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REVIEW ARTICLE

Microplastic Pollution in Bangladesh: A Review of Ecological and Biochemical Impacts

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ABSTRACT

Microplastic pollution has emerged as a significant environmental and public health challenge globally, with Bangladesh being disproportionately affected due to rapid urbanization, industrial growth, high plastic consumption, and inadequate waste management. Microplastics, defined as plastic particles smaller than 5 mm, originate from primary sources such as microbeads and from the degradation of larger plastic debris. This review critically examines the sources, ecological impacts, biochemical effects, and mitigation strategies related to microplastic pollution in Bangladesh. Major sources include mismanaged plastic waste, single-use plastics, textile and garment industry effluents, agricultural practices, industrial discharges, and pandemic-related personal protective equipment. Microplastics are pervasive in rivers, sediments, coastal zones, soils, and the food chain, leading to habitat degradation, reduced biodiversity, soil and crop productivity loss, and bioaccumulation in aquatic organisms and livestock. Biochemically, microplastics act as vectors for toxic chemicals, heavy metals, and persistent organic pollutants, causing oxidative stress, endocrine disruption, genotoxicity, immunotoxicity, and transgenerational effects in exposed organisms. Effective mitigation requires integrated strategies, including improved waste management, stricter policy enforcement, promotion of biodegradable alternatives, industrial compliance, public awareness campaigns, and targeted research. This review highlights the urgent need for coordinated efforts from government, industry, academia, and society to mitigate microplastic pollution, safeguard ecosystems, protect public health, and ensure sustainable development in Bangladesh.

Keywords: Microplastics, Plastic pollution, Bangladesh, Ecological impact, Biochemical toxicity, Waste management, Food chain contamination

1. Introduction

Plastic pollution has become one of the most pressing environmental challenges of the 21st century, affecting both developed and developing countries alike. The massive production and widespread use of plastics over the last few decades have resulted in their extensive accumulation in natural ecosystems. Among different forms of plastic waste, microplastics, defined as plastic particles smaller than 5 mm in diameter, have drawn growing scientific and public concern due to their persistence in the environment, their

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ability to travel long distances, and their potential to interact with living organisms. Unlike larger plastic debris, microplastics are more easily ingested by organisms across multiple trophic levels, enabling them to enter food webs and ultimately pose risks to ecosystem stability and human health[1].

Bangladesh represents a critical hotspot for microplastic pollution because of its unique geographical, demographic, and socio-economic conditions. With a population exceeding 166 million and a dense network of rivers stretching over 24,000 kilometers, the country is highly vulnerable to both inland and marine plastic contamination. Rapid urbanization, unplanned industrial growth, population pressure, and inefficient waste management systems have significantly contributed to the increasing generation of plastic waste[2]. Over the past two decades, per capita plastic consumption in Bangladesh has risen sharply, from approximately 2.07 kg in 2005 to around 4.5 kg in recent years. As a result, the country now produces nearly 3,000 tons of plastic waste every day, which accounts for about 8% of total municipal solid waste. A large portion of this waste remains unmanaged and ultimately enters terrestrial and aquatic environments through open dumping, drainage channels, and river systems[3].

Microplastics originate from both primary and secondary sources within the Bangladeshi context. Primary microplastics include intentionally produced small plastic particles such as microbeads used in cosmetics, personal care products, and industrial abrasives. Secondary microplastics, on the other hand, are formed through the fragmentation and degradation of larger plastic items such as bags, bottles, fishing gear, and packaging materials. This breakdown occurs as a result of prolonged exposure to environmental factors such as ultraviolet radiation, mechanical abrasion, temperature fluctuations, and microbial activity[4]. In Bangladesh, the widespread use of single-use plastics, combined with poor disposal practices and exposure to harsh climatic conditions, accelerates the generation of secondary microplastics.

The extensive Ganges–Brahmaputra–Meghna (GBM) river system plays a central role in the transportation and distribution of microplastics throughout the country. These rivers act as major conduits, collecting plastic debris from urban centers, industrial zones, agricultural lands, and informal waste dumping sites, and eventually discharging them into the Bay of Bengal. This makes Bangladesh both a recipient and a contributor to regional and global marine plastic pollution. Although the government imposed a ban on thin polythene bags in 2002—the first of its kind in the world—the effectiveness of this policy has been significantly limited due to weak enforcement, continued illegal production, lack of affordable alternatives, and increasing demand driven by rapid urban expansion and population growth[5].

Given this alarming situation, there is an urgent need to comprehensively evaluate the magnitude and impacts of microplastic pollution in Bangladesh. This review aims to critically synthesize the existing scientific literature to explore the major sources and pathways of microplastic contamination in the country, along with their ecological impacts on freshwater, marine, and terrestrial ecosystems. Furthermore, it seeks to highlight the biochemical and toxicological consequences of microplastics on living organisms, with particular emphasis on oxidative stress, endocrine disruption, and bioaccumulation processes. Finally, this review discusses current mitigation efforts, regulatory frameworks, and future research priorities to address the growing microplastic crisis in Bangladesh and to support sustainable environmental management and public health protection.

2. Methodology

This review paper employed a comprehensive literature-based approach to assess the sources, ecological impacts, biochemical effects, and mitigation strategies of microplastic pollution in Bangladesh. The methodology involved the systematic identification, collection, and analysis of relevant peer-reviewed articles, government reports, and scientific databases. Relevant publications were identified through electronic databases such as PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. Keywords used for the search included "microplastic pollution Bangladesh," "plastic waste," "aquatic microplastics," "textile microfibers," "agricultural plastics," "marine pollution," "biochemical toxicity of microplastics," and "ecological impacts of plastics." Boolean operators (AND, OR) were applied to refine the search results, and references cited in retrieved articles were also examined to identify additional relevant studies.

Studies were selected based on specific inclusion and exclusion criteria. Studies were included if they focused on microplastic pollution in Bangladesh or South Asian contexts with comparable environmental conditions, reported ecological, biochemical, agricultural, or human health impacts of microplastics, and were peer-reviewed articles, government or NGO reports, or credible scientific reviews published between 2000 and 2025. Studies were excluded if they focused solely on macroplastics without addressing microplastics, lacked quantitative or qualitative data relevant to Bangladesh, or were non-English publications without accessible translations.

Information from the selected studies was systematically extracted, including details on sources and pathways of microplastic pollution such as industrial, urban, and agricultural contributions, ecological impacts on aquatic and terrestrial ecosystems, biochemical and toxicological effects on aquatic organisms, livestock, soil organisms, and humans, and management strategies, policies, and mitigation measures implemented or recommended. The extracted data were synthesized qualitatively, emphasizing patterns, trends, and research gaps. Quantitative results from studies, such as microplastic concentrations and affected species, were summarized in tables and figures to highlight environmental contamination levels and impacts.

As a narrative review, this study is limited by the availability of published data on microplastics in Bangladesh, particularly regarding long-term health effects, soil impacts, and transgenerational studies in humans and livestock. Some estimates were extrapolated from studies in similar South Asian or tropical contexts. Despite these limitations, the review provides a comprehensive overview of microplastic pollution in Bangladesh, highlighting its ecological and biochemical implications and potential mitigation strategies.

3. Sources and distribution of microplastic pollution in bangladesh

3.1. Mismanaged plastic waste

Mismanaged plastic waste represents the most dominant and persistent source of microplastic pollution in Bangladesh. The country generates approximately 800,000 tons of plastic waste annually, a substantial portion of which remains unmanaged or improperly disposed of due to inadequate infrastructure, limited waste collection coverage, and weak enforcement of waste management policies. It is estimated that nearly 25% of this plastic waste ultimately reaches rivers, canals, wetlands, and marine environments, either through direct dumping or via stormwater runoff and drainage systems. In many urban and peri-urban areas, household waste is often discarded in open spaces, roadsides, or nearby water bodies due to lack of formal waste collection services. These open dumping practices expose plastics to sunlight, rainfall, temperature fluctuations, and mechanical stress, accelerating their fragmentation into smaller particles and eventually into microplastics[6]. In densely populated cities such as Dhaka, Chattogram, and Khulna, the situation is even more critical. The drainage systems are frequently clogged with plastic litter, which not only exacerbates urban flooding but also serves as a continuous source of microplastics during heavy rainfall events. During monsoon seasons, vast quantities of accumulated plastic waste are washed into nearby rivers and canals, where they are dispersed across large distances. Informal waste dumping sites along riverbanks and low-lying lands further contribute to this issue, as plastics from these sites are easily eroded and transported by flowing water. Furthermore, limited landfill capacity and poor landfill management often result in plastic leakage into surrounding soil and water bodies, increasing the load of microplastics in both terrestrial and aquatic ecosystems[7].

Another significant challenge in waste management in Bangladesh is the heavy reliance on an informal recycling sector. While informal waste pickers recover valuable plastic materials for recycling, a large fraction of low-value or contaminated plastics remains unrecovered and is either burned or dumped openly. Open burning not only releases harmful toxic gases but also leaves behind plastic residues that can further degrade into microplastics in the environment. In the absence of structured source segregation, modern recycling plants, and effective waste-to-energy systems, mismanaged plastic waste continues to be a critical driver of microplastic contamination across the country[8].

3.2. Single-use plastics

Single-use plastics contribute significantly to the formation of secondary microplastics in Bangladesh. These include commonly used items such as shopping bags, beverage bottles, food packaging materials, disposable cups and plates, drinking straws, and protective packaging films. Despite Bangladesh introducing an early ban on thin polythene bags in 2002, single-use plastics remain widely used due to convenience, low cost, and lack of affordable biodegradable alternatives. The rapid growth of urban lifestyles, takeaway food culture, and e-commerce packaging has further intensified the consumption of single-use plastic materials in recent years. Once discarded, these plastic products undergo degradation through a combination of physical, chemical, and biological processes. Exposure to ultraviolet radiation causes photo-degradation, making plastic materials brittle and more susceptible to fragmentation. Mechanical forces such as vehicle movement, wave action, and sediment abrasion further break down these plastics into smaller fragments, which eventually become microplastics. In coastal regions and riverine environments, plastic fishing nets, ropes, and gear discarded by small-scale and commercial fishing operations also play a significant role. These fishing materials, often made of polyethylene, polypropylene, or nylon, persist in the environment for decades and continuously shed microplastic fibers and fragments over time[8].

The widespread use of plastic packaging in street food markets and rural grocery shops additionally contributes to microplastic pollution in terrestrial environments. Thin plastic wrappers and sachets are often discarded directly onto the ground and become embedded in soil, where they slowly degrade into microplastics. These soil-borne microplastics can alter soil properties, reduce water retention capacity, and affect microbial communities, thereby impacting agricultural productivity. Furthermore, during rainfall and irrigation, these soil microplastics are transported into nearby water bodies, creating a continuous link between terrestrial and aquatic pollution. The absence of a strong circular economy, combined with poor enforcement of existing regulations on single-use plastics, has made these products a long-term environmental burden. Without proper control strategies and behavioral change among consumers, the contribution of single-use plastics to microplastic pollution in Bangladesh is expected to increase further in the coming decades[9].

3.3. Textile and garment industry

Bangladesh's textile and garment industry, which is one of the largest in the world and a major contributor to national export earnings, plays a crucial role in microfiber pollution. The country hosts thousands of textile manufacturing units, dyeing facilities, and washing plants that process enormous volumes of synthetic fabrics such as polyester, nylon, and acrylic every day. During the manufacturing process, mechanical abrasion, cutting, stitching, and washing release large quantities of microscopic synthetic fibers into wastewater. It has been estimated that textile operations in Bangladesh can release between 30,000 to 465,000 microfibers per square meter of fabric, depending on the fabric type and processing method. Most textile effluents in Bangladesh are discharged into nearby rivers and canals, often with insufficient treatment due to malfunctioning or absent effluent treatment plants (ETPs). Even where ETPs exist, conventional treatment systems are not designed to efficiently remove microfibers, allowing these particles to pass through treatment stages and enter natural water bodies. Major industrial zones such as Savar, Gazipur, Narayanganj, and Chattogram have become hotspots for microfiber pollution, with surrounding rivers like the Buriganga, Turag, Shitalakkhya, and Karnaphuli receiving high loads of textile-derived microplastics on a daily basis[10].

In addition to industrial sources, domestic washing of synthetic garments also contributes significantly to microfiber pollution. With the increasing popularity of polyester-based clothing due to its affordability and durability, household laundry activities have become another major source of microplastic fibers. Washing machine effluents largely flow into municipal drainage systems, which are often directly connected to rivers without advanced filtration mechanisms. This results in a continuous discharge of microfibers into aquatic environments, where they are ingested by zooplankton, fish, and benthic organisms. The ecological implications of microfiber pollution are profound, as these fibers have been found in river sediments, fish digestive tracts, and even drinking water sources in Bangladesh. Given the economic importance of the garment sector, addressing microfiber pollution remains a major challenge that requires the integration of sustainable manufacturing practices, advanced wastewater treatment technologies, and strict environmental regulations[11].

3.4. Urban wastewater and runoff

Rapid urbanization in Bangladesh has significantly intensified microplastic pollution through municipal wastewater and stormwater runoff, especially in highly populated megacities such as Dhaka, Chattogram, and Sylhet. These urban centers generate enormous volumes of domestic and industrial wastewater containing microplastics derived from synthetic textiles, degraded plastic products, personal care items, household dust, tire wear, and disposable packaging. Dhaka alone, one of the most densely populated cities in the world, is estimated to release over 6,628 billion microplastic particles annually into surrounding rivers and aquatic ecosystems, particularly the Buriganga, Turag, Shitalakkhya, and Balu rivers. A major contributor to this problem is the inefficiency and limited coverage of wastewater treatment plants (WWTPs). Most urban wastewater in Bangladesh remains untreated or poorly treated before being discharged into natural water bodies. Even in functioning treatment plants, conventional wastewater treatment processes are not fully capable of removing microplastics, especially fibers smaller than 100 µm. As a result, a large fraction of microplastics bypass filtration mechanisms and enters freshwater ecosystems[12].

Stormwater runoff further increases the microplastic load in urban water bodies, particularly during the monsoon season. Plastic debris from roads, open drains, landfills, construction sites, and marketplaces is transported into rivers through surface runoff. Tire wear particles, road dust, and degraded plastic waste from open dumping sites also serve as significant non-point sources of microplastics. Poor drainage systems, frequent waterlogging, and unplanned urban development worsen the situation by increasing the direct flow of polluted runoff into natural water reservoirs. The long-term ecological impacts include contamination of aquatic organisms, bioaccumulation in the food chain, alteration of sediment quality, and degradation of aquatic biodiversity. Fish and other aquatic species often ingest microplastics, mistaking them for food particles, which can lead to digestive blockage, reduced growth, reproductive issues, and chemical toxicity. This also poses potential risks to human health, as microplastics can enter the human body through the consumption of contaminated fish and drinking water. Therefore, addressing urban microplastic pollution requires urgent intervention, including the modernization of wastewater treatment infrastructure, development of microplastic filtration technologies, improved waste management systems, and strong policy enforcement in urban planning and environmental protection[13].

3.5. Agricultural activities

Agricultural practices in Bangladesh play a critical role in introducing microplastics into terrestrial ecosystems. The use of plastic materials has increased substantially in modern agriculture due to their affordability and effectiveness. Plastic mulching films, irrigation pipes, greenhouse coverings, seedling trays, fertilizer bags, and pesticide containers are commonly used, especially in vegetable farming and commercial agriculture. Over time, these plastic materials degrade under exposure to sunlight, temperature fluctuations, mechanical stress, and microbial activity, leading to the formation of secondary microplastics in agricultural soils. Plastic mulching films, which are widely used to conserve soil moisture, suppress weeds, and increase crop productivity, are one of the most significant contributors. In Bangladesh, improper collection and recycling of these films result in their fragmentation into microplastics, which become permanently embedded in the soil matrix. Additionally, contaminated organic fertilizers and sewage sludge applied as soil conditioners may also introduce microplastics into farmlands[14].

Microplastics in soil can alter soil physical and chemical properties, such as porosity, water retention capacity, and bulk density. They interact with soil microbes, affecting nutrient cycling, enzyme activity, and overall soil fertility. Some studies suggest that microplastics may also facilitate the transport of toxic chemicals, such as pesticides and heavy metals, due to their high adsorption capacity. This can further disrupt soil ecosystems and negatively impact plant health. Moreover, there is growing concern that microplastics and associated contaminants could be absorbed by plant roots and transported to edible parts of crops, potentially entering the human food chain. Although the extent of plant uptake is still under scientific investigation, the possibility of microplastic contamination in food crops represents a serious food safety issue for a densely populated country like Bangladesh. Therefore, sustainable agricultural policies should promote biodegradable alternatives to plastic mulch, proper disposal and recycling of agricultural plastics, and awareness programs for farmers. Further experimental research is needed to assess the long-term effects of microplastics on soil health, crop productivity, and food safety[15].

3.6. Industrial effluents and recycling plants

Industrial effluents are one of the most concentrated sources of microplastic pollution in Bangladesh. A wide range of industries, including plastic manufacturing units, garment factories, packaging industries, paint industries, detergent factories, and cosmetic product manufacturers, generate microplastics either as raw materials or as byproducts of production processes. These microplastics enter environmental compartments mainly through untreated or inadequately treated industrial wastewater. Plastic pellet spills, synthetic fiber residues, resin powders, and polymer fragments are commonly found in industrial discharge streams. The situation is particularly alarming in industrial zones such as Savar, Gazipur, Narayanganj, Chattogram, and Tongi, where a high concentration of textile and plastic industries exists. Many of these factories lack proper effluent treatment plants (ETPs), and even those with ETPs often fail to operate them efficiently due to high operational costs or poor regulatory monitoring. Informal and poorly regulated plastic recycling plants pose an even greater threat. In Bangladesh, informal recycling sectors dominate the plastic waste management system. These facilities often operate in residential or semi-urban areas without adhering to environmental standards. Plastic washing, shredding, and melting processes release a mixture of microplastics, contaminated wastewater, and toxic chemicals into surrounding soil and water bodies[16]. The recycling process itself generates fine plastic dust and pellets, which are easily transported by wind and water. These pollutants accumulate in river sediments, agricultural lands, and nearby residential areas, leading to long-term environmental contamination. Aquatic ecosystems near industrial zones show higher concentrations of microplastics compared to less industrialized regions. Moreover, industrial microplastics often carry hazardous additives, such as plasticizers, flame retardants, and stabilizers, increasing their toxicity. Weak enforcement of environmental regulations, lack of regular inspections, and corruption contribute to this growing pollution problem. Effective mitigation requires strict implementation of industrial discharge standards, upgrading wastewater treatment facilities, regulation of informal recycling sectors, and promotion of cleaner production technologies[17].

3.7. COVID-19 pandemic impact

The COVID-19 pandemic dramatically accelerated global plastic consumption and waste generation, leading to a sharp increase in microplastic pollution in both terrestrial and aquatic environments. In Bangladesh, this impact has been particularly severe due to high population density, poor waste segregation practices, and inadequate post-consumer plastic management systems. During the pandemic, the use of personal protective equipment (PPE) such as disposable face masks, gloves, face shields, protective gowns, and testing kits increased exponentially across healthcare facilities, public spaces, households, and industrial sectors.

Most PPE items are made from synthetic polymers, primarily polypropylene (PP), followed by polyethylene (PE) and polyethylene terephthalate (PET). These materials are non-biodegradable and highly resistant to environmental degradation. When improperly discarded, PPE waste undergoes physical, chemical, and photo-degradation under sunlight, heat, and mechanical stress, eventually breaking down into microplastics and even nanoplastics. Studies suggest that a single disposable surgical mask can release thousands of microplastic fibers during environmental degradation, especially when exposed to UV radiation and water currents[18].

In Bangladesh, poor enforcement of medical waste management systems worsened the situation. During peak pandemic periods, many hospitals, diagnostic centers, households, and quarantine facilities disposed of PPE waste along with general household garbage or directly into open environments. This led to increased contamination of urban drainage systems, roadside areas, rivers, and coastal zones. Informal waste collectors, who often work without protective gear, were exposed to both biological and plastic hazards, increasing occupational health risks. Moreover, improperly managed PPE waste became a direct source of microplastics in water bodies. Flooding during monsoon seasons further transported pandemic-related plastic waste into rivers and ultimately into the Bay of Bengal. Studies have identified a significant rise in PP-based microfibers in urban water bodies after 2020 compared to pre-pandemic levels. This situation highlights the urgent need for specialized PPE waste management systems, public awareness campaigns, biodegradable alternatives to conventional PPE, and stricter environmental regulations during future public health emergencies to prevent further microplastic contamination[19].

3.8. Microplastic types and polymer composition

The nature and chemical composition of microplastics play a crucial role in determining their environmental behavior, degradation pattern, toxicity, and biological impacts. In Bangladesh, studies examining water, sediment, soil, and biota have identified several dominant polymer types. The most commonly detected microplastic polymers include:

- Polyethylene (PE) – widely used in packaging and shopping bags
- Polypropylene (PP) – used in food containers, bottle caps, face masks, and textiles
- Polyethylene terephthalate (PET) – used in beverage bottles and synthetic fibers
- Polyvinyl chloride (PVC) – used in pipes, construction materials, and insulation

- Polystyrene (PS) – used in foam packaging and disposable containers

Among these polymers, PP and PET fibers dominate due to the heavy presence of the textile and garment industry in Bangladesh. Fiber-shaped microplastics are the most abundant form found in aquatic and urban environments, especially near industrial zones and wastewater discharge points. These fibers originate mainly from synthetic clothing, industrial discharge, washing activities, and sewing/knitting processes[20].

Microplastic shapes commonly observed include fibers, fragments, films, pellets, and foams. Each shape behaves differently in aquatic environments. Fibers are easily transported by water and wind and remain suspended for long periods, increasing their likelihood of ingestion by aquatic organisms. Fragments and films tend to settle in sediments, contributing to benthic contamination. Additionally, many microplastics contain toxic additives such as plasticizers, flame retardants, UV stabilizers, and colorants. These chemicals may leach into the environment or accumulate within biological systems after ingestion, increasing toxicity. Furthermore, microplastics can adsorb environmental pollutants such as heavy metals, pesticides, and persistent organic pollutants (POPs), acting as carriers of toxic substances across ecosystems[21]. Understanding polymer composition is essential for developing targeted mitigation strategies, identifying pollution sources, and designing effective recycling and substitution policies.

3.9. River and marine pathways

Bangladesh's extensive river network plays a central role in the transportation of terrestrial microplastics into marine ecosystems. The Ganges–Brahmaputra–Meghna (GBM) river system, one of the largest river systems in the world, serves as a major pathway for plastic and microplastic transport from inland regions to the Bay of Bengal. It is estimated that the GBM system carries approximately 72,845 tons of microplastics annually, ranking it among the highest global contributors. These rivers receive microplastics from multiple sources, including urban wastewater discharge, industrial effluents, agricultural runoff, and solid waste dumping. Seasonal floods and monsoon rains significantly intensify this transport process by mobilizing plastic debris accumulated on land, streets, and open dumping sites into river channels[21]. Once microplastics reach the Bay of Bengal, they spread across coastal waters, estuaries, mangrove ecosystems (such as the Sundarbans), and deep marine environments. Marine currents and tidal forces distribute these particles over large areas, contaminating coastal fisheries, coral beds, and benthic ecosystems. Marine organisms including plankton, mollusks, crustaceans, and fish often ingest microplastics, mistaking them for food particles. This directly affects the marine food web and contributes to bioaccumulation and biomagnification. Over time, microplastics have been detected in commercially important fish species, raising concerns over seafood safety and human exposure. Thus, river systems act both as carriers and reservoirs of microplastics, linking land-based pollution to global marine contamination. Controlling inland plastic waste is therefore essential to protecting coastal and marine biodiversity[22].

3.10. Environmental contamination levels

Studies conducted in different environmental compartments of Bangladesh reveal alarming concentrations of microplastics, demonstrating their widespread distribution across ecosystems. Reported levels vary depending on location, sampling method, and environmental matrix. In sediments, microplastic concentrations range from 68–84 particles/kg in relatively less contaminated regions to over 100,000 particles/kg in urban and industrial zones. Riverbeds near Dhaka, Narayanganj, and Chattogram industrial areas show extremely high sediment contamination, indicating long-term accumulation. In surface waters, concentrations have been recorded at approximately 38 particles per cubic meter in the Ganges River, with significantly higher levels in urban canals and drainage systems. These values increase significantly during the rainy season due to enhanced runoff and waste transportation[23].

Microplastics have also been detected in fish feed, with reported concentrations ranging from 550 to 11,600 particles per kilogram, indicating contamination in aquaculture systems. This is highly concerning as contaminated feed can introduce microplastics into farmed fish, which are widely consumed by the population. Additionally, studies have confirmed the presence of microplastics in table salt, seafood, and drinking water, proving that these particles have successfully entered the human food chain. The long-term health effects of chronic microplastic exposure are still under investigation but may include inflammatory responses, oxidative stress, and disruption of endocrine functions due to associated toxic chemicals.

These findings indicate that microplastic contamination is not localized but widespread across environmental, agricultural, and food systems in Bangladesh. Continuous monitoring, standardized assessment methods, and national-level microplastic surveillance programs are urgently needed to understand the scale of contamination and design effective mitigation strategies[24].

4. Ecological impacts of microplastic pollution

4.1. Habitat degradation and biodiversity loss

Microplastic pollution significantly alters both the structural and functional properties of natural habitats, leading to widespread habitat degradation and loss of biodiversity. In aquatic ecosystems, microplastics accumulate in water columns, sediments, and benthic layers, where they modify sediment texture, porosity, and nutrient cycling processes. The presence of plastic particles in sediments interferes with gas exchange and reduces oxygen penetration, creating hypoxic conditions that negatively affect benthic organisms such as worms, mollusks, and bottom-dwelling fish species. In freshwater systems like rivers and wetlands, microplastic contamination disrupts planktonic communities and affects the primary producers, such as algae and phytoplankton, which form the base of the aquatic food web. In terrestrial ecosystems, microplastics contaminate agricultural soils, industrial lands, and urban green spaces[7]. These particles alter soil structure by changing water-holding capacity, aeration, and aggregation properties. This in turn affects soil microorganisms, earthworms, and beneficial insects, leading to a reduction in soil fertility and ecosystem services. The disturbance of soil microbial diversity also affects vital biogeochemical cycles such as carbon and nitrogen cycling. Over time, these disruptions reduce habitat suitability for many native species, leading to population decline and species loss. Moreover, microplastics can carry toxic chemicals and invasive microorganisms, introducing additional ecological stressors into already vulnerable ecosystems. This combined impact ultimately results in reduced biodiversity, altered species composition, and ecosystem instability in both freshwater and marine environments, particularly in developing countries like Bangladesh where pollution control measures are still evolving[9].

4.2. Ingestion and physical damage

One of the most direct and harmful ecological effects of microplastics is their ingestion by aquatic organisms. Due to their small size and similarity in appearance to natural food particles, microplastics are often mistaken for prey by a wide range of aquatic species, including zooplankton, fish, crustaceans, and mollusks. Once ingested, these particles accumulate in the digestive system, causing intestinal blockage, abrasion of gut lining, and obstruction of nutrient absorption. This leads to decreased feeding efficiency, poor growth rates, and increased vulnerability to diseases. Microplastic ingestion also causes a phenomenon known as false satiation, where organisms feel full due to plastic particles occupying their digestive tract, reducing their appetite for actual nutritious food. As a result, affected organisms suffer from chronic malnutrition, energy depletion, and impaired reproduction[5]. In severe cases, this can lead to increased mortality, especially in juvenile and small-bodied species that have limited ability to expel foreign particles. Additionally, microplastics can impair physiological functions by affecting metabolic processes and inducing stress responses. Studies have shown that ingested microplastics can cause tissue inflammation, oxidative stress, and immune suppression in fish and invertebrates. These effects reduce the survival capacity of organisms in polluted environments, ultimately leading to population decline and ecosystem imbalance[2].

4.3. Impacts on fish populations

Microplastic pollution poses a serious threat to fish populations in both freshwater and marine ecosystems, especially in riverine and coastal environments of Bangladesh. Several studies have reported the presence of microplastics in commercially important fish species such as Harpadon nehereus (Bombay duck), where ingestion rates range from 3.20 to 8.72 particles per individual. These microplastic particles enter fish bodies mainly through contaminated prey, water, and sediment ingestion. Once inside the fish, microplastics accumulate in the gastrointestinal tract and, in some cases, translocate into other tissues such as the liver and muscles. This internal accumulation increases the risk of bioaccumulation and trophic transfer across the food chain, meaning that predators that consume contaminated fish also become exposed to microplastics[11]. Over time, this process leads to biomagnification at higher trophic levels, potentially affecting top predators, including humans. Microplastic exposure in fish has been associated with behavioral changes, reduced swimming performance, altered feeding behavior, suppressed immune response, and reproductive impairments. For example, exposure can reduce egg quality, disrupt hormonal balance, and affect larval development, leading to reduced population recruitment. In heavily polluted regions, such chronic exposure may contribute to declining fish stocks, threatening both biodiversity and food security in Bangladesh, where millions of people depend on fisheries for nutrition and livelihood. Furthermore, contaminated fish entering the human food chain raises serious public health concerns. Regular consumption of microplastic-contaminated fish may lead to indirect human exposure to toxic chemicals associated with plastics, highlighting the interconnected nature of ecological and human health risks[18].

4.4. Effects on filter feeders and benthic species

Filter-feeding organisms such as mussels, oysters, clams, and crabs are particularly vulnerable to microplastic pollution due to their feeding behavior and close association with sediments. These organisms filter large volumes of water to obtain food, inadvertently ingesting microplastic particles suspended in the water column. Once ingested, microplastics accumulate in their digestive tissues and gills, causing physical injury, reduced filtration efficiency, and decreased feeding capacity. Microplastic accumulation in filter feeders disrupts their natural biological functions. In mussels and oysters, microplastics have been shown to reduce energy reserves, impair growth rates, and interfere with reproductive processes such as gamete development and larval settlement[15]. These impacts not only threaten individual species but also disrupt ecosystem services, as filter feeders play a crucial role in maintaining water quality by removing suspended particles and contaminants. Benthic organisms, including crabs, worms, and bottom-dwelling fish, are also heavily affected because microplastics tend to settle and accumulate in sediments. Microplastics alter sediment composition and structure, affecting burrowing behavior, respiration, and feeding of benthic species. This leads to a decline in benthic biodiversity and disrupts nutrient cycling, which forms the foundation of aquatic food webs. In coastal and estuarine ecosystems of Bangladesh, where benthic organisms are vital for ecological stability and fisheries, microplastic contamination poses a serious environmental threat[21].

4.5. Impact on aquatic plants

Microplastic pollution significantly affects aquatic plant life, including phytoplankton, algae, and submerged macrophytes. The presence of suspended microplastic particles in water reduces light penetration by increasing turbidity, thereby limiting the availability of photosynthetically active radiation (PAR) for aquatic plants. This reduction in light availability lowers photosynthetic efficiency, leading to decreased biomass production and reduced oxygen generation in aquatic systems. In addition, microplastics can physically attach to the surfaces of aquatic plants, forming biofilms and obstructing gas exchange mechanisms. This interference affects carbon dioxide uptake and oxygen release, disrupting metabolic activities[22]. The decline in photosynthetic activity also impacts primary productivity, weakening the base of the aquatic food web and affecting higher trophic levels, including zooplankton and fish. Furthermore, microplastics act as carriers of harmful pollutants and pathogens. When these contaminated particles interact with aquatic vegetation, they introduce toxic substances that can damage cellular structures, inhibit enzyme activities, and cause oxidative stress in plants. Over time, these effects lead to habitat degradation, reduced biodiversity, and altered ecosystem functioning in freshwater bodies, wetlands, and coastal waters of Bangladesh[14].

4.6. Terrestrial ecosystem effects

Microplastic contamination in terrestrial ecosystems, particularly agricultural soils, is an emerging environmental concern in Bangladesh. These particles are introduced into soils through the use of plastic mulching films, irrigation with contaminated water, application of sewage sludge, and deposition from atmospheric sources. Once in the soil matrix, microplastics persist for long periods due to their resistance to biodegradation. Microplastics significantly affect soil physical properties, including reducing water retention capacity, soil porosity, and permeability. By altering soil aggregation and pore structure, they disrupt normal water movement and gas exchange within the soil, leading to poor root development and reduced nutrient availability for crops. This compromises plant growth and agricultural productivity. In addition, microplastics negatively impact soil biological health by reducing microbial diversity and enzyme activity. Soil microorganisms play a vital role in organic matter decomposition, nutrient cycling, and maintaining soil fertility. The presence of plastic particles alters microbial community structures, inhibits beneficial microbes, and promotes harmful ones. Moreover, studies have shown that microplastics reduce earthworm populations and activity, which are essential for soil aeration and organic matter turnover. The decline in earthworm movement and reproduction further deteriorates soil health and structure. Altogether, microplastic pollution in terrestrial ecosystems contributes to soil degradation, reduced crop yields, and long-term threats to food security, particularly in an agriculturally dependent country like Bangladesh[23].

4.7. Agricultural and livestock impacts

Agricultural ecosystems in Bangladesh, which account for approximately 70% of the country’s land area, are increasingly affected by microplastic contamination. Microplastics enter soils primarily through the use of plastic mulching films, packaging materials, irrigation with contaminated water, and application of agrochemical containers. Once embedded in soil, these particles interact with the physical, chemical, and biological properties of the land. They reduce water retention capacity and soil porosity, interfere with nutrient cycling, and negatively affect beneficial microorganisms, ultimately decreasing soil fertility and crop productivity[4]. The persistent accumulation of microplastics in agricultural soils can also disrupt the uptake of essential nutrients by plants, further compromising crop yield and quality. Livestock are also exposed to microplastics indirectly through contaminated feed, drinking water, and pasture. Studies indicate that microplastic particles in animal feed may cause gut dysbiosis, reduced nutrient absorption, and digestive irritation. Chronic exposure can lead to metabolic disruptions, including lipid accumulation and insulin resistance, as well as immune dysregulation and oxidative stress. In reproductive systems, microplastics have been associated with decreased sperm motility, reduced oocyte quality, and impaired gonadal development. This, in turn, affects the reproductive efficiency of livestock, potentially reducing population productivity over time. Collectively, these impacts compromise both agricultural productivity and food security, highlighting the need for integrated microplastic management strategies in Bangladesh's farming systems[18].

4.8. Flooding and public health risks

In addition to ecological and agricultural effects, microplastic pollution exacerbates flooding and public health risks in urban and peri-urban areas. Improperly disposed plastic waste, including bags, packaging, and PPE debris, frequently clogs drains, canals, and small rivers in cities such as Dhaka, Chattogram, and Khulna. During the monsoon season, these blockages impede natural drainage, resulting in frequent waterlogging and urban flooding, which not only damages infrastructure but also facilitates the spread of waterborne and vector-borne diseases. Stagnant floodwaters provide ideal breeding grounds for mosquitoes and other disease vectors, increasing the risk of vector-borne illnesses such as dengue, chikungunya, and malaria. Furthermore, floodwater contaminated with microplastics and associated pollutants can introduce chemical and biological hazards into communities[20]. These pollutants include heavy metals, persistent organic pollutants (POPs), and pathogenic microorganisms, which may cause gastrointestinal infections, skin diseases, and long-term health risks in affected populations. Flood-induced contamination also facilitates the transport of microplastics into agricultural lands and freshwater bodies, creating a feedback loop of environmental and health hazards. The combination of blocked drainage, increased flooding, and microplastic-associated chemical and microbial contamination represents a multifaceted threat to both ecological integrity and public health in Bangladesh. Addressing this issue requires coordinated urban waste management, improved drainage infrastructure, public awareness campaigns, and strict enforcement of waste disposal regulations to mitigate both environmental and human health risks[10].

5. Biochemical and toxicological impacts of microplastics

5.1. Chemical leaching and pollutant transport

Microplastics are not only physical pollutants but also serve as vectors for chemical contamination in ecosystems. Plastics are composed of synthetic polymers that include a variety of additives such as plasticizers, stabilizers, flame retardants, dyes, and UV absorbers, which can leach into surrounding environments under sunlight, heat, or chemical exposure. These leached compounds are biologically active and can interfere with metabolic pathways, enzymatic functions, and cellular signaling in exposed organisms. In addition to intrinsic additives, microplastics have a strong affinity for external contaminants such as heavy metals—lead (Pb), cadmium (Cd), chromium (Cr)—and persistent organic pollutants like polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). These pollutants adsorb onto the surface of microplastic particles due to their hydrophobic nature and high surface-area-to-volume ratio. Once ingested by aquatic or terrestrial organisms, microplastics act as carriers, facilitating the bioaccumulation and trophic transfer of these toxic chemicals along the food chain[3]. In Bangladesh, where rivers, sediments, and aquaculture systems are heavily contaminated, this transport mechanism is particularly concerning, as it increases the exposure risk for both wildlife and humans. The combination of leached additives and adsorbed pollutants creates a synergistic toxic effect, which can amplify oxidative stress, endocrine disruption, and genotoxicity in organisms. This dual role of microplastics as both physical irritants and chemical vectors underscores their significance as a persistent biochemical hazard in the environment[24].

5.2. Oxidative stress and inflammation

Ingestion or exposure to microplastics triggers significant oxidative stress in exposed organisms. Microplastics can induce the production of reactive oxygen species (ROS), unstable molecules that damage cellular components such as lipids, proteins, and DNA. Elevated ROS levels lead to lipid peroxidation, protein denaturation, mitochondrial dysfunction, and DNA strand breaks, collectively impairing cellular homeostasis. The resulting oxidative stress often activates inflammatory pathways, causing tissue damage and immune system disruption. In fish, crustaceans, and mollusks, microplastic exposure has been associated with hepatic stress, gill damage, and intestinal inflammation, which reduce nutrient absorption and overall fitness[16]. In soil organisms, such as earthworms and microbes, oxidative stress can impair enzyme activities critical for nutrient cycling and soil health. In livestock, chronic exposure to microplastics through feed can elevate systemic oxidative markers, induce liver stress, and compromise metabolic efficiency, ultimately reducing growth, reproduction, and productivity. Furthermore, oxidative stress is closely linked with cellular apoptosis and immunotoxicity. Persistent inflammation caused by microplastic accumulation can weaken the immune system, making organisms more susceptible to infections and environmental stressors. This highlights the importance of understanding oxidative mechanisms in assessing ecological and human health risks associated with microplastic contamination[25].

5.3. Endocrine disruption

Microplastics and their associated chemicals are increasingly recognized as endocrine-disrupting agents. Polymers such as polyvinyl chloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET) often contain additives like phthalates, bisphenol A (BPA), and flame retardants, which can interfere with hormonal signaling pathways. These compounds mimic or block natural hormones, leading to reproductive toxicity, developmental abnormalities, and metabolic disorders in exposed organisms. In aquatic species, endocrine disruption manifests as altered sex hormone levels, impaired gametogenesis, reduced fecundity, and abnormal larval development. In fish, for example, exposure to phthalate-contaminated microplastics can result in delayed gonadal maturation, skewed sex ratios, and intergenerational effects, with offspring exhibiting reproductive and developmental impairments. In terrestrial animals, including livestock, endocrine-disrupting compounds from microplastics may interfere with thyroid, adrenal, and gonadal hormone regulation, affecting growth, fertility, and metabolic homeostasis. Endocrine-disrupting microplastics also pose potential risks to human health, especially through consumption of contaminated seafood, water, and agricultural products. Chronic exposure to microplastic-associated endocrine disruptors is linked to reproductive disorders, developmental delays in children, and metabolic diseases in humans. These effects highlight the urgent need for detailed ecotoxicological studies and regulatory frameworks to limit microplastic exposure in both environmental and food systems[22].

5.4. PET and antimony toxicity

Polyethylene terephthalate (PET), commonly used in beverage bottles, packaging, and food containers, represents a major source of microplastic pollution in both aquatic and terrestrial environments. One of the critical concerns associated with PET is its ability to leach antimony (Sb), a metalloid used as a catalyst during PET production. Antimony leaching is influenced by environmental factors such as temperature, UV exposure, and mechanical abrasion, allowing Sb to enter surrounding water, soil, and biological systems. Once internalized by organisms, antimony exerts oxidative stress, leading to the overproduction of reactive oxygen species (ROS) that damage lipids, proteins, and nucleic acids. Mitochondrial dysfunction is a major consequence, impairing energy production and cellular metabolism. Chronic exposure to antimony has been linked to hepatotoxicity, renal stress, and genotoxicity, while long-term exposure may trigger carcinogenic processes in vertebrates and invertebrates. In ecosystems like the Ganges-Brahmaputra-Meghna basin, where PET bottles are prevalent, leached antimony poses a persistent biochemical hazard, particularly for aquatic species that bioaccumulate both microplastics and associated metals[15].

5.5. Molecular and cellular effects of microplastics

Microplastics exert significant effects at molecular and cellular levels, disrupting the normal physiological functioning of exposed organisms. Studies indicate that microplastic particles can alter gene expression, particularly genes involved in stress response, immunity, and detoxification pathways. For instance, antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) are often upregulated as a defensive response to oxidative stress, yet chronic exposure eventually overwhelms these mechanisms, resulting in cellular damage[7]. Microplastics also influence enzyme activity, reducing digestive efficiency, metabolic function, and detoxification capacity. Immune responses are impaired through suppression of cytokine signaling and reduction of phagocytic activity, which compromises the organism's ability to resist pathogens. Additionally, microplastic exposure can interfere with cellular signaling pathways, including apoptosis regulation, mitochondrial biogenesis, and hormonal signaling, causing cascading physiological and developmental disruptions. In extreme cases, microplastics induce DNA damage, chromosomal aberrations, and epigenetic modifications, highlighting the broad molecular toxicity potential that affects both individual organisms and population health[26].

5.6. Effects on fish and aquatic invertebrates

Fish and aquatic invertebrates are among the most vulnerable groups to microplastic exposure, experiencing a range of physiological, biochemical, and behavioral effects. One of the most commonly observed impacts is gut dysbiosis, where microplastics disrupt the normal microbial communities in the gastrointestinal tract. This imbalance affects nutrient absorption, digestion, and immune system function, making organisms more susceptible to disease and stress. Microplastic ingestion also reduces digestive enzyme activities, such as amylase, lipase, urease, and phenol oxidase, leading to decreased metabolic efficiency and poor growth rates[6]. At the tissue level, hepatic oxidative damage has been reported, manifested as lipid peroxidation, protein carbonylation, and DNA strand breaks. In parallel, immune system suppression occurs, indicated by reduced lymphocyte activity, altered cytokine expression, and impaired pathogen defense. Beyond the digestive and immune systems, microplastics induce neurotoxic effects, affecting behavior, sensory perception, and predator avoidance. Exposure can alter neurotransmitter levels, impair synaptic function, and affect locomotor activity, which may reduce survival and reproductive success. In benthic invertebrates such as crabs, mollusks, and shrimps, similar effects occur, including particle accumulation in gills and hepatopancreas, oxidative stress, and impaired reproductive output, threatening population stability and ecosystem functionality. Collectively, these biochemical and physiological impairments illustrate the profound toxicological consequences of microplastics on aquatic life in Bangladesh and globally[17].

5.7. Impacts on farm animals

Microplastic contamination in agricultural systems has increasingly been recognized as a significant threat to livestock health and productivity. Animals are exposed to microplastics primarily through contaminated feed, water, and soil, which contain plastic fragments from packaging, mulching films, and irrigation. Once ingested, microplastics accumulate in the gastrointestinal tract, liver, and other organs, inducing physical and biochemical stress[9]. Among the most severe reproductive impacts are reduced sperm motility, compromised oocyte quality, and delayed gonadal maturation, which collectively reduce fertility rates. In addition, microplastic exposure elevates systemic inflammatory responses in livestock, with increased production of cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α). These inflammatory mediators disrupt normal metabolic processes, leading to insulin resistance, lipid accumulation, and other metabolic disorders. Over time, chronic exposure can reduce growth rates, impair milk and meat quality, and compromise overall productivity. The persistent nature of microplastics in feed and water sources means that these impacts are not only immediate but may accumulate over time, representing a long-term threat to livestock health in Bangladesh's agricultural sector[19].

5.8. Transgenerational effects

Microplastic exposure can also have transgenerational consequences, affecting the health, development, and reproductive capacity of offspring. Studies in aquatic and terrestrial organisms indicate that parental exposure to microplastics and their associated chemical additives can cause developmental delays, including delayed gonadal maturation and impaired organogenesis. These developmental abnormalities are often accompanied by genetic and epigenetic modifications, such as DNA methylation changes and histone modifications, which can alter gene expression patterns in offspring. The reproductive success of exposed populations is significantly reduced, as offspring exhibit lower fertility, higher mortality rates, and reduced resilience to environmental stressors. Such transgenerational impacts may not be immediately observable but have long-term ecological and agricultural consequences, including potential reductions in fish stocks, livestock productivity, and overall biodiversity in ecosystems contaminated by microplastics[21]. This highlights the need to consider multi-generational exposure risks in environmental and agricultural risk assessments in Bangladesh.

5.9. Soil microbial and enzymatic alterations

Microplastics in soils disrupt critical microbial communities and enzymatic activities, which are fundamental for nutrient cycling, soil fertility, and ecosystem stability. The physical presence of microplastic fragments alters soil texture, reducing porosity, water retention, and aeration, which in turn affects microbial habitat suitability. Microplastics have been shown to reduce the abundance of beneficial bacteria and fungi while promoting opportunistic or pathogenic microorganisms. Enzyme activities essential for soil health, including urease, phosphatase, and dehydrogenase, are suppressed in the presence of microplastics. This impairs decomposition of organic matter, nitrogen fixation, and phosphorus availability, ultimately reducing nutrient availability for crops. Earthworms and other soil fauna are similarly affected, as microplastics interfere with their burrowing and feeding behavior, further limiting organic matter turnover[14]. Collectively, these biochemical and biological disturbances contribute to soil degradation, lower crop productivity, and reduced resilience of terrestrial ecosystems to environmental stress.

5.10. Human health implications

Humans are indirectly exposed to microplastics through contaminated seafood, crops, drinking water, and other environmental pathways. The ingestion of microplastics and associated chemical additives introduces risks for gastrointestinal irritation, chronic inflammation, and disruption of gut microbiota. Chemicals leached from plastics, such as phthalates and bisphenol A (BPA), act as endocrine disruptors, interfering with hormone regulation, fertility, and metabolic processes[7]. Long-term exposure may contribute to metabolic disorders including insulin resistance, obesity, and cardiovascular dysfunction, although epidemiological and clinical data from Bangladesh remain limited. Microplastics also serve as vectors for toxic substances and pathogens, increasing the potential for bioaccumulation in the food chain. These risks underscore the urgent need for comprehensive monitoring, public health assessments, and policy interventions to mitigate human exposure to microplastic contamination in Bangladesh[27].

6. Management, policy, and mitigation strategies

6.1. Strengthening waste management systems

Effective management of plastic waste is fundamental to reducing microplastic pollution in Bangladesh. Currently, only a fraction of generated plastic waste is formally collected and recycled, while the majority ends up in landfills, drains, or rivers. Expanding formal recycling systems and developing an efficient collection network are essential first steps. This includes establishing designated collection points, improving waste segregation at the source, and incentivizing private-sector participation in recycling operations. By preventing plastics from entering aquatic and terrestrial environments, these measures can significantly reduce the formation of secondary microplastics. Additionally, minimizing open dumping and uncontrolled river discharge through better municipal oversight and community involvement will reduce the direct input of plastic debris into waterways, mitigating downstream contamination in rivers, estuaries, and the Bay of Bengal.

6.2. Policy enforcement

While Bangladesh implemented a ban on thin polyethylene bags in 2002, enforcement remains weak, and compliance across urban and rural areas is inconsistent. Strengthening policy enforcement is critical for addressing microplastic pollution at its source. This includes rigorous implementation of existing plastic production regulations, environmental protection laws, and industrial discharge standards. Authorities must establish regular monitoring, inspection, and penalties for non-compliance. In addition, integrating local government bodies, law enforcement, and community organizations into regulatory frameworks can improve accountability and adherence to plastic-related policies. Policy measures should also incentivize reduction, reuse, and recycling practices, creating a structured legal and economic framework to curb plastic proliferation.

6.3. Promotion of eco-friendly alternatives

Reducing reliance on conventional plastics requires the promotion of eco-friendly alternatives across consumer, industrial, and agricultural sectors. Jute-based products, already widely cultivated in Bangladesh, present a biodegradable alternative to single-use plastics. Similarly, encouraging the use of biodegradable packaging materials, compostable containers, and reusable items can significantly decrease the introduction of microplastics into the environment. Public campaigns promoting low-plastic lifestyles, such as reducing single-use plastics, recycling household waste, and choosing sustainable materials, can instill behavioral changes at the community level. Industrial adoption of alternative materials in packaging, textile, and food industries further supports national efforts toward sustainable plastic management.

6.4. Industrial and wastewater treatment

Industrial effluents and untreated wastewater are major contributors to microplastic contamination, particularly from the textile, plastic manufacturing, and recycling sectors. Upgrading effluent treatment plants to incorporate microplastic filtration technologies and enforcing compliance with discharge standards are crucial steps to limit pollution. Industries should adopt best practices in waste minimization, recycling, and closed-loop water systems, reducing plastic fiber release into aquatic environments. Regular monitoring of industrial effluents, along with technical support for adopting advanced treatment methods, can ensure long-term compliance and environmental protection.

6.5. Public awareness and education

Addressing microplastic pollution requires nationwide awareness campaigns targeting multiple stakeholders, including consumers, students, communities, and industries. Educational programs should focus on plastic reduction strategies, proper disposal methods, and environmental consequences of microplastic pollution. Schools and universities can incorporate microplastic studies into curricula, while community-based initiatives can encourage local participation in cleanup drives and recycling efforts. Social media, mass media, and public service campaigns play a pivotal role in informing citizens about sustainable alternatives and fostering environmental responsibility, ultimately creating a culture of conscious consumption.

6.6. Research and innovation

Long-term mitigation of microplastic pollution relies on research and technological innovation. This includes the development of biodegradable polymers, alternative packaging materials, and sustainable textile fibers that minimize environmental persistence. Research into microplastic filtration technologies for wastewater treatment plants, rivers, and industrial effluents can reduce environmental release. Additionally, ecotoxicological studies specific to Bangladesh are necessary to assess the long-term impacts on biodiversity, agriculture, livestock, and human health, thereby guiding evidence-based policy and management strategies. Collaborative efforts among universities, government agencies, and private industry can accelerate innovation and provide sustainable solutions to the microplastic crisis.

7. Conclusion

Microplastic pollution in Bangladesh poses a serious environmental and public health challenge, affecting rivers, soils, coastal zones, agriculture, livestock, and human health. Sources include mismanaged waste, single-use plastics, industrial discharges, textile fibers, agricultural practices, and PPE from the COVID-19 pandemic. Microplastics disrupt ecosystems, reduce biodiversity, impair crop productivity, and cause metabolic, reproductive, and biochemical disturbances in animals, with risks extending through the food chain to humans. Effective mitigation requires integrated strategies: improved waste management, stricter policy enforcement, promotion of biodegradable alternatives, industrial compliance, public awareness, and targeted research. Coordinated efforts from government, industry, academia, and society are essential to safeguard environmental integrity, food security, and public health. Addressing microplastic pollution is critical for sustainable development and ensuring future generations inherit healthy ecosystems and safe food systems.

Conflict of interest

The authors declare no conflict of interest

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