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Plastic Pollutions in Aquatic Environment- A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Plastic pollution in aquatic ecosystems is a growing environmental concern, as it has the potential to harm ecology, imperil aquatic organisms and cost ecological damage. Although rivers and other freshwater environments are known to play an important role in carrying land-based plastic trash to the world's seas, riverine ecosystems are also directly impacted by plastic pollution. A detailed understanding of the origin, movement, fate, and effects of riverine plastic waste is critical for better quantifying worldwide plastic pollution transport and effectively reducing sources and dangers. In this review, we emphasize the current scientific state of plastic debris in rivers, as well as the existing knowledge gaps, providing a basic overview of plastics and the types of polymers commonly found in rivers and the threat they bring to aquatic ecosystems. We also go through the

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origins and fates of riverine plastics, as well as the mechanisms and factors that affect plastic debris transit and spatiotemporal variation. We give an overview of riverine plastic transport monitoring and modeling activities, as well as examples of typical values from throughout the world. Finally, we discuss what the future holds for riverine plastic research.

Keywords: Plastic; pollution; aquatic ecosystem, effect.

1. INTRODUCTION

Plastic is a hydrocarbon-based synthetic material that can be molded into solid objects of practically any shape or size [1]. Plastic pollution in an aquatic environment an emerging issue that might affect biological diversity and human health [2]. The increased usage of plastic by man is attributed to their portability, cheapness, versatility, durability and strength [3]. The global plastic production has tremendously increased over the years and tons of plastic waste enters into aquatic environment which causes pollution [4]. Crude oil is cracked to produce a range of petrochemicals, which are used to make plastics. Olefins are used to make plastics like polyethylene and polypropylene (PP), while aromatic hydrocarbons are used to make plastics like polystyrene (PS) and polyamide (PA) (nylon). Plastics are made up of spherical pellets or nurdles that are typically 0.5–5 mm in diameter. These preproduction materials are delivered to factories and heated, extruded, or blow molded into the desired shape. In addition, additives are applied based on the temperature for packaging. Packaging, construction, transportation, electronics, textiles, and safety and leisure are the main industries that use plastics today. In 2017, 348 million tons of plastic were manufactured worldwide, according to estimates [5]. Plastics have replaced heavier and more expensive materials such as glass, steel, and aluminum due to their properties. The use of plastic in packaging resulted in a high level of food preservation, reduced food waste, and extended the expiration date and transportation options. The use of plastic wrapping for transported goods resulted in a significant reduction in CO2 emissions per kilometre in the transportation sector [6]. Plastic has attained a pivotal status, with extensive commercial, industrial, medicinal and municipal applications [7]. Plastic ranks among themost widely used materials in the world [plastic Europe 2018]. Plastic has evolved into a valuable and adaptable material with a wide range of applications in the last 60 years [8, 9]. Every year, almost 300 million tons of new plastics are used. Half of these are only used once, and for less than 12 minutes on average. Every year, eight million tons of plastic wastes end up in the aquatic environment. Globally there is so much plastic in the water that it outnumbers plankton by a factor of 26 in certain locations around and volume of plastic waste was severely overestimated [10]. The amount of plastic trash entering the ecosystem was drastically overestimated by a UNEP assessment which put the figure at 8 million pieces per day [11]. It should be emphasized, however, that none of these estimations are licensed to any specific source and should therefore be used with caution. Because the world's seas are vast and diverse, determining the projected average level of plastic garbage is a tough undertaking [12].

Plastic production has increased dramatically since the 1950s, when it was only 1.5 million tons in the 1950s to approximately 280 million tons in 2011 [9]. Annual plastic production is estimated to hit 400 million tons by the year 2020 [10,11]. (Polyethylene (PE), polyethyleneterephthalate (PET), and polypropylene (PP) are the most common plastics [11]. The primary characteristics that make plastics so useful are that they are both flexible and durable. When plastics are utilized in everyday life, these features come very helpful, but when they are disposed into the environment, they become a problem [13]. Plastics can have a major impact on ecosystems due to their practically indestructible nature and the toxins they contain [13]. The most plastic waste is found in the ocean's major gyres [14]. Approximately 49% of all created plastics are buoyant, allowing them to float and so travel on ocean currents to any location on the planet [12]. There, the rotation of vortex centers, where it is now accumulating. Plastic waste has an impact on all marine species, and because we are at the top of the food chain, it also has an impact on people [11]. There is evidence that current approaches to production, use, transportation, and disposal of plastic materials have caused, and continue to cause, serious effects on wildlife, and are not sustainable [15].

Plastic in aquatic environments, and specifically microplastics (particles less than 5 mm), has been gaining global attention as a pervasive problem [16] because the effects of microplastics on many aquatic wildlife are still unknown, there is a growing interest in learning more about them [17,18]. Microplastics were originally discovered as spherules in plankton tows around the New England coast in the 1970s [19]. Since then, microplastics have been discovered in almost all big bodies of water (oceans, seas, lakes, and rivers). Plastics production has expanded from 1.5 million tons per year in the 1950s to 250 million tons per year in 2011, with an annual increase of 10% [20].

Plastic pollution has numerous detrimental effects on animals, and aquatic systems are thought to be sinks for preand postconsumer plastic [21]. Plastics pollutants are classified differently depending on their size, origin, shape, and content. While there are not internationally agreedupon size classes, microplastic generally refers to plastic particles smaller than 5 mm 22], and is often limited to particles larger than 333 m because in most openwater studies, the neuston net mesh size (333 m or 0.33 mm) is commonly used to collect samples [22,23]. Microplastics come in a variety of morphologies, including fragments, films, pellets, lines, threads, filaments, and granules, in addition to recognized plastic objects. They are often classified as either primary or secondary microplastics [22]. Primary microplastics are created raw plastic materials such as virgin plastic pellets, scrubbers, and microbeads that enter the ocean by runoff from land [18]. Secondary microplastics are created when bigger plastic things disintegrate, as opposed to deliberate use. Mechanical, optical (oxidative), or chemical disintegration are all possibilities which break the larger pieces into increasingly smaller plastic fragments which ultimately become undetectable to the naked eye [23,24].

Plastics, both macro and micro, serve a variety of purposes. Micro-plastic beads, for example, are used in exfoliants in face scrubs and other personal care products. In some medical applications, they're also used to deliver drugs [18]. Microplastics also include fibers shed from synthetic clothing and rope, as well as particles used in “media blasting” processes to clean boat hulls and large machinery [17,18]. Many of these microplastics, microbeads, and fibers are small enough to get past wastewater treatment plants and into the watershed [18]. Chemically and physically, microplastics come in a wide range of shapes and sizes. Their compositions refer to the polymer types, which in turn determine the density of microplastics.

Polyethylene (PE), polypropylene (PP), polystyrene (PS), polyamide (nylon), polyethylene terephthalate (PET or polyester), polyacrylonitrile (PAN or acrylic), polyvinyl chloride (PVC), and styrene butadiene rubber are among the polymers used in plastic products [25]. Non-plastic polymer cellulose acetate (i.e. rayon) is also widely seen and chemical additives, such as flame retardants, plasticizers, and colors, are found in high concentrations in many of these polymers [23]. Chemical characteristics influence the movement of microplastic particles through various environmental matrices [23].

Plastic contamination can have far-reaching ecological and economic repercussions in both marine and freshwater ecosystems. Entanglement, ingestion, hypoxia, and general debilitation are all well-known problems that frequently lead to death [26,27]. Plastic ingestion can cause internal bleeding, abrasions, ulcers, and digestive system blockage in animals [7]. Since the early 1970s, seabirds and marine mammals have become entangled in massive amounts of plastic garbage [28].

Similarly, fish and seabirds have been eating microplastics for around the same amount of time [19, 29] and the number of affected species, such as seabirds is growing [30]. Contaminants such as persistent organic pollutants (POPs) and heavy metals are carried by microplastics [31,32]. They've been recognized as artificial substrates that could disrupt ecological processes and make it easier for invasive species to spread [26].

Plasticizers and stabilizers, which leach out into the environment during degradation, are added to improve the characteristics and performance of plastics [33]. BisphenolA (BPA) and other plastic additives and chemicals have been shown to be carcinogens and mutagens [34]. These compounds have also been demonstrated to alter endocrine functions and have a deleterious impact on aquatic animal reproduction and development [35]. Microplastics have the potential to affect ecosystem changes and human health, as well as the aesthetics of beaches, shorelines, coasts, sea floors, and coral life have been jeopardized [36].

2. TYPES OF PLASTICS

There are different types of plastics based on their constituents and type of materials used in their production. Properties of different plastics and their usage are shown in Table 1 and their major source of pollution are shown in the images below.

2.1 Polyethylene Terephthalate (PET)

Polyethylene terephthalate (PET) is a smooth, translucent, and relatively thin plastic. It is also known as stomach plastics. Because PET is anti-inflammatory and totally liquid, it is often used in the production of disposable salad dressing, juice, mouthwash, vegetable oil, cosmetics, soft drinks, margarine, and water bottles. PET is also anti-air, as it prevents oxygen from entering it [38-40]. An inorganic substance called antimony trioxide is employed as a catalyst in the manufacturing of PET and rubber vulcanization [5]. PET plastics must be kept away from high temperatures to avoid the leaching of harmful chemicals such as acetaldehyde, antimony, and phthalates. Antimony has been identified as a possible human carcinogen [38-40] PET is often made for one-time usage only [38,40].

2.2 High-density Polyethylene

Polyethylene is the most often used plastic on a global scale. High-density polyethylene is a petroleum-based heat-resistant material. It is a main component of refrigerators, detergent bottles, toys, milk containers, and several types of plastic grocery bags, among other things. High-density polyethylene contains no phthalates or BPA [41]. Although some studies have shown that long-term exposure of plastics to sunlight can be detrimental, high density polyethylene containers are typically deemed acceptable for drink and food because there has been no observed health impact [38-40].

2.3 Polyvinyl Chloride (PVC)

Polyvinyl Chloride (PVC), a heat-resistant polymer, is used in the packaging of fruit juice, cooking oil, and other liquids. Because of the inclusion of chemical elements such as heavy metals, dioxins, BPA, and phthalates, PVC is regarded very dangerous. Because of the presence of phthalates, PVC is flexible depending on non-plasticization. Humans are poisoned by phthalates [38,40]. Because the entire PVC life cycle, including production, use, and disposal, is potential of posing serious environmental and public health problems, its use has been significantly limited. However, due to its low cost and adaptability, PVC is still widely used in the manufacture of consumer items. Chronic bronchitis, birth defects, genetic alterations, cancer, skin problems, deafness, eyesight failure, ulcers, liver dysfunction, and indigestion have all been linked to PVC [38,40].

2.4 Low-density Polyethylene

Heat resistance, fragility, flexibility, and rigidity are all characteristics of low-density polyethylene. It is typically found in milk, frozen foods, and juice containers. Because the plastic contains no hazardous components to the human body, it is considered acceptable for use in beverages and food [38, 40, 41].

2.5 Polypropylene

Polypropylene is a material that is both robust and semi-transparent. It is heavier and more durable than polyethylene. It is used to package medicines, yogurt, ketchup, and beverages, among other things. Polypropylene plastics contain no hazardous chemicals, and polypropylene containers, like polyethylene containers, are considered safe for humans to use as food and beverage packaging [38,40].

2.6 Polystyrene

Polystyrene, a petroleum-based plastic, includes benzene, which causes cancer in humans [40, 41]. Polystyrene is a common polymer used in the manufacture of insulators and packaging materials. Styrene-based products are detrimental to one's health and shows that long-term exposure to modest amounts of styrene can be neurotoxic, generating cytogenetic, carcinogenic, and hematological consequences [42]. Styrene has been classified as a human carcinogen by the International Agency for Research on Cancer (IARC) [38,40]

2.7 Polycarbonate

Polycarbonates are utilized in consumer products packaging, such as reusable bottles, and BPA is used in their manufacture. BPA can be leached from polycarbonated containers into the drink or food held in them due to high temperature exposure [41]. Because of the health risks associated with BPA, which have been documented in several studies, the use of polycarbonated plastics has significantly declined since early 21st century [38-40]

3. EFFECT OF PLASTIC POLLUTION ON AQUATIC ORGANISMS

When introduced into an aquatic environment, the qualities of plastic that make it appealing for modern society can make it harmful for aquatic animals and other wildlife [15]. Plastic pollution affects a wide range of species, mostly because organisms become entangled in plastic nets or can eat plastic garbage by mistake [43]. Another issue with plastic pollution is that it encourages the spread of species; alien species hitchhike on floating garbage and invade new ecosystems, producing a shift in species composition or possibly the extinction of other species [44]. When plastics are consumed, they also transfer toxins to the environment or to creatures [44]. Although plastic is frequently buoyant, it can sink to the seafloor when dragged down by bottom-hugging currents, oceanic fronts, or rapid and extensive fouling. Sediment may also aid in the retention of plastic on the seafloor [9]. Plastic is likely to alter the functioning of the ecosystem once it reaches the seafloor. According to Goldberg [45] the plastic sheets could behave like a blanket, limiting gas exchange and resulting to anoxia or hypoxia (low oxygen levels).

Fig. 1. Source of plastic pollution in aquatic environment

Table 1. Type of plastics, their characteristics and common uses

Types of plastics	Characteristics	Common uses	Recycled into	Sources
Polyethylene terephthalates	Clear, tough, solvent resistant, barrier to gas and moisture, softens at 80 °C.	Soft drinks, water bottles, containers, salad dressing, biscuit trays and salad domes.	Pillow and sleeping bag filling, clothing, soft drink bottles, carpeting, building insulation	[37, 38]
High density polyethylene (HDPE)	Hard to semi-flexible, resistant to chemicals and moisture, waxy surface, opaque, softens at 75 °C, easily coloured, processed and formed	Shopping bags, freezer bags, buckets, shampoo, milk bottles, ice cream containers, juice bottles, chemical and detergent bottles, rigid agricultural pipe, crates	Recycling bins, compost bins,	[37, 38]
Polyvinyl Chloride (PVC) Plasticized Polyvinyl chloride PVC-P.	Strong, tough, softens at 80 °C, can be clear, can be solvent welded. Flexible, clear, elastic, can be solvent welded	Cosmetic container, plumbing pipes and fittings, electrical conduct, blister packs, wall cladding, roof sheeting, bottles, garden hose, Shoe soles, cable sheathing, blood bags and tubing.	Compost bin	[37, 38]
Low density polyethylene (LDPE)	Soft flexible, waxy surface, translucent, softens at 70 °C, scratches easily.	Refuse bags, Irrigation tubings, mulch film, cling wrap, garbage bags, squeeze bottles	Bin liners, pallet sheets	[37, 38]
Polypropylene (PP)	Hard and translucent, soften at 140 °C, translucent, withstands solvents, versatile.	Microwave dishes, lunch boxes, packaging tape, garden furniture, kettles, bottles and ice cream tubs, potato chip bags, straws	Pegs, bins, pipes, pallet sheets	[37, 38]
Polystyrene (PS) Expanded polystyrene (PS-E)	Clear, glassy rigid, opaque, semitough, soften at 95 °C, Affected by fat, acids and solvents, but resistant to alkalis, salt solutions, Low water absorption, when not pigmented is clear, is odour and taste free. Special types of Polystyrene (PS) are available for special applications.	CD cases, plastic cutlery, imitation glassware, low cost brittle toys, video cases/foamed polystyrene cups, protective packaging, building and food insulation	Recycle bin	[37, 38]
Other	properties dependent on plastic or combination of plastics	Automotive and appliance components, computers, electronics, cooler bottles, packaging Includes all resins and multimaterials (e.g. laminates)	Recycle bins	[37, 38]

3.1 Effect on Animal Communities

Over the previous several decades, the amount of plastic pollution brought into the aquatic environment has greatly increased. Wildlife is frequently wounded because of entanglement or ingestion of plastics prevalent in the environment [11]. Plastic debris entanglement and ingestion has been found to harm at least 267 marine species globally [43]. When such contact happens, organisms are severely harmed, almost always resulting in death. Because plastic waste cannot be directly viewed, it is extremely difficult to determine the entire impact of plastic debris in the ocean or predict the repercussions for organisms that ingest or otherwise come into contact with it [43]. Entanglement, on the other hand, can be seen and is the most evident consequence of plastic trash on species in the aquatic environment. Laist [43] researched and compiled a thorough list of species that were entangled as a result of debris entanglement. However, the precise level of entanglement encountered by marine creatures is difficult to quantify because entanglement typically occurs in locations away from human activities. Drowning, suffocation, strangulation, or hunger can all result from entanglement [11]. Birds, tiny whales, and seals frequently perish in ghost nets. Because of their entanglement, they may also lose their capacity to catch food or evade predators [11]. Aquatic birds, animals, turtles, and fish frequently consume plastic garbage that pollutes the aquatic ecosystem [11, 43]. Plastic ingestion occurs largely when it is mistaken for food, but it can also occur because of incidental intake. Ingested materials frequently consist of micro and meso-debris sized bits that can sometimes pass through the gut without harming the organisms. However, in most cases, fragments become caught inside the stomach, throat, or digestive tract, causing harm or a false impression of fullness, which leads to famine. Table 2 summarizes the aquatic creatures impacted by plastic trash. According to the list of impacted species, aquatic debris affects many species [11]. It impacts as least 267 species globally, including 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species [43]. The problem may go unnoticed over broad swaths of ocean because they sink or are consumed by predators [46]. Plastic waste is known to impact at least 23% of marine mammal species, 36% of seabird species, and 86% of sea turtle species worldwide [47].

3.2 Effect on Plant Communities

When compared to risks to animals, the impact on plant populations is minor. Natural flotsam of both marine and terrestrial origin (seaweeds and plants) tends to accumulate around high tidal strandlines, where it is frequently referred to as "the wrack" [26]. These places are frequently ephemeral, dynamic, and seasonal habitats that amass substantial amounts of manufactured items, particularly those composed of plastic and other non-destructible materials [11]. As a result, wrack habitats are frequently ugly, and requests from local governments to clear up the mess are frequent and can be costly [29]. The greatest impact on floral communities is shown in the form of microplastics, which are easily ingestible by small creatures such as plankton species and form a channel for contaminants to enter the food chain [11]. Plastic, like any natural or man-made floating debris, can provide a pathway for encrusting and fouling organisms to disperse over long distances [49]. For millennia, logs, pumice, and other flotsam have traveled the open ocean, and the introduction of hard plastic debris into the marine ecosystem may provide an enticing and alternative substrate for some opportunistic colonizers [26, 50]. It is anticipated that biotic mixing might reduce worldwide marine species diversity by up to 58 percent [50]. Due to the input of anthropogenic trash, the propagation of fauna in the water has more than doubled in the tropics and more than tripled in high latitudes [49,50]. Plastics' harsh surfaces make a perfect foundation for opportunistic colonists. Bivalve mollusks are the most prevalent encrusting species on pelagic plastics; however, bacteria, diatoms, algae, and barnacles are all encrusting creatures [11,26,51].

Plastic substrates may also house multispecies habitats, which are made up of creatures that would ordinarily inhabit diverse ecological niches [49]. Drifting plastic waste may also expand the range of certain marine invertebrates or introduce species to previously uninhabited regions [11]. The advent of undesired and aggressive alien species could have a severe impact on sensitive or at-risk littoral, intertidal, and shoreline ecosystems, thereby causing environmental damage [11,26,49]. The lack of biological creatures on plastic debris could indicate that the particles were not in the marine environment long enough for fouling to occur. These items, on the other hand, are more likely to have a local, land-based origin (beachgoers, storm-water drainage) than more thickly

Table 2. summary of effect of plastic waste on some aquatic organisms

Species	Plastic types	Effect	Sources
Aquatic birds	Plastic particles like bottle caps and pellet	Ingestion which leads to Starvation due to gastrointestinal obstruction and Stomach perforation	[38,48]
Sea turtles	Plastic bags and other debris	Impediment of hatchling movement towards the sea,exposure to predator and locked and injures cloaca, impedes laying of egg	[38,48]
Fish	Fragment lines, particulate plastic, plastic bags and microplastics	Ingestion of plastic fragments, Hepatic stress from exposure to plastic pollutant. Leached monophenol additives caused mortality, inhibited hatching, decreased growth rate andaltered behavior	[38,48]
Mammals	Plastic particles like plastic rings, bags, debris and fishing gears	Bioaccumulation of particulate plastic from prey fish, Stomach rupture and starvation and entanglement caused mortality	[38,48]
Invertebrates	Microplastic particles such as Polyethylene pellets	Causes injuries and Blockage of digestive systems	[38,48]
		Interference with energy uptake and reproduction	
		Ingestion and accumulation of plastics in the gut	

encrusted detritus [51]. Plastic garbage may foster the invasion of species that favor hard surfaces, displacing indigenous species, particularly those that prefer sandy and muddy bottoms [9].The ecosystems are made up of national flotsam and jetsam, such as washed-up seaweed driftwood, and frequently contain plastic debris. Beach clean-ups are an effective approach to eliminate plastic debris; however it is sometimes expected that the beach would revert to its pre-clean-up state once the cleanup is over [9, 11].

3.3 Plastic and Ecotoxicology

Plastics are considered biochemically inert due to their large molecular structures; they do not react with or permeate an organism's cell membrane [11,15] Most plastics, however, are not pure. Aside from their polymeric structure, they are made up of a range of compounds, each of which contributes to a different attribute of the plastics [11,15]. Additives, which are generally of small molecular size, are frequently not chemically linked to a polymer and can thus leak from the plastics. Because they are largely lipophilic, they permeate cell membranes, interact biochemically, and induce harmful consequences; also, plastic debris in the marine environment contains chemicals (Contaminants) absorbed from the surrounding water [15]. The hydrophobic surface of plastics attracts various hydrophobic pollutants, which are drawn up from the surrounding water and collect on and in the plastics trash. This method has gotten a lot of attention for micro trash or micro plastics since they are easily swallowed by organisms and serve as a channel for chemicals to enter a creature [23]. Plastic trash in the marine environment may include two types of harmful contaminants: additives and hydrophobic compounds that are adsorbed from the surrounding water [9]. The absorption of pollutants by polymers in the marine environment is typically researched using meso-plastic and microplastic detritus. Absorption lowers pollutant movement and diffusion. Hydrophobic organic pollutants prefer plastics such as polyethylene, polypropylene, and PUC over natural sediments [38, 48]. Flame retirements are also present as plastic additives and have been incorporated to many ordinary items. Most flame retardants (BFFs) BFF are commonly used in plastics production because they have just a little impact on material prosperity and are quite effective at avoiding combustion.

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Recycling is the current strategy for preventing plastics from entering the aquatic environment. Chemicals in plastics can be detrimental to marine life. Education is especially important because it serves as the foundation for teaching the next generation about the effects of throwing plastics and other garbage into the world's oceans. With the evidence currently available, it is not possible to draw any sound conclusions about the direct risks posed by the presence of microplastics particles in the marine environment, or the influence of microplastics on the risk posed to environmental and human health when combined with hazardous substances such as additives.Plastics do not degrade and will remain in our surroundings indefinitely, threatening aquatic life until pollution levels are decreased. Every living organism on this planet requires water to survive. If this resource is so valuable that life cannot live without it, we should not pollute it.

4.2 Recommendation

Quality indigenous and homegrown technology for plastic waste management and recycling of all plastic items are being developed. Policy development and execution for plastic waste management should consider the needs of all levels of society. Social responsibility for plastic trash management should be instilled at all levels of our educational system, beginning with primary school. The health and safety implications of all degrees of plastic trash recycling should be made known to local people.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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