Plastic and Microplastic Pollution in the Sea

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Plastics are materials that consist of varieties of synthetic or semi-synthetic organic compounds. They are malleable and can be moulded into solid objects of various shapes and sizes. Currently, plastics have become indispensable materials used in many sectors of our day-to-day life, like automotive, agriculture, health, construction/building, packaging, and textiles (Plastics Europe, 2017). Most meet only single-use needs; hence, a substantial proportion comprises 54% of the global mass of anthropogenic waste is constituted by plastic (Hoellein et al., 2014)**.** The convenience offered by these materials comes at a significant cost to the environment.

Polymer is the major ingredient in plastic. Among the varieties, the marine litter is dominated by polypropylene (PP), polyethene (PE), polyvinyl chloride (PVC), polyurethane (PUR), poly terephthalate (PET), and polystyrene (PS), which together comprise approximately 80 per cent of total plastics production (PlasticsEurope 2017). Usually, the discarded plastics, whether in the form of single-use items or larger debris, find their way into water bodies, where they persist and degrade into microplastics over time. This process is accelerated by environmental factors such as sunlight, waves, and microbial action, releasing tiny particles that permeate oceans and waterways.

About 5.25 trillion pieces of plastic debris have been estimated in the ocean and about 2,69,000 tons float on the surface waters (Nammalwar, 2020). The first reports of plastic litter in the oceans are in the early 1970s (Coe and Rogers, 1996). Collected plastic waste is disposed of in landfills or incinerated to generate electricity in many countries. The widespread use of plastic materials and inadequate waste management practices have led to the pervasive contamination of marine ecosystems. Plastic pollution directly threatens marine life and presents potential risks to human health through the food chain.Thus, plastic is considered the latest threat to the sustainable health of the ocean and its inhabitants and, indirectly, the livelihood of dependent mankind.

Sources of plastic pollution in the sea

The major portion of marine plastic litter is terrestrial in origin, like riverine discharge or from coastal effluents. In contrast, only a minor contribution is from marine sources like discharges from shipping and fishing activities (~25% of the total terrestrial discharge) **(**Li, et al., 2016). Aquatic ecosystems are interconnected with the terrestrial environment; therefore, changes in one system impact another (Lebreton et al., 2017)**.** Thus, the perception of the sources of plastic and microplastic pollution in the sea is crucial for developing effective strategies to mitigate their impact on marine life and ecosystems.

Primary Sources of Plastic Pollution in the sea:

1.Single-Use Plastics:

Single-use plastics, such as bags, bottles, and packaging, contribute significantly to marine pollution. These items are designed for short-term use but remainin the environment for many more years. Improper disposal and inadequate waste management systems allow these plastics to enter rivers and oceans.

2. Fishing Gear:

Deserted, lost, or thrown awayfishing gear, commonly known as ghost nets, poses a severe threat to marine life. These nets, made of durable synthetic materials, continue to trap and entangle marine organisms, leading to injury or death. The breakdown of these materials also contributes to the microplastic load in the ocean.

3. Industrial Discharges:

Industrial processes release large amounts of plastic particles into water bodies. Plastic pellets, also known as nurdles, are the primary matterused in the manufacturing of plastic items. Accidental spills and inadequate containment during transportation lead to the release of these pellets into rivers and oceans.

4. Stormwater Runoff:

Urban areas with impermeable surfaces contribute to plastic pollution through stormwater runoff. Rainwater washes plastics

from streets, sidewalks, and other surfaces into storm drains, ultimately reaching rivers and oceans. This source could be more problematic in densely populated coastal regions.

Plastic debris in the surface waters of Andaman and Nicobar Island

Microplastic Sources:

1. Fragmentation of Larger Plastics:

Mechanical and environmental forces, such as sunlight and wave action, break down larger plastic items into smaller fragments. These microplastics can be less than five millimetersin size and are often invisible to the naked eye. The process of degradation can take years, if not decades, depending on the type of plastic.

2. Synthetic Fibers:

The washing of synthetic textiles, such as polyester and nylon, releases microplastic fibers into wastewater. These fibers enter water bodies through sewage systems and ultimately contribute to the microplastic burden in oceans. The ubiquity of synthetic fibers in clothing exacerbates this issue.

3. Cosmetics and Personal Care Products:

Microbeads, minute plastic particles used in cosmetics and beauty–relatedproducts, pose a direct threat to marine life. When these products are washed off, the microbeads enter water systems and, eventually, the oceans. Many countries have implemented bans on the use of microbeads in makeup to address this issue.

4. Plastic Pellet Spills:

Accidental spills of plastic pellets during transportation and manufacturing contribute to the presence of microplastics in the sea. These small, pre-production pellets can absorb pollutants from the surrounding environment and harm marine organisms upon ingestion.

Impact of plastic pollution in marine life:

Plastic impacts the ocean and its inhabitants both directly and indirectly. Direct effects are due to ingestion or entanglement in litter and fishing gear. Indirect effects include the evading of invasive species and pathogens with floating plastics, impacts on biodiversity, and loss of ecosystem services (GESAMP 2015).

Impact on Marine Life:

To date, nearly 700 marine species have been observed interacting with marine debris (Gall & Thompson 2015), with ingestion and entanglement being the two primary forms of interaction. The consequences of plastic pollution on marine life are profound and multifaceted. Ingestion of plastic is a pervasive issue, as marine species mistake plastic particles for food.

1. Ingestion:

This ingestion can lead to internal injuries, blockages, malnutrition, and, ultimately, death. This has detrimental effects on their health, disrupting ecosystems and jeopardizing biodiversity (Savoca et al., 2017).

2. Entanglement:

Abandoned fishing gear lead to a significant entanglement risk to sea life. Whales, dolphins, sea turtles, and seabirds can become ensnared in nets and lines, causing injuries, hindering movement, and often leading to death (Tschernij and Larsson, 2003).

3. Chemical contaminations:

Plastics can absorb and concentrate harmful chemicals from the surrounding environment. The toxic chemicals present in plastic materials can also contaminate the tissues of marine organisms, introducing harmful substances into the food web. When ingested, these chemicals may disrupt endocrine systems, impair reproductive health, and accumulate through the food chain, ultimately impacting human health (Hermabessiere et al. 2017).

Microplastics Impacts:

Microplastics particles permeate the marine environments, from surface waters to ocean

sediments. These microplastics are ingested by a variety of marine organisms, including plankton, filter-feeders, and bottom-dwelling species. This ingestion not only poses direct physical harm but also introduces plastic-associated toxins into the organisms, with potential implications for human health through the seafood chain (Ristetal.2018).

Ecosystem-Level Consequences

The impact of plastic and microplastic pollution extends beyond individual species to entire ecosystems. Coastal habitats, such as coral reefs and mangroves, are particularly vulnerable to plastic contamination. Microplastics can alter the physical and chemical properties of marine sediments, affecting nutrient cycling and the health of benthic communities (Zettler, Mincer, and Amaral-Zettler2013). Additionally, the presence of plastic debris may facilitate the transport of invasive species, further disrupting ecosystem dynamics. Marine plastic pollution deteriorates the aesthetic appeal of the environment and hinders fishing and tourism activities (Adam 2021). It also damages the disruption of cultural ties to natural resources' accessibility and viable recreational activities.

Economic Implications:

Removing plastic waste from the environment poses a financial burden to society, costing millions of dollars annually (Onyena et al., 2022).The economic consequences of marine plastic pollution are significant. Fishing and tourism industries, which are vital for many coastal communities, suffer as plastic pollution harms fish populations, degrades habitats, and affects the overall aesthetic appeal of coastal areas (Constanza et al., 2014).

Mitigation Measures:

Plastic pollution has emerged as a global environmental crisis, affecting ecosystems, marine life, and human health. In India, the problem is particularly acute due to the country's large population and rapid economic development. Mitigating plastic pollution requires a comprehensive and multifaceted approach that addresses both the production and consumption of plastic. Controlling plastic and microplastic pollution in the sea requires a combination of preventive measures, effective waste management, and global cooperation. The following strategies outline a holistic framework to address and control plastic and microplastic pollution:

1. Reduce Plastic Production and Consumption:

Advocate for policies restricting the making and use of single-use plastics.Encourage the development and utilization of alternative materials that are biodegradable or easily recyclable. Promote responsible consumer behaviour through awareness campaigns highlighting the environmental impact of plastic consumption.

2. Improve Waste Management:

Invest in and enhance waste collection and disposal systems, particularly in coastal areas and regions with high plastic pollution. Enforce strict regulations for proper plastic waste disposal and impose penalties for illegal dumping. Develop and expand recycling infrastructure to make it more accessible and efficient. Encouraging the segregation, reuse and recycling of waste at the household level or point of generation is a better option. Recycling of materials like paper, plastics, organic matter, metals and glassinto usable products can also be advocated. (Ampofo, 2013).

3. Educate and Raise Awareness:

Conduct public awareness campaigns to educate communities, businesses, and individuals about the consequences of plastic and microplastic pollution. Foster responsible behaviour, including proper waste disposal and recycling, through educational programs and outreach efforts. The plastics used for transporting goods, plastic components in goods such as vehicles, and electronic equipment have the potential for re-use or re-manufacture (Hopewell et al. 2009).

4. Innovate and Develop Sustainable Alternatives:

Invest in research and development of alternative materials that are biodegradable, compostable, and less harmful to the environment. Support and incentivize industries to adopt sustainable practices and materials, reducing their reliance on traditional plastics. Materials derived from renewable natural resources with similar functionalities to that of oil-based products need to be supported and has to be utilized in packaging applications (Wabnitz,C&Nichols,W.J.,2010).

5. Regulate Microplastics in Consumer Products:

Enact regulations to restrict or ban the use of microplastics in consumer products, such as personal care items and cleaning agents.Many

countries have taken measures to regulate the inclusion of microbeads in cosmetic products. Some other countries encourage the industry's product choice (Drohmann, et al.,2018). The replacement of microplastics in the manufacturing process, such as Chitin microbeads in place of non-degradable skin exfoliators, is gaining momentum (Ju et al., 2021).

6. Address Plastic Pellet (Nurdle) Spills:

Nurdle spillages due to maritime accidents have been frequently reported worldwide (Sewwandi et al., 2023). Implement measures to prevent spills of plastic pellets during transportation and manufacturing. Establish protocols for the clean-up and containment of pellet spills to prevent their entry into water bodies.

7. Enhance International Cooperation:

Given the trans boundary nature of marine pollution, international collaboration is crucial. India should actively participate in global efforts to address plastic pollution, sharing knowledge, best practices, and technologies with other nations. Develop and implement international agreements and treaties to collectively tackle plastic pollution (Thushari and Senevirathna, 2020).

8. Support Beach Clean-up Initiatives:

Periodic beach and ocean clean-up can raise awareness and subsequent research on shoreline litter status and trends.Engaging local communities, non-governmental organizations (NGOs), and volunteers in clean-up efforts to remove existing plastic debris from shorelines can raise awareness and promote a sense of responsibility (Wabnitz, C. & Nichols, W.J., 2010).

9. Research and Monitoring:

Support scientific research to better understand the sources, distribution, and impacts of plastic and microplastic pollution. Monitor and assess the effectiveness of implemented measures to control plastic pollution and adjust strategies accordingly. Research should be promoted on the pathways and mechanism of adsorbing the chemicals that leach from microplastics into the tissues of aquatic organisms. Similarly, rather than laboratory studies on single species, the ecosystem-level impacts of microplastic pollution using multiple species and trophic levels are required. Bio-magnification of chemical pollutants from ingested microplastics and the impact on higher trophic levels organisms are required. Long-term monitoring is essential to specify microplastics and their interactions with persistent organic pollutants. The process of the fragmentation of microplastics into nanoplastics is also has to be studied.Continued re-assessment of community and government strategies for plastic waste reduction is required (Onyena et al., 2022).

10. Encourage Circular Economy Practices:

Promote a circular economy by encouraging the recycling and reuse of plastics rather than their disposal. Encourage businesses to adopt sustainable and eco-friendly packaging practices (Wabnitz, C. & Nichols, W.J., 2010).

11. Clean-up Technologies:

Invest in technologies designed to remove plastic debris and microplastics from water bodies. This includes the development of innovative clean-up devices and systems. Many new technologies have been considered in this line, which representthe cardinal efforts in the fight against plastic pollution (Schmaltz et al., 2020).

12. Engage Businesses and Industries:

Many countries have adopted extended producer responsibility (EPR), which provides the producers with the responsibility to manage their products until the post-consumer stage.This system has been successfully implemented for electronic waste in most developing countries. Due to the rising concern about the marine plastic issue, several developing countries, including those in Asia, have also started to implement this system for packagingand container waste (Johannes et al., 2021).Encourage businesses to take responsibility for their plastic footprint through initiatives like extended producer responsibility (EPR).

13.Legislative Measures:

The creation of more legislative bodies, such as the international protocol to prevent and reduce pollution from ships, has more impact. The protocol, which has been approved by several countries, helps to regulate the release of garbage from ships and prohibits the disposal of plastics into the sea. This agreement ensures the maintenance of Garbage record books, by which

the estimated amounts of garbage that is incinerated or discharged are regularly monitored.

Conclusion:

Plastic and microplastic pollution significantly threaten the well-being of marine ecosystems and its inhabitants. The consequences extend from individual organisms to entire ecosystems, impacting biodiversity, ecosystem services, and human well-being. Urgent and collective action is needed to curb the proliferation of plastic pollution, safeguarding the seas for current and future generations. Mitigating plastic pollution is a complex and on-going process that requires a combination of regulatory measures, public awareness campaigns, technological innovation, and collaborative efforts. The commitment of the government, active participation of communities, and the engagement of various stakeholders are crucial in achieving a significant reduction in plastic pollution. By adopting a holistic approach and continuing to explore sustainable alternatives, we can pave the way for a cleaner and more environmentally friendly future.

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