics. Among the methods for removing microplastics, membrane bioreactors, adsorption on green microalgae, and conventional activated sludge are among the most efficient methods [45-48]. In the membrane bioreactor method, catalysis is promoted by biological catalysts such as bacteria, enzymes, and is accompanied by a separation process carried out by a membrane system (see Figure 9) [49]. Algae-based separation technologies are very promising for the removal of pollutants. These methods are based on the mechanisms of bioadsorption, bioaccumulation, and

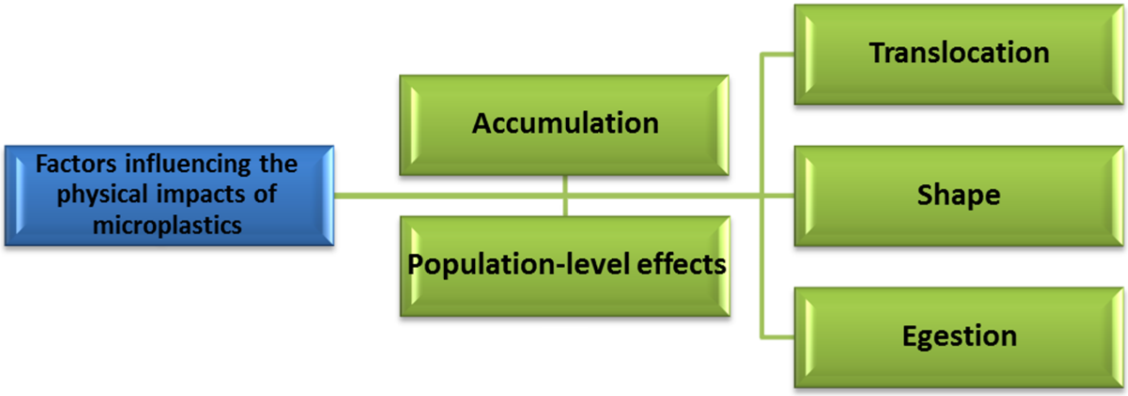


Figure 8. Factors influencing the physical impacts of microplastics.

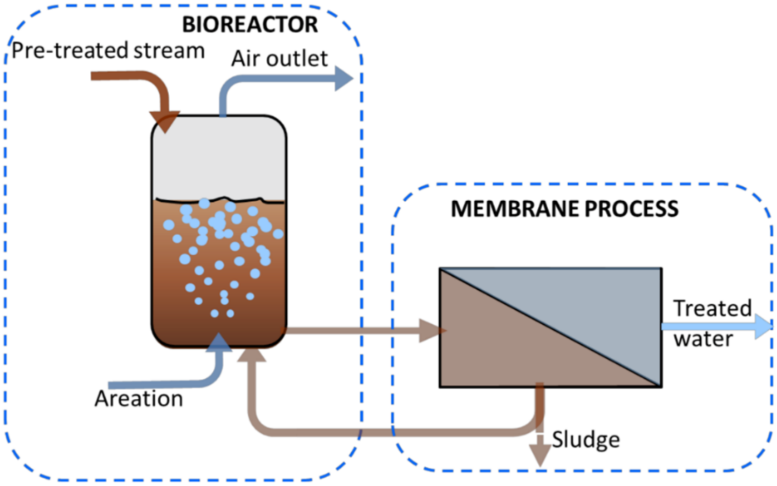


Figure 9. Schematic representation of a membrane bioreactor process. Reprinted with permission from [45]. 2019, MDPI.

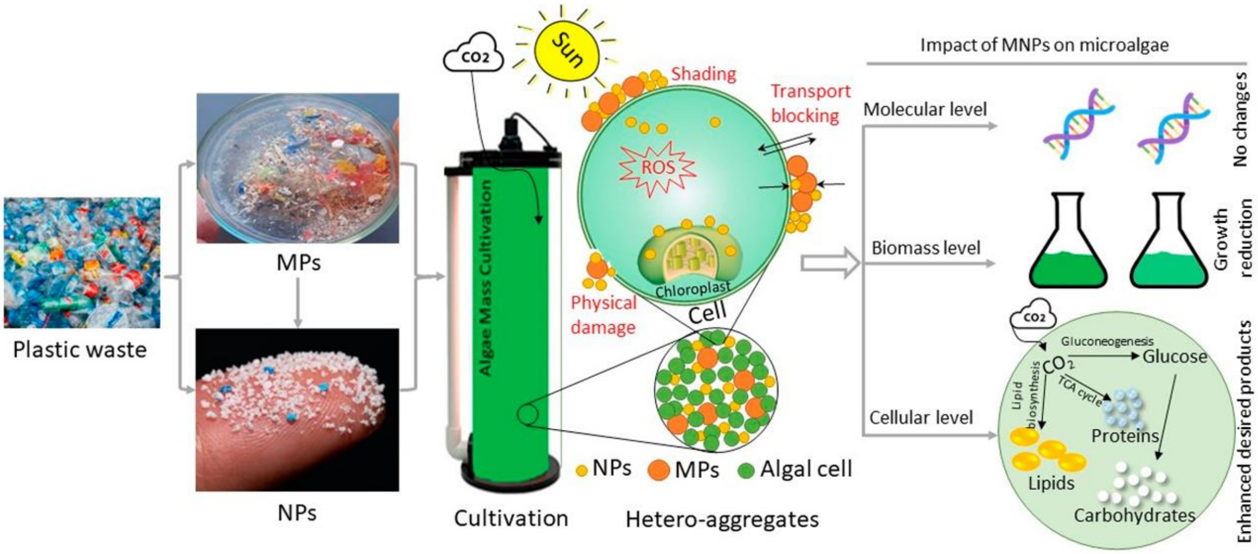
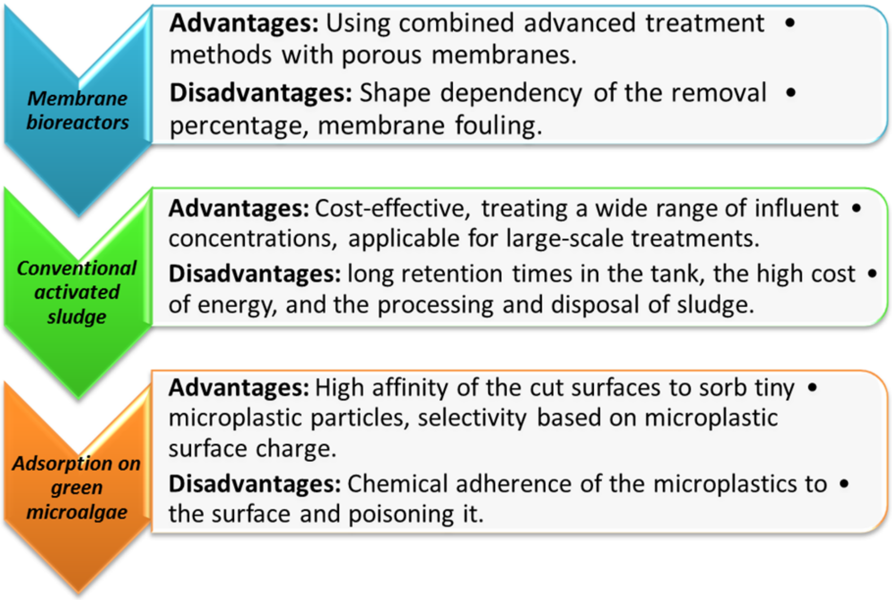


Figure 10. The modes of action and effects of microplastics and nanoplastics on microalgal cells and biomass production. Reprinted with permission from [65]. 2022, MDPI.

biodegradation. For example, studies have shown that the microalgae *Chlamydomonas* sp. and *Chlorella vulgaris* are very effective in the adsorption of pollutants [50]. Their cell walls are rich in polysaccharides, proteins, and lipids that contain functional groups that effectively interact with hydrophobic microplastic particles (see Figure 10) [46, 50]. Reports have shown that effluent and sludge contain high concentrations of microplastics [51]. Therefore, conventional activated sludge processes remove a significant fraction of microplastics, although the removal efficiency depends on the wastewater treatment plant configuration and operating parameters [52]. Figure 11 shows a comparison of these three methods.

4. Conclusions

To sum up, microplastics can be considered one of the most important pollutants in the world today, in which only humans play a direct role. Microplastics can easily cause environmental pollution, and their removal is very expensive, and in some cases, it can be said that their complete removal is not possible. The most important



Advantages: Using combined advanced treatment methods with porous membranes. •

Disadvantages: Shape dependency of the removal percentage, membrane fouling. •

Advantages: Cost-effective, treating a wide range of influent concentrations, applicable for large-scale treatments. •

Disadvantages: long retention times in the tank, the high cost of energy, and the processing and disposal of sludge. •

Advantages: High affinity of the cut surfaces to sorb tiny microplastic particles, selectivity based on microplastic surface charge. •

Disadvantages: Chemical adherence of the microplastics to the surface and poisoning it. •

Figure 11. Comparison of some different methods for removing microplastics from the environment.

factor in controlling this pollution is the use of fewer plastics and replacing them with other materials. Proper management of plastic waste is of great importance because its entry into the environment depends on this factor. Currently, marine organisms are most harmed by microplastics because they come into contact with them in water and sediments while feeding and breathing, but in the future, humans will increasingly encounter them.

Conflict of Interest

The authors declare no conflict of interest.

References

1. S. Tong, et al. Current and future threats to human health in the Anthropocene. *Environment International*, **2022**, *158*, 106892.
2. N.P. Hariram, et al. Sustainalism: An Integrated Socio-Economic-Environmental Model to Address Sustainable Development and Sustainability. *Sustainability*, **2023**, *15*, 10682.
3. M. Sheydaei. Heavy Metals Contamination in Soil and Rice and their Removal Processes: A Brief Review. *Geomicrobiology Journal*, **2024**, *41*, 721.
4. M. Sheydaei. Investigation of Heavy Metals Pollution and Their Removal Methods: A Review. *Geomicrobiology Journal*, **2024**, *41*, 213.
5. S.C. Heath. Navigating psychosocial dimensions: understanding the intersections of adaptation strategies and well-being outcomes in the context of climate change. *Current Opinion in Environmental Sustainability*, **2025**, *72*, 101493.
6. F.R. de Paula, et al. Timing since deforestation for pastures implementation in the western Amazon: Impacts on stream water biogeochemistry. *Science of The Total Environment*, **2025**, *976*, 179320.
7. M. Sheydaei, et al. PVCS/GO nanocomposites: investigation of thermophysical, mechanical and antimicrobial properties. *Journal of Sulfur Chemistry*, **2022**, *43*, 376.
8. H.M. Magbool. Sustainability of utilizing recycled plastic fiber in green concrete: A systematic review. *Case Studies in Construction Materials*, **2025**, *22*, e04432.
9. M. Cordier, et al. Reducing plastic production: Economic loss or environmental gain? *Cambridge Prisms: Plastics*, **2024**, *2*, e2.
10. R.y. Öztekin and D.a.T. Sponza. Removal Mechanisms of Polyethylene, Polypropylene, Polyvinyl Chloride, Polyamide (Nylon), Polystyrene and Polyethylene Terephthalate in Wastewater Treatment Plants by Chemical, Photocatalytic, Biodegradation and Hybrid Processes. *International Journal of Environmental Engineering and Development*, **2023**, *1*, 206.
11. F.A.S. Islam. The Impact of Plastic Waste on Ecosystems and Human Health and Strategies for Managing It for A Sustainable Environment. *International Journal of Latest Technology in Engineering Management & Applied Science*, **2025**, *14*, 706.

12. O. Novillo-Sanjuan, et al. Microplastics in Lampanyctus crocodilus (Risso 1810, Myctophidae), a Common Lanternfish Species from the Ibiza Channel (Western Mediterranean). *Microplastics*, **2023**, *2*, 242.

13. X. Meng, et al. A Review of Sources, Hazards, and Removal Methods of Microplastics in the Environment. *Water*, **2025**, *17*, 102.

14. S.L. Wright, R.C. Thompson, and T.S. Galloway. The physical impacts of microplastics on marine organisms: A review. *Environmental Pollution*, **2013**, *178*, 483.

15. R.P. Mofokeng and D. Glassom. Time Integrated Metal Accumulation on Pellets in an Industrial Harbour "Durban Harbour". *Microplastics*, **2021**, *1*, 3.

16. T.D. Moshood, et al. Sustainability of biodegradable plastics: New problem or solution to solve the global plastic pollution? *Current Research in Green and Sustainable Chemistry*, **2022**, *5*, 100273.

17. M. Padervand, et al. Removal of microplastics from the environment. A review. *Environmental Chemistry Letters*, **2020**, *18*, 807.

18. J. Lawrence, et al. Freshwater Lacustrine Zooplankton and Microplastic: An Issue to Be Still Explored. *Toxics*, **2023**, *11*, 1017.

19. L. Lei, et al. Microplastic particles cause intestinal damage and other adverse effects in zebrafish Danio rerio and nematode Caenorhabditis elegans. *Science of The Total Environment*, **2018**, *619*, 1.

20. R. Sussarellu, et al. Oyster reproduction is affected by exposure to polystyrene microplastics. *Proceedings of the National Academy of Sciences*, **2016**, *113*, 2430.

21. K.L. Law, et al. Distribution of Surface Plastic Debris in the Eastern Pacific Ocean from an 11-Year Data Set. *Environmental Science & Technology*, **2014**, *48*, 4732.

22. E. Milad, et al. Protective Nanocomposite Coating Based on Ginger Modified Clay and Polyurethane: Preparation, Characterization and Evaluation Anti-Corrosion and Mechanical Properties. *Polymer Science, Series B*, **2022**, *64*, 756.

23. E. Alinia-Ahandani, et al. Some effective medicinal plants on cardiovascular diseases in Iran - a review. *Journal of Global Trends in Pharmaceutical Sciences*, **2020**, *11*, 8021.

24. E. Alinia-Ahandani, Z. Alizadeh-Tarpoei, and M. Sheydaei. Some Pointed Medicinal Plants to Treat the Tick-Borne Disease. *Open Access Journal of Biogeneric Science and Research*, **2020**, *28*, 12.

25. C. Simoneau, L. Van den Eede, and S. Valzacchi. Identification and quantification of the migration of chemicals from plastic baby bottles used as substitutes for polycarbonate. *Food Additives & Contaminants: Part A*, **2011**, *29*, 469.

26. K.D. Cox, et al. Human Consumption of Microplastics. *Environmental Science & Technology*, **2019**, *53*, 7068.

27. O. Setälä, V. Fleming-Lehtinen, and M. Lehtiniemi. Ingestion and transfer of microplastics in the planktonic food web. *Environmental Pollution*, **2014**, *185*, 77.

28. J.-Q. Jiang. Occurrence of microplastics and its pollution in the environment: A review. *Sustainable Production and Consumption*, **2018**, *13*, 16.

29. H.G. Dam, et al. Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. *PLoS ONE*, **2014**, *9*, e111913.

30. Z. Long, et al. Microplastic abundance, characteristics, and removal in wastewater treatment plants in a coastal city of China. *Water Research*, **2019**, *155*, 255.

31. J. Sun, et al. Microplastics in wastewater treatment plants: Detection, occurrence and removal. *Water Research*, **2019**, *152*, 21.

32. T.R. Walker. (Micro)plastics and the UN Sustainable Development Goals. *Current Opinion in Green and Sustainable Chemistry*, **2021**, *30*, 100497.

33. O. Bajt. From plastics to microplastics and organisms. *FEBS Open Bio*, **2021**, *11*, 954.

34. M.A. Browne, et al. Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks. *Environmental Science & Technology*, **2011**, *45*, 9175.

35. L. Nizzetto, M. Futter, and S. Langaas. Are Agricultural Soils Dumps for Microplastics of Urban Origin? *Environmental Science & Technology*, **2016**, *50*, 10777.

36. E. Huerta Lwanga, et al. Incorporation of microplastics from litter into burrows of Lumbricus terrestris. *Environmental Pollution*, **2017**, *220*, 523.

37. E.C. Hunter, et al. Quantification and Characterisation of Pre-Production Pellet Pollution in the Avon-Heathcote Estuary/Ihutai, Aotearoa-New Zealand. *Microplastics*, **2022**, *1*, 67.

38. P.L. Corcoran, et al. Hidden plastics of Lake Ontario, Canada and their potential preservation in the sediment record. *Environmental Pollution*, **2015**, *204*, 17.

39. A.A. Horton, et al. Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities. *Science of The Total Environment*, **2017**, *586*, 127.

40. F. Lagarde, et al. Microplastic interactions with freshwater microalgae: Hetero-aggregation and changes in plastic density appear strongly dependent on polymer type. *Environmental Pollution*, **2016**, *215*, 331.

41. M. Sheydaei. Breast Cancer and the Role of Polymer-Carriers in Treatment. *Biomedical Journal of Scientific & Technical Research*, **2021**, *34*, 27057.

42. M. Sheydaei and E. Alinia-Ahandani. Cancer and the Role of Polymeric-Carriers in Diagnosis and Treatment %J Journal of Advanced Biomedical Sciences. **2020**, *10*, 2408.

43. M. Edraki, et al. Characterization and antimicrobial properties of Matcha green tea %J Chemical Review and Letters. **2022**, *5*, 76.

44. S. Arossa, et al. Microplastic removal by Red Sea giant clam (Tridacna maxima). *Environmental Pollution*, **2019**, *252*, 1257.

45. M. Li, et al. Review of Techniques for the Detection, Removal, and Transformation of Environmental Microplastics and Nanoplastics. *ACS Applied Materials & Interfaces*, **2025**, *17*, 20560.

46. M.A.A. Amparán, et al. Review and future outlook for the removal of microplastics by physical, biological and chemical methods in water bodies and wastewaters. *Environmental Monitoring and Assessment*, **2025**, *197*, 429.

47. J. Lu, et al. Insights into the role of attapulgite clay on the efficient removal of microplastics by sand filters in various waters. *Chemical Engineering Journal*, **2025**, *504*, 159085.

48. H.K. McIlwraith, et al. Positive controls with representative materials are essential for the advancement of microplastics research. *Microplastics and Nanoplastics*, **2025**, *5*, 9.

49. T. Poerio, E. Piacentini, and R. Mazzei. Membrane Processes for Microplastic Removal. *Molecules*, **2019**, *24*, 4148.

50. F. Lotfigolsefidi, et al. Removal of microplastics by algal biomass from aqueous solutions: performance, optimization, and modeling. *Scientific Reports*, **2025**, *15*, 501.

51. M.M. Maw, et al. Microplastics in wastewater and sludge from centralized and decentralized wastewater treatment plants: Effects of treatment systems and microplastic characteristics. *Chemosphere*, **2024**, *361*, 142536.

52. G. Di Bella, et al. Occurrence of Microplastics in Waste Sludge of Wastewater Treatment Plants: Comparison between Membrane Bioreactor (MBR) and Conventional Activated Sludge (CAS) Technologies. *Membranes*, **2022**, *12*, 371.

53. N.N. Phuong, et al. Factors influencing the microplastic contamination of bivalves from the French Atlantic coast: Location, season and/or mode of life? *Marine Pollution Bulletin*, **2018**, *129*, 664.

54. I.L.N. Bråte, et al. Mytilus spp. as sentinels for monitoring microplastic pollution in Norwegian coastal waters: A qualitative and quantitative study. *Environmental Pollution*, **2018**, *243*, 383.

55. A. Gomiero, et al. First occurrence and composition assessment of microplastics in native mussels collected from coastal and offshore areas of the northern and central Adriatic Sea. *Environmental Science and Pollution Research*, **2019**, *26*, 24407.

56. K. Gedik and A.R. Eryaşar. Microplastic pollution profile of Mediterranean mussels (Mytilus galloprovincialis) collected along the Turkish coasts. *Chemosphere*, **2020**, *260*, 127570.

57. N. Digka, et al. Microplastics in mussels and fish from the Northern Ionian Sea. *Marine Pollution Bulletin*, **2018**, *135*, 30.

58. X. Qu, et al. Assessing the relationship between the abundance and properties of microplastics in water and in mussels. *Science of The Total Environment*, **2018**, *621*, 679.

59. M. Renzi, et al. Marine litter in stomach content of small pelagic fishes from the Adriatic Sea: sardines (Sardina pilchardus) and anchovies (Engraulis encrasicolus). *Environmental Science and Pollution Research*, **2018**, *26*, 2771.

60. C. Lefebvre, et al. Microplastics FTIR characterisation and distribution in the water column and digestive tracts of small pelagic fish in the Gulf of Lions. *Marine Pollution Bulletin*, **2019**, *142*, 510.

61. G. Pellini, et al. Characterization of microplastic litter in the gastrointestinal tract of Solea solea from the Adriatic Sea. *Environmental Pollution*, **2018**, *234*, 943.

62. C. Tsangaris, et al. Using Boops boops (osteichthyes) to assess microplastic ingestion in the Mediterranean Sea. *Marine Pollution Bulletin*, **2020**, *158*, 111397.

63. O. Garcia-Garin, et al. Boops boops as a bioindicator of microplastic pollution along the Spanish Catalan coast. *Marine Pollution Bulletin*, **2019**, *149*, 110648.

64. L. Cheung, C. Lui, and L. Fok. Microplastic Contamination of Wild and Captive Flathead Grey Mullet (Mugil cephalus). *International Journal of Environmental Research and Public Health*, **2018**, *15*, 597.

65. A. Abomohra and D. Hanelt. Recent Advances in Micro-/Nanoplastic (MNPs) Removal by Microalgae and Possible Integrated Routes of Energy Recovery. *Microorganisms*, **2022**, *10*, 2400.
