Scilight

Earth: Environmental Sustainability
https://www.sciltp.com/journals/eesus

Review

A Review of Microplastics Pollution in the River Basin of Vietnam in Comparison with the World Context

Huynh Do Hieu Nhu and Tran Le Luu *

Master Program in Water Technology, Reuse, and Management, Vietnamese German University, Ho Chi Minh City 700000, Vietnam
* Correspondence: luu.tl@vgu.edu.vn; Tel.: +84-096-891-3909

How To Cite: Nhu, H.D.H.; Luu, T.L. A Review of Microplastics Pollution in the River Basin of Vietnam in Comparison with the World Context. *Earth: Environmental Sustainability* **2025**, *1*(2), 343–355. https://doi.org/10.53941/eesus.2025.100026

Received: 16 July 2025
Revised: 9 November 2025
Accepted: 10 November 2025
Published: 24 November 2025

Abstract: Microplastics have raised serious environmental and health concerns worldwide due to their widespread presence as a common pollutant in aquatic environments. This study offers a comprehensive examination of microplastic pollution in river basins in Vietnam, drawing on global studies to assess its potential impact on water resources. The results indicate that microplastic pollution is present in significant concentrations in surface water, sediments, *Aquatic organisms*, and mangrove ecosystems throughout Vietnam, particularly in coastal areas such as Da Nang and Thanh Hoa, as well as in urban rivers like the Saigon River, with the highest concentration found being 519,000 pieces per cubic meter of water. Urban runoff, wastewater, and plastic waste from domestic, manufacturing, and tourism activities are important sources of emissions. High concentrations of microplastics, primarily fibers and debris such as nylon, PE, and PP, are highly persistent and bioaccumulate in *Aquatic organisms*, posing potential problems due to the presence of chemical additives. Comparative data from around the world also show similar environmental risks, including microplastic consumption by marine life, possible impacts on ecosystem function, biodiversity, and ultimately human health risks through the food chain. The study also highlights the importance of improving waste management, enhancing pollution monitoring, and implementing sustainable measures to mitigate microplastic pollution in various areas of Vietnam.

Keywords: microplastic pollution; river basin; environmental impact; Vietnam; aquatic ecosystems

1. Introduction

Plastics, including microplastics, are synthetic polymers created through the polymerisation of petroleum-derived monomers and moulded to meet the precise demands of their applications across various sectors. The global plastic production trend has generally increased from 1950 to 2023. The global production was only 2 million tons per year in the 1950s. However, by 2019, after nearly 70 years, annual production had grown steadily to about 230 million tons, peaking at 460 million tons and continuing to increase until 2023 [1]. Plastic products are increasingly popular and produced with outstanding properties such as durability, chemical inertness, good abrasion resistance, light weight, and convenience [2]. Plastic waste is mainly generated from large cities and densely populated areas. Plastic waste generated from wastewater treatment systems, urban drainage systems, tourist areas, entertainment areas, and inland areas can flow into the sea through rivers [3]. People living in residential areas near rivers, estuaries, and regions lacking operative waste management systems often dispose of plastic waste directly into the environment, thus contributing significantly to plastic pollution. According to some studies in 192 coastal cities, it was reported that each year, 4.8 to 12.7 million tons are directly dumped into the marine environment [4,5]. Plastic bags and small pieces of plastic generated from daily activities, littered on the streets, sidewalks, or improperly disposed of in landfills, will be washed away by the city's drainage system into rivers during heavy rains. Eventually, these plastic wastes will be carried to the sea, where they are most likely to be contained. Plastics have been documented to persist in the environment for hundreds to thousands of years. Disposing of plastic waste is a complex process, and most plastic waste is handled by traditional methods, such as recycling and landfilling.

Polyethylene terephthalate (PET), polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and polyurethane (PUR) are the most widely produced polymers, accounting for approximately 92% of total global plastic production [1]. However, the wide range of physicochemical properties of plastics plays a key role in determining their everyday applications and environmental behavior. For instance, plastics like PET, PVC, and nylon sink in water, whereas PS, PP, and PE are more buoyant and typically float to the surface. Biofouling and environmental exposure can alter these original buoyancy characteristics, leading to shifts in how plastics are distributed across different ecosystems [6]. Furthermore, to enhance plasticity, color, flame retardancy, and UV resistance, organic or inorganic flavors are added to plastics. These additives, which may be present in significant proportions by weight, tend to migrate with the plastics from which they are made [7]. Gradually, this plastic waste, under the influence of solar radiation, waves, wind, or other environmental impacts, decomposes into microscopic pieces called secondary microplastics [8]. In addition, another type is primary microplastics, which are used in manufacturing, industry, agriculture, and daily life with a size usually less than 5mm, including particles in cosmetics, hair care, detergents, clothing, and pesticides [2,9]. Microplastics are ubiquitous, persistent, and can bioaccumulate in living organisms, posing a significant threat to aquatic ecosystems [10]. Research on zooplankton has indicated that microplastics negatively impact their health and metabolic processes, primarily because zooplankton often mistake these small (1–5 mm), dark-colored particles for food [11]. Plastic waste in the form of long, thin fibers is present at various depths in the water column, making it easy for them to entangle fish and sea turtles, which can result in death or serious injury [12]. For microplastic and nanoplastic waste, the size of microplastics and nanoplastics is tiny, facilitating their entry into the food chain of organisms in rivers and seas, such as zooplankton, invertebrates, echinoderm larvae, seabirds, fish, and crustaceans, accumulating over time, from which humans will indirectly absorb them, seriously affecting health. With hydrophobic and persistent properties, the accumulation of microplastics when entering the body has been shown to cause liver stiffness, granuloma formation, chronic pneumonia or bronchitis, pneumothorax, bronchial reactions, changes in gut microbiota composition and metabolism, respiratory tract damage, and cognitive impairment [13–15].

In Vietnam, rapid urbanization and increased consumer demand have resulted in the production and disposal of plastic products exceeding the capacity of systems to handle and control them. It is estimated to contribute approximately 0.28–0.73 million tons of plastic waste to the ocean each year [16]. However, comprehensive overview studies on microplastic pollution in river basins in Vietnam are still very restricted, especially on the potential impact on water resources. This reduces the ability to assess pollution trends over time and quantify the flow of microplastics from freshwater systems into the marine environment. Studies in Vietnam have used different sampling methods, digestion techniques, and identification methods, making it difficult to compare results between studies. Furthermore, current studies only provide a limited understanding of the spatial distribution of microplastics in Vietnam, and studies on microplastic pollution in mangrove ecosystems are still very few despite their ecological importance. Therefore, this paper will comprehensively review the current status of microplastic pollution in river basins in Vietnam. At the same time, based on global studies, it is possible to compare and assess more broadly the impact of microplastics on water quality and ecosystems. After that, there is a general overview basis, contributing to support urgent needs in microplastic pollution, such as planning effective waste management, improving management capacity, improving community education, and standardizing research methods in subsequent studies.

The methodology of this study was based on a literature search using major academic databases, including Scopus, Web of Science, and Google Scholar, using a combination of keywords such as "microplastics", "plastic pollution", "Vietnam", "world", "global", "river", "river basin", "surfacewater", "estuary", "concentration", etc. The initial group of articles was then screened, and final inclusion was determined based on three main criteria: relevance, scientific credibility, and novelty. Relevance was the criterion to ensure that all included studies were directly relevant to the scope of the review, which included (a) quantitative or qualitative assessment of microplastic pollution (including quantity, distribution, and composition) in river basins in Vietnam, including surface water, sediments, and/or *Aquatic organisms*; and (b) provide essential global or regional context (e.g., major international river studies, global pollution summaries) to enable the comparisons required by this review. Scientific credibility means that the articles are peer-reviewed by reputable scientific journals. Credibility is further assessed on the basis of methodological rigor. Priority is given to studies that provide clear and reproducible methodologies for (a) sample collection, (b) microplastic extraction and separation (e.g., density fractionation, filtration), and (c) polymer identification. Studies that go beyond simple visual classification and confirm polymer types using analytical techniques, such as Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy, or pyrolysis gas chromatography/mass spectrometry (Py-GC/MS), are considered to be of high credibility. At the same time, microplastics research is a rapidly evolving field, with methodologies and reported concentrations changing significantly over the past decade. Therefore, this study focused on novelty to ensure that the review reflected the current state of knowledge. The search focused primarily on studies published within the last 10 years. Foundational or groundbreaking studies that were widely cited from earlier periods were only included if they provided essential historical context or established a core concept.

2. Microplastic Pollution in Vietnam

Recent studies on plastic and microplastic pollution have primarily focused on their presence in various environments, including surface water, sediments, and sand [17–21]. Additionally, studies have investigated bivalve mollusks, farmed oysters, and fish to examine microplastic contamination in aquaculture organisms [22–24]. Moreover, mangrove ecosystems inadvertently act as significant sinks for plastic waste, as debris becomes trapped within roots and trunks, increasing pollution risks. These mangrove structures facilitate the physical breakdown of plastic, which may potentially exacerbate microplastic contamination in surrounding environments [25]. Therefore, below are the studies reviewed to contribute to understanding the level of microplastic pollution and the risks to human health, organisms, and the environment. Figure 1 provides an overview of the microplastic contamination situation in these studies.

2.1. Surface Water

Ý et al. (2022) surveyed the microplastic contamination of a lake in Da Nang city. The study illustrates that the density of microplastics ranged from 850–1300 microplastics/m^3 with six main color groups: white, blue, green, red, black, and yellow. According to Ý et al. (2022), fibrous microplastics and fragments were the most prevalent, with fibrous microplastics mostly measuring under 2 mm in size, accounting for over 79% of the total microplastics observed. Fragments comprised 98.5% of the total number of identified microplastics [26]. Lahens et al. (2018) studied the Saigon River, where the concentration of fragmented microplastics, mainly PP and PE, ranged from 172,000 to 519,000 pieces per cubic meter, and the content of fibrous PES ranged from 10 to 223 fibers per cubic meter [27]. In addition, Strady et al. (2020) investigated the changes in microplastic concentrations, rainfall, monthly water flow, and physical-chemical water conditions in the Saigon River system across different seasons. Monthly data for 6 to 12 months showed that the concentration of microplastic fibers ranged from 22 to 251 microplastics per liter, and the variation in microplastic concentrations was not related to rainfall or water flow. However, the distribution of color and length showed monthly variations and was linked to changes in sources and reservoirs [28]. In 2021, Strady and colleagues expanded their assessment of microplastic pollution in eight provinces and cities in Vietnam by analyzing surface water at 21 locations. The results indicated that microplastics in surface water ranged from 0.35 to 2522 pieces/m^3, with rivers having the highest concentrations and bays having the lowest. Fibrous microplastics were predominant compared to fragmented forms across most studied environments, accounting for approximately 47% to 97% of the identified microplastics [19]. The study demonstrates a relationship between microplastic concentrations and human activities. Thus, determining the origin of microplastics is a near-term priority. In the Saigon River, the canals, and the Can Gio sea, the occurrence and distribution of microplastics, as well as polycyclic aromatic hydrocarbons (PAHs), were investigated. This study noted that microplastics were detected at all sampling points, with average concentrations in decreasing order from 104.17 ± 162.44 to 0.60 ± 0.38 pieces/m^3 in canals, seas, and rivers, respectively. The three common shapes of microplastics are fragments, fibers, and beads. A total of 13 polymers and copolymers were identified. Total concentrations of PAHs associated with microplastics ranged from 232.71–6448.66 ng/g in the Can Gio sea area, from 30.94–8940.99 ng/g in canals, and 432.95–3267.88 ng/g in the Saigon River [29]. Cham et al. (2021) analyzed surface water samples from various beaches in Thanh Hoa and found microplastic concentrations ranging from 15.5 to 44.1 microplastics per cubic meter, with fragmented microplastics accounting for approximately 50.2% to 80.2% of the total. The authors attributed these microplastics mainly to coastal waste discharged into rivers and transported to estuarine areas. Additionally, domestic wastewater from coastal communities, as well as fishing, aquaculture, and seafood processing activities, were identified as significant contributors to microplastic contamination [30]. A more recent study directed by Cham's group of researchers at the three most extensive beaches in Thanh Hoa examined plastic waste and microplastics in surface water. They observed that debris collected primarily originated from fishing vessels and styrofoam food containers, representing 98% of the total waste. The maximum recorded microplastic concentration was 44.1 items/m^3, with fragments identified as the dominant form, comprising approximately 61.4 ± 14.3% of the collected microplastics. The authors concluded that the distribution and buildup of microplastics are related to human activities and environmental dynamics [31]. The above studies suggest that variations in microplastic concentrations across river systems in Vietnam may reflect differences in urbanization, waste treatment infrastructure, and flow intensity. For example, higher concentrations reported in the Saigon River correspond to high population density and industrial discharge, while lower concentrations in coastal Thanh Hoa are consistent with less urbanized areas. To facilitate a comprehensive comparison of the findings discussed above, key data on microplastic pollution in surface water are summarized in Table 1.

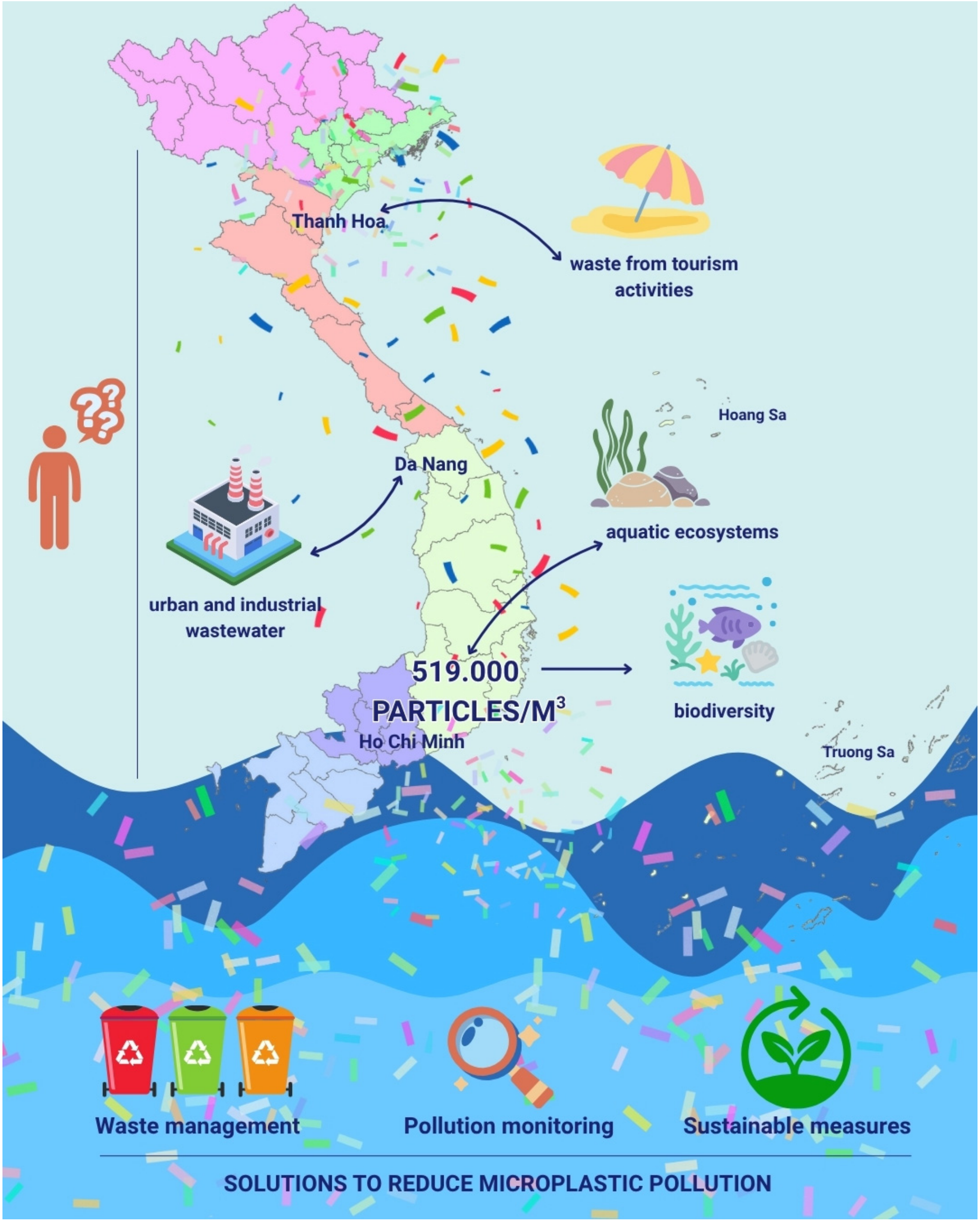

Figure 1. Overview of the status of microplastic pollution in Vietnam.

Table 1. A summary of the studies on surface water in Vietnam.

No	Country	Composition	Concentration	Reference
1	A lake in Da Nang city	Shapes: fibres and fragments Sizes: <2 mm. Colors: White, blue, green, red, black, yellow	850–1300 items/m^3	[26]
2	Saigon River	Shapes: fibres and fragments Sizes: 50–250 µm (fibres) >500 µm (fragments) Colors: various colors Types: PP, PE, PET	Fragments: 172,000–519,000 pieces/m^3 Fibers: 10–223 fibers/m^3	[27]
3	Rivers, lakes, bays, and beaches of 8 provinces in Vietnam	Shapes: fibres and fragments Sizes: 1mm	0.35 to 2522 items/m^3	[19]
4	Saigon River, canals, Can Gio sea	Shapes: Fragments, Fibers, Beads. Types: 3 polymers and copolymers	Canals: 104.17 ± 162.44 particles/m^3 River: 0.60 ± 0.38 particles/m^3	[29]
5	Beaches in Thanh Hoa	Shapes: Fragments. Sizes: >500 µm Colors: white, yellow, and black	15.5–44.1 items/m^3	[30]
6	3 major beaches in Thanh Hoa	Shapes: Fragments Types: Styrofoam	44.1 items/m^3	[31]
7	Saigon River	Shapes: fibers Sizes: 40–300 µm Colors: blue, red, grey, back, and green	22–251 items/liter	[28]

2.2. Sediments

Manh and colleagues examined the characteristics of microplastic pollution in Da Nang, reporting concentrations ranging from 1460 to 29,232 particles/kilogram. The majority of these were polytetrafluoroethylene (PTFE), ethylene vinyl alcohol (EVOH), and polyamide (PA) with a size smaller than 150 µm [32]. Strady et al. (2021) assessed microplastic pollution in eight provinces and cities in Vietnam by analyzing sediments at 21 locations, providing a baseline database to advance the consideration of microplastic pollution in Vietnam. Despite the ecological importance of mangroves, research on microplastic contamination within these ecosystems remains scarce. One study analyzing sediment cores from mangroves in northern Vietnam reported microplastic concentrations ranging from 0 to 4941 particles/kg, including fibers, fragments, foams, and films. In the Red River Delta, microplastics were present at depths of 0–50 cm, whereas in Tien Yen Bay, they were detected as deep as 50–65 cm [21]. A complementary investigation of sediment samples from mangrove forests in Hai Phong revealed microplastic concentrations ranging from 0 to 3150 particles/kg, with microfibers accounting for approximately 80% of the total, followed by microfoams, microfragments, and microfilms. These concentrations were significantly higher than those recorded at similar sites globally [25]. Overall, the transport of microplastics from land to the coast is well documented for their accumulation in sediments, and further research is needed on how these materials are distributed and concentrated along beaches and coastal areas.

2.3. Beach Sand and Coastal Debris

Bui et al. (2022) surveyed to assess and characterize microplastic pollution on Can Gio Island, Vietnam, across both wet and dry seasons. Findings indicated that fishing-related marine debris was more prevalent during the wet season, while single-use plastics declined, likely due to reduced tourism resulting from the COVID-19 pandemic. The study highlights the severity of marine debris pollution and offers valuable insights for strategies aimed at managing and reducing marine waste [33]. In another study, Fruergaard and colleagues assessed the load, structure, and origin of plastic waste at seven beaches in Nha Trang, Vietnam. The results showed that plastic waste pieces larger than 2.0 cm in size, originating from fishing and aquaculture activities, accounted for 62% by weight and 38% by number of the total 4754 pieces collected [34]. In 2022, Nguyen's research group also published a study on plastic waste on 14 beaches in Vietnam. The selected locations included tourist beaches, ecological reserves, aquaculture areas, and fishing grounds. A total of 20,744 plastic waste samples (>2.5 cm) with a total mass of 100,371.2 g were collected. The results show that most plastic waste samples collected were fishing gear and soft plastic pieces, accounting for 48.48% of the samples collected [29]. Generally, these findings indicate that activities related to fishing, aquaculture, and tourism are the main sources of plastic waste on beaches and coastal areas in Vietnam, highlighting the urgent need for integrated coastal management and waste reduction strategies to further reduce marine pollution.

2.4. Biota (Aquatic organisms)

Do et al. (2022) analyzed microplastics in oysters cultivated in Da Nang Bay, revealing the presence of microplastics in all oyster samples, with an average concentration of 18.54 ± 10.08 particles/individual. Fragments predominated, especially those smaller than 100 µm in size. Nylon was the most prevalent of the 15 polymer types detected, comprising 50.56%. The primary forms of microplastics identified were fragments (73.71%), fibers (25.84%), and beads (0.45%). The observed accumulation levels and polymer composition provide essential baseline data for future research assessing the potential to human health [22]. Microplastics can also take up persistent organic pollutants in water, accumulate, and cause harm to organisms exposed to them [35]. Polychlorinated biphenyls (PCBs) and PCB-related microplastics in clams and giant freshwater prawns were also studied and compared. After a 28-day stress experiment, significant amounts of plastic were observed in the organisms' digestive systems. Additionally, microplastic-related PCB-153 had a substantial impact on the weight gain of clams [36]. A 21-day exposure study on Daphnia magna assessed the effects of polyethylene microbeads (PEMBs) and PCB-153-associated PEMB (PEMB–PCB). Results showed a time-dependent accumulation of PEMB, with a greater survival risk observed under PEMB exposure compared to PEMB–PCB exposure. These findings underscore the persistent ecological threat posed by microplastic pollution [37].

3. Around the World

Transitions and tides transport microplastics, ultimately accumulating in water bodies, sediments, or organisms. In estuarine and coastal regions, their accumulation is further shaped by intense turbulence as well as interactions with sediments and biological aggregates [38]. Additionally, the processes governing the fate and transit of microplastics remain poorly understood, while they may endure for prolonged durations in nearshore waters. Recent studies have shown that coastal ecosystems, particularly mangroves, are experiencing a decline in their ecological productivity, posing significant risks to local communities due to exposure to microplastic pollution [39,40]. Mangrove ecosystems frequently serve as primary reservoirs for plastic debris originating from diverse sources [41]. Plastics often get entangled in the root and aerial systems of mangroves, hindering nutrient uptake and negatively impacting mangrove growth and density [42–44]. Furthermore, plastic particles contribute to eutrophication and increase water toxicity, negatively impacting aquatic flora and fauna, as well as the entire food chain [45,46]. Macroplastic fragments sinking to the seafloor will form a thick layer that blocks a large amount of light from reaching the sea, hindering the photosynthesis of underwater plants. Mangrove sediments have been reported to harbor a higher number of microplastic-contaminated organisms than other environments [47]. High microplastic concentrations in marine ecosystems can significantly modify the physicochemical characteristics of sediments. According to Carson et al. (2011), microplastics increased sediment permeability and reduced its capacity for heat absorption. These changes have critical implications for marine organisms; for instance, sediment temperature directly influences the gender determination of turtle eggs, while increased permeability may elevate the risk of desiccation for organisms inhabiting these sediments [48]. Shaw et al. (1994) confirmed that plankton cannot distinguish between microplastics and food, and they often absorb white and light-colored microplastics. Small-density plastics (polyethylene, polystyrene) adrift on the surface may be erroneously identified as sustenance by plankton, including larvae of some commercially valuable species [49].

The increasing microplastic contamination in aquatic environments poses a substantial risk of microplastic uptake by organisms, which is a growing concern. For instance, Ryan et al. (2009) identified plastic fragments in the digestive systems of seabirds [50]. Similarly, research conducted by a Dutch team revealed that nearly 94% of the bird specimens examined contained microplastics, with some individuals having as many as 34 plastic fragments [51]. By slicing sardines caught in the central Pacific Ocean, about 35% of the samples contained microplastics in their guts [52]. In another study, Davison and Asch (2011) found plastic fibers, beads, and sheets in the stomachs of sardines from the North Pacific, with microplastics present in approximately 13 out of 141 fish [53]. In the Clyde Sea near Scotland, microplastic ingestion was recorded in roughly 83% of Nephrops specimens [54]. Plastic fibers, measuring approximately 1–15 µm in size, are easily mistaken for food by plankton. When absorbed, these fibers tend to clump or knot, hindering the excretion of organisms [55]. About 60% of the 6000 plankton samples surveyed from 1986 to 2008 showed that plastic particles were detected [56]. The greatest accumulation of plastic in organisms was found in the North Atlantic, with 80% of samples containing plastic debris, at a rate of 20,328 ± 2324 pieces/km^2. Another study that examined the amount of plastic waste in the bodies of organisms in the Mediterranean Sea concluded that up to 58% of collected fish samples contained microplastics [57]. Ingesting microplastics can harm organisms, inhibit their growth, reproduction, and survival, causing an imbalance in the marine ecosystem's food chain. This is particularly concerning due to the impact of microplastic particles, which are so small that they cannot be seen with the naked eye and enter the food chain, ultimately reaching humans as the final consumer. The study by Köhler (2010) found that plastic particles, measuring 2–4 μm in size, are present in the bodies of humans. However, the translocation and presence of microplastics in the human body do not cause death, but can lead to the formation of granulomas in the digestive tract [58]. Many studies have shown that microplastic consumption can cause metabolic disorders, neurotoxicity, and increased cancer risk [59,60]. On the other hand, plastic waste impacts the ecological environment and socio-economic development, including the tourism industry, as this industry is highly dependent on the health of coastal and marine ecosystems, as well as the beauty of the environment, which represents the largest source of employment within the ocean economy. Marine debris on beaches can directly influence visitor behavior, potentially deterring tourists and negatively impacting the economic stability of coastal communities that rely on tourism revenues. According to recent studies, the frequency of tourists encountering and contacting plastic waste on beaches is increasing [34]. Coastal litter is considered one of the main reasons why tourists spend less time or do not return to these areas [61]. Several studies have demonstrated that plastic pollution can result in millions of dollars in annual damage to the marine tourism industry, ranging from cleanup expenses to loss of tourism revenue [62]. According to Beaumont et al. (2019) study assessing the global ecological, economic, and social impacts of marine microplastics showed typical figures such as the loss or reduction of 1% to 5% of the services provided, thereby causing a loss of up to 2500 billion dollars annually [61]. Conversely, tourism revenue could increase by more than 32% with research in coastal tourist areas along the East China Sea when beach trash is cleaned up [63]. They also directly affect the physical well-being and mental health of tourists and resort staff [64]. In addition, fishing and aquaculture also suffer severe consequences from plastic pollution, such as having to repair boats and aquaculture facilities when plastic waste gets stuck in propellers or cooling systems [62,65]. The European Union has to pay 65.7 million USD in total repair costs annually [66,67].

Besides harmful effects on the landscape, organisms, and the economy, plastic waste also poses environmental risks due to the chemical additives that persist on its surface, such as polybrominated diphenyl ethers, which are used to enhance heat resistance, nonylphenol, which serves as an antioxidant, and triclosan, which is added to prevent biodegradation. These additives are considered potential hazards to organisms due to their toxicity [68]. Incomplete polymerization during the plastic production process is a primary cause of additive leakage. For example, phthalate additives help soften plastic, and in PVC plastic, phthalates can account for about 50% of the plastic mass [69]. Bisphenol, a primary monomer in the manufacture of polycarbonate plastics, is extensively utilized in food and beverage packaging. Because of chemical instability, it exhibits a high propensity to leach from discarded products in landfill sites, thereby contributing to environmental contamination [70]. When animals ingest plastic waste containing surface additives, these substances can enter the food chain. Both additives and monomers are recognised to disrupt the endocrine system, impair reproductive and developmental processes, and elevate the risk of cancer in both wildlife and humans [71,72]. Exposure to these chemical additives can lead to hormonal disruptions in organisms, trigger morphological changes, and even cause sex reversal in species such as turtles. Phthalates, in particular, have been shown to impair the activity of invertebrates and fish, negatively impacting reproductive processes and influencing sex determination in fish [73]. Bisphenol A is known to harm the reproductive and developmental systems of various organisms. At elevated concentrations, Bisphenol A can harm both crustaceans and insects. Prolonged exposure in humans causes cardiovascular disease, diabetes, and hormonal imbalances [74]. Plastic waste pollution is expected to continue increasing and may become alarming by 2025 [75]. Therefore, the environmental impact of plastics is substantial, primarily affecting organisms living in aquatic environments, as well as humans and other species.

However, the reasonable production costs, lightweight nature, and convenient transportation of plastic goods have contributed to the growth of plastic production over time, alongside economic development and population growth [76]. In 2018, worldwide plastic output totalled roughly 359 million tonnes, with only about one-third of that quantity being recycled or repurposed. The remaining two-thirds ended up as environmental waste [1]. In 2010, approximately 275 million tonnes of plastic waste were generated in 192 countries, with an estimated 4.8 to 12.7 million tonnes ultimately entering the ocean. In Bangkok, Thailand, the daily plastic waste increased from 2115 tons in 2019 to 3432 tons in 2020. Jambeck and colleagues examined improperly managed plastic garbage, identifying the Philippines, China, Indonesia, and Vietnam as the most significant contributors to unmanaged and marine plastic debris (measured in million tons per year). The study also examined how economic status, coastal population, waste generation, and mismanagement influence plastic waste issues [16]. This plastic dumping significantly contributes to microplastic pollution in the ocean and mangrove regions, which are situated at the interface between land and sea. Additionally, ocean waves tend to deposit microplastics along coastlines, so increased plastic waste in the marine environment is likely to lead to higher future microplastic accumulation near coastal areas.

When compared to observations from Vietnam, the reported concentrations are consistent with trends seen in other developing coastal countries, such as Thailand, Indonesia, and the Philippines, where rapid urbanization and inadequate solid waste management practices have increased plastic leakage into rivers. However, long-term monitoring data from Vietnam are relatively scarce, limiting the ability to assess over time and quantify flows from freshwater systems to the marine environment. In contrast, developed regions such as Europe and Japan have more specific analytical procedures and data sets. In addition, studies from Vietnam have used different sampling grid sizes, digestion methods, and particle identification techniques, which makes cross-comparison difficult and may partly explain the large differences in reported results. Overall, these studies provide only a limited understanding of the spatial distribution of microplastics. To improve data comparability and reliability, future studies should employ standardized procedures, integrate hydrological and socioeconomic parameters, and combine field surveys with modeling methods to estimate source-to-path relationships and assess downstream locations, thereby obtaining the clearest correlation results and applying them to more feasible management processes. Other research results on microplastics in rivers and seas can be observed in Table 2.

Table 2. Other studies on microplastics in rivers and seas.

No	Country	Composition	Concentration	Reference
1	Río de la Plata estuary (South America)	Shapes: fibres Sizes: >500 ≤1000 µm. Colors: blue	139 pieces/m^3	[77]
2	Klang River estuary, Malaysia	Shapes: fibres Sizes: 30 to 1850 µm. Colors: black Types: PE-PDM, Polyester	0.50 to 1.75 particles/g or from 0.25 to 0.88 particles/individual	[78]
3	Red River Estuary, Vietnam	Shapes: fiber and fragment. Sizes: <500 µm. Colors: blue, white, and red. Types: polypropylene (PP), polyethylene (PE), polyurethane (PU), polyamide (PA), and polystyrene (PS).	800–3817 items per kg of dried weight	[35]
4	Yangtze Delta area	Shapes: fiber. Sizes: 20 to 5000 µm. Colors: blue and red. Types: Polyester	1.8–2.4 items/L in freshwater bodies and 0.9 items/L in coastal water	[79]
5	Freshwater of 21 major cities across China	Shapes: fiber. Sizes: <3 mm. Colors: white and black. Types: polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), and polystyrene (PS)	3502.6 n/m^3	[80]
6	Abu Dhabi Emirate, U.A.E.	Shapes: filaments, rounded, and irregular shapes. Sizes: 100–5000 µm. Colors: red and transparent. Types: acrylonitrile-butadiene-styrene (ABS), nylon 6,6 (PA66), cellulose acetate (CA), and polyethylene terephthalate (PET)	4.5–12 particles/L in water and 2.5 to 11.5 particles/100g in sediment	[81]
7	Rhine-Main Area in Germany	Shapes: fragments, fibers, and spheres. Sizes: 630–5000 µm. Colors: non-colored, white, blue, and silver. Types: polyethylene, polypropylene, and polystyrene	1 g/kg or 4000 particles/kg	[82]
8	Southeast Asian region (Chao Phraya River (Thailand), Citarum River (Indonesia), and Saigon River (Viet Nam))	Shapes: fragments and fibers Sizes: 0.05–0.3 mm. Types: polypropylene and polyethylene	6–80 items/m^3	[83]

4. Conclusions

In conclusion, microplastic pollution in rivers, lakes, ponds, coastal areas, and marine ecosystems is becoming an alarming issue worldwide, including in Vietnam, which may impact the quality of the water resources. In Vietnam, many studies have described high concentrations and a wide variety of microplastics across different environments. The primary bases of microplastic pollution in Vietnam include municipal waste, wastewater discharge, and human activities related to living and production. Across the world, research has also highlighted the negative impacts of microplastics, including their entry into food chains, which can harm wildlife and pose risks to human health through contaminated food and water. These risks arise from high persistence, tendency to bioaccumulate, and interaction with harmful chemical additives of microplastics. Furthermore, microplastics significantly affect socio-economic aspects by diminishing the aesthetic value of the environment. Due to the profound environmental, ecological, and socio-economic impacts, urgent action is required to manage and mitigate plastic pollution. It is imperative to formulate efficient waste management plans, encompassing the establishment of plastic waste collecting and sorting systems, as well as the development of sophisticated recycling facilities and wastewater treatment plants equipped with microplastic filtration technologies. Secondly, it is imperative to enhance public awareness through comprehensive educational activities incorporated into school curriculum, mass media campaigns, and community projects like beach and river cleanups. These initiatives must emphasize the effects of human activities on the environment and foster a culture of environmental responsibility across all societal levels. Third, it is essential to enhance management capabilities, invest in training initiatives for environmental officers, supply advanced analytical tools for microplastic detection, formulate standardized monitoring protocols, and fortify the legal framework by instituting explicit discharge requirements and enforcement mechanisms. International collaboration and agency coordination can proficiently tackle technological issues and share knowledge. Establish sustainable economic development frameworks, shift towards a circular economy by reducing plastic consumption and enhancing material reuse through tax incentives for eco-friendly industries, endorsing enterprises that manufacture biodegradable products, instituting economic strategies such as plastic levies and green procurement policies, and allocating resources for research and development of innovative materials.

Author Contributions

H.D.H.N.: Writing original draft, and editing. T.L.L.: Supervision and review. All authors have read and agreed to the published version of the manuscript.

Funding

The present study was sponsored by The Vietnam Ministry of Education and Training (MOET) under grant number B2024-VGU-05.

Institutional Review Board Statement

The study did not involve humans or animals.

Informed Consent Statement

Not applicable

Data Availability Statement

Data will be available on request

Acknowledgments

The present study was sponsored by The Vietnam Ministry of Education and Training (MOET) under grant number B2024-VGU-05.

Conflicts of Interest

The authors declare that there are no conflicts of interest related to this publication. Given the role as Editorial Board Member, Tran Le Luu had no involvement in the peer review of this paper and had no access to information regarding its peer-review process. Full responsibility for the editorial process of this paper was delegated to another editor of the journal.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

References

1. Geyer, R.; Jambeck, J.R.; Law, K.L. Production, Use, and Fate of All Plastics Ever Made. *Sci. Adv.* **2017**, *3*, e1700782. https://doi.org/10.1126/sciadv.1700782.
2. Cole, M.; Lindeque, P.; Halsband, C.; et al. Microplastics as Contaminants in the Marine Environment: A Review. *Mar. Pollut. Bull.* **2011**, *62*, 2588–2597. https://doi.org/10.1016/j.marpolbul.2011.09.025.
3. De Melo Nobre, F.S.; Santos, A.A.; Nilin, J. What Remains on the Beach after Tourists Leave? The Case of Abaís Beach (Sergipe, Brazil). *Mar. Pollut. Bull.* **2021**, *171*, 112700. https://doi.org/10.1016/j.marpolbul.2021.112700.
4. Caldwell, J.; Petri-Fink, A.; Rothen-Rutishauser, B.; et al. Assessing Meso- and Microplastic Pollution in the Ligurian and Tyrrhenian Seas. *Mar. Pollut. Bull.* **2019**, *149*, 110572. https://doi.org/10.1016/j.marpolbul.2019.110572.
5. Eriksen, M.; Lebreton, L.C.M.; Carson, H.S.; et al. Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. *PLoS ONE* **2014**, *9*, e111913. https://doi.org/10.1371/journal.pone.0111913.
6. Van Melkebeke, M.; Janssen, C.; De Meester, S. Characteristics and Sinking Behavior of Typical Microplastics Including the Potential Effect of Biofouling: Implications for Remediation. *Environ. Sci. Technol.* **2020**, *54*, 8668–8680. https://doi.org/10.1021/acs.est.9b07378.
7. Hale, R.C.; Seeley, M.E.; La Guardia, M.J.; et al. A Global Perspective on Microplastics. *J. Geophys. Res. Ocean.* **2020**, *125*, e2018JC014719. https://doi.org/10.1029/2018JC014719.
8. Browne, M.A.; Galloway, T.; Thompson, R. Microplastic--an Emerging Contaminant of Potential Concern? *Integr. Environ. Assess. Manag.* **2007**, *3*, 559–561. https://doi.org/10.1002/ieam.5630030412.
9. Duis, K.; Coors, A. Microplastics in the Aquatic and Terrestrial Environment: Sources (with a Specific Focus on Personal Care Products), Fate and Effects. *Environ. Sci. Eur.* **2016**, *28*, 2. https://doi.org/10.1186/s12302-015-0069-y.
10. *Freshwater Microplastics: Emerging Environmental Contaminants*? Wagner, M., Lambert, S., Eds.; The Handbook of Environmental Chemistry; Springer International Publishing: Cham, Switzerland, 2018; Volume 58; ISBN 978-3-319-61614-8.
11. Cole, M.; Lindeque, P.; Fileman, E.; et al. Microplastic Ingestion by Zooplankton. *Environ. Sci. Technol.* **2013**, *47*, 6646–6655. https://doi.org/10.1021/es400663f.
12. Lozano, R.L.; Mouat, J.; International, K. *Marine Litter in the North-East Atlantic Region*; OSPAR Commission: London, UK, 2009.
13. Campanale, C.; Massarelli, C.; Savino, I.; et al. A Detailed Review Study on Potential Effects of Microplastics and Additives of Concern on Human Health. *IJERPH* **2020**, *17*, 1212. https://doi.org/10.3390/ijerph17041212.
14. Chang, X.; Xue, Y.; Li, J.; et al. Potential Health Impact of Environmental Micro- and Nanoplastics Pollution. *J. Appl. Toxicol.* **2020**, *40*, 4–15. https://doi.org/10.1002/jat.3915.
15. Hwang, J.; Choi, D.; Han, S.; et al. Potential Toxicity of Polystyrene Microplastic Particles. *Sci. Rep.* **2020**, *10*, 7391. https://doi.org/10.1038/s41598-020-64464-9.
16. Jambeck, J.R.; Geyer, R.; Wilcox, C.; et al. Plastic Waste Inputs from Land into the Ocean. *Science* **2015**, *347*, 768–771. https://doi.org/10.1126/science.1260352.
17. Hien, T.T.; Nhon, N.T.T.; Thu, V.T.M.; et al. The Distribution of Microplastics in Beach Sand in Tien Giang Province and Vung Tau City, Vietnam. *J. Eng. Technol. Sci.* **2020**, *52*, 208–221. https://doi.org/10.5614/j.eng.technol.sci.2020.52.2.6.
18. Kieu-Le, T.-C.; Thuong, Q.-T.; Truong, T.-N.-S.; et al. Baseline Concentration of Microplastics in Surface Water and Sediment of the Northern Branches of the Mekong River Delta, Vietnam. *Mar. Pollut. Bull.* **2023**, *187*, 114605. https://doi.org/10.1016/j.marpolbul.2023.114605.
19. Strady, E.; Dang, T.H.; Dao, T.D.; et al. Baseline Assessment of Microplastic Concentrations in Marine and Freshwater Environments of a Developing Southeast Asian Country, Viet Nam. *Mar. Pollut. Bull.* **2021**, *162*, 111870. https://doi.org/10.1016/j.marpolbul.2020.111870.
20. Tran Nguyen, Q.A.; Nguyen, H.N.Y.; Strady, E.; et al. Characteristics of Microplastics in Shoreline Sediments from a Tropical and Urbanized Beach (Da Nang, Vietnam). *Mar. Pollut. Bull.* **2020**, *161*, 111768. https://doi.org/10.1016/j.marpolbul.2020.111768.
21. Viet Dung, L.; Huu Duc, T.; Thi Khanh Linh, L.; et al. Depth Profiles of Microplastics in Sediment Cores from Two Mangrove Forests in Northern Vietnam. *J. Mar. Sci. Eng.* **2021**, *9*, 1381. https://doi.org/10.3390/jmse9121381.
22. Do, V.M.; Dang, T.T.; Le, X.T.T.; et al. Abundance of Microplastics in Cultured Oysters (*Crassostrea Gigas*) from Danang Bay of Vietnam. *Mar. Pollut. Bull.* **2022**, *180*, 113800. https://doi.org/10.1016/j.marpolbul.2022.113800.
23. Karami, A.; Golieskardi, A.; Choo, C.K.; et al. Microplastic and Mesoplastic Contamination in Canned Sardines and Sprats. *Sci. Total Environ.* **2018**, *612*, 1380–1386. https://doi.org/10.1016/j.scitotenv.2017.09.005.
24. Nam, P.N.; Tuan, P.Q.; Thuy, D.T.; et al. Contamination of Microplastic in Bivalve: First Evaluation in Vietnam. *Vietnam. J. Earth Sci.* **2019**, *41*, 252–258. https://doi.org/10.15625/0866-7187/41/3/13925.

25. Linh, L.T.K.; Duong, H.A.; Duc, T.H.; et al. Contamination of Microplastics in Mangrove Sediment Cores from Lach Huyen Area, Hai Phong City, Vietnam. *IOP Conf. Ser. Earth Environ. Sci.* **2023**, *1226*, 012005. https://doi.org/10.1088/1755-1315/1226/1/012005.
26. Nguyễn, H.N.Ý.; Linh P.T.T.; Linh V.Đ.H.; et al. Ô nhiễm vi nhựa trong nước mặt hồ nội thành tại thành phố Đà Nẵng, Việt Nam. *UD-JST* **2022**, *8*, 88–92.
27. Lahens, L.; Strady, E.; Kieu-Le, T.-C.; et al. Macroplastic and Microplastic Contamination Assessment of a Tropical River (Saigon River, Vietnam) Transversed by a Developing Megacity. *Environ. Pollut.* **2018**, *236*, 661–671. https://doi.org/10.1016/j.envpol.2018.02.005.
28. Strady, E.; Kieu-Le, T.-C.; Gasperi, J.; et al. Temporal Dynamic of Anthropogenic Fibers in a Tropical River-Estuarine System. *Environ. Pollut.* **2020**, *259*, 113897. https://doi.org/10.1016/j.envpol.2019.113897.
29. Nguyen, T.-T.T.; Ha, N.-H.; Bui, T.-K.L.; et al. Baseline Marine Litter Surveys along Vietnam Coasts Using Citizen Science Approach. *Sustainability* **2022**, *14*, 4919. https://doi.org/10.3390/su14094919.
30. Dao Dinh, C.; Duong Thi, L.; Nguyen Quang, B.; et al. Distribution and Characteristics of Microplastics in Surface Water at Some Beaches in Thanh Hoa Province, Viet Nam. *Vietnam J. Catal. Adsorpt.* **2021**, *10*, 193–200. https://doi.org/10.51316/jca.2021.120.
31. Dao, C.D.; Duong, L.T.; Nguyen, T.H.T.; et al. Plastic Waste in Sandy Beaches and Surface Water in Thanh Hoa, Vietnam: Abundance, Characterization, and Sources. *Environ. Monit. Assess.* **2023**, *195*, 255. https://doi.org/10.1007/s10661-022-10868-1.
32. Do, V.M.; Dang, T.T.; Le, X.T.T.; et al. Characterisation of Microplastic Debris in Beach Sediment of the Coastal Zone in Vietnam: A Preliminary Study in Da Nang. *VMOST* **2021**, *63*, 7–13. https://doi.org/10.31276/VJST.63(11DB).07-13.
33. Bui, T.-K.L.; Pham, Q.-K.; Doan, N.-T.; et al. Marine Litter Pollution along Sandy Beaches of Can Gio Coast, Ho Chi Minh City, Vietnam. *IOP Conf. Ser. Earth Environ. Sci.* **2022**, *964*, 012017. https://doi.org/10.1088/1755-1315/964/1/012017.
34. Fruergaard, M.; Laursen, S.N.; Larsen, M.N.; et al. Abundance and Sources of Plastic Debris on Beaches in a Plastic Hotspot, Nha Trang, Viet Nam. *Mar. Pollut. Bull.* **2023**, *186*, 114394. https://doi.org/10.1016/j.marpolbul.2022.114394.
35. Le, N.D.; Hoang, T.T.H.; Duong, T.T.; et al. Microplastics in the Surface Sediment of the Main Red River Estuary. *Vietnam. J. Earth Sci.* **2023**, *45*, 19–32. https://doi.org/10.15625/2615-9783/17486.
36. Trinh, B.-S.; Le, L.T.; Tran, L.M.; et al. Comparative Accumulation and Effects of Microplastics and Microplastic-Associated PCB-153 in the White Hard Clam (*Meretrix lyrata*) and Giant River Prawn (*Macrobrachium rosenbergii*) Following Chronic Exposure. *Environ. Technol. Innov.* **2024**, *34*, 103581. https://doi.org/10.1016/j.eti.2024.103581.
37. Phung, N.H.T.; Lien, L.T.; Nguyen Ha, K.-B.; et al. Effects of Chronic Exposure to Microplastics and Microplastics Associated with Polychlorinated Biphenyl 153 on *Daphnia Magna*. *Hum. Ecol. RiskAssess. Int. J.* **2024**, *30*, 22–39. https://doi.org/10.1080/10807039.2023.2268217.
38. Wang, T.; Zhao, S.; Zhu, L.; et al. Accumulation, Transformation and Transport of Microplastics in Estuarine Fronts. *Nat. Rev. Earth Environ.* **2022**, *3*, 795–805. https://doi.org/10.1038/s43017-022-00349-x.
39. Owuor, M.A.; Icely, J.; Newton, A. Community Perceptions of the Status and Threats Facing Mangroves of Mida Creek, Kenya: Implications for Community Based Management. *Ocean. Coast. Manag.* **2019**, *175*, 172–179. https://doi.org/10.1016/j.ocecoaman.2019.03.027.
40. Maghsodian, Z.; Sanati, A.M.; Tahmasebi, S.; et al. Study of Microplastics Pollution in Sediments and Organisms in Mangrove Forests: A Review. *Environ. Res.* **2022**, *208*, 112725. https://doi.org/10.1016/j.envres.2022.112725.
41. Deng, H.; He, J.; Feng, D.; et al. Microplastics Pollution in Mangrove Ecosystems: A Critical Review of Current Knowledge and Future Directions. *Sci. Total Environ.* **2021**, *753*, 142041. https://doi.org/10.1016/j.scitotenv.2020.142041.
42. Deng, J.; Guo, P.; Zhang, X.; et al. Microplastics and Accumulated Heavy Metals in Restored Mangrove Wetland Surface Sediments at Jinjiang Estuary (Fujian, China). *Mar. Pollut. Bull.* **2020**, *159*, 111482. https://doi.org/10.1016/j.marpolbul.2020.111482.
43. Hitchcock, J.N. Microplastics Can Alter Phytoplankton Community Composition. *Sci. Total Environ.* **2022**, *819*, 153074. https://doi.org/10.1016/j.scitotenv.2022.153074.
44. Van Bijsterveldt, C.E.J.; van Wesenbeeck, B.K.; Ramadhani, S.; et al. Does Plastic Waste Kill Mangroves? A Field Experiment to Assess the Impact of Macro Plastics on Mangrove Growth, Stress Response and Survival. *Sci. Total Environ.* **2021**, *756*, 143826. https://doi.org/10.1016/j.scitotenv.2020.143826.
45. Kumar, R.; Ivy, N.; Bhattacharya, S.; et al. Coupled Effects of Microplastics and Heavy Metals on Plants: Uptake, Bioaccumulation, and Environmental Health Perspectives. *Sci. Total Environ.* **2022**, *836*, 155619. https://doi.org/10.1016/j.scitotenv.2022.155619.
46. Kumar, R.; Sinha, R.; Refat Jahan Rakib, M.; et al. Microplastics Pollution Load in Sundarban Delta of Bay of Bengal. *J. Hazard. Mater. Adv.* **2022**, *7*, 100099. https://doi.org/10.1016/j.hazadv.2022.100099.
47. Maghsodian, Z.; Sanati, A.M.; Ramavandi, B.; et al. Microplastics Accumulation in Sediments and *Periophthalmus Waltoni* Fish, Mangrove Forests in Southern Iran. *Chemosphere* **2021**, *264*, 128543. https://doi.org/10.1016/j.chemosphere.2020.128543.

48. Carson, H.S.; Colbert, S.L.; Kaylor, M.J.; et al. Small Plastic Debris Changes Water Movement and Heat Transfer through Beach Sediments. *Mar. Pollut. Bull.* **2011**, *62*, 1708–1713. https://doi.org/10.1016/j.marpolbul.2011.05.032.
49. Shaw, D.G.; Day, R.H. Colour- and Form-Dependent Loss of Plastic Micro-Debris from the North Pacific Ocean. *Mar. Pollut. Bull.* **1994**, *28*, 39–43. https://doi.org/10.1016/0025-326X(94)90184-8.
50. Ryan, P.G.; Moore, C.J.; van Franeker, J.A.; et al. Monitoring the Abundance of Plastic Debris in the Marine Environment. *Philos. Trans. R. Soc. B Biol. Sci.* **2009**, *364*, 1999–2012. https://doi.org/10.1098/rstb.2008.0207.
51. van Franeker, J.A.; Blaize, C.; Danielsen, J.; et al. Monitoring Plastic Ingestion by the Northern Fulmar Fulmarus Glacialis in the North Sea. *Environ. Pollut.* **2011**, *159*, 2609–2615. https://doi.org/10.1016/j.envpol.2011.06.008.
52. Boerger, C.M.; Lattin, G.L.; Moore, S.L.; et al. Plastic Ingestion by Planktivorous Fishes in the North Pacific Central Gyre. *Mar. Pollut. Bull.* **2010**, *60*, 2275–2278. https://doi.org/10.1016/j.marpolbul.2010.08.007.
53. Davison, P.; Asch, R. Plastic Ingestion by Mesopelagic Fishes in the North Pacific Subtropical Gyre. *Mar. Ecol. Prog. Ser.* **2011**, *432*, 173–180. https://doi.org/10.3354/meps09142.
54. Murray, F.; Cowie, P.R. Plastic Contamination in the Decapod Crustacean Nephrops Norvegicus (Linnaeus, 1758). *Mar. Pollut. Bull.* **2011**, *62*, 1207–1217. https://doi.org/10.1016/j.marpolbul.2011.03.032.
55. Frias, J.P.G.L.; Sobral, P.; Ferreira, A.M. Organic Pollutants in Microplastics from Two Beaches of the Portuguese Coast. *Mar. Pollut. Bull.* **2010**, *60*, 1988–1992. https://doi.org/10.1016/j.marpolbul.2010.07.030.
56. Law, K.L.; Morét-Ferguson, S.; Maximenko, N.A.; et al. Plastic Accumulation in the North Atlantic Subtropical Gyre. *Science* **2010**, *329*, 1185–1188. https://doi.org/10.1126/science.1192321.
57. Güven, O.; Gökdağ, K.; Jovanović, B.; et al. Microplastic Litter Composition of the Turkish Territorial Waters of the Mediterranean Sea, and Its Occurrence in the Gastrointestinal Tract of Fish. *Environ. Pollut.* **2017**, *223*, 286–294. https://doi.org/10.1016/j.envpol.2017.01.025.
58. Köhler, A. Cellular Fate of Organic Compounds in Marine Invertebrates. *Comp. Biochem. Physiol. Part A Mol. Integr. Physiol.* **2010**, *157*, S8. https://doi.org/10.1016/j.cbpa.2010.06.020.
59. Ren, P.; Dou, M.; Wang, C.; et al. Abundance and Removal Characteristics of Microplastics at a Wastewater Treatment Plant in Zhengzhou. *Environ. Sci. Pollut. Res.* **2020**, *27*, 36295–36305. https://doi.org/10.1007/s11356-020-09611-5.
60. Tang, N.; Liu, X.; Xing, W. Microplastics in Wastewater Treatment Plants of Wuhan, Central China: Abundance, Removal, and Potential Source in Household Wastewater. *Sci. Total Environ.* **2020**, *745*, 141026. https://doi.org/10.1016/j.scitotenv.2020.141026.
61. Beaumont, N.J.; Aanesen, M.; Austen, M.C.; et al. Global Ecological, Social and Economic Impacts of Marine Plastic. *Mar. Pollut. Bull.* **2019**, *142*, 189–195. https://doi.org/10.1016/j.marpolbul.2019.03.022.
62. McIlgorm, A.; Campbell, H.F.; Rule, M.J. The Economic Cost and Control of Marine Debris Damage in the Asia-Pacific Region. *Ocean. Coast. Manag.* **2011**, *54*, 643–651. https://doi.org/10.1016/j.ocecoaman.2011.05.007.
63. Qiang, M.; Shen, M.; Xie, H. Loss of Tourism Revenue Induced by Coastal Environmental Pollution: A Length-of-Stay Perspective. *J. Sustain. Tour.* **2020**, *28*, 550–567. https://doi.org/10.1080/09669582.2019.1684931.
64. Santos, I.R.; Friedrich, A.C.; Wallner-Kersanach, M.; et al. Influence of Socio-Economic Characteristics of Beach Users on Litter Generation. *Ocean. Coast. Manag.* **2005**, *48*, 742–752. https://doi.org/10.1016/j.ocecoaman.2005.08.006.
65. Iñiguez, M.E.; Conesa, J.A.; Fullana, A. Marine Debris Occurrence and Treatment: A Review. *Renew. Sustain. Energy Rev.* **2016**, *64*, 394–402. https://doi.org/10.1016/j.rser.2016.06.031.
66. Arcadis; Directorate-General for Environment (European Commission); Van Acoleyen, M.; et al. *Marine Litter Study to Support the Establishment of an Initial Quantitative Headline Reduction Target*; Publications Office of the European Union: Luxembourg, 2014; ISBN 978-92-79-40845-8.
67. Mouat, J.; Lozano, R.; Bateson, H. *Economic Impacts of Marine Litter*; Kommunenes Internasjonale Miljøorganisasjon (KIMO): Lerwick, UK, 2010. Available online: https://www.semanticscholar.org/paper/Economic-impacts-of-marine-litter-Mouat-Lozano/ceb36c1bb00080deefb19d5e01ff0b58acf3c489 (accessed on 2 October 2025).
68. Browne, M.A.; Galloway, T.S.; Thompson, R.C. Spatial Patterns of Plastic Debris along Estuarine Shorelines. *Environ. Sci. Technol.* **2010**, *44*, 3404–3409. https://doi.org/10.1021/es903784e.
69. Teuten, E.L.; Saquing, J.M.; Knappe, D.R.U.; et al. Transport and Release of Chemicals from Plastics to the Environment and to Wildlife. *Philos. Trans. R. Soc. Lond B Biol. Sci.* **2009**, *364*, 2027–2045. https://doi.org/10.1098/rstb.2008.0284.
70. vom Saal, F.S.; Myers, J.P. Bisphenol A and Risk of Metabolic Disorders. *JAMA* **2008**, *300*, 1353–1355. https://doi.org/10.1001/jama.300.11.1353.
71. Lithner, D.; Damberg, J.; Dave, G.; et al. Leachates from Plastic Consumer Products—Screening for Toxicity with *Daphnia magna*. *Chemosphere* **2009**, *74*, 1195–1200. https://doi.org/10.1016/j.chemosphere.2008.11.022.
72. Lithner, D.; Larsson, Å.; Dave, G. Environmental and Health Hazard Ranking and Assessment of Plastic Polymers Based on Chemical Composition. *Sci. Total Environ.* **2011**, *409*, 3309–3324. https://doi.org/10.1016/j.scitotenv.2011.04.038.
73. Oehlmann, J.; Schulte-Oehlmann, U.; Kloas, W.; et al. A Critical Analysis of the Biological Impacts of Plasticizers on Wildlife. *Philos. Trans. R. Soc. Lond B Biol. Sci.* **2009**, *364*, 2047–2062. https://doi.org/10.1098/rstb.2008.0242.

74. Galloway, T.; Cipelli, R.; Guralnik, J.; et al. Daily Bisphenol A Excretion and Associations with Sex Hormone Concentrations: Results from the InCHIANTI Adult Population Study. *Environ. Health Perspect.* **2010**, *118*, 1603–1608. https://doi.org/10.1289/ehp.1002367.
75. Zhang, D.; Cui, Y.; Zhou, H.; et al. Microplastic Pollution in Water, Sediment, and Fish from Artificial Reefs around the Ma'an Archipelago, Shengsi, China. *Sci. Total Environ.* **2020**, *703*, 134768. https://doi.org/10.1016/j.scitotenv.2019.134768.
76. Statista Cumulative Plastic Production Volume Worldwide from 1950 to 2050 Available online: https://www.statista.com/statistics/1019758/plastics-production-volume-worldwide/ (accessed on 16 August 2024).
77. Pazos, R.S.; Bauer, D.E.; Gómez, N. Microplastics Integrating the Coastal Planktonic Community in the Inner Zone of the Río de La Plata Estuary (South America). *Environ. Pollut.* **2018**, *243*, 134–142. https://doi.org/10.1016/j.envpol.2018.08.064.
78. Zaki, M.R.M.; Zaid, S.H.M.; Zainuddin, A.H.; et al. Microplastic Pollution in Tropical Estuary Gastropods: Abundance, Distribution and Potential Sources of Klang River Estuary, Malaysia. *Mar. Pollut. Bull.* **2021**, *162*, 111866. https://doi.org/10.1016/j.marpolbul.2020.111866.
79. Luo, W.; Su, L.; Craig, N.J.; et al. Comparison of Microplastic Pollution in Different Water Bodies from Urban Creeks to Coastal Waters. *Environ. Pollut.* **2019**, *246*, 174–182. https://doi.org/10.1016/j.envpol.2018.11.081.
80. He, H.; Cai, S.; Chen, S.; et al. Spatial and Temporal Distribution Characteristics and Potential Sources of Microplastic Pollution in China's Freshwater Environments. *Water* **2024**, *16*, 1270. https://doi.org/10.3390/w16091270.
81. Thankamony, R.; Hashmi, A.H.A.; Hammadi, H.A.A.; et al. A First Study on the Distribution of Microplastics in Sea Water and Sediments of Abu Dhabi Emirate, U.A.E. *Eur. J. Environ. Earth Sci.* **2025**, *6*, 1–9. https://doi.org/10.24018/ejgeo.2025.6.4.530.
82. Klein, S.; Worch, E.; Knepper, T.P. Occurrence and Spatial Distribution of Microplastics in River Shore Sediments of the Rhine-Main Area in Germany. *Environ. Sci. Technol.* **2015**, *49*, 6070–6076. https://doi.org/10.1021/acs.est.5b00492.
83. Babel S.; Ta A.T.; Loan N.T.P.; et al. Microplastics pollution in selected rivers from Southeast Asia. *APN Sci. Bull.* **2022**. https://doi.org/10.30852/sb.2022.1741.