

WOOD

4

sustainability

*p*_{rocessing}

*c*_{onstruction}

*p*_{roduct}

*d*_{esign}

2024

Wood 4 Sustainability

Processing, Construction, Products and Design

2024

Főszerkesztő: Dr. Csiha Csilla

Wood 4 Sustainability

Processing, Construction, Products and Design

2024



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Főszerkesztő

Dr. Csiha Csilla Mária

Szerkesztők

Prof. Dr. Kósa Balázs, Prof. Dr. Magoss Endre, Dr. habil. Németh László

Lektorok

Gerencsér Kinga Címzetes Egyetemi Tanár, Szabadhegyi Viktor Címzetes Egyetemi Docens,
Prof. Dr. Alpár Tibor, Prof. Emeritus Tolvaj László, Prof. Dr. Markó Balázs

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Ecological and Health Implications of Microplastics in Water: A Short Review

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Omar Saber Zinad^a, Csilla Csiha^a, Dhafer Saber Zinad^b, Ali Fahem Al-Mamoori^c

^aUniversity of Sopron, Faculty of Wood Engineering and Creative Industries, Bajcsy-Zsilinszky. u. 4., Sopron, Hungary. Email: omar.saber.khalaf.zinad@phd.uni-sopron.hu

^bApplied Science Department, University of Technology, Baghdad, Iraq. Email: 100416@uotechnology.edu.iq

^cFaculty of Forestry, University of Sopron, Sopron, Hungary

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ABSTRACT

Microplastics, which have become a critical threat, are seeping into aquatic ecosystems and posing an increasing risk to human health. This review categorizes the pollution sources: consumer products, (like microbeads in toiletries) as primary sources and secondary sources coming from degraded plastic waste. Ocean currents transport these particles globally, enabling them to carry toxic heavy metals and persistent organic pollutants (POPs), intensifying their environmental impact. Accumulation in marine organisms leads to physical blockages, latent toxicity and mortality, while its presence in seafood directly affects human health. Addressing microplastic pollution demands innovative, multi-faceted solutions. Key recommendations include reducing reliance on single-use plastics, advancing water treatment technologies, and exploring robotic filtration to purify water. The study emphasizes the necessity for global and sustainable efforts to mitigate these pollutants, which represent a long-term ecological and health hazard.

Keywords: Microplastic Pollution, Aquatic Ecosystems, Environmental Impact, Pollutant Vectors, Waste Management, Industry, innovation and infrastructure

1. Introduction

Sometimes, the most recent advancements in polymer science, such as polymer materials, commenced with Bakelite, ‘the first synthetic plastic’ more than a century ago. The polymer was hailed as a novel material and used all over, but it gradually became global (Frias & Nash, 2019). This material is used in many products such as construction, chemical materials.. etc. (Csiha et al., 2025; Zinad & Csiha, 2024; Dawood et

al., 2020). They first introduced the term "microplastics" into the literature to describe microscopic plastic particles found in the underwater marine sediments and water columns within European Water (Thompson et al., 2004). Then later, in 2009, Arthur et al. reached a consensus on the upper size of microplastics, defining it as anything smaller than 5 mm plastic (Arthur et al., 2009). The definition was made more

restrictive by Cole et al. in 2011, who placed the microplastics in two broad subcategories depending on their origin: primary microplastics, in which they are deliberately made from polymeric macromolecules, and secondary microplastics, which result from weathering other plastic materials (Cole et al., 2011). The definition of microplastics in terms of diameter as given by the Joint group of experts on the scientific aspects of Marine Environmental Protection GESAMP is plastic particles measuring less than 1 mm, including nano-type plastic particles 1 nm, which provides global comparability of the term (GESAMP, 2015, GESAMP, 2016). Microplastics can be traced from various origins and are commonly categorized into micromorphological and non-micromorphological forms. For instance, microbeads in cosmetics or micro-abrasives in industry are considered primary microplastics as they have been created to be small-sized (Shahnawaz et al., 2019). On the other hand, secondary microplastics form from large pieces of plastic debris undergoing physical and photolytic

degradation (Andrady & Koongolla, 2022). Such sources are treated wastewater, agricultural field runoff, and city sewage effluents. Microplastics are ubiquitous in marine environments, affecting surface waters and deep-sea sediments. Their small size allows for widespread distribution via ocean currents, making them prevalent from the poles to the equator. Beyond their physical presence, these particles are carriers of harmful pollutants from the surrounding environment. This indirect impact on marine life is significant, as these particles can accumulate toxins and transport them across vast distances.

This has significant implications for marine organisms, which can ingest these particles, leading to physical and toxicological effects. Primary and secondary origins classify microplastics, with polyethylene and polypropylene making up the majority due to their low density, which causes them to float and affect the ocean surface, while denser materials sink and impact the seafloor (Narayanan, 2023; Schirinz, 2020; Buenaventura, 2017; Kane & Clare, 2019).

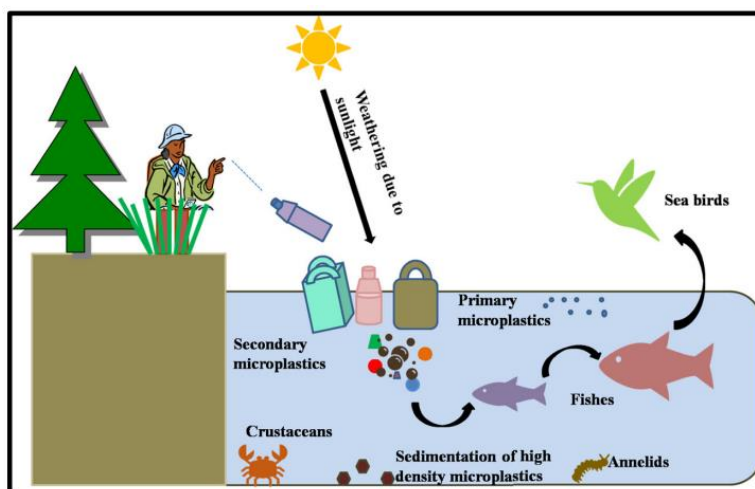


Figure 1. Microplastic pathway in organisms (Issac & Kandasubramanian, 2021)

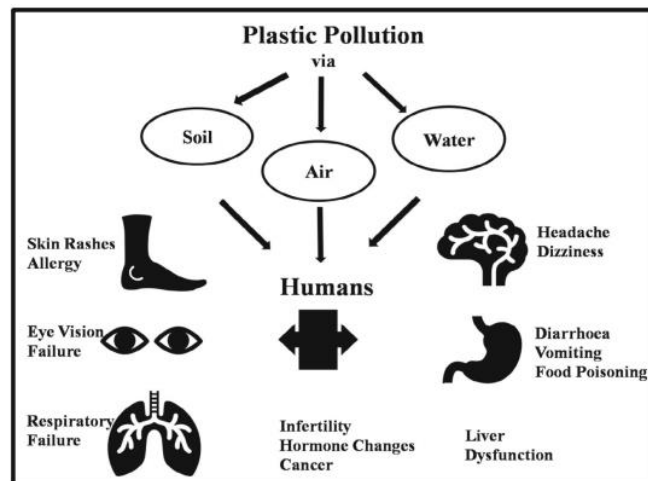


Figure 2. Pollution impacts on humans (Issac & Kandasubramanian, 2021)

This article will focus on the effectiveness of microplastic materials in water and discuss their significant environmental impact in water, focusing on their persistence and harmful effects. Here are the key points related to the effectiveness of microplastic materials in water (Issac & Kandasubramanian, 2021):

I. Persistence and Distribution

Due to their durability and resistance to degradation, microplastics are highly persistent in aquatic environments. They can be found floating on the surface, suspended in the water column, or settled in sediments (Ahmed et al., 2021).

II. Transport and Contamination

Microplastics function as vectors for harmful pollutants. Due to their large surface area-to-volume ratio and hydrophobic nature, they can absorb contaminants from the surrounding environment. These contaminants can be transported long distances or transferred to aquatic organisms upon ingestion (Agboola & Benson, 2021).

III. Impact on Aquatic Life

Microplastics ingested by aquatic organisms have adverse effects, disrupting their physiological functions. The uptake of microplastics and their contaminants poses a significant hazard to marine and freshwater ecosystems.

IV. Sources and Entry Points

Synthetic textiles and domestic washing are primary sources of microplastic pollution. They release significant amounts of microfiber into wastewater, and many of these microplastics end up in water bodies in regions with inadequate wastewater treatment.

V. Variability in Sampling and Processing

The methods for sampling and processing microplastics vary widely, affecting the detection and quantification of microplastics in different studies. Standard methods include filtration and density separation for water and sediment samples.

2. Well-detailed documentation of the problem (reasons, processes that result in the problem)

Microplastics in water have become a significant global challenge due to various processes and sources contributing to their presence in aquatic environments. The primary reasons for the prevalence of microplastics in water include the fragmentation of larger plastic debris, industrial activities, and everyday human activities.

Large plastic items, such as bottles, bags, and packaging materials, degrade into microplastics through mechanical, photochemical, and biological processes. Mechanical forces like wave action and physical abrasion, combined with sunlight's photochemical degradation, break down plastics into smaller particles (Kutralam-Muniasamy et al., 2020). Industrial processes contribute significantly to microplastic pollution. For example, plastic pellets used in manufacturing can be spilled and enter water bodies. Furthermore, the abrasion of vehicle tires produces microplastic particles that wash into waterways. Paints and coatings on buildings and roads can also deteriorate and release microplastics (Sutkar et al., 2023). Its sources can be extensive (e.g., synthetic fibers from laundry, microplastic beads in personal-care products) or exceedingly small (tiny pieces of single-use plastics). During the washing of synthetic textiles, microfibers (exceptionally fine fibers) are released, which wastewater treatment plants are unable to fully capture, leading to their entry into rivers, lakes, and oceans. This is becoming a more significant problem for the well-being of aquatic systems and

human health. Marine organisms often ingest these microscopic plastic particles, which can cause physical damage to their organs, exposure to toxic agents, or interference with fundamental biological functions. Their threat does not end there, as microplastics often absorb pollutants and could even infiltrate the human food chain when we eat seafood. The microplastic challenge will have to be tackled holistically. The solutions can take redesigning wastewater treatment plants to ensure we better capture those particles, boosting recycling rates, cutting back on single-use plastic use, and even exploring modern technologies such as this robotic fish that hunts microplastics in water bodies. Nevertheless, more research and international cooperation are necessary if we want to move forward considerably concerning the spread and impact of microplastics (Sutkar et al., 2023).

3. Global Survey and the Global Problem of Microplastic Pollutants

1.1. Global Distribution of Microplastics

Microplastics have been detected in various environments across the globe, including remote locations such as the Arctic and deep-sea sediments. Studies have shown their presence in all major oceans, freshwater bodies, soil, air, human food, and drinking water. For example, microplastics were found in the Atlantic Ocean at an average concentration of 13 particles per cubic meter of surface water (Hale et al., 2020). In another study, microplastics in river sediments ranged from 1.3 to 8.9 mg/kg (Beibei, 2021).

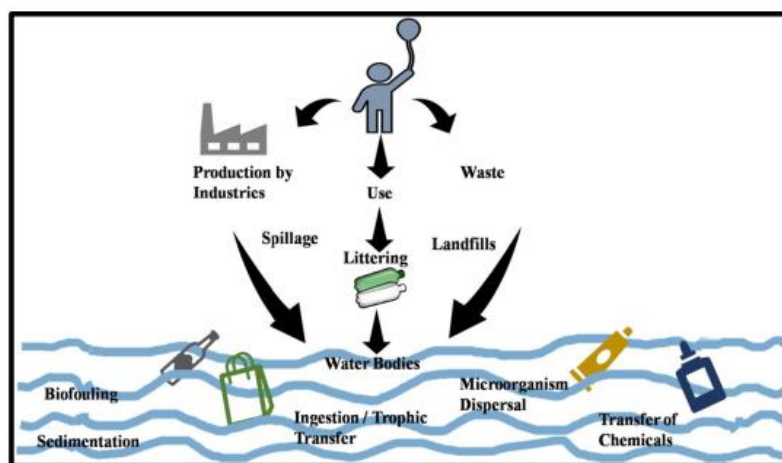


Figure 3. Microplastic distribution (Issac & Kandasubramanian, 2021).

3.2. Regional Research

Europe and Asia have conducted the most extensive research on microplastic pollution, accounting for approximately 38% and 36% of studies, respectively. In contrast, Latin America has conducted far fewer studies. Only limited research has been conducted in Argentina, Brazil, Chile, Colombia, and Mexico. For instance, a study in Mexico found concentrations of up to 26.5 particles per liter in surface water from the Grijalva River (Ziani et al., 2023).

3.3. Environmental Impact

Microplastics pose significant risks to both marine and freshwater organisms. They can cause physical damage, such as blockages and abrasions. They can also carry toxic substances like bisphenol A (BPA) and persistent organic pollutants (POPs) that accumulate in the food chain. According to a study by NOAA, 56% of small fish collected in the Pacific Ocean had ingested microplastics, which reduced growth, oxidative stress, and, in some cases, premature death (Ziani et al., 2023).

3.4. Human Health Concerns

Microplastics in drinking water and food raise concerns about potential health impacts. Microplastics have been detected in tap water, bottled water, seafood, and other food products. For instance, a study in Germany found that bottled water contained between 0.1 and 2.5 plastic particles per liter (Haleen et al., 2023). Although the long-term health effects of ingesting microplastics are still being investigated, there is increasing concern about their impact on the digestive and immune systems.

3.5. Pollutant Carriers

Microplastics carry harmful pollutants, such as heavy metals (mercury, cadmium) and pesticides. Research shows that microplastics can absorb these contaminants from their surroundings, increasing the likelihood of spreading pollutants across ecosystems. In San Francisco Bay, microplastics contained high concentrations of pesticides and heavy metals, which were then transferred to marine organisms that ingested, leading to bioaccumulation (Rafa et al., 2023).

4. Identify hotspots where the problem is most significant (Issac & Kandasubramanian, 2021)

Microplastic pollution is a global concern, with certain regions identified as hotspots due to their significant contamination levels. These hotspots are areas where the concentration of microplastics is notably higher, posing severe threats to local ecosystems and potentially human health. Key factors contributing to these hotspots include high population densities, industrial activities, tourism, and inadequate waste management systems. Here are some notable hotspots for microplastic pollution:

- a. Asian Coastal Regions, China: Rapid industrialization and population growth have led to severe microplastic contamination in coastal waters. The Yangtze River is a prominent plastic debris conduit that enters the East China Sea.
- India: Urban coastal areas like Mumbai exhibit prominent levels of microplastics, primarily from domestic and industrial waste (Zhang et al., 2021)
- b. European Waters, Mediterranean Sea: This semi-enclosed sea is particularly vulnerable due to heavy maritime traffic, tourism, and densely populated coastal cities. Microplastic concentrations here are among the highest globally.
- North Sea: Proximity to heavily industrialized nations and significant shipping activities contribute to its status as a microplastic hotspot (Sharma et al., 2021).
- c. North America, Great Lakes (USA/Canada): These large freshwater bodies are significantly impacted by microplastic

pollution from urban runoff, wastewater effluents, and plastic manufacturing. Gulf of Mexico: Industrial activities and riverine inputs, especially from the Mississippi River, lead to high microplastic concentrations in this region (Kye et al., 2023).

- d. South America, Coastal Argentina and Brazil: High population density and urban activities contribute to significant microplastic pollution in coastal waters. Studies show notable contamination in estuaries and coastal beaches (Pegado et al., 2024).
- e. Africa, Nile River Delta: The Nile River transports much plastic waste from inland areas to the sea, contributing significantly to Mediterranean plastic pollution.
- South African Coast: Urban and industrial activities in coastal cities like Cape Town contribute to high levels of microplastic pollution in the surrounding marine environment (Yakubu et al., 2024).
- f. Oceania, Sydney Harbour (Australia): Urban runoff and wastewater discharge are significant sources of microplastics in this area, affecting local marine life and water quality.
- Pacific Islands: Remote islands often accumulate large amounts of marine debris, including microplastics, transported by ocean currents. The Great Pacific Garbage Patch is a well-known example (Hossain et al., 2025).

5. Identify organizations that can deal with the problem

Several organizations are actively working to address the global challenge of microplastic pollution in water. Here are some key organizations:

a. *United Nations Environment Program (UNEP) (Wang et al., 2020)*: UNEP leads global environmental efforts and works on various initiatives to combat marine plastic pollution, including microplastics. They provide scientific assessments, support policy development, and promote international cooperation.

b. *International Union for Conservation of Nature (IUCN) (Canton, 2021)*: IUCN focuses on the impact of microplastics on marine biodiversity. Their research projects and reports, such as "Primary Microplastics in the Oceans: A Global Evaluation of Sources," provide valuable data and recommendations for mitigating microplastic pollution.

c. *The Ocean Cleanup (Areas, 2012)*: This non-profit organization develops advanced technologies to remove plastic from the oceans and prevent it from reaching marine environments. Their efforts include addressing microplastic pollution through innovative cleanup solutions.

d. *Plastic Pollution Coalition (Gibbs, 2019)*: This global coalition of organizations and individuals is committed to tackling plastic pollution by advocating for change, raising awareness, and promoting sustainable alternatives to single-use plastics. Their efforts include addressing the issue of microplastic pollution on multiple fronts.

e. *Marine Conservation Society (MCS) (Skold, 2020)*: MCS focuses on marine conservation, with a particular emphasis on addressing microplastic pollution.

Their efforts include organizing beach cleanups, running public awareness campaigns, and advocating for policies to reduce plastic waste in marine ecosystems.

f. *Greenpeace (Bloomfield & Solandt, 2006)*: Greenpeace campaigns against plastic pollution, including microplastics, by advocating for policy changes, conducting scientific research, and organizing public awareness initiatives to reduce plastic waste at its source.

5. Conclusion

This study presents the risk linked to microplastics that have been expanding for the type of pollution. This factor gets blown over due to microplastic's potential to spread poisonous materials over so many miles, which makes them one of the most dangerous waste materials today. Such particles have been shown to interfere with biological endeavors, stunt the growth of water-living creatures, and increase labor for the oxidative processes, causing the death of many before their timeline allows. The problem of tiny plastic particles being consumed by fish, and eventually humans, is a significant concern to which nobody is offering any solutions. Because of their environment, these microplastics are more likely to sorbate toxic pollutants. These plastics pose a potential danger as carriers. Such substances can exist along with the marine food webs, potentially resulting in severe fish poisoning, which could harm humans. More Cropped: Geographically, microplastic pollution is most pronounced in densely populated and highly industrialized areas with poor systems for waste disposal.

For instance, among the rivers that discharge plastic waste the most, China's Yangtze River sends many microplastics to the East China Sea. The Mediterranean Sea was identified within the same study as one of the sea basins with the highest microplastic liberated concentration and the highest relief from land due to jam-packed shipping and tourism activities. The Great Lakes region and the Gulf of Mexico also share the same cleansed water in which pollution from inner city flush and industrial processes is redressed. Alternative approaches and more demonstrations will

be engaged in such strategies addressing growing pollution. These pertain to waste management reform, behavioral modification toward plastic products or refusing to use them, and new means to cope with already polluted waters. Robotic solutions and edible microplastic-capturing fish robots are a significant step, but one solution is not enough without people's support. It is also critical that such research continues if people are to understand the complexities regarding the health of human populations and ecosystems brought about by microplastic pollution.

Author statement

O.S.Z. (Omar Saber Zinad) wrote the main manuscript, A.F.A. (Ali Fahem Al-Mamoori) collected the references, D.S.Z. (Dhafer Saber Zinad) were responsible for checking and reviewing the manuscript and Cs. Cs. (Csilla Csiha) checked and edited the manuscript. All authors reviewed the manuscript and contributed to the last version.

References

- Agboola, O. D., & Benson, N. U. (2021). Physisorption and chemisorption mechanisms influencing micro (nano) plastics-organic chemical contaminants interactions: a review. *Frontiers in Environmental Science*, 9, 678574.
<https://doi.org/10.3389/fenvs.2021.678574>
- Ahmed, M. B., Rahman, M. S., Alom, J., Hasan, M. S., Johir, M. A. H., Mondal, M. I. H., ... & Yoon, M. H. (2021). Microplastic particles in the aquatic environment: A systematic review. *Science of The Total Environment*, 775, 145793.
<https://doi.org/10.1016/j.scitotenv.2021.145793>
- Andrady, A. L., & Koongolla, B. (2022). Degradation and fragmentation of microplastics. *Plastics and the Ocean: Origin, Characterization, Fate, and Impacts*, 227-268.
<https://doi.org/10.1002/9781119768432.ch8>
- Areas, P. (2012). International Union for Conservation of Nature. IUCN Pakistan, IUCN.
- Arthur, C., Baker, J., & Bamford, H. (2009). Proceedings of the International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris. NOAA Technical Memorandum NOS-OR&R-30.
- Bloomfield, A., & Solandt, J. L. (2006). The Marine Conservation Society Basking Shark Watch 20-year report (1987-2006). Ross on Wye, UK: Marine Conservation Society.
- Buenaventura, N. (2017). Microplastic pollution in an urban Norwegian river sediment-an investigation of freshwater sediment extraction by elutriation (master's thesis).

- Canton, H. (2021). United Nations Environment Programme-UNEP. In *The Europa Directory of International Organizations 2021* (pp. 188-214). Routledge.
<https://doi.org/10.4324/9781003179900-30>
- Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: a review. *Marine pollution bulletin*, 62(12), 2588-2597.
<https://doi.org/10.1016/j.marpolbul.2011.09.025>
- Csiha, C., Hofmann, T., & Zinad, O. S. (2025). Investigation into Adhesion of Coatings and Adhesives of Eucalyptus and Grey Poplar for Building Applications. *Forests*, 16(2), 287.
<https://doi.org/10.3390/f16020287>
- Dawood, E. T., Al-Attar, A. A. A., & Zinad, O. S. (2020, March). The influence of wood ash on different cement mortar mixes. In *AIP Conference Proceedings* (Vol. 2213, No. 1). AIP Publishing.
<https://doi.org/10.1063/5.0000392>
- Frias, J. P., & Nash, R. (2019). Microplastics: Finding a consensus on the definition. *Marine pollution bulletin*, 138, 145-147.
<https://doi.org/10.1016/j.marpolbul.2018.11.022>
- Gibbs, B. R. (2019). Monitoring the Potential Fish Aggregating Device Effect of The Ocean Cleanup's Barrier in the Great Pacific Garbage Patch (Doctoral dissertation, University of Miami).
- Hale, R. C., Seeley, M. E., La Guardia, M. J., Mai, L., & Zeng, E. Y. (2020). A global perspective on microplastics. *Journal of Geophysical Research: Oceans*, 125(1), e2018JC014719.
<https://doi.org/10.1029/2018JC014719>
- Haleem, N., Kumar, P., Zhang, C., Jamal, Y., Hua, G., Yao, B., & Yang, X. (2023). Microplastics and associated chemicals in drinking water: A review of their occurrence and human health implications. *Science of The Total Environment*, 169594.
<https://doi.org/10.1016/j.scitotenv.2023.169594>
- He, B. (2021). Availability and mobility of microplastics in river sediments (Doctoral dissertation, Queensland University of Technology).
- Hossain, R., Ghose, A., & Sahajwalla, V. (2025). Microplastics pollution in Australia: Sources, impacts, and mitigation strategies. *Case Studies in Chemical and Environmental Engineering*, 11, 101036.
<https://doi.org/10.1016/j.cscee.2024.101036>
- Issac, M. N., & Kandasubramanian, B. (2021). Effect of microplastics in water and aquatic systems. *Environmental Science and Pollution Research*, 28, 19544-19562.
<https://doi.org/10.1007/s11356-021-13184-2>
- Kane, I. A., & Clare, M. A. (2019). Dispersion, accumulation, and the ultimate fate of microplastics in deep-marine environments: a review and future directions. *Frontiers in earth science*, 7, 80.
<https://doi.org/10.3389/feart.2019.00080>
- Kutralam-Muniasamy, G., Pérez-Guevara, F., Elizalde-Martínez, I., & Shruti, V. C. (2020). Review current trends, advances, and analytical challenges for contaminating microplastics in Latin America. *Environmental Pollution*, 267, 115463.
<https://doi.org/10.1016/j.envpol.2020.115463>
- Kye, H., Kim, J., Ju, S., Lee, J., Lim, C., & Yoon, Y. (2023). Microplastics in water systems: A review of their impacts on the environment and their potential hazards. *Heliyon*, 9(3).
<https://doi.org/10.1016/j.heliyon.2023.e14359>
- Narayanan, M. (2023). Origination, fate, accumulation, impact, of microplastics in a marine ecosystem and bio/technological approach for remediation: a review. *Process Safety and Environmental Protection*.
<https://doi.org/10.1016/j.psep.2023.07.013>

- Pegado, T., Andrades, R., Noleto-Filho, E., Franceschini, S., Soares, M., Chelazzi, D., ... & Giarrizzo, T. (2024). Meso-and microplastic composition, distribution patterns and drivers: A snapshot of plastic pollution on Brazilian beaches. *Science of The Total Environment*, 907, 167769. <https://doi.org/10.1016/j.scitotenv.2023.167769>
- Rafa, N., Ahmed, B., Zohora, F., Bakya, J., Ahmed, S., Ahmed, S. F., ... & Almomani, F. (2023). Microplastics as carriers of toxic pollutants: Source, transport, and toxicological effects. *Environmental Pollution*, 123190. <https://doi.org/10.1016/j.envpol.2023.123190>
- Richard C. Thompson et al., Lost at Sea: Where Is All the Plastic? *Science* 304, 838-838 (2004). DOI:10.1126/science.1094559 <https://doi.org/10.1126/science.1094559>
- Schirinzì, G. F. (2020). Chemical and ecotoxicological assessment of microplastics and emerging risks in the coastal environments.
- Shahnawaz, M., Sangale, M. K., Ade, A. B., Shahnawaz, M., Sangale, M. K., & Ade, A. B. (2019). Microplastics. *Bioremediation technology for plastic waste*, 11-19. https://doi.org/10.1007/978-981-13-7492-0_2
- Sharma, S., Sharma, V., & Chatterjee, S. (2021). Microplastics in the Mediterranean Sea: sources, pollution intensity, sea health, and regulatory policies. *Frontiers in Marine Science*, 8, 634934. <https://doi.org/10.3389/fmars.2021.634934>
- Skold, S. (2020). *Ecological Art Exhibition as Transformative Pedagogy* (Doctoral dissertation, The University of Nebraska-Lincoln).
- Sutkar, P. R., Gadewar, R. D., & Dhulap, V. P. (2023). Recent trends in degradation of microplastics in the environment: A state-of-the-art review. *Journal of Hazardous Materials Advances*, 100343. <https://doi.org/10.1016/j.hazadv.2023.100343>
- Wang, T., Wang, L., Chen, Q., Kalogerakis, N., Ji, R., & Ma, Y. (2020). Interactions between microplastics and organic pollutants: Effects on toxicity, bioaccumulation, degradation, and transport. *Science of The Total Environment*, 748, 142427. <https://doi.org/10.1016/j.scitotenv.2020.142427>
- Yakubu, S., Miao, B., Hou, M., & Zhao, Y. (2024). A review of the ecotoxicological status of microplastic pollution in African freshwater systems. *Science of The Total Environment*, 174092. <https://doi.org/10.1016/j.scitotenv.2024.174092>
- Zhang, Z., Deng, C., Dong, L., Liu, L., Li, H., Wu, J., & Ye, C. (2021). Microplastic pollution in the Yangtze River Basin: heterogeneity of abundances and characteristics in different environments. *Environmental Pollution*, 287, 117580. <https://doi.org/10.1016/j.envpol.2021.117580>
- Ziani, K., Ioniță-Mîndrican, C. B., Mititelu, M., Neacșu, S. M., Negrei, C., Moroșan, E., ... & Preda, O. T. (2023). Microplastics: a real global threat for environment and food safety: a state of the art review. *Nutrients*, 15(3), 617. <https://doi.org/10.3390/nu15030617>
- Zinad, O. S., & Csiha, C. (2024). Improving sustainability of mortar by wood-ash and Nano-SiO₂. *Case Studies in Chemical and Environmental Engineering*, 9, 100597. <https://doi.org/10.1016/j.cscee.2023.100597>