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MICRO AND NANOPLASTICS POLLUTION IN MARINE ENVIRONMENT

Manju Lekshmi N

Fishing Technology Division

Email ID: *Manjuarem@gmail.com*

UNEP defined “Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; or accidentally lost, including material lost at sea in bad weather”. Marine litter is a pressing global concern, with plastics constitutes over 80% of all litter. Plastics encompass a wide range of synthetic or partially synthetic materials that use polymers as their main building blocks with intrinsic flexibility makes it possible to shape solid things with a variety of shapes by molding, extruding, or pressing. This property, along with numerous of other qualities including light weight, durability, adaptability, and cost-effective manufacture, has driven their widespread acceptance. Chemicals made from fossil fuels, particularly natural gas and petroleum, are a major component in modern plastic manufacture. However, recent advancements in industrial methodologies have introduced alternatives manufactured from renewable resources, including derivatives sourced natural materials.

Plastics have become an integral part of modern life and are used in various industries, including packaging, construction, electronics, automotive, healthcare, fishing and more. The production of plastic experienced a remarkable surge, escalating from 2 million tons in 1950 to an astonishing 200 million tons by the year 2020. Notably, 40% of the global plastic output finds application in packaging purposes. Most of the packaging purposes use single-use plastics. Single-use plastics do pose significant environmental challenges and have been widely recognized as a major contributor to plastic pollution. Single-use plastics are described as plastic products that are intended to be used just once before being discarded. Due to their affordability, toughness, and adaptability, these polymers are frequently utilised for convenience and packaging. Plastic straws, water bottles, plastic bags, plastic cutlery, and other food packaging materials are all examples of single-use plastics.

In the marine litter, approximately 35% plastic waste materials are denser than seawater which results the sinking of these materials to the seafloor and infiltrating the depths of our oceans. The remaining 65% remains buoyant on the ocean's surface, capable of traversing extensive distances through wind-driven currents. Plastic production and consumption persist at current levels, projections from the UNEP suggest that by 2050, the oceans will contain more plastic (in terms of weight, measured in thousands of tonnes) than fish. Furthermore, UNEP estimates that approximately 99% of seabirds have ingested plastic, underscoring the widespread and concerning impact of plastic pollution on wildlife and marine life.

Different types of plastics in the marine environment

Polyethylene (PE): This is one of the most widely used plastics. It comes in different forms, such as Low-Density Polyethylene (LDPE) and High-Density Polyethylene (HDPE). LDPE is flexible and used in items like plastic bags and squeeze bottles, while HDPE is stiffer and used for containers, pipes, and toys. HDPE is also used as a webbing material in fishing industry.

Polypropylene (PP): PP is renowned for withstanding heat and chemicals. It is utilized for packaging, automotive components, laboratory equipment, and ropes in the fishing industry.

Polyvinyl Chloride (PVC): PVC is versatile and used in pipes, cables, flooring, and a variety of products. It can be rigid or flexible, depending on additives used during production.

Polystyrene (PS): PS can be found in two main forms: expanded (EPS) and solid. EPS is used in packaging and insulation, while solid PS is used for items like disposable cutlery and CD cases.

Polyethylene Terephthalate (PET): PET is commonly used for beverage bottles and food packaging due to its clarity and resistance to gas and moisture. PET bottles are the most widely recycled plastic in the world.

Polycarbonate (PC): PC is known for its impact resistance and transparency. It's used in items like eyeglass lenses, medical devices, and electronic components.

Acrylonitrile Butadiene Styrene (ABS): ABS is a strong and rigid plastic used in products like toys, automotive parts, and consumer electronics.

Polyamide (PA) or Nylon: Nylon is known for its strength, abrasion resistance, and heat tolerance. It's used in textiles, industrial components, mechanical parts and as webbing material in fishing industry.

Polyurethane (PU): PU is highly flexible and can range from soft foam to rigid plastics. It's used in furniture, footwear, insulation, and more.

Bioplastics: These are derived from renewable resources like corn and cotton.Compared with fossil-based plastics, bio-based plastics can have a lower carbon footprint and exhibit advantageous materials properties

Sources of plastic debris

There are many different sources of plastic debris, including both human and natural processes. These sources all contribute to the buildup of plastic trash in the environment. One of the main causes of plastic debris is improperly managing the disposal of plastic waste. A significant portion of plastics derived from land and sea based sources like fishing industry, offshore platforms, recreational shipping, household and industrial wastes. Inadequate waste management systems, littering, and a lack of recycling infrastructure led to plastics getting into the environment and polluting rivers, oceans, and even natural landscapes. The widespread usage of single-use plastics is an equally important source of plastic waste. The weight of plastic trash is further increased by items like plastic bottles, bags, straws, and other kinds of packaging that make up a sizeable amount of plastic garbage and have a limited useful life before being discarded. Transport and shipping activities also contribute to the environmental pollution of plastic garbage. Plastic packaging, wrapping, and containers are especially vulnerable to accidental loss or deliberate disposal during transit in marine commerce. Rain, in the form of stormwater runoff and urban runoff, aggravates the problem by removing plastic waste from streets and urban areas, transporting it down storm drains, and ultimately disposing of it in rivers and oceans. Even coastal areas are not immune to plastic debris, often due to the practices of beachgoers, tourists, and recreational activities that leave behind litter. This debris can then be transported into the ocean by tides and currents, posing a direct threat to marine ecosystems. Fishing and maritime activities also play a role in the formation of marine litter which results from abandoned, lost, or discarded fishing gear and abandoned end-of-life boats adding to the accumulation of marine plastic debris. These discarded materials pose serious hazards to marine life. About 20% of the plastics in the marine environment is contributed by the fishing sector.

Plastics from fishing sector

Plastics from fishing gears: The fishing gear materials made of cotton is very popular before the introduction of synthetic materials like nylon. The cotton materials decompose relatively quickly within 2-3 months and its impacts on marine life is negligible while materials like nylon persist for an astonishingly long time. This advantage of synthetic materials make more popular and acceptable but same time it adversely affected the marine life. Synthetic materials like nylon may take 500 to 600 years to break down. The damaged and discarded synthetic material causes pollution. A significant portion of this pollution is attributed to ALDFG, which encompasses nets, ropes, traps, and other fishing equipment that has been abandoned, lost, or discarded in marine environments. ALDFG is defined by the UNEP as a collection of fishing equipment that has been abandoned or thrown into the water and that continues to trap both targeted marine species and undesired ones, resulting in ghost fishing. Ghost fishing refers to a phenomenon where abandoned, lost, or discarded fishing gear continues to actively capture and entangle marine life in a seemingly never-ending cycle. The discarded fishing gear includes nets, lines, traps, and other equipment, becomes a lethal hazard for marine organisms long after it has been left in the ocean. Ghost fishing poses a grave threat to various marine species, as the ensnared animals can suffer injury, suffocation, or death. This process not only harms the targeted fish but also affects unintended species, disrupting ecosystems and perpetuating a destructive cycle.

Plastics from fishing vessels: Fiberglass Reinforced Plastic (FRP) is a boat building composite material which became popular in boat construction since late 1940s as an alternative to traditional materials due to scarcity and cost constraints. FRP boats offer benefits such as corrosion resistance, durability, light weight, and high strength-to-weight ratio, making them suitable for small fishing vessels. FRP is made by binding glass fibers with a thermosetting plastic resin. Glass fibers are used in the form of glass mat and woven roving to create thick layers, which are bonded together using resin, catalyst, and accelerator. Polyester resins, including biphenolic, ortho and isophthalic resins, make up around 75% of the FRP matrix.

FRP is maintenance-free and has many benefits over typical wood materials. Its sleek finish and light weight help the fishermen to navigate quickly. Earlier FRP was used as a sheathing material for fishing vessels constructed with plywood and wood. But presently many of fishing vessels are constructed with FRP as the primary material. The life span of sheathed vessels is only a life of less than 10 years while boats constructed only with FRP having a life more than 30 years.

As the numbers of boats are increasing disposal became an issue for the ELB (End of Life Boats) FRP fishing boats. Due to lack of recyclability, it became a burden to the owners when it comes to an end of its service life. Because there is no simple way to dispose of plastic ELBs and existing options are quite expensive, it may seem tempting to get rid of the problem by dumping them some place in nature or in the sea. Abandoned or derelict vessels (ADVs) are a sort of maritime debris that are aground, broken apart, submerged, exhibit no signs of maintenance or usage, or are generally deteriorated. Abandoned boats are commonly observed on the foreshores, intertidal flats and reefs, throughout the coast. There is currently no financially viable solution for recycling FRP materials used in the hull of ships and boats that are manufactured with thermoset resins. Such composite hull components cannot be formed by melting, rolling, thermal forming, or molding into other usable physical forms. In 2016, London convention and protocol discussed and identified abandoned FRP boats is an environmental threat and to be regulated.

Environmental interactions of plastics

Weathering of plastics: Formation of micro and nano plastics: Weathering is a process that entails the transformation of plastic materials when subjected to various environmental factors, including sunlight, temperature fluctuations, and mechanical forces. This prolonged exposure leads to the gradual breakdown of larger plastic items into smaller fragments. Based on size, these breakdown fragments are classified into Mega (>100mm),Macro (21-100 mm),Meso (5-20 mm) and Micro (<5 mm) plastics and nanoplastics (1 to 1000 nm). Nano & microplastics, produced through weathering, encompass a wide range of sizes and are more prone to ingestion by various organisms, potentially entering the food chain and accumulating up the ecological hierarchy. The adverse effects extend to human health as microplastics and associated contaminants can infiltrate the food chain through seafood consumption. The IUCN (International Union for Conservation of Nature) has documented that South Asia, including India, is discharging 274,000 metric tonnes of primary microplastics into the ocean. On a global scale, the yearly average release of primary microplastics into the ocean is estimated to be 1.5 million metric tonnes. Notably, research conducted by IIT Mumbai has revealed the presence of microplastics even in sea salt sourced from Indian waters.

Microplastic can further undergo weathering to form nano plastics. Nanoplastics refer to extremely small plastic particles that have dimensions in the nanometer range, typically ranging from 1 to 1000 nanometers in size. These particles are even smaller than microplastics and are a subset of the broader category of plastic pollution.Because of their tiny size, nanoplastics have unique properties and behaviors that differentiate them from larger plastic particles. They have a higher surface area relative to their volume, which can lead to increased interactions with other substances in the environment, including chemicals and pollutants. This characteristic makes nanoplastics potentially more chemically reactive and capable of adsorbing or carrying pollutants from the surrounding environment.

They may spread out quickly in a variety of habitats, including soil, water, and the air thanks to their tiny size. Nanoplastics may take on a variety of shapes, from spherical to asymmetrical, which impacts how they interact with the environment and living things. They demonstrate higher mobility and bioavailability due to their large surface area compared to volume, which might cause them to enter the food chain and have an impact on diverse creatures. Their potential toxicity, ecological effects, and function as carriers of pollutants are still being studied. Regulations and more research are essential to address the possible dangers of nanoplastics and reduce their prevalence in the environment since they are a growing problem.

Leaching of plastics: *Leaching* refers to the release of chemical additives present in plastics into the surroundings, often triggered by interactions with water or other solvents. Plastic products, including single-use items and larger plastic structures, often contain various chemical additives to enhance their properties, such as flexibility, flame resistance, or color stability. These additives can include plasticizers, stabilizers, flame retardants, and pigments. When plastic items degrade or interact with their environment, either through weathering, mechanical stress, or exposure to different temperatures, these additives can gradually leach out into the surrounding environment.

In aquatic environments, leaching can occur when plastic items like bottles, packaging, or microplastics come into contact with water. As water interacts with the plastic surface, it can dissolve and carry away the additives, potentially releasing them into the water. This process can lead to the contamination of water bodies with these chemical compounds, raising concerns about their impact on aquatic life and ecosystems.Leaching can also be relevant in the context of landfill sites where plastic waste is disposed of. Rainwater or other liquids can percolate through landfills, causing the leaching of chemicals from the decomposing plastics and potentially contaminating groundwater.

Plastics may survive for decades or even centuries because of their strength and resistance to degradation. This persistence can lead to various ecological and environmental issues.

Impacts on Flora and fauna

Animals can mistake plastic items for food or become entangled in plastic debris. Ingesting plastics can lead to choking, internal injuries, and even death. This is a significant concern for marine life, birds, and other animals.

Ecotoxicity: Plastics can contain additives and chemicals that are toxic to both wildlife and humans. These toxins can leach into the environment, posing a threat to aquatic ecosystems and the organisms living in them.

Habitat Degradation: Accumulations of plastic waste can alter natural habitats, disrupt ecosystems, and damage fragile environments like coral reefs and coastal areas.

Aesthetic Impacts: Plastic pollution can tarnish the beauty of landscapes and water bodies, affecting tourism and recreational activities. Cleanup efforts also incur significant costs.

Social and livelihood impacts: Plastic pollution raises the issue by encroaching upon the spaces traditionally used for fish landing and various related activities. As plastic waste accumulates along coastlines, beaches, and water bodies, it diminishes the available area for fishing operations, processing, and other essential tasks. This not only disrupts the livelihoods of fishing communities but also hampers the overall efficiency of the fisheries industry.

Mitigation initiatives for fishing plastics

Addressing environmental concerns related to fishing gear and boat disposal requires a different approach.These include the implementation of stringent gear regulations, marking for easy tracking and identification, to enhance responsible fishing practices. Encouraging the adoption of biodegradable materials for fishing material construction contributes to reducing environmental impacts. Additionally, the proper disposal of fishing materials including end-of-life Fiberglass Reinforced Plastic (FRP) fishing boats necessitates the establishment of clear guidelines. Ensuring the construction of FRP fishing boats adheres to set standards is essential for long-term sustainability. Creating awareness within the fishing community can be achieved through seminars, symposiums, and field demonstrations. Incentive-based programs for litter collection by fishers, as well as promoting recycling options, provide practical ways to combat pollution. Initiatives like the "SuchitwaSagaram", a Kerala government project which aimed for the eradication of plastics from the sea, further contribute to effective waste management in coastal areas, collectively driving the pursuit of a more environmentally conscious fishing industry.

The 6Rs represent a set of principles aimed at promoting sustainable and responsible consumption and waste management in the case of plastics. Each "R" stands for a different action that individuals and communities can take to minimize their environmental impact.

Rethink: Reevaluating our consumption habits and considering the environmental and social consequences of our choices.

Refuse: The "refuse" principle encourages saying no to products or items that are unnecessary or harmful to the environment. This can include refusing single-use plastics, excessive packaging, and other items that contribute to waste.

Reduce: This principle promotes the idea of consuming less and minimizing our overall consumption. By using resources more efficiently and avoiding overconsumption, we can reduce our ecological footprint.

Reuse: Reusing involves finding ways to use items again instead of throwing them away after a single use. This can include using durable containers, repairing and repurposing items, and participating in activities like thrift shopping.

Recycle: Recycling involves the proper sorting and processing of materials to create new products from old ones.

Repair: Repairing items instead of discarding them helps extend their lifespan and reduces the demand for new products. This contributes to a more circular economy where items are used for as long as possible before being recycled or disposed of.

It's important to note that addressing plastic pollution requires global cooperation and individual actions to reduce plastic consumption and improve waste management practices.

References

Andrady, A. L. (Ed.). (2003). Plastics and the Environment.John Wiley & Sons.

Hammer, J., Kraak, M. H., & Parsons, J. R. (2012). Plastics in the marine environment: the dark side of a modern gift. Reviews of environmental contamination and toxicology, 1-44.

https://www.plasticsforchange.org/blog/different-types-of-plastic

Macfadyen, G., Huntington, T., & Cappell, R. (2009). Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).

Miljö, A. (2001). Marine Litter--Trash that Kills.Swedish Environmental Protection Agency.

UNEP Regional Seas Programme, et al. "Marine litter: an analytical overview." (2005).

United Nations Environment Programme. (2009). Marine litter: a global challenge. UNEP.

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