Volume 2, Issue 2, 2025

Intuitions & Insights

An Interdisciplinary Research Journal

ISSN: 3048-6793

An overview of microplastic pollution as a risk to human health and the ecosystem

Prasenjit Mahato

Department of Chemistry, Raghunathpur College, Raghunathpur, Purula, India

Email: prasen.mahato@gmail.com

Abstract: Environmental pollution is advancing alongside societal development. Among the various types of pollution, microplastic (MP) pollution has emerged as a recent and pressing threat to both ecosystems and the broader environment. The daily use of plastic continues to rise, and once discarded, it interacts with environmental elements like sunlight, heat, air, water, and microorganisms. Over time, these conditions cause plastics to degrade into microplastics, which then make their way into ecosystems. These microplastics can infiltrate the food chain, posing risks to aquatic life and human health. The increasing reliance on plastics in agriculture, packaging, and transportation is worsening this issue. One potential solution to MP pollution is transitioning from conventional plastics to bioplastics derived from non-edible sources such as algae.

Keywords: Microplastics, Plastics, Pollution, Health, Ecosystem, Hazard, Food cycle.

[*]**Corresponding author:** P. Mahato

Received: 10.03.2025; **Accepted**: 26.07.2025; **Published**: 30.07.2025

1. Introduction

Plastics are essential to human civilization. It becomes an integral part of our routine life. The benefit of the use of plastic can't be denied. As the society is developing the needs of plastic is increasing enormously.[i,ii] The larger part of the municipal waste contains various types of plastics, which were dumped outside of the city and used for land filling as well as land leveling.[iii]

When exposed to sunlight, air, and water, the discarded plastics began to break down into microplastics.[iv]

As a result, microplastics began to pollute soil and the food chain, endangering both the ecosystem and human health.[v] Microplastic pollution has turned out as a serious ecological problem, notably impacting biosphere across the world.[vi] These tiny plastic particles, typically measuring less than 5 millimeters, originate from various sources, including the diminution of larger plastic garbage, synthetic fabrics, and industrial processes.[vii] Their pervasive presence in terrestrial and aquatic environments poses serious threats to biodiversity, food webs, and ecosystem health.[viii]

Research indicates that microplastics can be consumed by an ample range of organisms, from plankton to larger aquatic species, leading to physical harm and potential toxicological effects. The accumulation of microplastics in food chains raises concerns about biomagnification and the subsequent effects on human well-being.[ix] Additionally, microplastics act as transporters for pollutants and microbes, further complexing their environmental impact.

Efforts to address microplastic pollution are ongoing, with strategies focusing on reducing plastic production, improving waste management, and enhancing public awareness. However, comprehensive studies are still needed to fully understand the long-term consequences of microplastic exposure on ecosystems and to develop effective mitigation measures.[x] This review highlights the urgent need for interdisciplinary approaches to combat microplastic pollution and safeguard ecological integrity.

As the thrown plastics come in touch of the environment it slowly degrades to the microplastics and contaminate the soil aquatic system, food cycle as well as the human health (Figure 1). It becomes a great threat to the civilization. The microplastic contamination can be analyzed using various analytical tools such as FTIR and Raman spectroscopy. Raman spectroscopy identified that the sizes of the microplastics are within 1-50 μm[xi].

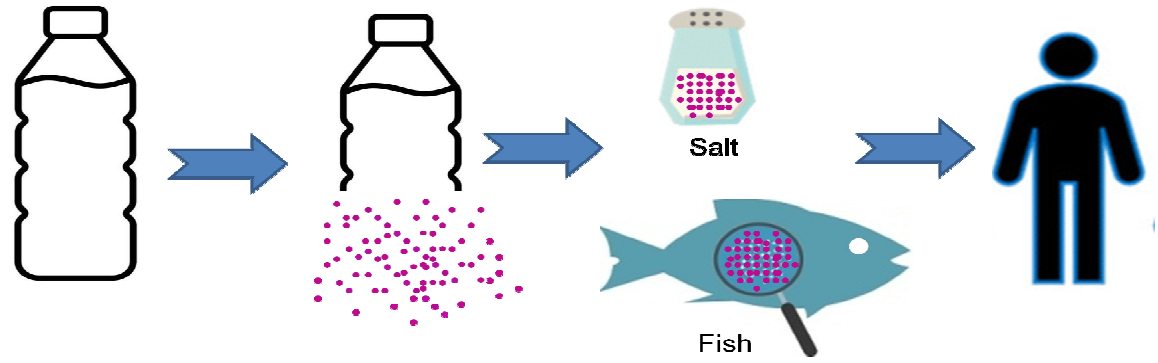

Figure 1: The degradation of unused plastics in to microplastics and its transfer mechanism to human being.

The broad breadth of microplastic study includes the detection, measurement, and analysis of microplastic contamination in a variety of habitats, including freshwater, marine, air, soil, and even live animals. There are still a number of topics covered in this field, including microplastics and nanoplastics in agricultural soils, ocean plastic cleanup technologies, microplastics and nanoplastics, their fate in freshwater and marine aquatic environments, their effects on the environment, their effects on human health, etc. I wanted to highlight scientific gaps in our knowledge of the movement of microplastics in the environment in this review. I have reviewed the literature in an effort to provide potential interactions between microplastics, other soil contaminants, various facets of microplastic pollution, and the detection of MP through interdisciplinary methods and existing analytical techniques. In order to give guidance for future research on mitigating the worldwide threat posed by MP pollution to the environment and living things, the review also looks for research gaps.

Discussion

2. Origin and classification of microplastics

Microplastics are primarily composed of polymers derived from petrochemical sources. Common types include polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC). These materials undergo various chemical processes during production, including polymerization, which links monomers into long chains. Additives, such as plasticizers, stabilizers, and colorants, are often incorporated, affecting their chemical properties and environmental behavior. Over time, these polymers degrade into smaller fragments through processes like photodegradation, oxidation, and mechanical abrasion, resulting in microplastics.

Microplastics originate from various sources, and they can be mainly classified into two principal kinds: primary microplastics and secondary microplastics.[xii]

Primary Microplastics

These are tiny plastic particles that are manufactured at a microscopic size for specific uses. Common origins include:

- **Cosmetics and Personal Care items:** Exfoliating beads in scrubs, toothpaste, and other beauty products (Figure 2 & 3).

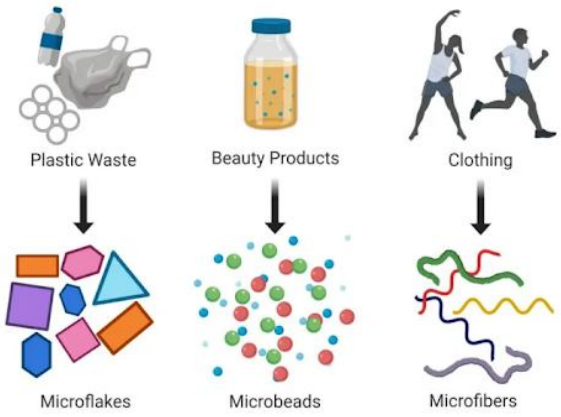

Figure 2: Degradation of various plastic materials in to different microplastics (microflakes, microbeads and microfibers).

- **Plastic waste:** Waste made of plastic, such as bottles, bags, and packaging, is difficult to get rid of. Rather, it disintegrates into smaller fragments. Physical abrasion (such as wind or waves), temperature changes, and exposure to sunshine (UV radiation) are the main causes of this deterioration. The plastic material becomes weaker as a result of these forces, breaking up into ever-tinier bits.
- **Industrial Processes:** Plastic pellets (nurdles) used in manufacturing that can spill during transport or processing.
- **Fibre and Textiles:** Synthetic fibers expelled during washing of fabrics made from polyester, nylon, and other materials (Figure 2 & 3).

- **Fishing industry: Nowadays commercial fishing industry used plastic made gear, nets, lines, traps etc to catch various organisms in the sea. Cheaper** plastic made nets and traps are regularly discarded at sea by the fishing industry which eventually degraded in to microplastics (Figure 3).

- **Shipping Line:** Ocean microplastic contamination is a serious worldwide environmental issue. Since polymers are utilized as binding agents in all anticorrosive and antifouling marine coatings, the paints used on commercial ships have been found to be a source of microplastics. Additionally, in-water cleaning procedures to eliminate biofouling may increase the release of microplastics from coatings.
- **Air blasting with microplastics:** Air blasting with tiny plastic particles has been used to clean engines, boats, and machinery of rust, paint, and other waste. When breathed, MPs produced by these activities can pose health hazards.

• **Wastewater treatment plants:** The wastewater treatment plants (WWTPs) have long been recognized as a potentially significant source of microplastic (MPs) pollution in aquatic environments. WWTPs can remove a significant portion of microplastics (50-99%), some particles, particularly smaller ones and fibers, can still pass through the treatment processes and be released into the environment.

- **Industrial Processes:** Plastic pellets (nurdles) used in manufacturing that can spill during transport or processing.
- **Textiles:** Synthetic fibers expelled during washing of fabrics made from polyester, nylon, and other materials (Figure 2 & 3).

Secondary Microplastics

These originate from the breakdown of larger plastic materials through various processes, including:

- **Plastic fragmentation by mechanical friction:** The breakdown of larger plastic objects into secondary microplastics, which are subsequently discharged into the environment, is mostly facilitated by mechanical friction (Figure 3). Abrasion, wear and tear, and impact forces are some of the mechanisms that might cause this fragmentation process, particularly in places where people deal with plastics frequently or where there is a lot of physical activity.
- **Plastic degradation by microorganisms:** Microorganisms break down plastic polymers into simpler chemicals through a process known as microbial degradation. Plastic breaks down into smaller

molecules like carbon dioxide and water as a result of a number of processes, including biodeterioration, depolymerization, assimilation, and mineralization.

- **Plastic breakdown by UV and sunlight:** Through a process known as photodegradation, sunlight—more especially, UV radiation—causes plastic to decompose. Chemical connections inside the plastic polymer are broken during this process, which lowers the molecular weight of the material and modifies its characteristics. Certain polymers degrade more quickly than others, and the degree of breakdown varies depending on the kind and content of the plastic.

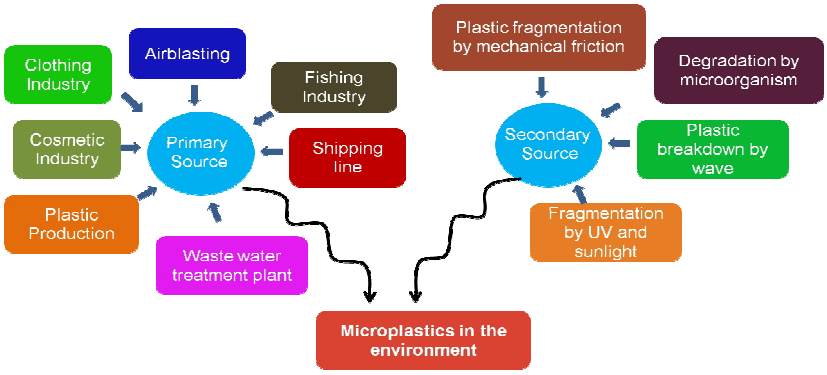

Figure 3: Schematic diagram representing of Primary and secondary sources of Microplastics.

3. Effect of Microplastric exposure on human health

The extensive environmental exposure to microplastics has sparked serious health concerns and possible negative effects on human health. These are some significant health risks associated with microplastics:

Chemical Exposure: Microplastics usually absorb dangerous chemicals from the ecosystem viz., heavy metals (Hg, Cd, Pb etc.), pesticides, persistent organic and inorganic pollutants. When ingested or inhaled such substances may enter the body and pose health risks.[xiii]

Inflammation and Immune Response: Microplastics can also activate inflammatory responses in the body. Such inflammation can lead to chronic health issues and influence immune function.[xiv]

Toxicity: Bisphenol A (BPA) and dangerous phthalates, which are known to have endocrine-disrupting effects, are present in certain microplastics. These substances may interfere with the hormone systems and cause issues related to development and reproduction.[xv]

Digestive Issues: Consumption of microplastics through contaminated foodstuff and water may lead to gastrointestinal problems. Microplastics could also effect on gut health and microbiome balance.[xvi]

Respiratory Problems: Microplastics contaminated dust also be inhaled, especially in the township areas and disrupt the respiratory system and may cause asthma.[xvii]

Bioaccumulation: Aquatic creatures that humans may eat may be impacted by microplastics that make their way up the food chain. Concerns over prolonged exposure to harmful compounds are raised by this bioaccumulation. [xviii]

Potential Carcinogenic Effects: According to some research, some microplastics may be carcinogenic, however further study is required to completely comprehend this risk.[xix]

Psychological Impact: Awareness of microplastics and their prevalence in the environment can contribute to anxiety and stress about environmental pollution and health risks.[xx]

Reducing exposure to microplastics and tackling pollution at its source are crucial for public health protection in light of these possible risks. To completely comprehend the long-term health effects of microplastics on people, more research is required.

4. Absorption Mechanisms of Microplastics

Size and Shape: Smaller microplastic particles may be more easily absorbed by cells in the gastrointestinal tract or lungs. Their shape can also influence how they interact with biological tissues.[xxi]

Endocytosis: Cells may take up microplastics through endocytosis, a process where the cell membrane engulfs particles, allowing them to enter the cell. This mechanism is particularly relevant for nanoplastics.

Transcytosis: Some studies suggest that microplastics can cross cell barriers (like the gut lining) via transcytosis, a process involving vesicles that transport substances across a cell.

5. Biological Effects of Microplastics

Inflammation: Microplastics can provoke an immune response, leading to inflammation. Chronic

exposure may contribute to various health issues.

Toxicity: Microplastics can carry harmful chemicals (e.g., additives, pollutants) that may leach into the body, potentially causing toxic effects.

Cellular Stress: The presence of microplastics may induce oxidative stress and disrupt cellular functions, affecting overall health.

6. How to control microplastic pollution

Controlling microplastic pollution is a multifaceted challenge, but there are several effective strategies we can pursue:

Cut Down on Plastic Use

Promote Alternatives: Instead of using single-use plastics, we have to promote the usage of reusable or biodegradable items.

Consumer Awareness: People have to be informed about the negative effects of plastic and the significance of cutting back on use.

Improve Waste Management

Enhanced Recycling: Government have to invest in better recycling facilities and technology to ensure that more plastics are recycled.

Proper Disposal: Plastics has to be properly disposed and community clean-up initiatives have to be taken in order to reduce littering.

Regulatory Measures

Bans and Regulations: Use of microbeads in cosmetic products and single-use plastics has to be banned.

Incentives for Companies: Incentives has to be Provide for companies that use sustainable materials or practices.

Innovative Filtration Solutions

Wastewater Treatment: We need to improve the wastewater treatment facilities in order to catch microplastics before they lost into rivers.

Stormwater Management: Superior filtration systems should be implemented in stormwater runoff areas to trap microplastics.

Community Engagement

Local Initiatives: Local authorities have to take urgent initiatives to reduce plastic use and promote sustainability.

Education Programs: Educational campaigns need to be started in school, college, universities and communities to raise awareness about microplastic pollution.

Collaboration and Partnerships

Global Cooperation: Collaborative work with international organizations should be started in order to tackle microplastic pollution on a larger scale.

Industry Partnerships: Joint venture with industries needs to develop more sustainable products and practices.

Promote Circular Economy

Design for Longevity: Encourage designs that extend the life of products and facilitate repair.

Recycling Innovations: In order to extend the useful life of plastics, government have to support technologies that allow closed-loop recycling.

By implementing these strategies collectively, we can make significant strides in controlling microplastic pollution and protecting our environment.

7. Current Research on Microplastics**:**

As the problem of microplastic pollution is becoming worse, research on microplastics is currently being conducted in many different areas, from environmental science to health effects.
These are some of the main fields of contemporary research:

Effects on the Environment

• **Ecosystem Contamination**: Research is looking at the effects of microplastics on aquatic and terrestrial ecosystems, especially how they build up in food webs. Researchers are trying to figure out how microplastics get into and impact marine systems, from plankton to fish to animals.[xxii]

• **Soil and Sediment**: In addition to water bodies, soils and sediments also contain microplastics. The destiny of microplastics in soil settings and their possible effects on agriculture and terrestrial biodiversity are the subjects of ongoing research.

• **Distribution and Degradation**: Scientists are investigating how long microplastics remain in ecosystems and how they decompose under various environmental circumstances. This involves research on how plastics break up into tiny bits and how they are transported across great distances.

Threat to Human Health

• **Inhalation Exposure**: Research is looking into the possible dangers of breathing in microplastic fibers, particularly in industrial and urban settings where they may become airborne. Understanding whether microplastics are harmful to respiratory health depends on this research.

• **Cellular Interaction**: Scientists are investigating the molecular interactions between microplastics and human cells, examining potential oxidative stress, inflammation, and other biological reactions that may result in endocrine disruption or diseases like cancer.[xxiii]

Measurement and Detection

• **Innovative Detection Techniques**: To find microplastics at trace levels in biological, water, and air samples, new technologies and techniques are being developed. More sensitive methods for identifying and

measuring microplastics are being employed, such as microscopy, FTIR (Fourier-transform infrared) spectroscopy, and Raman spectroscopy.

Microplastic Remediation

• **Chemical treatment and bioremediation**: Researchers are examining methods to eliminate or decomp ose microplastics from the environment.

This include investigating chemical treatments that can convert the polymers into less hazardous forms as well as biological methods, such as employing specific bacteria or fungi that can destroy plastics.

• **Technological Advancements**: New materials or methods for removing microplastics from the air and water are being created.

For instance, some scientists are developing novel materials that may absorb MPs from aquatic habitats or sophisticated filtration systems for wastewater treatment facilities.[xxiv]

8. Analytical techniques for the detection of MPs

Several modern analytical techniques were developed for the detection of MPs in diversified samples, which include:

Spectroscopic Techniques

These are widely used for **MPs identification**:

- **Fourier Transform Infrared Spectroscopy (FTIR)**
    - **μ-FTIR (Micro-FTIR)** for particles down to ~10 μm
    - Identifies polymer type based on IR absorption spectra.
- **Raman Spectroscopy**
    - High spatial resolution (down to ~1 μm)
    - Can be used on dark or pigmented plastics, but prone to fluorescence interference.
- **Near-Infrared Spectroscopy (NIR)**
    - Non-destructive, rapid, less detailed than FTIR.

Thermal Analysis Techniques

Used to detect and quantify microplastics by analyzing their **thermal degradation behavior**:

- **Differential Scanning Calorimetry (DSC)**
  Analyzes melting and crystallization behaviors of polymers.
- **Thermogravimetric Analysis (TGA)**
  Measures weight loss as temperature increases; can estimate polymer content.
- **Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS)**
  Breaks down polymers thermally and identifies products via GC-MS. Highly sensitive and useful for complex mixtures.

Mass Spectrometry Techniques

- **Direct Mass Spectrometry (e.g., MALDI-TOF-MS)**
  Direct polymer identification using mass-to-charge ratios.
- **LC-MS and GC-MS**
  After extraction, useful for identifying **plastic additives** and degradation products.

Emerging and Combined Techniques

- **Automated Particle Recognition Systems**
  Combine microscopy with FTIR/Raman for automated analysis (e.g., FPA-based FTIR imaging).
- **Machine Learning with Imaging**
  Improves particle classification and reduces manual bias.
- **Nano-FTIR or AFM-IR**
  For **nanoplastic** detection (<1 μm), though still largely in research stages.

9. Research gaps in the research of MPs pollution

Research on microplastics is still in its early stages, and many gaps remain in our understanding of their full impact. However, the increasing recognition of their pervasiveness and potential dangers is driving further investigations into both the science and solutions to address microplastic pollution. Here are **key research gaps** in the field of **microplastic pollution** that can help provide direction for future research:

(i) **There is a la**ck of standardized protocols for sampling, extraction, identification, and quantification of microplastics in different environments (water, soil and air). Thus researchers have to develop universally accepted, reproducible methods to allow reliable comparison across studies.

(ii) **There is** inadequate understanding of how microplastics and associated chemicals affect human health at cellular and systemic levels. To understand such effect long-term in vivo epidemiological studies have to be done.

(iii) Incomplete knowledge of how microplastics move through and persist in ecosystems (e.g., sedimentation, degradation, bioaccumulation).

(iv) Limited data on the sub-lethal and long-term ecological impacts of microplastic ingestion by wildlife and its transfer through trophic levels.

(v) Unclear role of microplastics as carriers of toxic chemicals and microorganisms (e.g., heavy metals, antibiotics, pathogens).

(vi) Investigate sorption/desorption mechanisms and potential for microplastics to introduce foreign contaminants into organisms.

(vii) Scarce data on nanoplastics due to detection challenges and unknown biological effects.

(viii) Poor understanding of environmental degradation processes and rates of different plastic polymers.

(ix) Limited integration of social science perspectives on microplastic awareness, consumer behavior, and policy effectiveness.

(x) Incomplete knowledge of primary sources and pathways (e.g., wastewater, synthetic textiles, tire wear).

10. Conclusion

Environmental MP contamination is increasing everywhere. Human society's use on plastic is growing significantly, which causes MPs pollution to rise as well. When plastic litter enters the soil, it gradually breaks down into MPs, after which biotic and abiotic transport takes place. The MPs are ingested and transported by a variety of microorganisms, including vertebrates, macro, meso, and micro invertebrates. Additionally, Mps contaminates ground water, deeper soil, and other areas. Smaller creatures like earthworms or snails absorb Mps, which is subsequently consumed by humans, chickens, ducks, sheep, and goats. Wind is another abiotic way that MPs are transported. Higher exposure levels to MPs in experiments revealed harmful consequences. Higher surface energy microplastics also absorb heavy metals, and the

toxicity level is raised by hydrophobic organic compounds.

The majority of Indians are ignorant of its harmful effects. Individuals typically use a lot of plastic products and discard them in the trash. Drinking hot liquids like tea or coffee in throwaway cups or eating hot food on throwaway plates can also cause the body to absorb Mps. When hot food is present, the plastic coating on these plates readily transforms into MPs. In order to reduce plastic trash and MPs contamination, the government, non-governmental organizations, and the media must take the initiative. They must educate both urban and rural residents on the proper usage and recycling of plastics.

Acknowledgment: The author is thankful to the editor and the referee for their valuable suggestions and comments.

References

[i]. Kataria, N.; Garg, V. K.; Han, C.; Rene, E. R. Microplastic Pollution - Occurrence, Health Risk and Challenges; CRC Press, 2025.

[ii]. North, E. J.; Halden, R. U. Plastics and Environmental Health: The Road Ahead. *Rev. Environ. Health* **2013**, *28* (1), 1–8. https://doi.org/10.1515/reveh-2012-0030.

[iii]. Cirrincione, L.; La Gennusa, M.; Peri, G.; Rizzo, G.; Scaccianoce, G. The Landfilling of Municipal Solid Waste and the Sustainability of the Related Transportation Activities. *Sustainability* **2022**, *14*, 5272. https://doi.org/10.3390/su14095272.

[iv]. Hale, R. C.; Seeley, M. E.; La Guardia, M. J.; Mai, L.; Zeng, E. Y. A Global Perspective on Microplastics. *J. Geophys. Res.* 2020, *125*, e2018JC014719. https://doi.org/10.1029/2018JC014719.

[v]. Cverenkárová, K.; Valachovičová, M.; Mackuľak, T.; Žemlička, L.; Bírošová, L. Microplastics in the Food Chain. *Life* **2021**, *11* (12), 1349. https://doi.org/10.3390/life11121349.

[vi]. Villarrubia-Gómez, P.; Cornell, S. E.; Fabres, J. Marine Plastic Pollution as a Planetary Boundary Threat – The Drifting Piece in the Sustainability Puzzle. *Mar. Policy* **2018**, *96*, 213-220.

[vii]. Moore, C. J. Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environ. Res.* **2008**, *108* (2), 131–139. https://doi.org/10.1016/j.envres.2008.07.025.

[viii]. Reid, A. J.; Carlson, A. K.; Creed, I. F.; Eliason, E. J.; Gell, P. A.; Johnson, P. T. J.; Kidd, K. A.; MacCormack, T. J.; Olden, J. D.; Ormerod, S. J.; Smol, J. P.; Taylor, W. W.; Tockner, K.; Vermaire, J. C.; Dudgeon, D.; Cooke, S. J. Emerging Threats and Persistent Conservation Challenges for Freshwater Biodiversity. *Biol. Rev.* **2019**, *94* (4), 849–873. https://doi.org/10.1111/brv.12480.

[ix]. Elizalde-Velázquez, G. A.; Gómez-Oliván, L. M. Microplastics in Aquatic Environments: A Review on Occurrence, Distribution, Toxic Effects, and Implications for Human Health. *Sci. Total Environ.* **2021**, *780*, 146551. https://doi.org/10.1016/j.scitotenv.2021.146551.

[x]. Prata, J.C.; Silva, A.L.P.; da Costa, J.P.; Mouneyrac, C.; Walker, T.R.; Duarte, A.C.; Rocha-Santos, T. Solutions and Integrated Strategies for the Control and Mitigation of Plastic and Microplastic Pollution. Int. J. Environ. Res. Public Health 2019, 16, 2411. https://doi.org/10.3390/ijerph16132411.

[xi]. Catarina F. Araujo, Mariela M. Nolasco, Antonio M.P. Ribeiro, Paulo J.A. Ribeiro-Claro, Identification of microplastics using Raman spectroscopy: Latest developments and future prospects,
Water Research, Volume 142, 2018, Pages 426-440, ISSN 0043-1354, https://doi.org/10.1016/j.watres.2018.05.060.

[xii]. Osman, A. I.; Hosny, M.; Eltaweil, A. S.; Omar, S.; Elgarahy, A. M.; Farghali, M.; Yap, P. S.; Wu, Y. S.; Nagandran, S.; Batumalaie, K.; Gopinath, S. C. B.; John, O. D.; Sekar, M.; Saikia, T.; Karunanithi, P.; Hatta, M. H. M.; Akinyede, K. A. Microplastic Sources, Formation, Toxicity and Remediation: A Review. *Environ. Chem. Lett.* **2023**, *4*, 1–41. https://doi.org/10.1007/s10311-023-01593-3.

[xiii]. Hu, L.; Zhao, Y.; Xu, H. Trojan Horse in the Intestine: A Review on the Biotoxicity of Microplastics Combined with Environmental Contaminants. *J. Hazard. Mater.* **2022**, *439*, 129652. https://doi.org/10.1016/j.jhazmat.2022.129652.

[xiv]. Zhao, B.; Rehati, P.; Yang, Z.; Cai, Z.; Guo, C.; Li, Y. The Potential Toxicity of Microplastics on Human Health. *Sci. Total Environ.* **2024**, *912*, 168946.

https://doi.org/10.1016/j.scitotenv.2023.168946.

[xv]. Ohore, O. E.; Zhang, S. Endocrine Disrupting Effects of Bisphenol A Exposure and Recent Advances on Its Removal by Water Treatment Systems. A Review. *Sci. Afr.* **2019**, *5*, e00135. https://doi.org/10.1016/j.sciaf.2019.e00135.

[xvi]. Emenike, E. C.; Okorie, C. J.; Ojeyemi, T.; Egbemhenghe, A.; Iwuozor, K. O.; Saliu, O. D.; Okoro, H. K.; Adeniyi, A. G. From Oceans to Dinner Plates: The Impact of Microplastics on Human Health. *Heliyon* **2023**, *9* (10), e20440. DOI: 10.1016/j.heliyon.2023.e20440. PMID: 37790970; PMCID: PMC10543225.

[xvii]. Lin, Y. D.; Huang, P. H.; Chen, Y. W.; Hsieh, C. W.; Tain, Y. L.; Lee, B. H.; Hou, C. Y.; Shih, M. K. Sources, Degradation, Ingestion, and Effects of Microplastics on Humans: A Review. *Toxics* **2023**, *11* (9), 747. DOI: 10.3390/toxics11090747. PMID: 37755757; PMCID: PMC10534390.

.

[xviii]. Miller, M. E.; Hamann, M.; Kroon, F. J. Bioaccumulation and Biomagnification of Microplastics in Marine Organisms: A Review and Meta-Analysis of Current Data. *PLoS One* **2020**, *15* (10), e0240792. https://doi.org/10.1371/journal.pone.0240792. PMID: 33064755, PMCID: PMC7567360.

[xix]. Kumar, R.; Manna, C.; Padha, S.; Verma, A.; Sharma, P.; Dhar, A.; Ghosh, A.; Bhattacharya, P. Micro(nano)plastics Pollution and Human Health: How Plastics Can Induce Carcinogenesis to Humans? *Chemosphere* **2022**, *298*, 134267. https://doi.org/10.1016/j.chemosphere.2022.134267.

[xx]. Sun, J.; Peng, S.; Yang, Q.; Yang, J.; Dai, Y.; Xing, L. Microplastics/Nanoplastics and Neurological Health: An Overview of Neurological Defects and Mechanisms. *Toxicology* **2025**, *511*, 154030. https://doi.org/10.1016/j.tox.2024.154030.

[xxi]. Bermúdez, J. R.; Swarzenski, P. W. A Microplastic Size Classification Scheme Aligned with Universal Plankton Survey Methods. *MethodsX* **2021**, *8*, 101516. https://doi.org/10.1016/j.mex.2021.101516.

[xxii]. Roy, P.; Mohanty, A. K.; Misra, M. Microplastics in Ecosystems: Their Implications and Mitigation Pathways. *Environmental Science Advances* **2022**, *1* (1), 9-29. https://doi.org/10.1039/d1va00012h.

[xxiii]. Mahmud, F.; Sarker, D. B.; Jocelyn, J. A.; Sang, Q.-X. A. Molecular and Cellular Effects of Microplastics and Nanoplastics: Focus on Inflammation and Senescence. *Cells* **2024**, *13*, 1788. https://doi.org/10.3390/cells13211788.

[xxiv]. Ahmed, M. B.; Rahman, M. S.; Alom, J.; Hasan, M. S.; Johir, M. A. H.; Mondal, M. I. H.; Lee, D.-Y.; Park, J.; Zhou, J. L.; Yoon, M.-H. Microplastic Particles in the Aquatic Environment: A Systematic Review. *Science of The Total Environment* **2021**, *775*, 145793. https://doi.org/10.1016/j.scitotenv.2021.145793.