MICROPLASTIC: A POLLUTANT IN ECOSYSTEM

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What are Microplastics?

Microplastics are small, less than 5 millimeter-sized plastic particles found in various forms, such as fibres, fragments, beads, or pellets. They are found in various environments, including oceans, rivers, soil, and air. Microplastics pose environmental and health concerns due to their persistence, potential toxic substance accumulation, wildlife ingestion, and potential entry into the food chain, impacting ecosystems and human health.[1]

Types of Microplastics:

1) ***Primary Microplastics:*** These are intentionally manufactured as small plastic particles for use in products like exfoliating scrubs, cosmetics, and industrial abrasives. Primary microplastics can also include pellets or nurdles used in plastic production processes.
2) ***Secondary Microplastics:*** These are formed through the degradation and fragmentation of larger plastic items such as bottles, bags, and packaging materials. Mechanical forces like wave action, UV radiation, and abrasion break down these plastics into smaller particles.

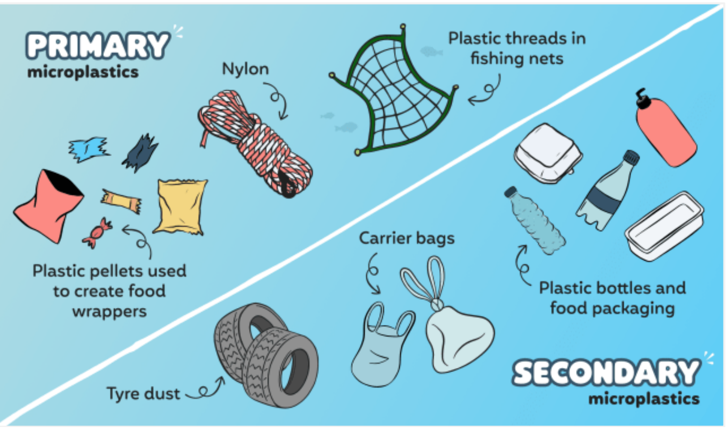

Figure 1. Schematic of the primary microplastics and secondary microplastics

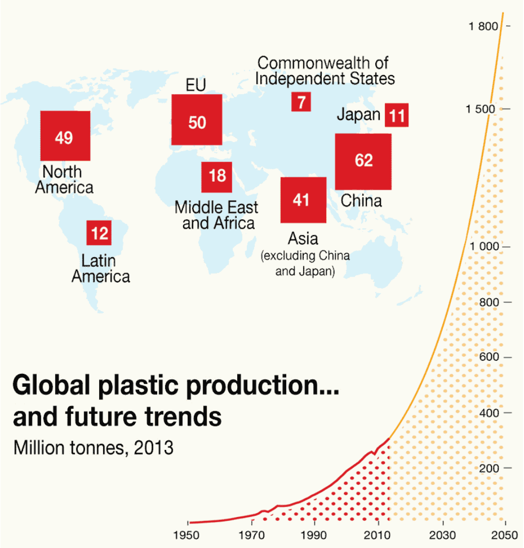

Figure 2. Projected four-fold increase in plastic production tonnage by 2050

According to WHO, plastic products are widely used in various sectors due to their lightweight design and convenience However, the increasing demand for plastics leads to increased production rates and waste accumulation, particularly single-use plastics. The rate of plastic production has grown faster than any other material since the 1970s, with a projected **1800** million tonnes by **2050**. This surge in plastic pollution poses significant threats to environmental stability, with much likely ending up in landfills or oceans, where it fragments and degrades into microplastics and nanoplastics.[2]

Source And Transports

- **Atmospheric environment**

Microplastics in the atmospheric environment originate from urban runoff, road traffic emissions, industrial activities, agricultural practices, and marine sources, with particles released into the air through various processes such as wear and tear, mechanical breakdown, and fragmentation. Once airborne, microplastics can be transported over long distances by wind and atmospheric currents. They may undergo processes such as deposition onto surfaces like soil and water bodies, or scavenging by precipitation. Additionally, microplastics can be vertically transported in the atmosphere through convection and turbulence.[3]

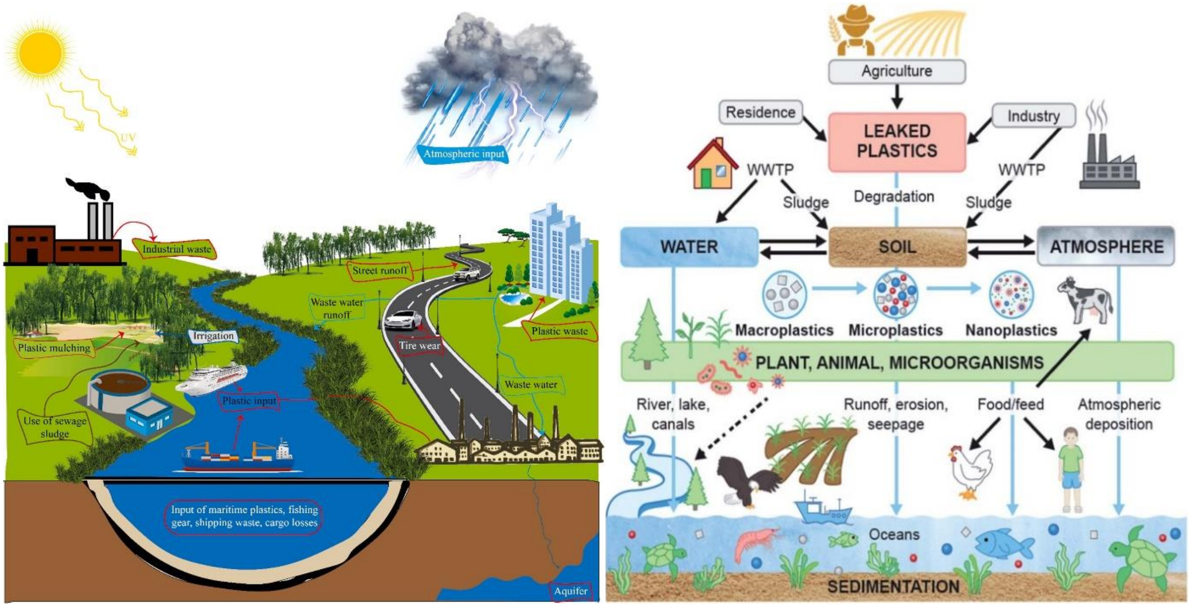

Figure 3. Conceptual illustration of microplastic sources in the environment and their transportation routes

- **Aquatic environment**
  The main sources of microplastics in aquatic habitats are the breakdown of larger plastic objects such as bottles and bags and the release of microplastics from synthetic textiles during washing. They can enter water bodies through urban and agricultural runoff, transporting through rivers, streams, and stormwater systems. Marine sources like fishing gear and coastline debris also contribute to microplastic pollution. Once in the water, microplastics can be transported by currents, tides, and waves, dispersing across oceanic regions. They can also be ingested by aquatic organisms and transported through food webs, potentially accumulating in higher trophic levels. The diverse sources and transport pathways of microplastics pose significant ecological impacts on marine ecosystems.[4]
- **Terrestrial environment**

  Microplastics in terrestrial environments come from various sources, including the degradation of larger plastic items, agricultural plastics, and synthetic textiles. They can also be introduced through plastic mulches and fertilizers, landfills, and illegal dumping sites. Once in the environment, microplastics can be transported through erosion, runoff, and organism movement. They can also be redistributed within ecosystems through bioturbation. Moreover, the COVID-19 pandemic introduced new materials to meet urgent needs and led to the spread of more microplastics than ever before. The causes and routes of microplastics entering terrestrial environments are varied and constantly changing, leading to extensive diffusion and buildup in soils, sediments, and terrestrial ecosystems.[5]

Impacts Of Microplastics on Ecosystems

Microplastics have several significant impacts on ecosystems:

1) ***Nutrient Dynamics:*** Microplastics can influence nutrient dynamics in aquatic environments through various mechanisms. For example, microplastics can adsorb and release nutrients such as nitrogen and phosphorus, altering nutrient availability and cycling. Additionally, microplastics can act as surfaces for microbial colonization and nutrient uptake, affecting microbial activity and nutrient transformation processes.

2) ***Bioaccumulation and Biomagnification:*** Microplastics can be ingested by a wide range of organisms, from zooplankton to large marine mammals. Once ingested, they can accumulate in the tissues of these organisms over time. As predators consume prey with microplastics, the concentration of microplastics can increase through biomagnification, leading to higher levels of exposure in organisms higher up the food chain, including humans.

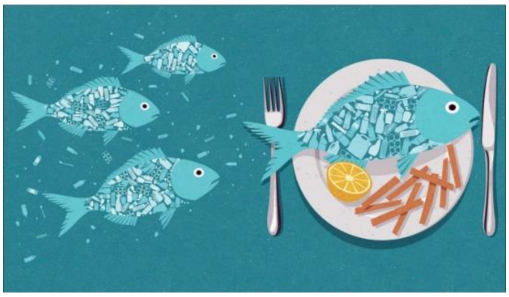
Figure 4. Biomagnification illustration

3) ***Physical Harm and Blockages:*** Microplastics can cause physical harm and blockages in the digestive systems of marine organisms, leading to malnutrition, internal injuries, and death. Ingestion of microplastics can also impair feeding efficiency and reduce the ability of organisms to obtain essential nutrients.

4) ***Chemical Contamination:*** Microplastics have high surface area-to-volume ratios and can adsorb various chemicals from the surrounding water, including nutrients, heavy metals, and organic pollutants (POPs). This adsorption process can alter the distribution and availability of these substances in the water column, affecting biogeochemical cycling and ecosystem dynamics. Furthermore, microplastics can serve as vectors for the transport of these adsorbed chemicals, potentially spreading contaminants to different locations within aquatic ecosystems. When ingested by organisms, these chemicals can leach into tissues, potentially causing toxic effects, disrupting physiological processes, and impairing reproductive success.

5) ***Disruption of Behaviour and Physiology:*** Exposure to microplastics can disrupt the behaviour, physiology, and biochemical processes of organisms, including feeding behaviour, reproduction, growth, and development. This can have cascading effects on population dynamics, ecosystem structure, and ecological interactions.

6) ***Habitat Alteration:*** Microplastics can alter habitats and ecosystems by accumulating in sediments, soils, and water bodies, affecting nutrient cycling, sediment stability, and the distribution of benthic organisms. Microplastics can accumulate in sediments, where they interact with benthic organisms and sedimentary processes. Microplastics deposited in sediments can alter sediment stability, organic matter decomposition rates, and nutrient cycling. They may also serve as substrates for microbial colonization and biofilm formation, influencing sediment-water interactions and biogeochemical fluxes at the sediment-water interface, further altering ecosystem dynamics.

7) ***Transport of Pathogens:*** Microplastics can act as vectors for the transport of pathogens, including bacteria, viruses, and harmful algal species, in aquatic environments. This can increase the spread of disease among marine organisms and impact ecosystem health and resilience. They can harbour diverse microbial communities, including bacteria, algae, and fungi, forming biofilms on their surfaces. These microbial communities can interact with microplastics through

processes such as colonization, degradation, and nutrient cycling. Microbes attached to microplastics may enhance nutrient cycling by promoting the breakdown of organic matter and the release of nutrients such as nitrogen and phosphorus. However, microbial degradation of microplastics can also release additional carbon and other compounds into the water, potentially altering biogeochemical processes.

8) ***Carbon Sequestration and Cycling:*** Microplastics can influence carbon sequestration and cycling in aquatic ecosystems by serving as substrates for microbial growth and organic matter decomposition. Microbial colonization of microplastics can lead to the production of microbial biomass and extracellular polymeric substances (EPS), which contribute to carbon storage and cycling in aquatic environments. Furthermore, the degradation of microplastics by microbes can release carbon compounds into the water, potentially impacting carbon fluxes and ecosystem dynamics.

9) ***Ecological Impacts:*** The cumulative effects of microplastics on marine ecosystems can lead to shifts in community structure, changes in species composition, and declines in biodiversity. These ecological impacts can have far-reaching consequences for ecosystem function, stability, and resilience.

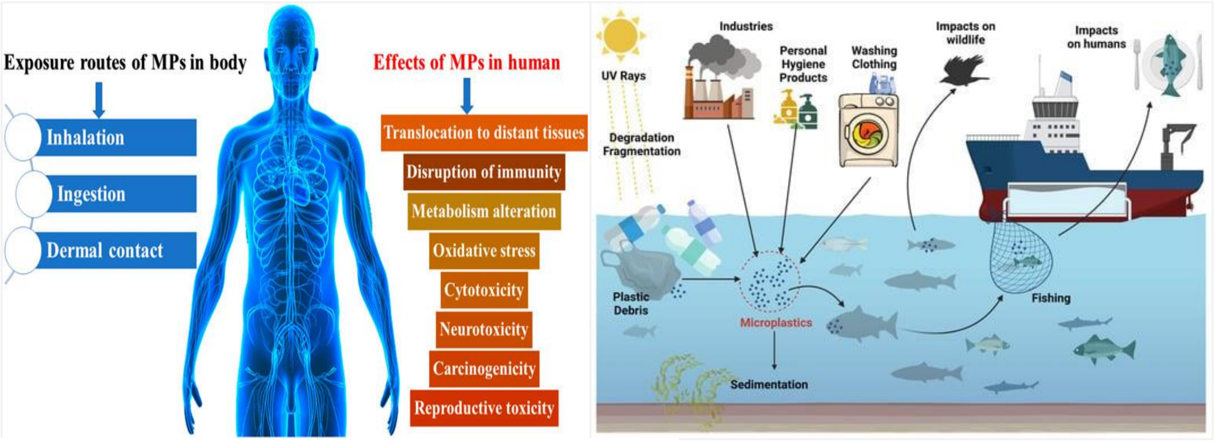

Figure 5. Impact of Microplastics on Ecosystem

Microplastic remediation

☞ ***Source Reduction:*** One of the most effective ways to address microplastic pollution is to prevent it at the source by reducing plastic production, consumption, and waste generation. This can be achieved through measures such as promoting sustainable alternatives to plastic products, implementing policies to limit single-use plastics, and improving waste management practices, including recycling and proper disposal.

☞ ***Wastewater Treatment:*** Enhancing wastewater treatment processes can help prevent the release of microplastics into the environment. Advanced treatment technologies, such as membrane filtration, activated carbon adsorption, and ozonation, can effectively remove microplastics from wastewater effluent before it is discharged into water bodies.

☞ ***Stormwater Management:*** Implementing green infrastructure and stormwater management practices can help reduce the transport of microplastics from urban areas to waterways. These practices include vegetated swales, permeable pavements, and retention ponds, which capture and filter stormwater runoff, preventing microplastics from reaching rivers, lakes, and oceans.

- ***Bioremediation:*** Microorganisms have the potential to degrade and mineralize certain types of plastics under specific conditions. Bioremediation strategies involve harnessing the metabolic activities of bacteria, fungi, and other microorganisms to break down microplastics into harmless byproducts. Research is ongoing to develop and optimize bioremediation techniques for effectively degrading microplastics in different environments.

- ***Physical Removal:*** Mechanical methods can be used to physically remove microplastics from the environment, particularly in areas with high concentrations of pollution. These methods include manual collection, sediment dredging, and the use of specialized filtration devices and skimmers. While physical removal may be effective on a small scale, it is often impractical for large-scale remediation efforts.

- ***Natural Remediation Processes:*** Natural processes such as sedimentation, bioturbation, and photodegradation can help sequester and break down microplastics in the environment over time. Enhancing these natural remediation processes through habitat restoration, shoreline stabilization, and ecosystem management can help reduce the accumulation and persistence of microplastics in aquatic and terrestrial ecosystems.

- ***Policy and Regulation:*** Effective governance and regulatory frameworks are essential for addressing microplastic pollution at local, national, and global levels. Policy measures such as bans on single-use plastics, extended producer responsibility schemes, and pollution control regulations can help incentivize plastic reduction, improve waste management practices, and promote sustainable alternatives.

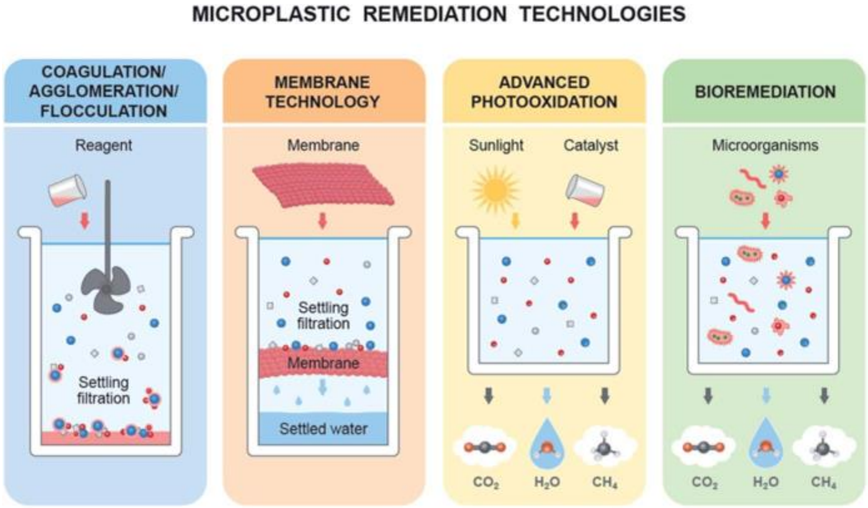

Figure 6. An overview of microplastic remediation technologies

Conclusion

In summary, microplastics represent a pervasive and insidious pollutant in ecosystems worldwide, with far-reaching implications for biodiversity, ecosystem function, and human health. Originating from various sources and dispersing through terrestrial, freshwater, and marine environments, microplastics infiltrate every level of the food chain, posing risks to organisms ranging from microscopic plankton to top predators and ultimately impacting ecosystem stability and resilience. Moreover, the ability of microplastics to adsorb and transport toxic chemicals further exacerbates their ecological and health impacts. To effectively tackle the issue of microplastic pollution, it is imperative to implement comprehensive approaches like source reduction, enhanced waste management, technological advancements, and policy interventions. Thus, by prioritizing the mitigation of microplastic pollution, we can strive to preserve the integrity of ecosystems, safeguard biodiversity, and protect human health for present and future generations.

References

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