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PRESENCE OF MICROPLASTICS AND ORGANIC POLLUTANTS IN BANGLADESH'S FRESHWATER ENVIRONMENT: A REVIEW

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ABSTRACT

Water pollution is an alarming concern in developing nations like Bangladesh, where the majority of people rely on water resources both directly and indirectly. Microplastics (MP) and organic pollutants (OP) have a synergistic effect on the aquatic ecosystem due to the bioaccumulation process. The purpose of this review is to determine the most influential aspects of MP and organic pollutants on freshwater environments, which serve as sites of accumulation and habitat for biota, which are important components of food webs and play a critical role in resource management, but are still underplayed. Debris in the environment and improper waste management have harmed ecosystems all over the world. Because MP plays the role of a vector for carrying organic pollutants towards the aquatic environment. These pose a global danger due to their extensive distribution in aquatic habitats and the possible consequences of their ecotoxicological impacts. The study is based on a global critical evaluation of current literature that included 40 research articles, as well as 24 global viewpoints and 16 Bangladesh perspectives (freshwater 2, marine 8, review 4, and other 2 papers). The result showed that very few research has been conducted in Bangladesh and there is no different from the rest of the world. However, there has been a tiny but continuous effort to quantify the amount of MP and OP's garbage and its repercussions. It has been observed that a high amount of old plastic and organic pollutants is mistreated in Bangladesh, posing a serious environmental and human health risk. Empirical researches have been conducted to determine the presence and effects of MPs and OPs in the marine environment. On the other hand, the presence of MPs combined pollution of organic pollutants in freshwater environments is still underexplored, making data reclamation difficult. However, the study's aim is to inspire researchers to conduct in-depth investigations into plastic pollution along with organic pollutants in freshwater system in Bangladesh.

Keywords: Microplastic, Freshwater, Environment, Eco-toxicological, Organic pollutants

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INTRODUCTION

Bangladesh is nature's gift, containing some of the most diversified and extensive inland and marine fisheries resources, such as ponds, lakes, rivers, borrow pits, haors, floodplains, oxbow lakes, estuaries, coastal belts, and vast sea waters. Among them, most of the water bodies are suitable for the production of fisheries organisms. The ponderosity of fisheries resources is unlimited and uncountable for our country because fish culture is now pondering and contemplating as one of the most fascinating and popular practices throughout the world. Bangladesh is one of the abounding countries in the world in terms of having good fisheries resources, blessed with a magnificent magnitude of diversified fauna. It is a floodplain country with approximately 700 small, medium, and large rivers, as well as three key waterways, such as the Meghna, Ganges, and Brahmaputra, that arise in the Himalayas, span the country, and then combine before draining into the Bay of Bengal. Bangladesh's rivers stretch for nearly 24,000 kilometers, accounting for nearly 6% of the country's total land. Aside from rivers, natural wetlands such as canals, beels, haors, baors, mangrove swamps, and for 5–6 months of the year, places that flood seasonally abound. Water quality has recently become one of the most significant emerging countries' environmental issues, with Bangladeshi water pollution reaching an all-time high. Bangladesh's water quality may have deteriorated as a consequence of the high rate of population growth, industrialization, rapid urbanization, poor sanitation, and usage of agrochemicals. The MP is of particular concern because their bio-concentration potential increases as their size is reduced. MP is swallowed by a variety of organisms, including plankton, fish, birds, and even mammals, and accumulates in the aquatic system (Wright et al., 2013). As a result, these compounds may be consumed by animals, and MP can deed as a vector for a variety of other organic contaminants (Zarfl and Mathies, 2010), exposing wildlife to chemicals (Oehlmann et al., 2009; Teuten et al., 2009). MP concentrations have been exposed in rivers (Klein et al., 2015; Lechner et al., 2014), lakes (Blettler et al., 2017; Fischer et al., 2016), estuaries (Peng et al., 2017), wastewater treatment facilities (Blettler et al., 2017; Fischer et al., 2016), and sediments (Blettler et al., 2017; Fischer et al., 2016), and sediment (Peng et al., 2017). Under some situations, larger plastic items decompose into MPs (Wagner et al., 2014), or segments and sub elements are openly injected into the ecosystem (Napper et al., 2015). Aquatic organisms have the ability to eat microplastics due to their tiny size, motility, and broad availability (Lusher et al., 2013; Ory et al., 2017). In research, MP consumption by wild freshwater creatures such as annelids, mollusks, crustaceans, fish, birds, and mammals has been recorded (Beaumont et al., 2019; P. Li et al., 2020; Woods et al., 2020). As a consequence, concern regarding the impact of MPs on freshwater and marine

environments are valid, and further research is needed (Blettler and Wantzen, 2019; C. Li et al., 2020). Plastic pollution is an increasing issue in Bangladesh, particularly considering the government's earlier detection of the problem, which led to Bangladesh became the first country on the earth to prohibit the use of plastic bags in 2002 (Giacovelli, 2018). The plastics company has flourished in importance in Bangladesh during the last few centuries (Afrooz, 2016). Because the development of the plastics industry has a multiplicative effect on a number of critical sectors of the country's economic condition, the government of Bangladesh offered this industry a high priority (Hossain, 2016). Despite its opportunities for development and export, the plastics industry faces a number of obstacles, including waste minimization and the industry's poor image in the eyes of the public (Islam, 2011).

Plastic pollution's impact is growing concern for the environment which increases research interest for governments, corporations, and the general public, and it's attracting a huge amount of attention around the world (Nielsen et al., 2020). Nevertheless, according to the most recent research, significant amounts of plastic waste will continue to affect the sea, freshwater, and terrestrial environments unless immediate and extreme action is taken (Borrelle et al., 2020; Lau et al., 2020). The quantity of plastic rubbish is strongly influenced by socioeconomic position (Hardesty et al., 2017). Due to greater consumption, richer nations produce more community trash than developing nations (Lynn et al., 2016). However, freshwater systems are an extremely important focus of research. Coastal plastic emissions are predicted to be between 2.8 and 18.6%.

The river serves as a transporter of land-based plastic pollutants to the sea. The Ganges River is the second largest contributor of MP pollution. It is essential to point out that detailed information about the origin, fate, movement, and critical things of MP and organic pollutants in the freshwater environment is essential for existing research needs.

Although Bangladesh has been identified as a globally important country in the microplastic pollution disaster, this article detects a severe gap in information, awareness, and ability to identify and manage this vital public health and environmental issue. In this paper, we investigated all relevant research articles on microplastic contamination and organic pollutants in Bangladesh and their effects on the freshwater ecosystem, as well as identified the critical study areas for future perspectives.

METHODOLOGY

Study area

Bangladesh situated between the 20º34′ and 26º38′ latitude in the north and 88º01′ and 92º41′ longitudes in the east. The north, northeast and west part are surrounded by India and southeast part by Myanmar and south part by Bay of Bengal. The country has a total area of 147,570 square kilometers (Ahmed and Roy, 2007). It is low line floodplain originated by the three major river system the Ganges, Meghna and Brahmaputra, covers the majority of the land surface. These rivers drain 1.72 million km^2 of land in India, Nepal, China, Bhutan, and Bangladesh, with Bangladesh accounting for only 8% of the catchment area. As indicated in Figure 1, the headwaters of these main rivers and their tributaries are located outside of Bangladesh, and nearly 90% of their annual flow originates there. There are around 700 rivers in the country, with a total length of 22155 kilometers. Bangladesh's river system is depicted in the diagram (Figure 1), and about 5% of the land surface is covered by rivers and water bodies (Ahmed and Roy, 2007).

Information compilation by search

We used a variety of search engines to locate all accessible scientific literature on water pollution, namely heavy metals, feces pollution, pesticides, and emerging contaminants in Bangladesh's freshwater ecosystem, as well as the health effects of such pollutants in water. The Google search engine and Google Scholar were searching for scientific publications. The key search terms were "water pollution" or "water quality" or "organic pollutants" or "microplastics effects" or "pesticide pollution in water" or "freshwater ecosystem" and "Bangladesh". For this study, different published documents were identified from 2005 to 2022 for review. Moreover, we also looked for scientific reports, because there were so few journal papers published during this time period.

Publication categorization steps

The selected journal articles were in detail examined in order to eliminate duplicate and unwanted publications that were unrelated to the main study. After examination, 40 relevant journal articles were found and reviewed for the present study. The flow diagram (Figure 2) shows the separation procedure of the publications used for this review.

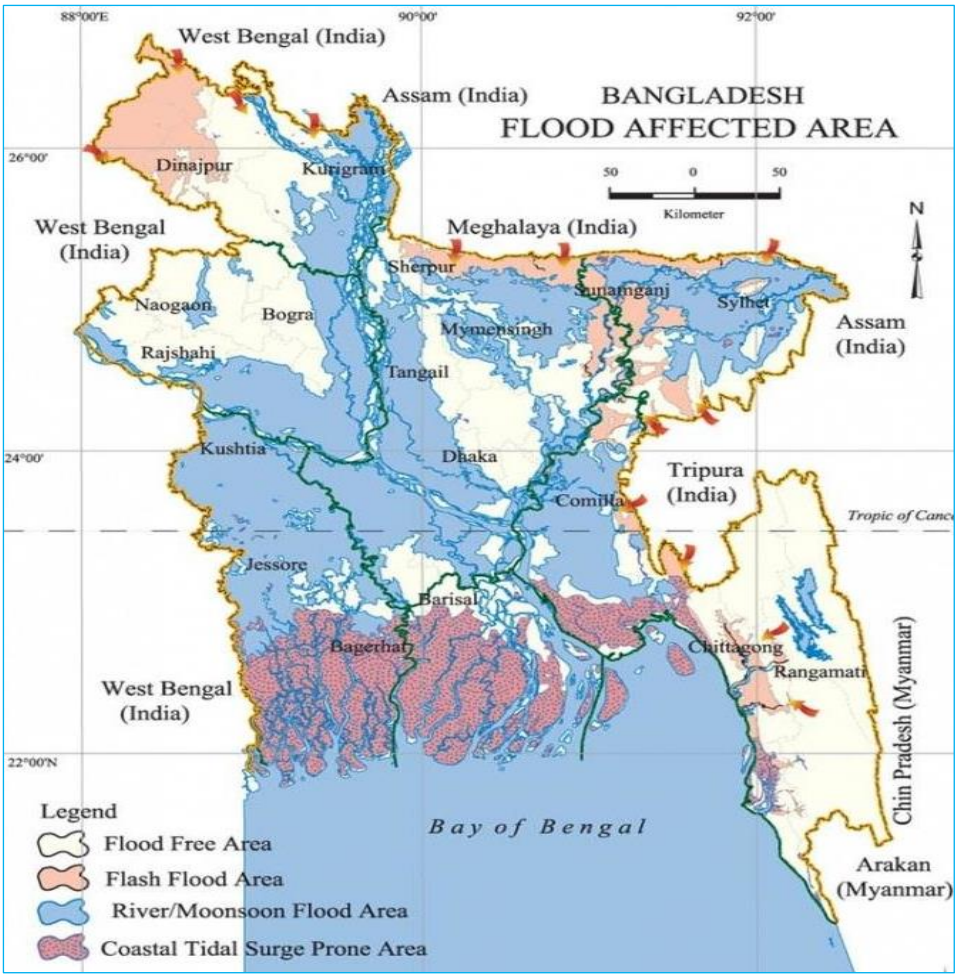

Figure 1. Map showing the freshwater area in Bangladesh (www.researchgate.net)

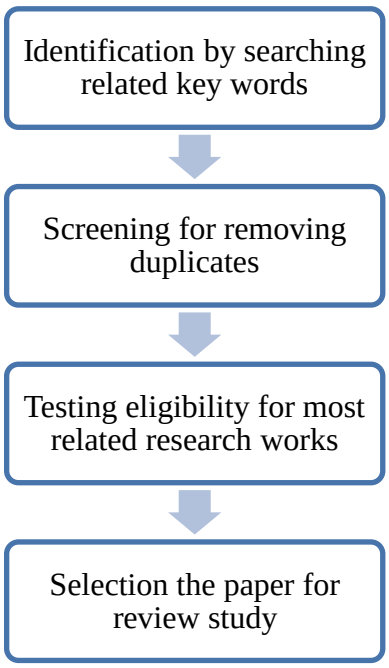

Figure 2. Flow diagram of the reliable publications identification

RESULT AND DISCUSSION

Microplastic in water environment

Microplastics (MPs) are incredibly minute plastic particles that damage the environment. According to the NOAA (National Oceanic and Atmospheric Administration), the word "microplastic" refers to plastic particles with a diameter of less than 5 mm. Scientists first discovered microscopic plastic fragments in the water in the early 1970s. Many researchers have investigated the potential consequences linked to what we now refer to as "microplastics" since then. Microplastic waste in aquatic habitats is currently regarded as one of the world's most significant pollution issues. Microplastics are classified either as principal or secondary depending on how they have been made. Small plastic particles discharged directly or indirectly into the environment, including through home, industrial, spills, and sewage discharge, are known as primary MPs (e.g., via run-off). For usage in personal care goods or industrial applications, primary microplastic particles are purposefully created in sizes of less than 5 mm. Microbeads made of plastic have become ubiquitous in consumer items like toothpaste, body washes, and facial cleansers. It was found that in the environment, larger particles of plastic already exist, which progressively degrade and fragment due to circumstances by biodegradation, UV radiation, and chemical changes with the help of microbes (Cole et al., 2011). Microplastics are further formed into nanoplastics in the environment, which have mainly unknown fates and toxicological qualities when compared to other types of plastic litter (da Costa et al., 2016). Researchers found that secondary MPs are thought to be the most significant source of microplastic contamination in aquatic settings (Eriksen et al., 2013), with a continuing intake of plastic garbage from various sources. Different types of MPs are found in varied densities, such as irregular, film, fibre, and sphere. It was also noted by the researchers that the microplastics contain large surface areas and chemical sites. That is why they have the ability to combine other pollutants like waterborne metals (Ashton et al., 2010) and persistent, bioaccumulative, and toxic compounds (PBTs) (Koelmans et al., 2013). Engler (2012) conducted a research on the relation between plastic debris and PBTs (e.g., PCBs and DDT), and other studies on polycyclic aromatic hydrocarbons (PAHs) are available (Antunes et al., 2013; Bakir et al., 2014).

Occurrence of organic pollutants

Organic pollutants are often known as carbon pollution which is generated by different organic carbon containing matter such as sewage, treatment sludge and liquid manure etc. When

organic pollutants exceed permitted levels, they can cause a variety of disorders in humans. Persistent organic pollutants (POPs), sometimes known as "forever chemicals," because these organic matter are resistant they are unable to breakdown into the environment due to their biological, chemical and sometimes photolytic process. The chemical compounds found unbreakable, persistent in the environment, bioaccumulating in the food chain or food web and causing potential effects on the human body are called POPs. Pesticides (such as DDT), industrial chemicals (such as polychlorinated biphenyls, PCBs), and unintended by-products of industrial operations make up this category of priority pollutants (such as dioxins and furans). Persistent Organic Pollutants (POPs) are transferred across international borders, even to locations where they have never been used or manufactured. Organic pollutants in water can cause harmful compounds to form during disinfection.

Other major pollutants, such as medicines and endocrine-disrupting chemicals, are, nonetheless, understudied (EDCs). MP has been shown to contain nonylphenol and bisphenol A (Fries and Zarfl, 2012; Hirai et al., 2011). Various plastic additives, including some well-known EDCs, were found in MP by Fries et al. (2013). Wagner and Oehlmann (2011) also discovered that plastics absorb EDCs. Because the spectrum of contaminants in freshwater and marine systems differs, the chemical burden of freshwater MP must be investigated. As a result, their distribution varies in various compartments of the aquatic habitats (water surface, i.e., water and sediment), influencing their accessibility to species at various trophic levels, resulting in significant toxicity to both aquatic life and the aquatic environment.

Pathways of microplastics and organic pollutants inclusion in aquatic environment

Microplastic bioaccumulated with organic pollutants which were absorbed and ingested by creatures at the first tropic level, which contains the primary producers' phytoplankton and zooplankton. They provide a pathway in the food web of the food pyramid (Bhattacharya et al., 2010). Many zooplankton species migrate during the day. Migrating zooplanktons might be a source of microplastic pollution for the water column's occupants, by generation of the fecal or by the predating process of predation and that settles to the bottom (Wright et al., 2013). In the scat of fur seals (*Arctocephalus* spp.), the presence of microplastics was observed in the field (Eriksson and Burton, 2003). Microplastics were found in the stomach and haemolymph of the beach crab (*Carcinus maenas*) during feeding trials (Farrell and Nelson, 2013).

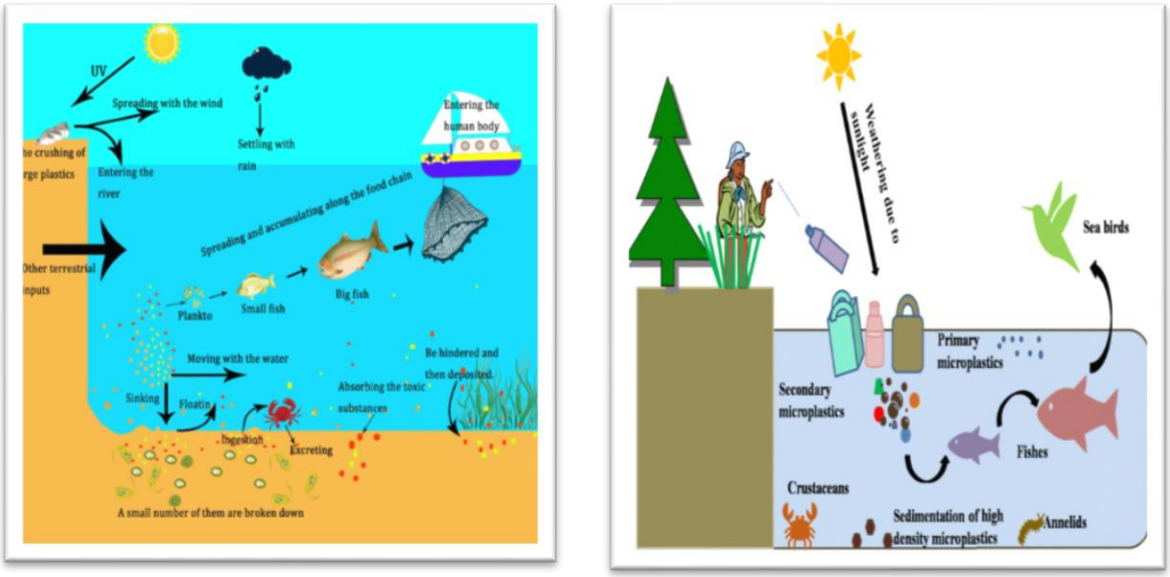

Figure 3. Microplastic inclusion in the freshwater ecosystem (www.researchgate.net)

Sway of microplastics and organic pollutants in the freshwater ecosystem

Freshwater environments are the major targets of many kinds of pollutants transported into watersheds because aquatic life is naturally found in valleys and lower elevation terrain. Pluvial flows carry plastics that have been improperly disposed of (e.g., on streets, roads, and open landfills) to aquatic bodies (Faure et al., 2015). Many direct discards can also be found in rivers, lakes, wetlands, and other freshwater bodies (Gasperi et al., 2014). In fact, dumping garbage and debris directly into rivers is a long-standing custom in both urban and rural places around the world, only now regulated by recent legislature. Today, a world without plastic is unimaginable. But their non-biodegradability poses a serious threat to the ecosystem, especially to the aquatic environment. Probable adverse effects of MPs include adsorption of persistent organic pollutants, bio-accumulation, and the death of various aquatic organisms, which eventually lead to the loss of biodiversity. Though the freshwater environment is closely associated with the origin of MPs and their transfer to the seas and oceans, limited studies have been conducted on the freshwater ecosystem matched to the marine environment. There is very little information available on microplastics in Bangladeshi waterbodies. Figure 4 shows plastic waste production combined with organic pollutants is increasing day by day, directly dumped into the aquatic environment, which pollutes the freshwater environment. Bangladesh's per capita plastic usage has increased dramatically, from 2.07 kg in 2005 to 3.5 kg in 2014 (Monjur et al., 2017), with a daily output of 3000 tons of plastic garbage, accounting for 8% of total waste generated (Mahmudul, 2019).

a) Environmental pollution agents (Banglapedia)

b) Garbage and plastic pollution on the river bank in Dhaka, Bangladesh (https://www.istockphoto.com)

c) Plastic trash in freshwater (Photo: From haor waterbody)

d) Dhaka city discharges about 4,500 tons of solid waste every day (https://www.nrdc.org/onearth/bangladesh)

Figure 4. Plastic and organic pollution (Photo: a-d) in the freshwater environment

Microplastics and organic pollutants impacts on freshwater biodiversity

There were 130 studies that reported on the ecotoxicological effects of MPs on aquatic species. Fish, mollusks, annelid worms, echinoderms, and rotifers were the most investigated taxonomic groups, followed by crustaceans, mollusks, annelid worms, echinoderms, and rotifers. These organisms can be found in a variety of places in aquatic food webs. In general, fish are intermediary or topmost predators (de Sá et al., 2015). MPs can be consumed directly or through the eating of MP-containing prey. Small crustaceans and planktonic rotifers are common primary eaters (Desforges et al., 2014). Mollusks are filter-feeding creatures that are both ecologically and commercially important. Mollusks are filter-feeding animals that are vital to both the environment and the economy. Because of their habitat and feeding habits, mollusks and other benthic creatures, such as annelid worms, are likely to be impacted by MPs. Mollusks include a huge number of filter-feeding species with high bioaccumulation potential. Because numerous

of these species (such as Mytiliusedulis) are commonly eaten as food, they might be a source of MPs or other pollutants for humans (Van Cauwen Berghe and Janssen, 2014).

The idea that microplastics, which are increasingly identified in marine species, constitute a hazard to biota is causing rising scientific concern (Fendall and Sewell, 2009). Microplastics have been reported to cause death, neurotoxicity, oxidative stress, damage, a drop in individual and community fitness, and a variety of other negative impacts on freshwater creatures (Au et al., 2015). Micro-and nanoplastics have been linked to a variety of negative outcomes, including immobility, death, eating inhibition, and reduced reproductive fitness, among others (Rehse et al., 2016).

Induction of MP and organic pollutants in the freshwater environment

Water quality has emerged recently as one of the most pressing environmental issues in developing countries, with Bangladesh experiencing severe water pollution. Bangladesh's water quality may be deteriorating due to population growth, industry, rapid urbanization, poor hygiene, and the use of agrochemicals. This study lead one of the most thorough literature reviews on Bangladesh's present water quality situation, with a focus on both traditional pollutants (heavy metals, pesticides, and feces pollution) and new contaminants. Heavy metal concentrations are higher in water bodies near industrial zones. The presence of fecal coliform in the water has been discovered. Pesticides from the organophosphate, carbamate, and organochlorine families have been discovered in wetlands around Bangladesh's irrigated land. Antibiotic residue, fluorescence with ending agent, and microplastics are among the various new pollutants that have lately been discovered in Bangladeshi water bodies. It's among the fastest developing countries, with more people using plastic than ever before, posing a serious risk to the environment and biodiversity.

In 2002, Bangladesh's government made it illegal to assemble, promote, or utilize polyethylene packs with a length of less than 55 meters (Bangladesh Environment Conservation Act No. 1 of 1995). In support of the 2002 prohibition, the legislature passed a law in 2010 requiring the use of jute fiber instead of polythene bags in bundling commodities (the Mandatory Jute Packaging Act (2010)). Polythene, on the other hand, was being made, traded, and used all throughout the country at the same time.

Plastic garbage has surged from 1.74 percent in 1992 to 7.5 percent in 2019 in Dhaka's entire landfills, according to statistics (Waste Concern, 2019).

Some startling figures about plastic in Bangladesh are given in Waste Concern, 2019:

a) Every day, 3,000 tonnes of plastic garbage are produced.

b) Plastic accounts for 8% of the total waste produced each year.

c) That's 800,000 tonnes in terms of numbers. Every day, 14 million polythene bags are used in the metropolis of Dhaka.

d) These are common in rivers and the ocean, posing a hazard to aquatic life.
Every day, over 73,000 tonnes of plastic garbage enter the sea via the Padma, Jamuna, and Meghna rivers.

e) Every month, over 250 tonnes of non-recyclable products, including straws and plastic cutlery, are sold in old Dhaka alone.

f) Bio waste output is up 5.2 percent, whereas plastic trash production is up 7.5 percent.

In Bangladesh, microplastic pollution is a new problem, and manufacturers and consumers are unaware of the negative consequences of these growing micropollutants. Polythene bags are manufactured in around 100 facilities throughout Dhaka, including Lalbagh, Hazaribagh, Sadarghat, and Chattogram. In 2015, the Environment and Social Development Organization (ESDO), a pioneering organization in anti-plastic campaigns and plastic bags, took the ground-breaking step of conducting a primary study on the extent of microplastic pollution in Bangladesh's three major urban areas (Dhaka, Chittagong, and Sylhet) (ESDO, 2016). The investigation discovered that sixty of Bangladesh's most popular and frequently used beauty and cleaning goods, such as face wash, detergent, body wash, nail polish, toothpaste, face wash, and body scrub, include microbeads or microplastics, making them the country's first of their type. According to the study, about 7928.02 billion microbeads are released into nearby water bodies and wastelands each month in and around Dhaka (approximately 6628.46 billion), Chittagong (roughly 1087.18 billion), and Sylhet (app. 212.38 billion) (ESDO, 2016). In the case of water pollution, over 100 fish samples were taken from several water bodies in Dhaka, Chittagong, and Sylhet city, including Rui (Labeo rohita), Catla (Gibelion catla), Mrigal (Cirrhinus mrigala), Ilish (Tenualosa ilisha), and Sarpunti (Puntius sarana). According to the previous study, larger fishes, such as rui, were found to be more contaminated with MPs than smaller fishes, such as sarpunti. Overall, MPs and organic pollutants continue to pollute wetlands, lakes, ponds, and rivers, which eventually wash into the Bay of Bengal, hurting marine life and biodiversity. If MP pollution is not controlled, it poses a serious threat to human and animal health, ranging from the death and destruction of marine life to the extensive distribution of these microplastic particles in human and animal food webs.

Research on microplastics and organic pollutants inclusion in freshwater environment

Microplastics research in aquatic environments is a rapidly growing, interdisciplinary field that includes and integrates oceanography and hydrology, as well as environmental sensing,

modeling, chemistry, and toxicology. In recent years, this coordinated effort has improved our understanding of the environmental impact of MP and organic contaminants, particularly through the sharing of extensive monitoring data. However, current research is nearly entirely focused on marine MP and organic pollutants. Freshwater ecological data is at best sporadic, if not completely lacking. This information gap makes it difficult to do a science-based environmental risk assessment of MP in freshwater environment. Such an assessment is required to promote public and political debate on the issue at national levels, which, depending on the findings, will finally lead to mitigating measures. For instance, the MP could be used as a descriptor of environmental condition.

Nevertheless, these worries and interests of the state are nearly entirely focused on marine plastic litter. On the other hand, microplastics are emerging freshwater pollutants, as per us. Three arguments support this claim. First, regardless of the evidence, MP is found in freshwater habitats. Second, MP traps and adsorbs pathogens and micropollutants. Third, laboratory studies show that marine organisms consume MP and experience negative consequences. While information on freshwater species is limited, there is no reason to believe they are unaffected. As a result, concerns about MP's impact on freshwater ecosystems are reasonable and should be given more scientific consideration (Wagner et al., 2014).

Environmental scientists must first fill in the gaps in their understanding of freshwater MP exposure and hazard, as well as the compounds linked to it. The study is based on a global critical evaluation of current literature, with a main emphasis on Bangladesh that included 40 research articles, as well as 24 global viewpoints and 16 Bangladesh perspectives (freshwater 2, marine 8, review 4, and other 2 papers) (Figure 5). The findings revealed that Bangladesh has undertaken relatively little research and that there is no difference between Bangladesh and the rest of the globe. However, a limited but continuous effort has been made to measure the quantity of microplastics and organic pollutants in garbage, as well as their implications. The existence and effects of MPs in the maritime environment have been investigated through empirical study. On the other hand, the existence of MPs in freshwater habitats with combined contamination of organic contaminants is still understudied, making data extraction challenging. In Bangladesh, a large amount of old plastic has been found to be mismanaged, posing a major environmental and human health concern. The study's goal, on the other hand, is to encourage scholars to perform further in-depth inquiries into the topic.

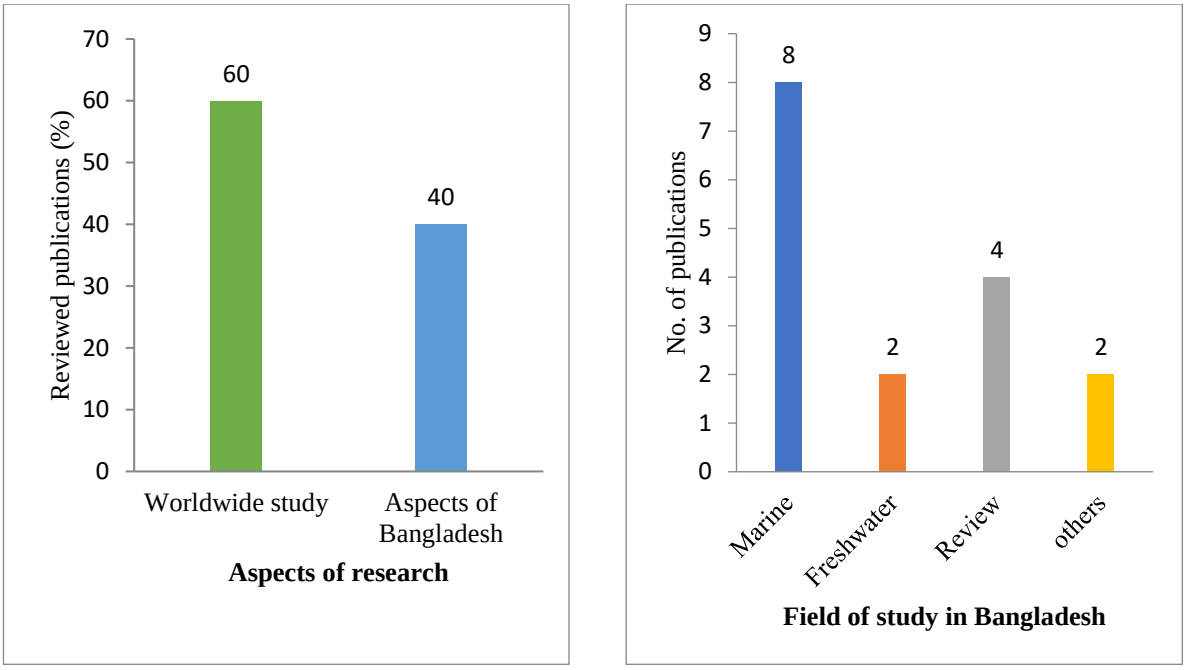

Figure 5. Graphical presentation of reviewed publications for microplastics and organic pollutants study

Future prospects of the MP and organic pollutants research in Bangladesh

Because of their widespread distribution and potential influence on freshwater ecosystems, MPs and organic pollutants are a global concern. MPs have been found in a variety of aquatic creatures due to their ability to be ingested, and accumulation along the food web has been seen in a variety of environments (Li et al., 2019). Plastic particles can also operate as biota-harmful chemical vectors (Verla et al., 2019). However, as the vector impact of MPs for pollutants currently yields inconclusive results (Koelmans et al., 2016), the negative consequences of MPs, particularly for adsorption–desorption equilibria in environmental situations, need to be investigated further. This review emphasized the dearth of research about MPs' effects on sediment and benthic organisms. More study is needed in this area since sediment is the final sink for many plastic particles, and benthic fauna is a critical link in the overall trophic web (Au et al., 2015). Figure 6 shows a list of important locations to investigate further under the focal point.

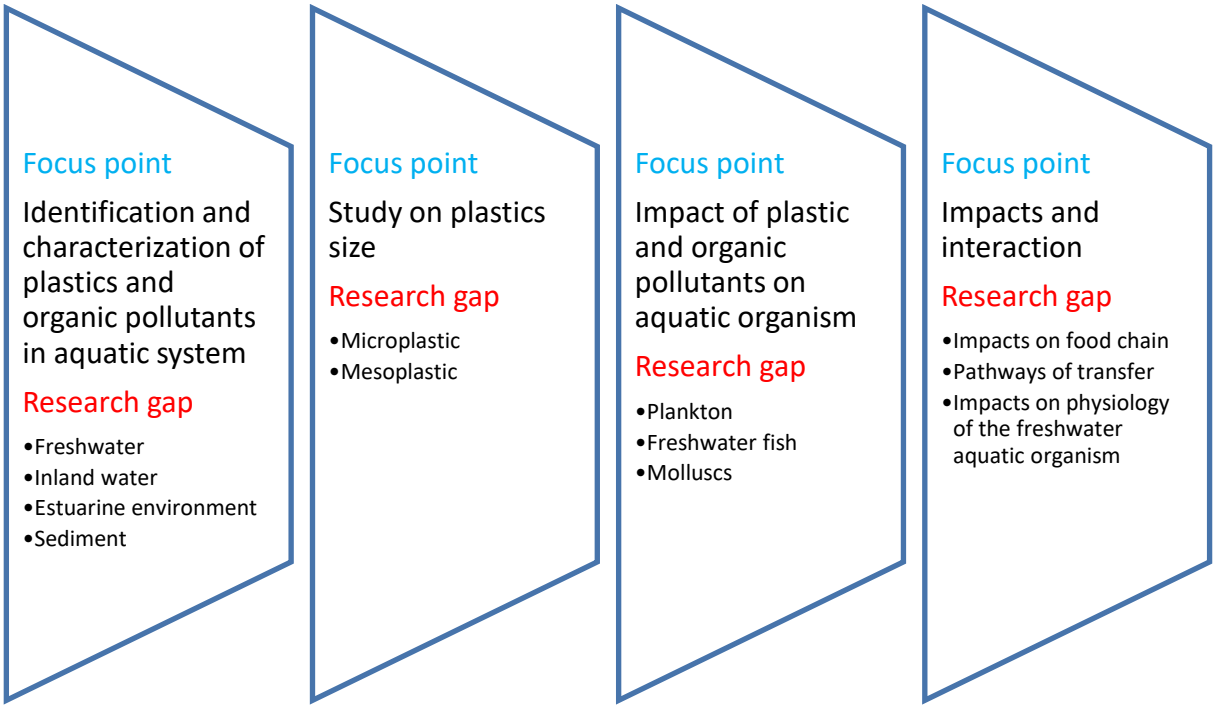

Figure 6: Consideration of key areas for future research

CONCLUSION

Microplastics and organic pollutants are posing a serious threat to the environment. The study suggests that freshwater fish are especially vulnerable to microplastics and organic pollutants pollution, and that urbanized areas appear to be a major contributor to the contamination of freshwater habitats. Despite this, just a few articles have been written about these events. Furthermore, the lack of common standards makes it difficult to duplicate and, as a result, validate the data. Furthermore, there is a high demand for more information about the movement of MPs and organic pollutants through the food chain, as well as the potential consequences for each community. The study of those environmental pollutants in aquatic settings is a fast-paced, interdisciplinary field of study that has enhanced our understanding of the environmental impact of this growing concern in recent years. However, as we highlighted in our review, research is now almost entirely concentrated on marine habitats, with very little data on freshwater habitats. This study will help in the future when environmental and financial incentives given by environmental agencies will assist in closing the information gaps that still exist about those burning microplastics and organic pollutants in freshwater.

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