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Analyzing the Impacts of Plastic Wastes in Water Bodies and Suitable Methodology to Prevent It

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ABSTRACT: Plastics are widely distributed across organisms of various trophic levels and in terrestrial, freshwater, marine, and other environments. Recently, plastics have emerged as significant environmental pollutants, attracting public concern. This systematic literature review identifies sources of plastic waste, including food packaging, household hazardous waste, and wood waste, highlighting their detrimental impacts on water bodies, environmental health, and animal life. Analytical techniques such as Scanning Electron Microscopy (SEM), Atomic Absorption Spectroscopy (AAS), and Differential Scanning Calorimetry (DSC) are essential for detecting and quantifying plastic pollutants. Prevention strategies, including source reduction, public awareness campaigns, legislative measures, and the implementation of pollution control techniques, are crucial in mitigating plastic waste in water bodies. Future research should focus on developing innovative materials and sustainable alternatives to plastics, enhancing waste management infrastructure, and fostering global collaboration to address the plastic pollution crisis effectively.

Keywords: Plastic Waste**,** Plastic Pollution, Water Bodies, Environmental Health, Pollution Prevention Strategies

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INTRODUCTION

High molecular weight polymers like plastic are typically derived from petroleum and other fossil fuel by products. Excellent chemical and physical qualities, such as good insulation and strong resistance to corrosion, characterize plastics. Plastic products are widely used in many different fields because they are affordable and simple to process. The amount of plastic produced worldwide has expanded by roughly 560 times in the last 60 years. Our everyday lives are now much more convenient as a result of the plastic industry's explosive growth. The amount of plastic produced worldwide has increased over the last 60 years. The phenomenon of waste plastics polluting the environment is sometimes referred to as "white pollution."

When plastic waste is subjected to different external forces, it breaks down into smaller pieces, a phenomenon known as "micro-plastic." Plastics are widely distributed in organisms of various trophic levels as well as in terrestrial, freshwater, marine, and other environments. Plastics are new environmental pollutants that have gained public attention in recent years. The origin, mode of analysis, and environmental risk of plastics have all been studied. Every aspect of human activity involves water, which also serves as a link between nearly all types of pollution and damages to the environment (Tehseen, Ghaffar, Mahmood, Younus, & Anam).

Water pollution by plastics is still a major concern, despite a recent change in the focus toward the importance of ecosystem protection due to an increased awareness of the critical role that water plays in maintaining of water-based and associated ecosystems, and the need to retain water quantum and ecological flows to ensure maintained availability of a range of crucial ecosystem services. The substantial advancements in water quality management techniques and technologies put into place in many parts of the world are largely to blame for this, as new categories of water pollutants have emerged and cannot be sufficiently addressed by them.

These pollutants include, for instance, the quickly developing problems associated with the contamination of water supplies by so-called persistent, mobile, and toxic (PMT) chemicals, which are increasingly found in surface waters and ground water and are derived from organic solvents, chemical substances used in agriculture, medicines, and personal care products. The provision of clean and safe drinking water is significantly hampered by PMTs because it can be expensive and technically challenging to locate the sources of these substances and extremely challenging to eradicate PMT contamination. Water resource pollution due to plastics and micro-plastics is another well-known instance of a new challenge that legal frameworks are finding difficult to address. These pollutants include, for example, the rapidly growing issues related to the pollution of water supplies by so-called constant, mobile, and toxic chemicals, which are derived from organic solvents and chemicals used in personal care, agriculture, and medicine (Ullah et al., 2024).

Managing plastic waste has become more complex as a result of the COVID-19 pandemic. Our behavioral patterns have been unintentionally altered by style and our fear of transmission. Examples of these include the use of disposable utensils, an increase in the demand for food and groceries packaged in plastic, and wearing personal protective equipment (PPE). Our current waste management system's shortcomings and inefficiencies in dealing with the increasing dependence on plastic may accelerate its improper handling and environmental leakage, leading to a new ecological disaster. Enforcing scientific sterilization and requiring sealed bags for the secure disposal of polluted plastic wastes ought to be the top priority to lower the danger of contamination to sanitation personnel (Fatima et al., 2024).

The recycling of plastic is being made easier by new technologies such as chemical recycling and new manufacturing techniques. New and proposed regulations worldwide are starting to recognize and address the potential harm that plastics can do to human health and the environment. Plastic products are not biodegradable, which makes them a major environmental risk even with their wide range of uses. If the current usage of plastic products is not reduced waste from it will end up in landfills and natural areas. In this study, we looked into the impacts of plastic wastes, particularly micro-plastics, on the soil ecosystem and its mitigation strategies.

THEORETICAL REVIEW

Types of Plastics and Plastic Waste

Plastics can be classified into several categories based on their components and the kinds of compounds used in their manufacture. Table 1 lists the many different types of plastics, their characteristics, typical applications, and recycling options.

Table 1: Types of plastics, their characteristics and Common Uses.

Plastic types	Common Uses	Characteristics	Recycled Info
Polyethylene terephthalates	Salad dressing, soft drinks, water bottles, bowls, biscuit trays, and salad domes	Clear, robust, resistant to solvents, gas and moisture barriers, and softening at 80 °C	Fillings for pillows and sleeping bags, clothes, bottles, and insulation for buildings
High density polyethylene (HDPE)	Household items like bags for shopping and storing food, containers for various products like shampoo and milk.	Varied stiffness, moisture/chemical resistant, colorful, waxy surface softens with heat, easy to shape	Compost bins
Polyvinyl Chloride,PVC	Blood bags, electrical conduit, wall cladding, shoe soles, cosmetic	High strength and impact resistance, allowing for clear or	Compost bins

	containers	welded applications	
Low Density Polyethylene	Garbage bags, mulch film, irrigation tubing, cling wrap, and reuse bags	Bendy and translucent material with a waxy surface, it's easily scratched and becomes even softer near 70°C	Bin liners and Pallet sheets
Polypropylene (PP)	Dishes for the microwave, lunchboxes, packing tape, garden furniture, ice cream tubs and bottles, bags for potato chips, straws	Transparent, withstands solvents, hard and translucent, softens at 140 °C, and multipurpose	Bins, pallet sheets, pipes, and pegs
Others	Automotive and appliance components, computers	Includes all resins and multi-materials properties	Recycle Bins

Types of Plastic Wastes

The use of plastic has grown over the past few decades. In Occidental Europe, 60 million tons of plastic are consumed annually, translating into 23 million tons of waste. Packing and packaging account for about 63 weight percent of this waste (Adrados et al., 2012). Plastics can be utilized for packing and packaging. The leftovers from material recovery facilities, which separate the local packing and packaging plastic debris for individual recycling, is one of these streams.

Industrial plastics production started in the 1940s, and the amount of plastic waste produced has grown ever since. Due to increased consumption, the problem of growing plastic waste was first recognized in the 1970s, especially in the fast food sector, which readily supplies food items on time. The amount of waste produced by the fast food industry is rising due to the increasing number of these restaurants worldwide. Traditionally, the majority of this industry's waste was disposed of in landfills; packaging waste makes up the majority of this solid waste (Waseem et al., 2023).

Using post-consumer heavy wastes of recycled plastic and wood, wood plastic composites (WPCs) were created to reduce waste, lessen plastic's negative environmental effects, preserve natural resources, and promote a circular economy for environmentally friendly production and consumption. Recycled WPC composites, or r-WPCs, were made using five different kinds of recycled plastics based on polypropylene (PP) or polyethylene (PE), as well as wood that was taken from bulky urban household waste. Maleic anhydrous transferred compatibility

(MAPP or MAPE) and wood flour (WF) were used to prepare virgin WPC (v-WPC) and r-WPC compounds in order to assess the impact of the compatibility and type of recycled polymer on mechanical properties *(Basalp, Tihminlioglu, Sofuoglu, Inal, & Sofuoglu, 2020).*

Wood fiber and plastic wastes are combined to create Wood Plastic Composites, a type of bio composite with high hydro-stability. Injection, extrusion, compression, and hot-press molding are steps in the WPC production process. When compared to conventional adhesive-bonded bio-composites, WPC exhibits the benefits of not requiring glue and producing no formaldehyde during the preparation phase. Many nations started using waste plastics from everyday life in the 1990s to make WPC. Many studies on the characteristics of wooden flour-based WPC made with varying amounts of wood flour as well as plastic wastes have been published in recent years (Tehseen, Mahmood, et al.).

Occurrence of Plastic Wastes in Water Bodies

Plastics are widely used and play a vital role in society. Because of consumer's careless disposal, marine pollution in rivers and coastal areas is growing more quickly. Research and development efforts are currently focused on determining whether marine organisms' ingestion of plastic waste results is hazardous exposures for seafood consumers, with a focus on heavy metals like methyl mercury, BPA, phosphates, and lead cadmium. Pollution's biological effects are correlated with the resulting losses and economic effects. The implementation of cost-effective, environmentally friendly, and genuinely sustainable waste management techniques in developing nations is a fundamental component of sustainable development.

The management of plastic waste is a crucial problem. More than 300 million metric tons of plastic are produced worldwide each year, with roughly half of that amount going toward products that are thrown away within a year of purchase. It is both our era's blessing and curse. Despite having many uses, the waste it produces and the pollution it causes clog our rivers, oceans, and lands and negatively impact biodiversity. When new synthetic products, implants, etc., reach the end of their useful lives, we must make plans for how to dispose of them.It should be strong, bio-compatible, and have options for surface treatment *(Singh & Sharma, 2016).*

Issues of Plastic Wastes in the Context of Environmental Health and Sustainability

While plastics offer significant advantages over other materials in terms of weight, durability, and low cost of manufacturing, the additives they contain include a variety of hazardous chemicals that can break down into plastic pollutants, which can lead to serious health problems, including respiratory disorders. Plastics are a sign of the fast and ongoing rise in plastic production and improper handling of plastic waste in the ecosystem. The pollution of the environment is caused by a number of processes, such as drainage, runoff from agriculture, maritime activities, and the disposal of household waste (Haidri & Qasim).

In addition, plastics are a constant source of exposure for humans due to ingestion, inhalation, and skin contact. The toxic material in micro-plastics can induce oxidative stress and inflammation, which can disrupt immune function, cause tumors, increase particle translocation, and cause neurotoxin. For instance, dioxins are deadly organic pollutants made from plastic polymers that harm the nervous system, cause cancer, and inhibit the development of the reproductive system. However, the reference suggested that more investigation and more thorough clinical studies are needed to examine the possible effects of the plastic contaminant on our health and environment, as there is currently insufficient proof to link the consumption of micro-plastics to human health.

Sources of Plastic Wastes

Littering and inadequate waste management are major culprits, allowing plastic bags, bottles, and other debris to be blown by wind or washed by rain into rivers and streams that eventually lead to oceans. Runoff from streets and cities also carries plastic pollution, as microplastics shed from car tires and synthetic clothing fibers intermingle with litter and debris as shown in figure 1. Industrial activities contribute as well, with plastic nurdles (raw plastic pellets used in manufacturing) sometimes spilled during transport, and plastic waste generated by factories finding its way into waterways. Even seemingly innocuous sources like laundry contribute, as synthetic textiles release microplastic fibers that make their way into wastewater treatment plants and potentially into rivers and oceans (Haidri, Fatima, et al., 2024).

Fig. 1. Main sources of plastic in water bodies

Effects of Plastic Wastes on Animals

Millions of tons of plastic waste are produced annually in the environment due to improper waste management systems, despite the fact that plastics are a blessing that we use on a daily basis. In addition to posing serious hazards to terrestrial life, the majority of plastic waste finds its way into marine environments, where it endangers marine life and the delicate ecological balance of the oceans. An alarming amount of plastic debris finds its way into marine environments each year. When marine life consumes plastic debris as food, it causes stomach suffocation and eventually death (Ummer et al., 2023).

Sometimes marine life becomes entangled in plastic waste, which leads to their starvation and eventual death. According to reports, each year millions of marine animals perish as a result of plastic waste. Table 2 shows the effects of different types of plastics on animals and the mechanism of action.

Table 2: Effects of plastic wastes on animals and their mechanism of action

Species	Specie Variant	Plastic Type	Effects
Sea Bird	Greater Shearwater	Plastic Bottle Cap	Starvation due to Gastrointestinal obstruction
	Magellanic penguin	Fragments, line and straws	Stomach perforation
Sea Turtles	Green Sea Turtles	Plastic Bags and other Debris	Impediment of hatchling movement towards the sea, exposure to predators
	Leatherback Turtle	Plastic Bags and Debris	Blocked and Injures Cloaca
Fish	Bigeye Tuna	Fragment Line	Ingestion of plastic fragments
	Orchid dotty back	Plastic Bags	Leached phenomenal additives caused mortality
Mammals	Sperm Whale	Plastic Bags and Debris	Stomach rupture and starvation
	Australia sea lion	Plastic Fishing Gear	Entanglement caused mortality
Invertebrates	Mussels	Micro-plastic particles	Accumulation of micro-plastic in circulatory system
	Oyster	Micro-plastic particles	Interference with energy uptake and reproduction

METHODOLOGY

Analytical Techniques used for Plastic Wastes Detection and Quantification

The potential of elemental data analysis of soil, sediment, and various other matrices using portable X-ray fluorescence (PXRF) spectroscopy has been demonstrated by numerous studies. Using PXRF elemental data, we also calculate the plastic content of water samples. Trace element levels in wastewater can be measured using various inorganic methods, such as atomic absorption spectroscopy using flames and graphite-furnace nuclear absorption spectroscopy. Depending upon the number of elements to be determined, expected concentration range of analyses and the number of samples to be run the most suitable technique for requirements can be chosen *(Baysal, Ozbek, & Akman, 2013)*. New analytical techniques, primarily based on spectroscopic techniques, facilitate the accurate identification of polymeric materials composition.

Atomic absorption spectroscopy has made it possible to quickly and affordably determine the concentrations of metals in a wide range of samples. Determining the concentrations of metals in soils and sediments is one such application. Concentrated reservoirs of these metals exist in soils and sediments, which can either become environmental sources or act as sinks for newly introduced trace metals (Perveen et al.).

Differential scanning calorimeter (DSC), a thermoanalytical technique, can be used to quantify plastics. It is a common procedure for testing quality in industrial polymer processing and production. It is a simple, a precise and cost effective method used to identify plastics in water bodies. The biodegradable plastics (poly-lactic acid, polyethylene dissipate-co-thalassotherapy) and non-biodegradable plastics (polyethylene thalassotherapy (PET), high-density polyethylene (HDPE), lower density polyethylene (LDPE), and polypropylene (PP)) were analyzed using differential scanning calorimeter (DSC) and elemental analyzer-isotope ratio mass spectrometer (Sulaiman et al., 2023).

RESULTS AND DISCUSSION

Strategies for Preventing Plastic Wastes in Water Bodies

1. ***Source Reduction Strategies***

Waste is now thought to be a sign of inefficiency. Waste production is a human activity rather than a natural one. Nowadays, common waste management methods include land-filling and destroying wastes; however, these methods harm the environment, water, soil, and air in addition to wasting raw materials. The novel idea of "Zero Waste" (ZW) views waste as an important resource.

A key component of the approach is creating and managing goods and procedures that lessen the amount of waste and toxicity and conserve and recover all resources rather than burying or burning them. Waste from one product—whether municipal use industrial, agricultural, biomedical, constructing, or demolition—may be able to become raw material for another through the use of reverse logistics, resource recovery, and scientific treatment techniques (Yazdani & Lakzian, 2023).

2. ***Public Awareness and Education Campaigns***

In addition to suitable legislation, strong technical assistance, and a sufficient budget, any waste administration program needs to involve the public in knowledge and involvement. Since waste is a result of human activity, individuals ought to be aware of problems related to waste management. Without this understanding, even the most well-thought-out waste management plan may not be successful (Nouman & Qasim). Public education campaigns can be utilized to assist people in making better decisions when they have limited knowledge about environmental issues. Our study attempts to assess the performance of a public education campaign aimed to raise citizens' awareness of the environmental issues caused by plastic bags in the marine environment and along coasts. The survey valuation procedure had no influence in any way on the information campaign.

3. ***Legislative and Regulatory Measures***

To combat plastic pollution in water bodies, legislators are enacting a multi-pronged approach: bans and fees on single-use plastics directly reduce their entry into waterways, while Extended Producer Responsibility policies hold manufacturers accountable for their products' lifecycle, encouraging design for recyclability. Investment in recycling infrastructure and stricter standards ensure plastic waste gets diverted from landfills, microplastic bans target tiny plastic particles harming marine life, and regulations promote compostable and biodegradable alternatives. Finally, international efforts towards a global plastic treaty aim to establish a comprehensive framework for tackling plastic pollution throughout its entire journey (Ummer et al., 2023).

4. ***Monitoring and Research Initiatives***

There is now enough evidence that littering is a significant human problem that appears to affect all natural systems. The last ten years have seen an exponential growth in research on marine plastic pollution; however,there is little information about the complete effects of marine plastic and how these effects affect ecosystem services, which in turn affect people's health, society, and the economy (Haidri, Qasim, et al., 2024).

The effects on living things are one of the main worries regarding the buildup of plastic waste in the ocean. As a result, tracking the rates at which impacts happen makes sense even though it only gives information on particular kinds of plastic litter. Entanglement and ingestion are the two primary effects, but keeping an eye on additional interactions with wildlife can also reveal important patterns, like the most direct way to assess the effectiveness of the campaign towards plastic pollution.

5. ***Implementation of Pollution Control Technologies***

The idea behind sustainable landfills is to quickly and safely integrate wastes into the environment around us by putting the latest techniques into practice. Solidification and the release of monomers, additives, and greenhouse gases can all result from polymer degradation in landfill environments. Upgrading these facilities is of the utmost importance given the thousands of tonnes of plastic waste that are land-filled every day, especially in developing nations.

Prioritizing different technological approaches can help reduce and manage plastic waste in landfills as well as control, treat, and monitor emissions from landfills to lessen their detrimental effects on the environment. A few developed laws and guidelines concerning plastic pollution and the role of technology in supplying and disclosing additional proof of plastic pollution. A thorough explanation is given of the limitations of commonly used technologies as well as current technologies for identifying plastic particles.

CONCLUSION AND RECOMMENDATIONS

Plastic pollution poses a serious risk to the marine environment, with effects that reach the molecular level, physiological functioning, and health of organisms, as well as the loss of ecosystem services. The pollution is distributed globally. Even if plastic production and disposal abruptly stopped, the damage to marine life would likely persist for many decades due to the long half-life of plastics in marine ecosystems. There are ways to combat plastic pollution, but they will need concerted efforts from many sectors and stakeholders on a global scale. The creation of the necessary legislative framework to support mitigation efforts that help reduce plastic waste at the source and encourage the cleanup of plastic pollution on beaches is largely the responsibility of governments and policy changes. To alter people's behavior concerning plastic consumption, education and awareness of the issues caused by plastic waste are crucial, but information by itself is probably not going to be enough.

FURTHER STUDY

The future of analyzing plastic pollution in water bodies holds promise for advanced microplastic detection, biomonitoring with aquatic species, and even using environmental DNA to trace plastic sources. Prevention strategies will focus on biodegradable and bio-based plastics, improved waste management infrastructure, and potentially using nanoparticles for microplastic removal. Stronger regulations, public education, and considering the impact of climate change on plastic breakdown will all be crucial in this ongoing battle for cleaner water.

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