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Environmental Occurrence, Toxicity and Mitigation Strategies of Micro-Plastics in the Aquatic Ecosystem

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ABSTRACT

The occurrence of micro-plastics in aquatic ecosystems significantly impact the structure, organism functions, and aesthetic values of the ecosystem. Here, an extensive search of databases such as PubMed, Scopus, Web of Science, Science Direct, Google Scholar, and African Journals Online was conducted to gather relevant research reports on microplastics. Microplastics are typically classified into primary and secondary microplastics originating from microbeads used in cosmetics, the ship-breaking industry, fertilizers, and indiscriminate plastics waste disposal. Plastic pollution in aquatic ecosystems poses a serious threat to aquatic organisms through entanglement, ingestion, and exposure to toxic plastic additives. The toxic effect Plastic additives can lead to oxidative stress, gastrointestinal obstruction, translocation, and trophic transfer. Bisphenol-A and phthalates, critical components of plastic, have serious endocrine-disrupting effects on organisms. Mitigation strategies to reduce plastic and microplastic pollution require interventions from governments at all levels to establish effective waste management programs, policies, and regulations. Designing eco-friendly and biodegradable plastic products is crucial for effective plastic waste management. Furthermore, remediating contaminated environments using eco-friendly methods is essential to address microplastic pollution in the aquatic ecosystem without imposing severe ecological risks.

Keywords: Micro-plastics, Occurrence, Toxicity, Ecological Consequences,

INTRODUCTION

The presence of micro-plastics in aquatic ecosystems impacts the structure, functions, and aesthetic values of the aquatic ecosystem. The late 1940s and early 1950s was a period of significant plastic production driven by technological advancements in petrochemical industries. This led to a surge in production of affordable and versatile plastics for various applications such as aircraft parts, packaging, construction, and more (Freinkel, 2011; Parker, 2020). Chronological report revealed that plastic production from fossil-based sources skyrocketed from 2 million tonnes in 1950 to 438 million tonnes in 2017 (Geyer, 2020), with oil and natural gas constituting about 99% of non-renewable hydrocarbon plastic polymers (British Plastics Federation, 2019). In the 21st century, the use of plastic products, including tyres, water bottles, electronics, medical devices, and more, surged, leading to the widespread presence of plastic and plastic-related materials in the environment (Figure 1) (Plastics Europe, 2008).

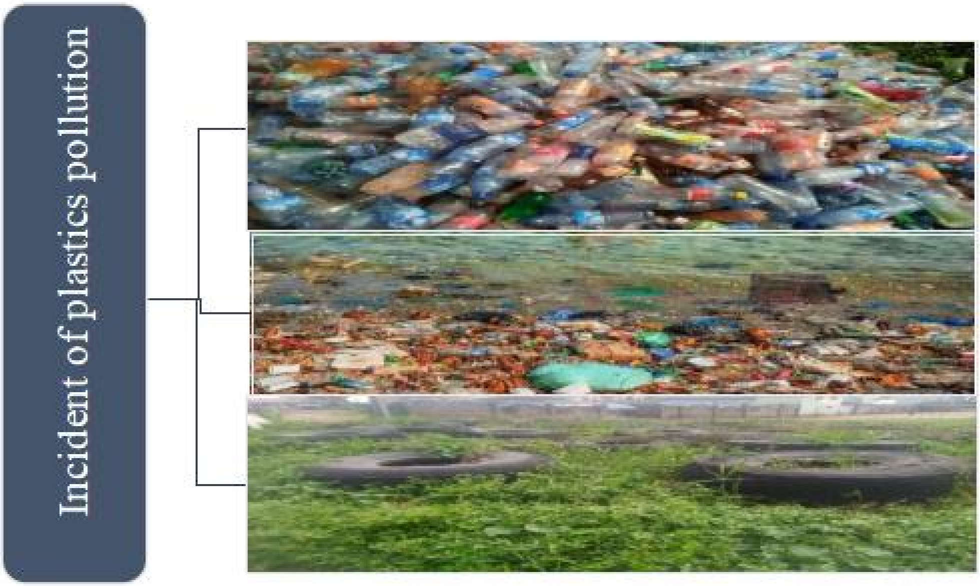

Figure 1: Photomicrograph of plastic and plastic-related pollutants in the environment

Currently, approximately 369 million tons of plastic waste are generated annually worldwide, with about 11 million metric tons finding their way to the ocean through wind action, runoff, and ice melt (UNCTAD, 2020). This is projected to triple by 2040 due to the unprecedented global production of plastics (UNCTAD, 2020).

The increasing environmental presence of micro-plastics poses a serious threat to the sustainability of aquatic ecosystems, food security, and human health (Thompson *et al*., 2009; Law, 2017).

Due to their durability, plastic materials often degrade into smaller particles known as "micro-plastics," which are widely distributed across all habitats (Allen *et al*., 2022). It was estimated that over 84 percent of drinking water samples globally contain micro-plastic particles (UNEA, 2018). Humans are primarily exposed to micro-plastics through the ingestion of contaminated food, water, and airborne particles in both indoor and outdoor environments (OECD, 2020). The impact of micro-plastic pollution has garnered significant attention across various human discipline, prompting the United Nations Environment Assembly to adopt a resolution on plastics pollution in March 2022, urging countries to promote material substitutes for plastics through national policies and multilateral developmental efforts to enhance the Harmonized System (Walker, 2022).

Unfortunately, recent trends indicate an increase in global plastic production, with approximately 369 million tons of plastics traded globally in 2020, valued at about $1.2 million (UNCTAD, 2020). This has strained the waste management capacities of many countries and states, underscoring the need to identify eco-friendly alternatives to plastics. Therefore, this paper seeks to examine the impact of micro-plastics and their implications for aquatic organisms and ecosystem sustainability.

MATERIALS AND METHODS

For this review, we performed a thorough search and examined peer-reviewed publications without any restrictions on the year of publication. By utilizing various databases such as PubMed (www.ncbi.nlm.nih.gov/pubmed), Scopus (www.scopus.com), Web of Science (www.webofscience.com), ScienceDirect (www.sciencedirect.com), Google Scholar (www.googlescholar.com), and African Journals Online (www.ajol.info). Additionally, other relevant literature from local and online newspapers, publications, inaugural lectures, undergraduate and postgraduate theses, as well as reports from organizations and national environmental agencies that are not published in traditional commercial channels and therefore not indexed in electronic databases were also consulted.

Classification of micro-plastics

Base on size plastics are classified as: macroplastics (>200 mm), mesoplastics (5–20 mm), large micro-plastics (1–5 mm), small micro-plastics (1µm –1000 µm), and nanoplastics (<1µm) (Kershaw, 2015; SCCWRP, 2021). Small and large micro-plastics have different environmental behaviors. However, scientific reports have consistently grouped and small and large micro-plastics (1µm–5mm) together. Micro-plastics are typically classified as primary or secondary micro-plastics (Hanvey *et al.,* 2017).

Primary micro-plastics are intentionally manufactured for domestic, industrial applications, and personal care purposes (Gore and Kandasubramanian, 2018; Kumar *et al.,* 2020; Sun *et al*., 2020a). Secondary micro-plastics are derived from deteriorated and fragmented processes such as oxidation, abrasion, photodegradation, and environmental collision of secondary plastics, resulting in <5 mm diameter micro-plastics with relatively lightweight (Kalogerakis *et al*., 2017). Other classifications of micro-plastics are based on their physical properties such as size, origin, polymer, and shape, highlighting their ubiquitous presence in the environment (Table 1) (He *et al*., 2020; Samandra *et al*., 2022).

Table 1: Summary of the characteristics and properties of plastic

Properties	**Description**	**References**
Classification	Plastics are a heterogeneous group of waste constituting significant volumes in the environment with different descriptors. Currently, there is little or no universal system for the classification of plastics. However, plastics are classified based on size, form, polymer types, color, and origin. With little emphasis on density	Wagner *et al.,* 2014.
Size	The following size classification systems are used to classify plastics viz: megaplastics (> 1m), macroplastics (<1m), mesoplastics (<2.5 cm), micro-plastics (<5 mm), and nanoplastics (<0.1 mm).	Lusher *et al.,* 2017a; Chatterjee and Sharma, 2019.
Origin	Primary and secondary plastics are the two major categories of micro-plastics. Primary micro-plastics are formed from resin pellets (plastic raw materials). Secondary micro-plastics result from the action of UV radiation, photo-oxidation, and physical and mechanical abrasion breaking down bigger polymers into smaller particles.	Lusher *et al.,* 2017a).
Polymers	The most common polymers found in the atmosphere are polypropylene (PP), polyethylene terephthalate (PET), high- and low-density polyethylene (HD / LD-PE), polystyrene (PS), and polyvinyl chloride (PVC). Also, polyamide (nylon) fibers from fishing gear are popular.	GESAMP, 2015.
Shape	Fragments (irregularly formed particles, crystals, fluff, powder, granules, shavings, flakes, films), fibers (filaments, microfibers, loops, threads), beads (grains, spherical microbeads, microspheres), foams (polystyrene, expanded polystyrene), and pellet (pellets of resin, nutrients, pellets of pre-production) are main plastic shapes.	Lusher *et al.,* 2017b.

Density	Occurrence and availability of micro-plastics in the water column are directly related to their density. Lower-density plastic such as polyethylene can easily develop biofilm within a few weeks and drain on the ocean surface.	Lobelle and Cunliffe,2011

(Adapted from He *et al.,* 2020; Samandra *et al*., 2022)

Major Sources of micro-plastics and the Role of Covid-19

The major sources of micro-plastics are plastic particles in the aquatic environment includes microbeads used in cosmetics making (Anderson *et al*., 2016), ship-breaking industry (Reddy *et al*., 2006), fertilizers (Katsumi *et al*., 2021, 2022, 2023) and indiscriminate disposal of waste and plastic materials. The degradation of larger plastics, such as plastic bags and containers also increases the plastic load in the aquatic environment (Gesamp 2016; Song *et al*., 2017).

Other primary sources of micro-plastics entering into the environment are cylindrical beads used in sewage treatments, clothes fibers, pharmaceutical products, facial scrubs, and cosmetic products. Additionally, the breakdown of large plastic materials like rubber, chairs, and nylon bags, as well as the wearing of tyres, contributes to significant amount of micro-plastic load in the environment (Napper and Thompson, 2016). Activities such as transport, shipping, construction, demolition, agriculture, and hospital waste disposal also contribute to the presence of micro-plastics in the aquatic environment (Figure 2).

The emergence of COVID-19 significantly increased the presence of micro-plastics in the environment. This global health crisis posed severe social, economic, and environmental threats (Martín *et al*., 2022). To control the spread of the virus, governments worldwide implemented preventive measures including social distancing, lockdowns, and the widespread use of personal protective equipment (PPE) such as gloves, masks, and hand sanitizers. The increased use of plastic to combat the pandemic led to a surge in micro-plastic due to the heightened disposal of single-use facemasks and gloves, coupled with inefficient waste management practices in many countries (Zambrano-Monserrate *et al*., 2020).

However, the increased production of medical waste and PPE to address the pandemic led to a rise in plastic waste accumulation in the environment (Abu Qdais *et al*., 2020; Zambrano-Monserrate *et al*., 2020). The environmental threats posed by plastic pollution were overshadowed by the focus on the public health consequences of the pandemic. Meanwhile, this adverse effects could have long-term ecological consequences.

By 2020, the improper disposal of face masks alone resulted in an estimated 0.15–0.39 million tons of plastic pollution worldwide (Chowdhury *et al*., 2021). Peng *et al*., (2021a) estimated 8.4 ± 1.4 million tons of plastic waste associated with the COVID-19 pandemic globally, with 12,000 tons being micro-plastics. Reports of plastic pollution from personal protective equipment have surfaced in various parts of the world, including Peru (De-la-Torre *et al*., 2021), Kenya (Okuku *et al*., 2022), and Canada (Prata *et al*., 2020). Consequently, plastic pollution resulting from COVID-19 has led to an increased micro-plastic load in the aquatic ecosystem which significantly impacting both health and aesthetic values of the aquatic ecosystem.

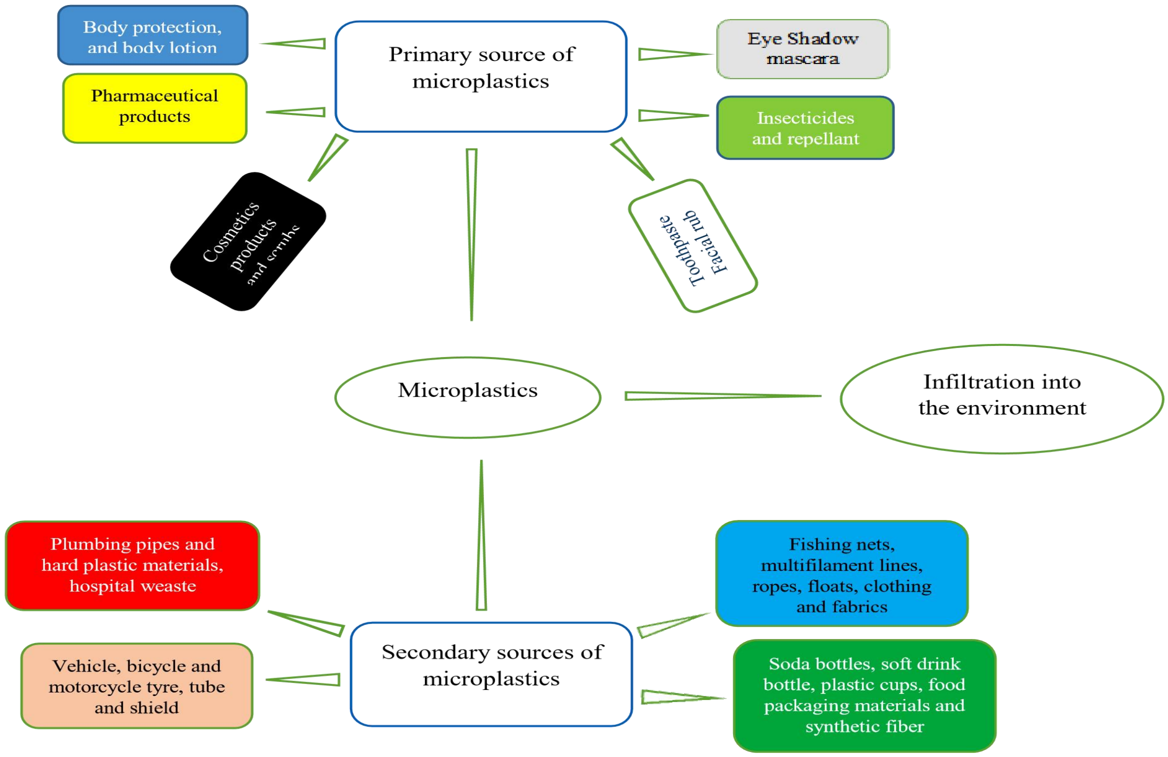

Figure 2: Sources of micro-plastics in the aquatic environment

Distribution of Micro-Plastics in Aquatic Environments

When plastic debris enters the environment, it breaks down, generating micro-plastics. These micro-plastics are carried into larger water bodies through streams, rivers, storm water and wastewater discharges, littering and disposal along shorelines, wind action, and weathering events (U.S. EPA, 2016). The size, weight, density and shape of plastics determine how far micro-plastics travel in the environment. Lightweight plastic products and particles such as bags, films, clothing fibers, pellets, and plastic bottles are transported at greater distances by wind, storm water, effluent discharges, and inputs from freshwater systems, compared to more dense and larger plastic items (U.S. EPA, 2016).

Effluents from wastewater discharges are significant transport mechanisms for primary and secondary micro-plastic particles. Dris *et al.,* (2016) reported an average of one polyester, acrylic, or polyamide fiber per liter of effluent from two Australian wastewater treatment plants. Research is yet to be conducted on airborne plastic fibers released from residential and commercial clothes dryers, which contribute a significant amount of micro-plastic to the environment. The transport and distribution of micro-plastics (MP) in different environmental compartments enhance their occurrence in extreme regions of the world, such as high mountain ranges, deep-sea, and the Polar Regions (Kukkola *et al*., 2022).

Natural phenomena such as ocean currents and ocean gyres play a significant role in conveying micro-plastics to enclosed basins in the aquatic ecosystem (Collignon *et al*., 2012). The distribution of micro-plastics in rivers, estuaries, and open water areas mirrors the patterns of sediment deposition (Sutton *et al.*, 2016; Wessel *et al*., 2016).

The spatial distribution and environmental fate of micro-plastics in the aquatic environment are strongly influenced by their transport, dispersal, potential deposition, and storage along river networks (de Carvalho *et al*., 2021; Margenat *et al*., 2021). However, in the hyporheic zone, flow conditions and river discharge also directly impact micro-plastic deposit, behaviour, residence time, and distribution (Drummond *et al*., 2020). Knowledge of the hydrological regime, characteristic rate, and transport patterns of micro-plastics in the respective river systems is currently limited (Campanale *et al*., 2020). The general model for existing large-scale plastic transport assumes a downstream convergence of particle fluxes along the river network (Barbarossa et al., 2020).

The distribution of plastic and micro-plastics in oceans and great lakes is also influenced by extreme phenomena such as floods, tsunamis, hurricanes, and tornadoes (Barnes *et al*., 2009). In Japan in 2011, a

9.0 magnitude earthquake off the coast of a highly urbanized region caused a tsunami that transported an estimated 5 million tons of debris, including plastics, into the marine environment (NOAA, 2015b). Data obtained about the world's oceans in 2012 indicated that plastic debris is expected to be transported through the North Pacific Current and California Current before looping back towards the Hawaiian Islands and eventually accumulating in the North Pacific Gyre (Bagulayan *et al*., 2012).

The movement and distribution of fishing nets and floats, as well as other tsunami debris, has been reported along the coast of Alaska, British Columbia, Washington, Oregon, and Hawaii (NOAA, 2013). In the tropics, extreme rainfall and wind circulation facilitate the transport and distribution of plastics and micro-plastics from land to the aquatic environment. Additionally, poor waste management strategies, indiscriminate waste disposal and lack of environmental awareness contribute to the presence of substantial amount of plastics and micro-plastics in the aquatic environment.

The impact of Micro-Plastics on Important Marine Life

Plastic pollution in aquatic ecosystems hurts aquatic organisms. These organisms often ingest micro-plastic particles and are exposed to additives that leach into the environment. While human exposure to micro-plastics is inevitable, the associated health implications are not well understood. micro-plastic particles are primarily ingested by ecologically vulnerable species in various environments such as beaches, aquaculture, estuaries, sea surfaces, water columns, benthos, and deep waters (Figure 3). (Lusher 2015; GESAMP 2016; Amoatey and Baawain, 2019; Pereao *et al*., 2020; Taylor *et al*., 2016).

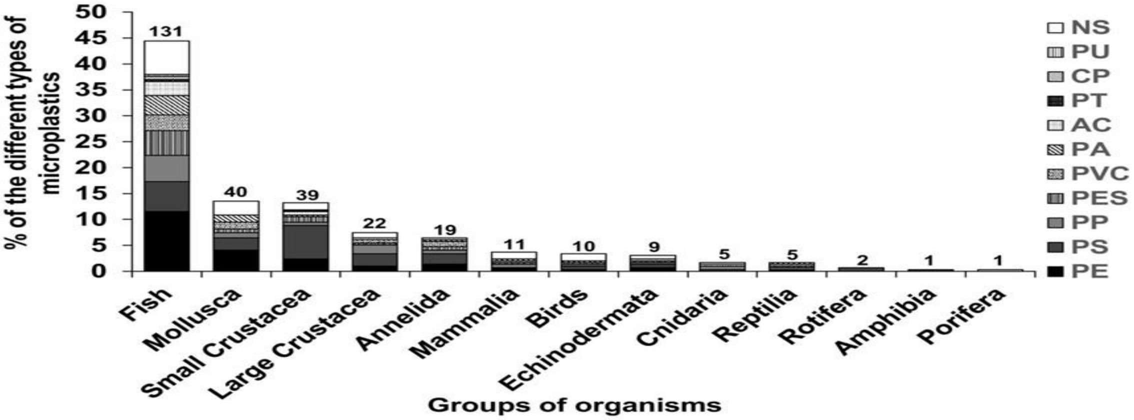

Figure 3: Fraction of plastic ingestion by different types of aquatic organisms. Each bar indicates the total number of different studies. Each study was based on the micro-plastics and the number of individuals per group of organisms. Plastic types encountered include NS-Not specified; PU-Polyurethane; CP-Cellophane; PT Polyether; AC-Acrylic; PA-Polyamide; PVC-Polyvinylchloride; PES-Polyester; PP-Polypropylene; PS-Polystyrene; PEPolyethylene (adapted from de Sá *et al.,* 2018)

More than 220 animal species globally have been reported to consume micro-plastic particles (GESAMP, 2016; UNEP, 2016). Understanding the ecological consequences of micro-plastic interactions in different flora and fauna is crucial. Interactions of micro-plastic particles with environmental variables, including pollutants and contamination, may have adverse effects on long-lived organisms at various stages of development (Ferreira *et al*., 2016; Wang *et al*., 2020b).

Reports have shown the presence of micro-plastics in marine mammals and sea birds, which are relevant to the ecosystem and humans. Many bird species, including those consumed by humans (seabirds), have been found to contain a significant number of micro-plastics in their digestive tracts (Van Franeker *et al*., 2011; Roman *et al*., 2019; Basto *et al*., 2019). Additionally, ingestion of micro-plastic particles has been reported in marine mammals such as baleen whales, *Mesoplodon mirus* (Lusher *et al*., 2015a), beaked whales, *Megaptera nevaeangliae* (Besseling *et al.,* 2015a), and seal stomachs *Phoca vitulina* (Bravo Rebolledo *et al.,* 2013). In marine animals, micro-plastics may be ingested by feeding on aquaculture materials or by consuming micro-plastic contaminated prey (Fossi *et al.,* 2016; Baini *et al.,* 2017; Lavers *et al.,* 2019; Kuhn and van Franeker, 2020).

Exposure to micro-plastic particles has been studied in bivalve species. Reports from the Minch and Orkney Islands in the North Sea using lobster revealed an increased quantity of plastics in the heavily damaged Clyde Sea area (Murray and Cowie, 2011; Welden and Cowie, 2016a), followed by common shrimp (*Crangon crangon*), and decapod crustacean samples (Devriese *et al.,* 2015). Blue Mussels from wild and farm sources (Li *et al.,* 2016; Van Cauwenberghe and Janssen, 2014), Pacific cup oysters from the coastal waters of the Atlantic Ocean (van Cauwenberghe and Janssen, 2014), Chinese mitten crab (*Eriocheir sinensis*) from coastal waters of the Baltic Sea (Wjcik-Fudalewska *et al.,* 2016), brown mussel (*Perna perna*) from the Santos Estuary of Brazil (Santana *et al.,* 2016), and

Manila clams (*Venerupis philippinarum*) from wild and farm sources (Davidson and Dudas, 2016) have all been reported to contain micro-plastic particles in their gut, enabling the transfer of chemical additives to the exposed organisms. Similarly, high occurrences of micro-plastics have been reported in the gastrointestinal tracts of small bivalves in Asian markets (Li *et al.,* 2015).

Micro-plastic particles have been found in both pelagic and benthic commercial fish in various regions worldwide, including the North Sea (Foekema *et al.,* 2013; Rummel *et al.,* 2016b), the North-Eastern Atlantic (Neves *et al.,* 2015), the English Channel (Lusher *et al.,* 2013), the Baltic Sea (Rummel *et al.,* 2016b), the Indian Ocean (Robin *et al.,* 2020), the Indo-Pacific Ocean (Rochman *et al.,* 2015; Jabeen *et al.,* 2016), the Adriatic Sea (Avio *et al.,* 2015b), and the Mediterranean Sea (Bellas *et al.,* 2016; Guven *et al.,* 2017). In China, fish purchased from markets in Shanghai have been reported to contain micro-plastics from Indonesian waters (Rochman *et al.,* 2015; Jabeen *et al.,* 2016).

In Africa, micro-plastic particles have been reported in the digestive systems of market-purchased freshwater fish, including Nile Tilapia (*Oreochromis niloticus*) and Nile Perch (*Lates niloticus*) from Lake Victoria (Tanzania). Recently, micro-plastic particles have been discovered in the digestive tracts of commercially valuable species of wild fish larvae from the English Channel (Steer *et al.,* 2017). While it is evident that many commercial fish consume micro-plastics, information on the trophic transfer of micro-plastics chemical additives to humans and their toxicity is limited. This necessitate further research on human consumption of micro-plastics from contaminated food and water.

Micro-plastics additives, Function/role and toxicity

The toxicity of micro-plastics and their additives on aquatic organisms is detailed in (Table 2).

Table 2: Micro-plastic additives, Functions in micro-plastics, and toxic response in organisms

Additives	Function/Role	Toxic response	Reference
UV Stabilizers/absorbers	Inhibits photodegradation	Mutagenic, and estrogenic effects	Hammer *et al.,* 2012
Surfactants	Change of surface properties	Destroy mucus layer, damage gills	Rani *et al.,* 2015
Flame retardants	Weaken flammability	Endocrine disruptors	Fred-Ahmadu *et al.,* 2020
Pigments	Color	Duplication of food resulting in gut blockage	Hammer *et al.,* 2012
Antioxidants	Delay oxidation prevents aging	Estrogenic effects	Hermabessiere *et al.,* 2017
Plasticizers	Make material pliable	Renal, reproductive, cardio/neuro-toxicity	Rowdhwal and Chen, 2018

(Adapted from Merlin and Balasubramanian, 2021).

Research on the toxicity of micro-plastics are primarily conducted in laboratory settings. These does not represent real environmental exposure scenarios. Plastic additives can lead to oxidative stress, gastrointestinal obstruction, translocation, and trophic transfer in the aquatic food web (Gall and Thompson, 2015). The endocrine-disrupting effects of

Bisphenol-A and phthalates are frequently studied, while the health impacts of other plastic additives/mixtures are less understood.

A 24-hour batched and 3-day diffusion test with water fleas (Daphnia) demonstrated the toxicity of chemicals desorbed from 32 plastic products (Lithner *et al.,* 2009). The study found that Daphnia was most affected by silver from a compact recordable disc, followed by leachate from plasticized PVC products and polyurethane items. EC_{50} values of 5-80 g for 48-hour toxicity testing were recorded for nine tested plastic products, while leachate from other plastic products did not show toxicity in Daphnia. This variation may be due to exposure duration, plastic-type, and the specific organism.

Browne *et al*. (2013) reported that Nonylphenol, phenanthrene, and PBDE-47 additives of PVC can transfer to lugworm tissues after micro-plastic ingestion. Toxic responses due to the ingestion of these compounds include altered feeding, immunotoxicity, and reduced antioxidant activity. Higher concentrations of polystyrene micro-plastics in sediment can result in weight loss in sediment-dwelling organisms in the aquatic ecosystem, such as *Amphidinium marina* (Besseling *et al.,* 2013).

In a 7-day study, *Mytilus gallaprovincialis* were fed polyethylene and polystyrene micro-plastics with and without adsorbed pyrene. The study found increased pyrene accumulation in the mussels' gills and digestive glands at concentrations higher than in the contaminated micro-plastics (Avio *et al.,* 2015). The effects reported in this study were not influenced by the type of polymer or contamination except for genotoxicity. Increased frequency of micronuclei was recorded after exposure to pyrene-contaminated polystyrene. Pyrene-contaminated plastics could pose a potential risk to the mussels with long-term, chronic exposure (Avio *et al.,* 2015).

Paul-Pont *et al.* (2016) showed that micro-plastics amended with fluoranthene did not change fluoranthene bioaccumulation in marine mussels, but continuous exposure to micro-plastics led to increased hemocyte mortality, oxidative stress, and poor energetic utilization in mussels, complex tissue alterations, and low antioxidant. Biochemical, cellular biomarkers, and behavioural analysis of micro-plastic ingestion in fish revealed altered immunological responses, lysosomal membrane stability, peroxisomal proliferation, antioxidant response, neurotoxic effects, genotoxicity, tissue damage, and behavioral changes. Others include slow swimming rate, DNA damage, intestinal damage, disruptive digestion, and inflammation in aquatic organisms (Figure 4) (Bhuyan, 2022).

The accumulative effect and toxicological consequences of PCBs and PBDEs in fish can be transferred via trophic interactions between fish, higher predators, and man (Rochman *et al.,* 2013a). PBDEs and PCBs bioaccumulation in fish can induce liver toxicity such as glycogen depletion, fatty vacuolation, single cell necrosis, down-regulation of chorionic in male fish, down-regulation of vitellogenin, choriogenin, and estrogen receptor in female fish which affect population growth, survival, and reproduction (Rochman *et al.,* 2013a; Ziccardi *et al.,* 2016).

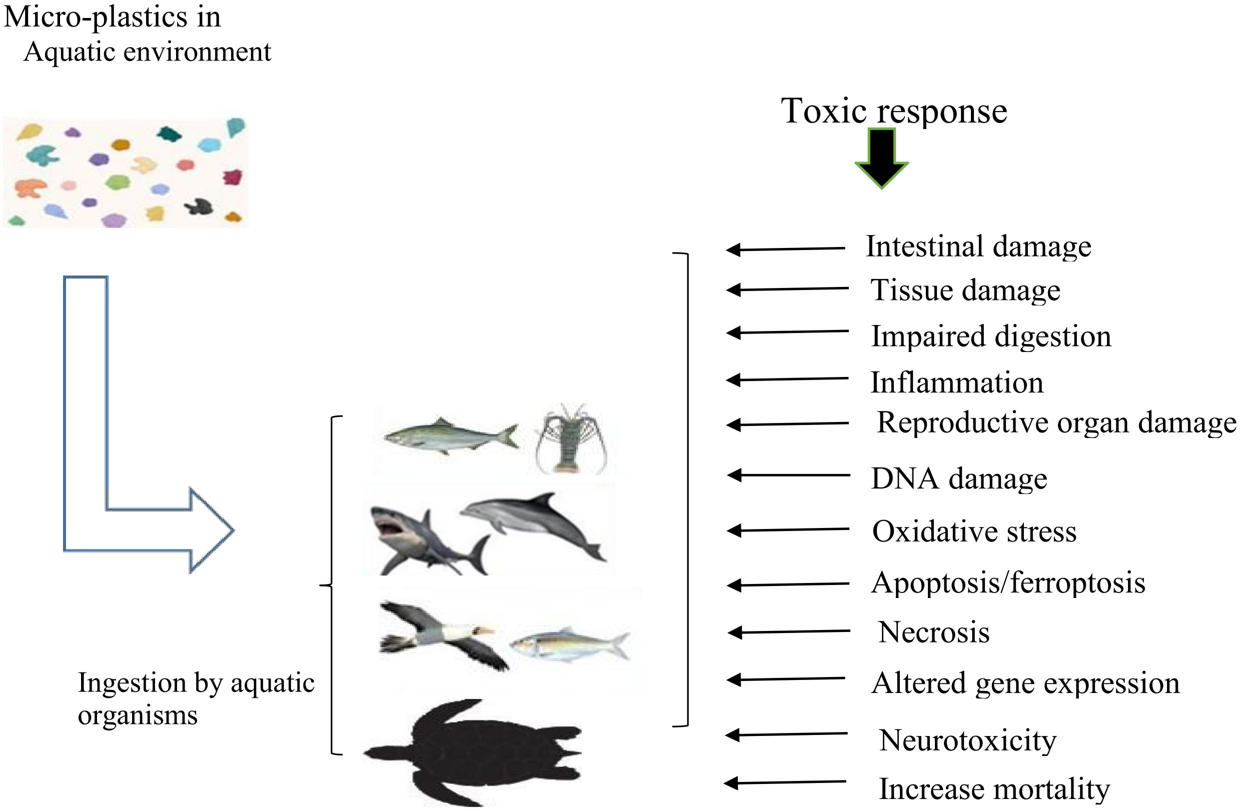

Figure 4: Summary of the possible toxic effect of exposure to micro-plastics in aquatic organisms.

Mitigation Approach to Cope with Micro-Plastic Pollution

Mitigation strategies to reduce plastic and micro-plastic pollution require comprehensive interventions across various levels of government to establish effective waste management programs (Raubenheimer and Urho, 2020). Government policies and regulations should prioritize maximum enforcement, compliance, collection, sorting, treatment, and prevention of plastic pollution in the environment. Process efficiency, transparency, innovation, and environmental protection should be fundamental considerations (Basel Convention, 2013).

Understanding the sources and pathways through which plastics and micro-plastics enter the aquatic environment necessitates proper monitoring plans and techniques. This will provide valuable knowledge for the improved design of national policies through an evidence-based approach, as well as for evaluating the effectiveness of existing policy and regulatory frameworks (Basel Convention, 2013).

Waste management plans focused on prevention, minimization, reuse, recycling, and recovery, including energy recovery, and final disposal should be integral components of national policies to address ongoing plastics and micro-plastic pollution (CIEL 2019a, and b). Additional policies aimed at implementing waste management should work to reduce pollution from chemical additives used in the production of plastic materials.

Designing eco-friendly and biodegradable plastic products is a vital aspect of effective plastic waste management (Basel Convention, 2019b). Products intended for reuse, repair, and recycling will aid in mitigating plastic pollution (OECD, 2018). Encouraging the collection and diversion of plastic waste from incineration or landfills is essential (EU, 2009).

Harmful plastic products, derived from materials with severe health and environmental consequences, should be removed from domestic markets (Raubenheimer and Urho, 2020). Voluntary phase-outs with industry or outright bans are crucial. Alternatives to microbeads in cosmetics, plastic bags, and other problematic single-use plastic products demand significant attention from the general public and government (Ocean Conservancy, 2019) (Figure 5).

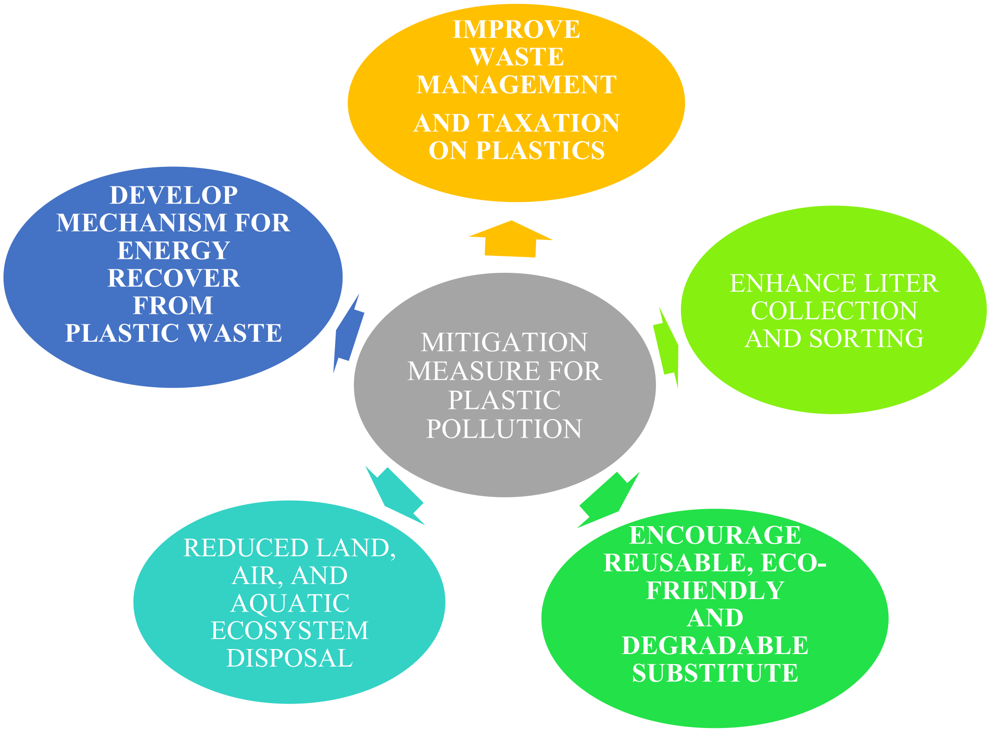

Figure 5: Schematic representation of the summary of the approach for mitigating micro-plastics

Reduction in per capita consumption through product taxes on plastics should be commonly applied to producers of plastic and micro-plastic products, and to consumers at the point of sale. The resulting increase in product price can discourage plastic purchases, thereby reducing consumption (Nielsen *et al.,* 2019; Thomas *et al.,* 2019). Ecological taxes on products that do not adhere to eco-friendly design principles and the relatively lower tax rate for products that are more manageable at end-of-life would encourage producers to redesign products that meet the lower tax criteria to save costs (OECD, 2019b).

Further Research

Noxious chemicals components in plastics and micro-plastic debris poses serious health and environmental risks. Processes such as chemical exchange kinetics under conditions of weathering, degradation, and biofilm formation are not well understood (Koelmans *et al.,* 2015). However, there is a research need to expand current knowledge regarding the impact of chemical additives in plastics under different environmental conditions after ingestion (U.S. EPA 2016). Evidence from laboratory experiments and modelling techniques had confirms the transfer of toxic chemicals from plastic and micro-plastics to organisms. However, environmental occurrence and biota-accumulation of similar classes of chemical compounds from other sources make it difficult to predict such transfer.

Little is known about nanoplastics when compared to other plastic sizes and classes. This is due to the lack of detection techniques for nanoplastics analysis. However, due to the relatively low surface area of nanoplastics, research to investigate the higher concentrations per unit weight than micro-plastics is needed in this area. It is also important to note that nanoplastics may also have additional impacts and potentially long retention times if these particles can cross tissue and cellular membranes, thereby increasing the risk of contamination in exposed organisms (Koelmans *et al.,* 2015).

Systematic mechanisms derived from scientific studies and research can be used to address the issue of plastic pollution. Currently, there is a knowledge gap in some aspects of plastic pollution such as sources, transport, fate, impacts, and solutions to plastic in the environment. Technical and scientific evidence to adequately understand aspects of plastic pollution would provide a clear snapshot and guidance to stakeholders (e.g., local community, policymakers, politicians, manufacturers, and consumers) to implement behavioural, technological, and policy solutions to properly address the issue of micro-plastics in the aquatic ecosystem (IUCN, 2020).

CONCLUSION

Microplastics are tiny plastic particles <5mm present in nearly all environmental settings, significantly impacting the aquatic ecosystem. Aquatic organisms ingest these particles due to their small size, shape, and color, leading to their detection in the tissues, brain, and circulatory systems of these organisms. The potential risk to aquatic life depends on the extent of ingestion, the type of microplastics, and their chemical composition. Chemicals used in plastic production vary among industries and types of plastics. The accumulation of plastics and microplastics in aquatic environments diminishes the recreational, aesthetic, and heritage value of the environment. To address microplastic pollution, collaborative efforts from the general public, socio-economic sectors, tourism, and industries are crucial. Remediation of contaminated environments using eco-friendly methods is essential to mitigate the impact of microplastics on the aquatic ecosystem and its organisms.

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