Marine Plastic Pollution: Causes, Effects and Preventions

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Abstract: Marine plastic pollution refers to the accumulation of plastic debris in the world's oceans, primarily originating from land-based sources, which significantly harms marine life by entanglement and ingestion, disrupting ecosystems and posing potential risks to human health through the food chain, with the majority of plastic waste breaking down into smaller microplastics that can be easily consumed by marine animals. Plastic pollution in the world's oceans is at record levels and rising by the day It is estimated that 1.7 million tons and 4.6% of the total plastic waste generated ends up in the ocean. That amounts to several million tons every year, the equivalent of an entire garbage truck of plastic every minute. Marine Plastic pollution is a major environmental challenge that threatens marine life, the food chain, human health, and the planet's aquatic environments. Unless urgent action is taken, the problem will get progressively worse over the coming decades. Preventing accumulation sources of plastic pollutants, 3Rs (Reduce-Recycle-Reuse), awareness & capacity building, and producer/manufacturer responsibility are practical approaches toward addressing the issue of plastic pollution. Existing and adopted policies, legislations, regulations, and initiatives at global, regional, and national level play a vital role in reducing plastic debris in the marine and coastal zones. This article aims to study in detail Marine Plastic Pollution, its meaning, major causes, sources, effects & consequences, control measures, and other related aspects.

Keywords: Marine Pollution, Plastic Pollution, Microplastic, Prevention Policies.

INTRODUCTION

Plastic has transformed human civilization in ways that were unimaginable just a century ago. It has driven economic growth due to its versatility, durability, and affordability. Plastics are widely used across nearly every sector- ranging from food packaging and shopping bags to consumer goods such as toys, clothing, and electronics. They are also essential components in the production of automobile parts, medical devices, and countless other products[1]. The introduction of plastic has revolutionized industries like healthcare, made homes more energy- efficient, and reduced reliance on natural resources such as wood, cotton, and metal by providing durable synthetic alternatives.

Today, plastics have become an indispensable part of modern economies. However, this very ubiquity is both a strength and a significant environmental challenge. One of the most defining characteristics of plastic is its durability—it is built to last. While this quality makes plastic valuable in many applications, it also means that plastic waste does not easily degrade, persisting in the environment for hundreds, if not thousands, of years. In contrast to the cyclical nature of natural ecosystems, where organisms grow, die, and are broken down to nourish future life, plastics disrupt this cycle because they are not biodegradable. Consequently, they accumulate in the environment, particularly in marine ecosystems, creating a global environmental crisis with wide-ranging ecological, economic, social, and health consequences[2].

SCALE OF THE PLASTIC PROBLEM

Since the 1950s, approximately 9.2 billion tons of plastic have been produced globally. Only around 30% remains in active use; the rest about 6.9 billion tons has become waste. Disturbingly, over 75% of this waste has been disposed of improperly, ending up in landfills, open dumps, unmanaged waste streams, and natural ecosystems, especially oceans. In 2018 alone, the world generated more than 343 million tons of plastic waste, and this number continues to rise with increasing demand. It is estimated that between 75 to 199 million metric tons of plastic are currently floating in our oceans. Without substantial intervention, plastic emissions into aquatic ecosystems are projected to

nearly triple by 2040, intensifying an already dire crisis[3].

Marine Plastic Pollution: Marine plastic pollution is the accumulation of plastic in the ocean, which harms wildlife, plants, and humans. It's a type of marine pollution that includes plastic waste in many forms, from large bottles and bags to microplastics.

Plastics enter the marine environment primarily through land-based sources, including improper waste disposal, littering, storm water runoff, and inadequate waste management systems, which carry plastic debris from urban areas into rivers and eventually into the ocean; additionally, ocean-based activities like fishing and maritime operations contribute to plastic pollution in the marine ecosystem.[4]

KEY PATHWAYS FOR PLASTIC ENTRY INTO THE OCEAN

Land-based sources:

Littering: Discarded plastic items like bottles, bags, straws, and food wrappers can be directly blown by wind or washed by rain into waterways, eventually reaching the ocean.

Stormwater runoff: When it rains, rainwater carries plastic debris from streets, gutters, and parking lots into storm drains, which then discharge into rivers and oceans.

Waste management failures: Inadequate waste collection and disposal practices, particularly in developing countries, can lead to large amounts of plastic waste entering the environment.

Illegal dumping: Deliberate dumping of plastic waste in rivers, streams, and coastal areas.

Industrial activities: Plastic waste from industrial processes can also be released into the environment through wastewater discharge.

OCEAN-BASED SOURCES

Fishing industry: Lost or discarded fishing gear like nets and lines can accumulate in the ocean, posing entanglement hazards for marine life.

Maritime activities: Plastic debris from ships, including packaging materials and waste from crew members, can be accidentally dropped overboard.

Coastal development: Coastal construction and erosion can mobilize plastic debris already present on beaches and contribute to marine pollution.[5]

Types of plastic debris: The main types of plastic polymers that contribute to marine pollution are Polypropylene (PP), Polyethylene (PE), Polyvinylchloride (PVC), Polyurethane (PUR), Polyterephthalate (PET), Polystyrene (PS), and Microplastics.

Macroplastics

• Size: Plastics larger than 20mm

• Examples: Fishing gear, six-pack rings, plastic bottles

• Threats: Large items of plastic can capture and entangle marine mammals and fish and stop them from escaping, usually leading to starvation, injury and predator vulnerability. Discarded fishing nets can also smother and break coral reefs, preventing healthy growth.

Mesoplastics

• Size: Plastics between 5-10mm

• Examples: Plastic pellets, fragments of broken-up larger plastics

• Threats: Small but visible plastic fragments can sit on the surface of the water and be mistaken for food by seabirds and other marine species, leading to issues including suffocation, starvation and toxic contamination over time.

Microplastics and Nanoplastics: When plastics break down in the marine environment, they transfer microplastics, synthetic and cellulosic microfibres, toxic chemicals, metals and micropollutants into waters and sediments and eventually into marine food chains.[6]

• Size: Plastics smaller than 5mm, small microscopic particles

• Examples: Granules in face scrubs and toothpaste, microfibres from textiles, disintegration from larger plastics

• Threats: Microplastics are invisible to the naked eye, making them easy for wildlife to consume.

Nurdles: Plastic pellet pollution is a type of marine debris originating from the plastic particles that are universally used to manufacture large-scale plastics. In the context of plastic pollution, these pre-production plastic pellets are commonly known as 'nurdles'. These microplastics are created separately from the user plastics they are melted down to form pellets. Loss can occur during both the manufacturing and transport stages. When released into the open environment, they create persistent pollution both in the oceans and on beaches. About 230,000 tonnes of nurdles are thought to be deposited in the oceans each year, where they are often mistaken for food by seabirds, fish and other wildlife. Due to their small size, they are notoriously difficult to clear up from beaches and elsewhere.

IMPACTS OF PLASTIC POLLUTION ON MARINE LIFE

Ingestion – Marine animals of all kinds – from apex predators down to the plankton at the base of the food chain – ingest plastic. This can cause serious harm to the animals, affecting food uptake by creating a false sense of satiation or blockages in digestive systems, as well as leading to internal injuries. Laboratory experiments have shown reduced growth in fish when their food is contaminated by high volumes of microplastics; while at the other extreme a single plastic drinking straw in its digestive system likely caused the death of a whale shark in Thailand. Plastic ingestion in seabirds is global, pervasive, and increasing. It has been estimated that up to 90% of all seabird and 52% of all sea turtle individuals nowadays ingest plastics.30 Many emaciated whales and dolphins found stranded are also found to have ingested macroplastics. Some studies have shown altered or decreased food uptake, and negative impacts on growth, immune response, fertility and reproduction as well as altered cell functions and behaviours in the impacted species.[7]

Entanglement: Items like ropes, nets, traps and monofilament lines from abandoned, lost or discarded fishing gear wrap themselves around marine animals causing strangulation, wounds, restricted movement and death. Birds also use marine debris for their nests, which can entrap parents and hatchlings. Fishing lines entangle 65% of coral colonies in Oahu, Hawaii, and 80% of these colonies were entirely or partially dead. Even in the remote Arctic deep sea, up to 20% of sponge colonies have been entangled with plastic, and entanglements increased over time.

Plastic pollution causes devastating wounds to wildlife The biggest cause of damage to wildlife is physical wounds or entrapment from plastic waste. Fish and marine birds becoming entangled in plastic packaging from things like plastic bags and plastic drink rings. This can cause painful wounds, strangulation or even drowning. Birds, mammals, and reptiles that live in the sea, but still need air to breathe, can become so entangled that they cannot surface for oxygen, and they drown.[8]

Microplastics in our food chain: A million tonnes of tiny microplastic enter our seas as small plastics like microbeads from cosmetics or fibres from synthetic clothing. But they can also be created at sea as the elements break down larger plastic items. Scientists are starting to find microplastics in our food chain. A recent study from Plymouth University, examined 504 fish caught off the coast of South West England and found one third contained microplastics. In sea birds alone, microplastics have been found to disrupt iron absorption of the small intestine and put stress on the liver.[9]

Plastic kills coral reefs: Plastic pollution around the world has been found to kill our ocean's coral reefs, which are an essential part of our ocean's ecosystems and home to thousands of species. Plastics carry bacteria, and they block light and oxygen from getting into the coral. Coral that has come into contact with plastic is 89% more likely to become diseased.

Effect on human life: Nanoplastics can penetrate the intestine tissue in aquatic creatures and can end up in the human food chain by inhalation (breathing) or ingestion (eating), particularly through shellfish and crustaceans. Ingestion of plastics has been associated with a variety of reproductive, carcinogenic, and mutagenic effects. The most well-known organic synthetic compound used in many plastics is bisphenol A (BPA). It has been linked with autoimmune disease and endocrine disrupting agents, leading to reduced male fertility and breast cancer. Phthalate

esters are also linked to causing reproductive effects due to being found in packing products for food. The toxins from phthalate esters affect the developing male reproductive system. Diethylhexyl phthalate is also suspected to disrupt the functions of the thyroid; however, studies are currently inconclusive.[10]

Plastics in the human body can stop or slow down detoxification mechanisms, causing acute toxicity and lethality. They have the potential to affect the central nervous system and reproductive system, although this would be unlikely unless exposure levels were very high and absorption levels were increased. In vitro studies from human cells showed evidence that polystyrene nanoparticles are taken up and can induce oxidative stress and pro-inflammatory responses.

Marine Ecosystem: Some organisms have adapted to live on floating plastic debris, allowing them to disperse with ocean currents and thus potentially become invasive species in distant ecosystems. Marine animals can experience internal injuries, lacerations, infections, starvation, and diminished swimming ability from injesting plastic or getting entangled in plastic garbage. Additionally, floating plastics aid in the spread of invasive marine organisms, endangering marine biodiversity and the food chain. Research in 2014 in the waters around Australia confirmed a wealth of such colonists, even on tiny flakes, and also found thriving ocean bacteria eating into the plastic to form pits and grooves. These researchers showed that "plastic biodegradation is occurring at the sea surface" through the action of bacteria, and noted that this is congruent with a new body of research on such bacteria.

Socio-economic effects by plastic pollution in respective ecosystems: Plastic pollution causes different socio-economic impacts on various aspects, such as commercial fishery, tourism, shipping, and human health, and negatively affects the national economy of the respective country by allocating an extra budget for waste removal. An overload of plastic contaminants in the ocean basins and coastal zones directly influence the commercial fishery, aquaculture, and tourism. In Scotland, debris removal, including plastic litter such as fishing gears and PVC pipes, causes loss of fishing time and extra expense for cleaning

The Great Pacific Garbage Patch: The Great Pacific Garbage Patch (GPGP) is a collection of marine debris in the central North Pacific Ocean. It's made up of plastic and other floating trash that comes from the Pacific Rim. It is about 1.6 million square kilometers, which is roughly the size of Texas or three times the size of France. It's the world's largest accumulation of plastic.

MITIGATION STRATEGIES

Waste management improvements: Implementing proper waste collection and recycling programs, promoting responsible waste disposal practices.[11]

Public awareness campaigns: Educating communities about the impacts of plastic pollution and encouraging responsible behavior.

Policy regulations: Enacting laws to reduce plastic use, promote biodegradable alternatives, and hold industries accountable for plastic waste management.

Clean-up initiatives: Supporting efforts to remove plastic debris from beaches and waterways.

Global Policies and treaties to prevent marine Pollution: There have been multiple laws, policies, and treaties put into place throughout history. In order to protect the ocean from marine pollution, policies have been developed internationally.[12,13]

In 1948, Harry Truman signed a law formerly known as the Federal Water Pollution Control Act that allowed the federal government to control marine pollution in United States of America.

In 1972, the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) was passed by the United States Congress, and regulates ocean dumping of waste in US waters.

In 1954, Convention for the Prevention of Pollution of the Sea by Oil and the 1973 International Convention for the Prevention of Pollution by Ships were weakly enforced due to a lack of respect for the laws from flag states.

In 1973 and 1978, MARPOL 73/78 was a treaty written to control vessel pollution, especially regarding oil. In 1983, the International Convention for the Prevention of Pollution from Ships enforced the MARPOL 73/78 treaty internationally.

In 1982, United Nations Convention on the Law of the Sea (UNCLOS) was established to protect the marine environment by governing states to control their pollution to the ocean. It put restrictions on the amount of toxins and pollutants that come from all ships internationally.

In 2006, the Marine Debris Research, Prevention and Reduction Act. was established by the National Oceanic and Atmospheric Administration (NOAA) to help identify, determine the source of, reduce and prevent marine debris.

In 2011, The United Nations Environment Assembly (UNEA) was created as the world's highest level decision-making body on the environment. From 2014 to date UNEA has adopted a number of key resolutions on marine litter and microplastics. It also adopted in 2019 a related resolution on addressing single-use plastic products pollution. At the most recent session of UNEA in 2022, 175 nations endorsed a historic resolution to forge an international legally binding agreement by 2024. The resolution addresses the full lifecycle of plastic, including its production, design and disposal. A UN treaty based on legally-binding global rules and comprehensive circular economy measures is a unique opportunity to accelerate systems change and end plastic pollution.

KEY POINTS ABOUT MARINE POLLUTION LAWS IN INDIA

Water (Prevention and Control of Pollution) Act, 1974: This act regulates the discharge of pollutants from land-based sources into the coastal waters, allowing State Pollution Control Boards to monitor and control such discharges.[14]

Maritime Zones of India Act, 1976: This act provides the legal framework for India to take necessary steps to protect the marine environment within its exclusive economic zone.

Indian Coast Guard Act, 1978: The Coast Guard is responsible for enforcing marine pollution laws and monitoring activities in the coastal areas.

Wildlife Protection Act, 1972: This act enables the designation of Marine Protected Areas (MPAs) to safeguard sensitive marine ecosystems and species[15].

Other relevant acts: The Merchant Shipping Act, 1974, and the Indian Fisheries Act, 1899, also play a role in regulating activities that could impact the marine environment.

In India, the primary law addressing marine plastic pollution is the Plastic Waste Management Rules, 2016, which includes a ban on plastic bags below a certain thickness, and recently amended in 2021 to specifically prohibit identified single-use plastic items with high littering potential, effectively tackling marine plastic pollution from land-based sources.[16]

This is very unfortunate that currently, India does not have a separate dedicated policy specifically addressing marine litter, but the Plastic Waste Management Rules are considered the main regulatory framework.

Conclusion: Plastic pollution has emerged as one of the most pressing environmental crises of our time, particularly in the context of marine ecosystems. Despite growing awareness and regulatory action at national and international levels, the volume of plastic entering our oceans continues to rise. If current trends persist, plastic leakage is expected to more than double by 2026 compared to 2010 levels. Efforts to mitigate the problem have been widespread but fragmented. The solution lies not just in treating the symptoms but addressing the entire life cycle of plastics from production and consumption to waste management and recycling. Coordinated action is required across governments, industries, communities, and individuals. Only through global cooperation, robust policy implementation, innovation, and public participation can we hope to reverse the tide of plastic pollution and restore balance to our oceans.

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