Microplastics (MPs) in Water Column of the Peripheral Rivers and Lake of Dhaka City

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A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree

of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

ISLAMIC UNIVERSITY OF TECHNOLOGY

June 2023

Approval

The paper titled " Microplastics (MPs) in water column of the peripheral rivers and lake of Dhaka City"submitted by Humaira Tasnim Oishi & Zarin Tasnim has been accepted as partial attainment of the requisite for the degree of Bachelor of Science in Civil Engineering.

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Declaration

It is hereby declared that this thesis/project has been performed by us under the supervision of Prof Dr. Md. Rezaul Karim. We have taken appropriate precautions to ensure that the work is original and has not been plagiarized. We can also make sure that the work has not been submitted elsewhere for the award of any Degree or Diploma.

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Dedication

We dedicate this thesis paper to our parents and other well-wishers , those who have been an unwavering source of inspiration and support throughout our academic journey. . Most importantly we want to show our gratitude towards Almighty Allah. Especial thanks to our supervisor Prof Dr. Md. Rezaul Karim Sir without whom our journey has not been defined by any efforts. We are gratefully presenting this work as evidence of our common dedication to learning and development.

Acknowledgment

Thanks to Almighty Allah, for Whom we were able to complete our research. Certainly He is the all-knowing and all-powerful, therefore nothing would have been possible without His mercy.

We would like to convey our heartfelt gratitude to our thesis supervisor Dr. Md. Rezaul Karim Professor Sir, Department of Civil and Environmental Engineering, IUT for his exceptional guidance, unwavering support, and invaluable expertise throughout the process of completing our thesis. Then we are gratefully acknowledging the support provided by the Materials Science Division, Atomic Energy Centre Dhaka (AECD), during the FTIR analysis at the AECD Laboratory

We would like to acknowledge Md. Tanvirul Islam bhai, current MSc student of University of West Virginia for the countless hours he invested in reviewing our work, providing insightful feedback, and challenging us to think critically and creatively.

Finally, we want to thank our beloved family and everyone else who helped us with the study we conducted, whether directly or indirectly.

Abstract

Microplastics (MPs) pollution in developing countries deserves more attention considering the rapid industrialization in such countries and toxic nature of MPs. The concern has attracted public attention in recent decadesdue to its pervasiveness, including massive adverse impacts. The lack of studies onmicroplastics in freshwater ecosystems has hindered understanding the source and fate of microplastics. The study of water column throughout the peripheral urban river systems and lake of Dhaka city is provided a first representative example of urban river input of microplastics from a mega-city of Bangladesh.Goals of this study to investigate occurrences of MPs(microplastics) in the urban river and lake environment. Thus, thirty-six (twenty locaions from rivers of peripherial rivers of Dhaka city and eight are from Dhanmondi lake) water column samples were collected from different locations that were exposed to various point sources as well as non-point sources of contaminants into the rivers named Buriganga ,Turag, Balu & Dhanmondi lake in Bangladesh. The samples were then analysed using modified NOAA laboratory analysis methods which involve digestion, density separation, and microscopic inspection. MPs were extracted from water samples using the density separation and wet peroxidation methods . . Attenuated total reflectance-Fourier transform infrared spectroscopy was used to identify the MP particles. This investigationresults indicated a medium-level abundance of microplastics in comparison with many other studies in the freshwater column throughout the world . The predominant characteristics were fibre shape. The abundance of extracted microplastics in rivers varied from 6 to 52 particles/L on average value of 29 particles/L. In terms of mass concentration, the value ranged from 10.65 to 57.44 mg/L on average of 34.045 mg/L. Meanwhile in Dhanmondi Lake , the abundance of microplastics varied from 8-40 particles/L and in terms of mass concentration the value ranged from 9.98-44.41 mg/L. In Dhanmondi Lake beside a huge amount of fibre , we got only two film particles which were not found in the river water column eventually. In our whole study we got highest amount and highest size of microplastics Turag river and those were mostly black in colour. Industrial and commercial regions in the study area tended to pose higher MPs concentration than open and residential area. The pollution load index (PLI) was used to evaluate the pollution level and risk category of MPs respectively. Most of the particles were found to be smaller (< 2 mm) in size with fibers and black being the predominant size and color, respectively. Assessment of microplastic pollution in river.

Sediment is essential for its role as a sink. In contrast, accumulation of microplastics in nver

Sediment can alter some physical properties of the sediment, such as bulk density, water-holding capacity, and also affect the functioning of benthic organisms (Amrutha et al., 2022) .This study can contribute to the source control of MPs pollution and urban planning in Dhaka city to achieve United Nations Sustainable Development Goals (SDGs).

Keywords: Microplastics, River water, Urban River, Buriganga River, Dhanmondi Lake

LIST OF ABBREVIATION

BaR	Balu River
BR	Buriganga River
EP	Epoxy Resin
ERI	Ecological Risk Index
FTIR	Fourier Transform Infrared Spectroscopy
LDPE	Low-Density Polyethylene
MP	Microplastic
MSDF	Marine Strategy Framework Directive
NOAA	National Oceanic and Atmospheric Administration
PES	Polyester
PET	Polyethylene Terephthalate
PLI	Pollution Load Index
PP	Polypropylene
PPS	Polyphenylene Sulfide
PS	Polystyrene
PVA	Polyvinyl Alcohol
PVC	Polyvinyl Chloride
STP	Sewage Treatment Plant
TR	Turag River
USGS	United States Geological Survey
UV	Ultraviolet
WPO	Wet Peroxide Oxidation
WWTP	Wastewater Treatment Plant

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CHAPTER 1: INTRODUCTION

1.1 Background

Plastic has become an increasingly substantial product with the advancement of technology and is being used extensively in many spheres of life (Di Mauro et al., 2017) . Microplastics cause more danger to the environment than larger plastics and it is estimated that almost 10% of the total plastic litter in the aquatic environment eventually converts into microplastics by various external forces such as UV radiation, heat, water, biota, etc (*Microplastics*, n.d.). These Plastic debris is prevalent due to the massive amount of production, inadequate management, as well as lack of reuse (Browne et al., 2010). Plastic waste less than 5 mm in size is considered as microplastics (MPs). Deep sea, surface water, sediment, soil, and living creatures, every place on earth has traces of microplastics. Microplastic(MPs) was discovered in 94% of all types of surface samples in the northeast Atlantic (Eriksen et al., 2014). Daily microplastic imposes in American rivers and lakes ranged from 3-23 billions of particles in 2016 (Baldwin et al., 2016) . Global plastics production reached 359 million tonnes in 2018, Asia produces 51% of all plastics, with China producing 30%, Japan 4%, and other Asian countries contributing 17%. 2019 (Plastics Europe). Plastics have a wide range of uses and applications, and For daily living, society, including the economy, they offer a number of benefits (Andrady & Neal, 2009). More than five percent of all plastic produced each year ends up in the water, where it persists and accumulates (Jambeck et al., 2015). In 2014, it was predicted that more than 250,000 tonnes of waste plastic were dumped into the ocean from land (Eriksen et al., 2014b).

But because of poor management, a lot of plastic debris has gotten into the ecosystem (Jambeck et al., 2015b). Increasing numbers of microplastics have been found in sediments and streams all around the world, with lakes and rivers having the highest concentrations. Recently, these tiny polymers have even been used in detected in Arctic polar water and deep-sea sediments (Yan et al., 2019). Because they are more readily available in smaller sizes that are easier for ingestion, The ocean's food chain can readily be affected by microplastics in the marine environment. Numerous marine animals, including zooplankton, bivalves, prawns, fish, and whales, have been seen to consume plastic particles (Yan et al., 2019).

Plastics can be defined as polymer-based materials manufactured from by-products of fossil fuels and usually processed with a variety of chemical additives (Fan et al., 2019; Gong & Xie, 2020). Due to their morphology, microplastics can be divided into five categories: The word "fragments" refers to larger plastic pieces that have been broken into smaller, jagged-edged shapes; enlarged polystyrene, foam, films—long, thin pieces of plastic created from polyethylene bags or other packaging—pellets—spherical plastics produced in pre-production, and individual care items, and Fibres, which are thread-like plastic particles with widths at least 1.5 orders of magnitude less and lengths in between 100 m and 5 mm (Baldwin et al., 2016b). Fibres make up the majority of the microplastics that are present in the environment. These could be found in clothing (Miller et al., 2017). Microplastics are good carriers for a variety of organic pollutants and heavy metals that are easily damaging to the environment because of their small size, high specific surface area, and strong hydrophobicity. Additionally, transfer and enrichment of microplastics occur in food, and they can stay in organisms for a long timewebs, which endanger the ecosystem's balance (Ding et al., 2019).

When it was initially characterised, plastic particles with a diameter of about 20 mm were referred to by the term "microplastic" (Thompson et al., 2004). The definition was eventually modified to include all plastic particles larger than 5 mm (Levett-Jones et al., 2011).

Dhaka city is surrounded by three main rivers (Buriganga, Turag and Balu) and Tongi Canal like a garland. The continuous disposal of untreated wastewater from various industries, urban and agrochemical outflows and dumping of waste in river systems are considered major sources of Microplastics (Uddin & Jeong, 2021).

For instance, during ploughing, plastic is broken down into microplastics, some of which remain on the soil's surface and others of which are buried under it (Ding et al., 2019b). Moreover, a wide range of variation is observed in the criteria of microplastics classification depending upon researchers. For example,(Wu et al., 2020) classified microplastics into four shapes such as fiber, foam, film, and fragment but (Liu et al., 2021) separated lines and fibers into two different categories.

1.2 Signifiance of the Study

Even though freshwater MPs pollution is getting more and more scientific attention, little is known about it currently. Despite recent findings of higher MP abundances and potential hazards, the information on the quantity, distribution, characteristics, and risks of MPs in freshwater habitats is still limited. Additionally, the locations, dangers, and effects of MPs contamination in riverine habitats are still insufficient. MPs are sourced from land-based applications of manufactured plastic particles, such as household and industrial detergents, agricultural fertilisers, Personal care items, industrial and household cleaners, and paints are examples of primary MPs. Secondary MPs are produced when larger plastics break down due to oxidizers, mechanical abrasion, weathering, deterioration, and other factors in various environmental conditions.

The major sinks of land-sourced MPs are thought to be marine ecosystems, despite rivers being hotspots for plastic pollution and the primary routes for their release into the oceans. According to estimates, rivers and the land contribute about 80% of the debris in the sea (Kabir et al., 2021) . More serious MPs contamination occurs in small freshwater bodies than in coastal waters, yet tiny rivers and their quantitative MPs emissions are still a problem remain virtually unknown (Qiu et al., 2020b). 94% of the water (Lusher et al., 2014).

Most microplastics found in waterways are made of polypropylene (PP), polyethylene (PE), polystyrene (PS), and polyethylene terephthalate.

PVC and polyethylene terephthalate (PET). varied materials used to make microplastics result in varied environmental behaviours. Those mostly constructed of PET and PVC are more prone to sink, whereas PP, PE, and PS more readily float. In addition, microplastics commonly contain polyvinyl alcohol and polyamide (PA) (Carr et al., 2016). Because these substances are difficult for microbes to degrade, microplastics regularly persist in the environment in a variety of forms, including table salt, beer, sugar, dust in our houses, and even bottled water samples (Kosuth et al., 2018). In addition to a significant rise in the amount of microplastics in the environment, worry about some of the effects of microplastics is growing (Yan et al., 2019b). MPs are present in many different types of organisms as well as in natural samples (such aerosols, sediments, soils, and water). Research on the detection of MPs in the aquatic environment has thus far been conducted in a few ordinary farms. These findings showed that MPs are now potentially polluting the aquatic ecosystem.Human food comes in large part from aquatic goods. Aquaculture output on a global scale has increased considerably in recent years. As a result, many pollutants, including potentially harmful MPs, were unavoidably added to aquaculture habitats like ponds, lakes, rivers, and seas. Because these pollutants aid in the growth and development of aquatic species, they eventually enter our bodies through the food chain (Xiang et al., 2022).Bangladesh is one of the Asian nations that is fast developing. It has a dense population and is becoming more industrialised, particularly in the expanding plastics industry (Nahian et al., 2023).

It is unknown how microfibre pollution from plastic and other sources may affect people's health. However, a deeper comprehension of the causes of microfibers in marine life is necessary in order to develop preventative and remedial measures (Miller et al., 2017b). Worry about the consequences of microplastics is expanding along with a significant increase in the amount of microplastics in the environment (Yan et al., 2019c). As a result, studies on microplastics in China's freshwater environments are still lacking. However, these studies can also help researchers better understand how different economic advancements and the industrial division of labour have an impact on the distribution of microplastics (Ding et al., 2019c). Almost 50% of the microplastics in the aquatic environment pose higher density than water and subsequently settle down in the sediment (Ballent et al., 2013). Assessment of microplastic pollution in river sediment is essential for its role as a sink (Matsuguma et al., 2017). In contrast, accumulation of microplastics in river sediment can alter some physical properties of the sediment, such as bulk density, water-holding capacity(Adomat & Grischek, 2020) and have an impact on how benthic creatures function (Bour et al., 2018). In addition, de-fouling, erosion, and high flow velocity all contribute to microplastics from sediment returning to the water column.

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1.3 Objectives of the Study

The following are the study's main objectives:

1. To research the quantity and density of MPs in the water column of Dhaka's outside rivers and lake.
2. FTIR analysis and pollution concentration of MPs of the water body.

1.4 Outline of Methodology

1.4.1 Sampling

Each sampling point's water column yielded about 1 Litre of water, which was taken. Here, we took some water samples using a 1 L glass container. The samples were collected during monsoon season. The sampling date for Buriganga river was 27 May, 2022 ; for Turag and Balu river was 1 April, 2023 ; for Dhanmondi lake was 13 November, 2022.To prevent contamination and provide quality standards, samples were kept at room temperature in glass jars.

1.4.2 Sample Preparation, Purification & Extraction

The laboratory examination of the sand sample used modified NOAA procedures [23]. Necessary adjustment in the standard NOAA methods was made based on the existing literature in Frias et al. [24].For primary extraction, filtration is done to trap microplastic particles and to separate impurities like clay and silt.Here sieving is avoided because the particles floating water were very finer. A vaccume filter is used to pass water through its filter paper where particles greater than 5 mm got removed as microplastics are typically categorized as anything less than 5 mm. Then the filtrated water was throne and particles were initially collected in filter paper. To eliminate the influence of humidity, the filter papers were dried in an oven at 65°C for roughly 24 hours.

Samples can contain many organic particles along microplastics.In order to prevent interference with correct extraction and classification of microplastics, sample purification or digestion is a pretreatment technique that removes organic debris from samples (Adomat & Grischek, 2020; Gong & Xie, 2020). Here, water column samples were treated using Fenton's reagent. Fenton's reagent, a combination of 20 mL of 30% H2 O2 solution and

20 mL of FeSO_4.7H2 O solution, was used to carry out wet peroxidation. The separated particles were placed in a beaker, and 20 mL of an aqueous 0.05M Fe (II) solution and 20 mL of 30% hydrogen peroxide were then added. The mixture was cooked at 65°C on a hotplate following 10 minutes of keeping it at room temperature. Once a gas bubble was visible on the beaker's surface, it was removed from the hotplate. After the liquid stopped boiling, it was heated for a further 30 minutes. If overflow reaction shows, distilled water will lessen the reaction.These actions would be repeated until no organic matter was left to be seen.

Before analysis, the sample must be separated or extracted since the collected sediment samples are combined with contaminants like inorganic clay (Gong & Xie, 2020).The density separation approach works on the basis that microplastic and non-microplastic particles have different densities (Gong & Xie, 2020). This method allows low-density particles like microplastics to float and high-density particles like contaminants to settle down because saturated or highly dense salt is extensively mixed with the sediment sample (Li et al., 2018). As a result, the solution's top layer is used to extract microplastics. For density separation, ZnCl2 solution was made adding 972g ZnCL2 to 1L water.Then particles from filter paper were collected and combined with 500 mL of aqueous ZnCl2 solution. A spatula was used for stirring the mixture briskly before allowing it to sit for the evening. Again The confirmed extracted particles to be in the required size range by passing the supernatant through vacuum filtration, it was then put into a beaker for storage. The step would be repeated for three times for thorough removal of inorganic particles. Then in an oven, the filter papers with removed particles were heated to 65°C and dried.

1.4.3. Identification and Quantification

The purpose of visual investigation is to sort out presumed microplastics for further identification based on physical attributes like shape, size, and color (Y. Zhang et al., 2020). Sorting can be done by the naked eye or in assistance with a microscope (Hidalgo-Ruz et al., 2012). Here, MP particles that had been isolated were examined visually using a stereo zoom microscope (SLX-3, Optika, Italy) at standard magnifications ranging from 7 to 45 (Witte et al., 2014; Hidalgo-Ruz et al., 2012). The microscope was equipped with a digital camera (C-B5, Optika, Italy), and the programme Optika Proview was used to directly measure the particle size. To prevent loss, identifying the microplastics is directly done on the filter surface (Yang et al., 2021), and the research should be carried out from top left to bottom right to prevent double counting (Simon-Sánchez et al., 2019).

The chemical makeup of microplastics is investigated via spectrometric analysis (Gong & Xie, 2020). Additionally, according to Constant et al. (2020), it may be used to evaluate visual sorting and adjust the particle count based on visual examination. The basic idea behind spectrometric analysis is to use agitated samples to detect vibration and then compare the resulting spectra to established reference spectra (Li et al., 2018). The most used spectroscope for the examination of microplastic is the Fourier transform infrared (FTIR) and Raman spectroscope (Hidalgo-Ruz et al., 2012).Here, The poly-mer content of the separated particles was examined using Fourier transform infrared spectroscopy (FTIR Spectrum Two, PerkinElmer C110303, UK) with Attenuated Total Reflection (PerkinElmer UATR Two). PerkinElmer Spectrum 10 Spectroscopy Software was used to get the spectrum data. Each MP measurement was preceded by background scans. Each MP particle, with diameters ranging from 0.1 mm to 5 mm, has an infrared the wavenumber between 4000 cm-1 and 400 cm-1, was individually scanned. Ten accumulated scans were then taken to provide spectra with a resolution of 16 cm-1. In order to determine the different kinds of polymers, the obtained FTIR spectra and Wiley's KnowItAll Spectral Libraries 2021 were compared.

1.5 Organization of the Thesis

The thesis has been presented in five chapters.

Chapter One presents the background of the study, objective, and outline of methodology in brief.

Chapter Two presents a review of the possible sources of microplastics pollution in the aquatie ecosystem, its impact on the overall environment and the means to mitigate the adverse effects. This chapter describes related works which have been performed previously.

Chapter Three presents the methodology followed in this research. It includes details of the sampling and analysis of microplastics in sediment samples, and it describes in detail the laboratory experiments carried out for the quantification and characterization of microplastics.Assessment procedure of ecological risk indices and weathering effect of MPs is also presented.

Chapter Four presents' abundances and mass concentration of microplastics, and the results of the laboratory experiments for the characterization (shape, size, color and polymer types) of Microplastic in the sediment of rivers around the periphery of Dhaka city. It also presents an assessment of the pollution load, polymeric hazard and ecological risk indices of microplastics including oxidation and weathering of MP particles in the sediment samples around Dhaka City.

Finally, **Chapter Five** summarizes the major conclusions from the present study. It also presents limitations of this study and recommendations for future study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The thesis's literature review chapter focused on various aspects connected to plastic particles (MPs) in the water column of Dhaka City's outlying rivers and lake. This chapter begins with the studies concerning about the study of abundance and the quantification of MPs and evaluating it’s chemical properties and risk factors. Subsequently, it examines the ecological and environmental aspects. Also this research will overcome these gaps like:

1. Complete understanding between sink and source behaviour of sediment & river water column in the peripheral rivers of Dhaka city.
2. Size.shape and colour of microplastics.

The thesis research started with an in-depth review of scholarly publications, articles, conferences, and other significant sources of information.

According to research by Naidoo et al. (2015), microfibers were discovered in 38 to 66% of South African estuaries. findings regarding concentration.The type of sample method used for these fibres affects the results, when compared to full water samples, net samples underestimate (Barrows et al, 2017).

According to (Moore et al., 2011) research, The Clyde Sea Area in Scotland, UK, was used to collect Norway lobsters (Nephrops norvegicus), and 62% of those lobsters contained microfibers. When examining these figures, it's crucial to keep in mind that the water was filtered through 300 m mesh in both river investigations. Later research has shown that mesh in the 300 m range is not small enough to accurately assess the scale of the microplastic(MPs)/microfiber pollution issue. The information above is a rough estimate. Due to the presence of WWTPs and high human density, studying river systems and watersheds offers the potential opportunity to identify specific microfibre pollution sources. Contrary to that, Ocean samples show the problem's current scope, with microfibers travelling locally and worldwide possibly lasting years up to decades. (Miller et al., 2017a).

Monitoring the contamination of surface water and sediments with microplastics in Bangladesh's Moheshkhali channel has not been studied.This study will measure the amount of microplastic pollution for the first time.In the Moheshkhali channel system, where microplastics are eventually released into the Bay of Bengal, as well as their sources, types, and fate. This study will establish a foundation for understanding the Moheshkhali channel's role in microplastic pollution in the Bay of Bengal, which will aid the governments of Bangladesh and the surrounding nations in managing and monitoring discharge into the Bay of Bengal (Nahian et al., 2023b). MPs are received by riverine and marine systems through point and other sources on earth (Jambeck et al., 2015; Siegfried et al., 2017; Kataoka et al., 2019; Baldwin et al., 2016).

According to Lebreton et al. (2017), between 1.15 and 2.41 million tonnes of MPs are predicted to enter the ocean through rivers each year, with the largest river catchments exporting between 5 104 and 6.3 103 tonnes of MPs daily. Therefore, in order to properly comprehend emissions of river-to-marine MPs, it is necessary to understand how plastic pollution changes, goes to marine sinks, and loads there. Only a few studies have looked on MPs emissions from rivers to seas thus far. According to Hu et al. (2018) and Luo et al. (2019), MPs pollution in small-scale freshwater bodies is worse than that in coastal waterways, yet small-scale rivers' quantitative MPs emissions are still significant , remain virtually unknown (Kabir et al., 2021c) . MPs are a group of persistent pollutants with a wide range of characteristics, including size, shape, colour, kind of polymer, plasticizer, stabiliser, and colourant. Persistent organic pollutants (POPs), such as heavy metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs), can also be absorbed by them, which are easily dispersed in aquatic habitats through long-distance transport. The migration of MPs across food webs may cause their exposure to all biotic and abiotic matrices, which is therefore inevitable. They also classed plastic polymers as having long-lasting effects on aquatic life, as well as being highly hazardous and mutagenic to humans. Consequently, newly elected MPs greater threats are posed by pollution to the environment, human health, and the sustainability and protection of the environment globally (Kabir et al., 2021d).

Nevertheless, the results of these studies are difficult to compare as they have performed microplastic analysis using different methodologies. Moreover, a wide range of variation is observed in the criteria of microplastics classification depending upon researchers. For example,(Wu et al., 2020) classified microplastics into four shapes such as fiber, foam, film, and fragment but (Liu et al., 2021) separated lines and fibers into two different categories.

2.2 Sources and Pathway of MPs In Water Column

We must distinguish between primary and secondary microplastics in order to understand the sources of microplastics (Waldschläger et al., 2020). Primary microplastics are created and manufactured in the microplastics size range (5 mm), and can be utilised as the primary component in personal care items, cosmetics, and other industrial goods (Gong & Xie, 2020; Simon-Sánchez et al., 2019; Yang et al., 2021). However, secondary microplastics are created when bigger plastics that have been exposed to the environment are broken down and fragmented by physical, chemical, and biological processes (Fred-Ahmadu et al., 2020; Waldschläger et al., 2020). Primary microplastics are designed and produced at the size range of microplastics, (<5 mm) which can be used as the raw material of personal care products, cosmetics, and other industrial products (Gong & Xie,2020; Simon-Sánchez et al., 2019; Yang et al., 2021), On the other hand, secondary microplastics are the result of physical, chemical, and biological degradation and fragmentation of larger plastics when exposed to the environment(Fred-Ahmadu et al., 2020; Waldschläger et al., 2020).

2.2.1 Sources of primary Microplastics

In personal care products like cosmetics, hand sanitizer, and facewash, microplastics (microbeads, sodium tetraborate decahydrate, etc.) with a diameter of less than 5 mm are used as a polishing agent to remove dead skin cells from the surface of the skin (Duis & Coors, 2016). An investigation on peeling, toothpaste, body wash, and scrub found that the amount of polyolefin microplastics used in consumer products ranges from 0.45 %(w/w) to 7.48 % (w/w) (Hintersteiner et al., n.d.). According to a different study, each facial washing product may produce enough energy to bake about 94500 loaves of bread (Ngo et al., 2019). Moreover, on average, 2450 particles/g were detected in facewash, and in Slovenia, this count reaches the maximum (3.11×10^6 particles/g)(Sun et al., 2020). Comparatively, fewer microplastics (2.15 particles/g) were found in body wash (Sun et al., 2020). One of the main sources of primary microplastics are resin pellets used in the manufacture of plastic and other industrial processes (Duis & Coors, 2016; Yang et al., 2021; Yurtsever, n.d.). Though numerous studies were conducted on the occurrence of plastic production pellets in the beach samples (Acosta-Coley & Olivero-Verbel, 2015; Antunes et al., 2013; Turner & Holmes, 2011), investigation in river sediment is still in headway. In Wen-Rui Tang River, pellets were 12.8% of the total microplastics (Z. Wang et al., 2018). Glitters which can be defined as tiny, smooth, and beautifying material made of biaxiallyoriented polyethylene terephthalate (BoPET) also comprise the source of microplastics (Yurtsever, n.d., 2019). An investigation performed on the wastewater treatment plants in Norway found that glitters contribute 1.7% (in weight) of total microplastics detected in the sample (A. L. Lusher et al., 2017). Microplastics such as acrylic, polyester (PES) used as blasting agents to remove paint or other contaminants from the metal surface, roughen any surface or clean mechanical engines are another possible source of primary microplastics (Duis & Coors, 2016; Waldschläger et al., 2020).

2.2.2 Sources of secondary microplastics

Due to high removal efficiency in the sewage treatment plant and proper caution during handling, usually less primary microplastic is identified in the river sediment (Duis & Coors, 2016; Gong & Xie, 2020). The primary source of microplastics in the river is hence secondary microplastics (Yang et al., 2021). Synthetic fibres like polyester, acrylic, cotton, and nylon make up about 60% of all manufactured fibres worldwide (Dalla Fontana et al., 2020). When washing fabric, these synthetic fibres might come off and be dumped into the environment as microplastics that are secondary (Waldschläger et al., 2020). Around 93% of the microplastics found in the silt of the Ciwalengke River were fibre, and Raman spectra investigation revealed that these microfibers were made from shredded textiles (Alam et al., 2019). A filter with a 5mm width and 4.7mm dia. was used in the laboratory to remove one to ten hundred microplastics from washing effluent, depending on the kind of clothes and washing method (Falco, 2017). Additionally, it is predicted that a textile industry's effluent can emit 6000000 microplastics per 5 kg of laundry (Yang et al., 2021). Even in home washing machines, there can be as much as 700000 fibres emitted for every 6 kg of laundry (Napper; ThoMPSon 2016). According to a different study (Belzagui et al., 2019), finished clothing releases microplastics at a rate of 175 to 560 microfibers per gramme (30000-465000 microfibers per m). When utilising softener in place of ordinary detergent during the washing process, the rate of microfibre detachment in woven polyester can be reduced by more than 35% (Falco, 2017). Plastic is an affordable, lightweight material that provides exceptional moisture protection (Andrady, 2011). Plastic is frequently used as a packaging material for food, dishes, silverware, and other products because of these qualities (Foschi & Bonoli, 2019). The overall output of 75–80 million tonnes of plastic containers are produced each year (Andrady, 2011). As a result, the packaging sector is thought to be the biggest contributor to pollution from plastic in China and Europe. (Tang et al., 2020). The majority of these containers are single-use, throwaway items that end up in the environment as secondary microplastics. Additionally, there is proof that slicing or ripping these packaging produces microplastics (Nir, n.d.). Rope, floating drilling rigs, and other fishing equipment used in aquaculture are frequently made from plastics such low-density polyethylene (LDPE) (Tang et al., 2020). During fishing operations, microplastics may come loose from these instruments due to abrasion or another factor (Chen et al., 2020). A potential source of secondary microplastics is therefore aquaculture and fishing (Andrady, 2011). A research on microplastic contamination brought on by fishing operations found 735 405 particles/kg silt in the nearby urban river, and 571 409 particles/kg sediment in the nearby suburban rivers of the Beibu Gulf (Xue et al., n.d.). Another investigation was carried out in the aquaculture water of the Pearl River Estuary, where two experimental stations extracted water samples containing 10.3-60.5 particles/L and 33.0-87.5 particles/L, respectively (Ma et al., 2020) the ocean or river sediment. One of the often utilised parts of car tyres is a polymer like butadiene rubber (BR) or styrene butadiene rubber (SBR) (Waldschläger et al., 2020). These polymers may deteriorate when driving as a result of friction between the road and tyre (Kole & Löhr, 2017).

As a result, Ngo et al. (2019) believe tyre wear and tear to be one of the major sources of secondary microplastics. In Japan, tyres release about 239,762 tonnes of wear and tear annually (Kole & Löhr, 2017), and microplastic emissions from wear and tear amount to about 240 kilotons annually (Ngo et al., 2019). Additionally, according to Kole and Löhr (2017), 3-7% of the dust, spores, and pollen (PM. particles) in the air come from microplastics found in car tyres. Aside from the sources already mentioned, other potential sources of secondary microplastics include artificial grass, goal nets, pipes used in construction, insulation, and other sporting products (Waldschläger et al., 2020). However, the study of their role in microplastic pollution is still in its early stages.

2.2.3 Degradation of plastics under aquatic environment

Degradation mostly refers to the chemical breakdown of plastics (Waldschläger et al., 2020). To put it another way, degradation involves the oxidation or hydrolysis of plastic, which causes the material to lose its structural stability and molecular weight (Andrady, 2011; Chamas et al., 2020). According to Cassidy and Aminabhavi (1981), it can be brought on by a variety of degradation mechanisms, including radiation (photodegradation), heat (thermal degradation), biological processes, and water (hydrolytic degradation). Any degradation mechanism disintegrates at a slower rate than photodegradation does (Andrady, 2011). Thus, only the light-induced degradation process—also known as photodegradation or photo-oxidation—along with biodegradation will be covered in this study.

2.2.3.1 Photodegradation

When plastics absorb UV-B radiation from sunshine, the process of photodegradation begins (Andrady, 2011). With a few exceptions, such as N-H, O-H, and C-H, the UV-B radiation that reaches earth (wavelength 2900–4000) has an energy range of 72–97 Kcal/mole, which is sufficient to dissolve any chemical bond (Cassidy & Aminabhavi, 1981; Fotopoulou & Karapanagioti, n.d.). When sunlight is applied to polymers, a chemical chain reaction is triggered that results in the removal of a hydrogen atom (H•) from an excited polymer molecule (RH) and the creation of a free polymer radical (R•) (Chamas et al., 2020).

$$\text{Initiation: RH} \xrightarrow{UV-B} RH^{*}$$

$$\text{R}H^{*} \rightarrow \text{R}\bullet + \text{H}\bullet$$

This polymer radical's (R•) reaction with oxygen (O) results in the formation of a peroxy radical (ROO•), which then reacts with a nearby polymer molecule (RH), removing hydrogen atoms (H•), to create a new polymer radical (R•) and a hydroperoxide (ROOH) group (Rnby, 1993).

$$\text{Propagation: R}\bullet + O_2 \rightarrow \text{ROO}\bullet$$

$$\text{ROO}\bullet + \text{RH} \rightarrow ROOH + \text{R}\bullet$$

In the presence of light, hydroperoxide (ROOH) can change (Yousif & Haddad, 2013). The photodegradation process continues by chain propagation as it degrades into alkoxy (RO•) and hydroxyl (OH•) radicals, each of which generates a new polymer radical (R•) (Chamas et al., 2020).

$$\text{Propagation: ROOH} \rightarrow \text{RO}\bullet + \text{OH}\bullet$$

$$\text{2ROOH} \rightarrow \text{RO}\bullet + \text{ROO}\bullet + H_2O$$

$$\text{RO}\bullet + \text{RH} \rightarrow \text{ROH} + \text{R}\bullet$$

Chain propagation terminates when radicals combine together and form non-radical stable products (Rånby, 1993; Yousif & Haddad, 2013).

Termination: ROO• + ROO•→ ROOR + O_2

R• + R•→ R-R

ROO• + R•→ ROOR

β-scission of alkoxy radical (RO•) results in the formation of oxidized groups such as carboxyl, carbonyl, etc., which may promote further chain scission by photolysis of Carbonyl functional groups (C=O) (Cassidy & Aminabhavi, 1981; Yousif & Haddad, 2013). Either the Norrish Type I or Norrish Type II reaction is used to promote carbonyl photolysis (Rnby, 1993). While Norrish Type I reaction refers to photochemically induced homolysis of carbonyl group into two free radical intermediates, Norrish Type II reaction is light-induced intramolecular extraction of a -hydrogen to produce alkene and enol or allow cyclization of carbonyl compounds to cyclobutanols (Chamas et al., 2020; Scheffer et al., 1986). Further deterioration can take place at a reasonable temperature without being exposed to sunlight because the primary function of radiation is to introduce chain initiation reactions (Andrady, 2011). Therefore, under normal circumstances, photodegradation and thermal deterioration are identical (Fotopoulou & Karapanagioti, n.d.). However, in the absence of UV radiation, Polyethylene (PE) must reach a minimum temperature of 100 °C before thermal deterioration can begin (Chamas et al., 2020). However, research has shown that polyacrylonitrile (PAN) is more easily degradable and less persistent than polyester (PET) and polyamide (PA) when exposed to sunshine (Sait et al., 2021).

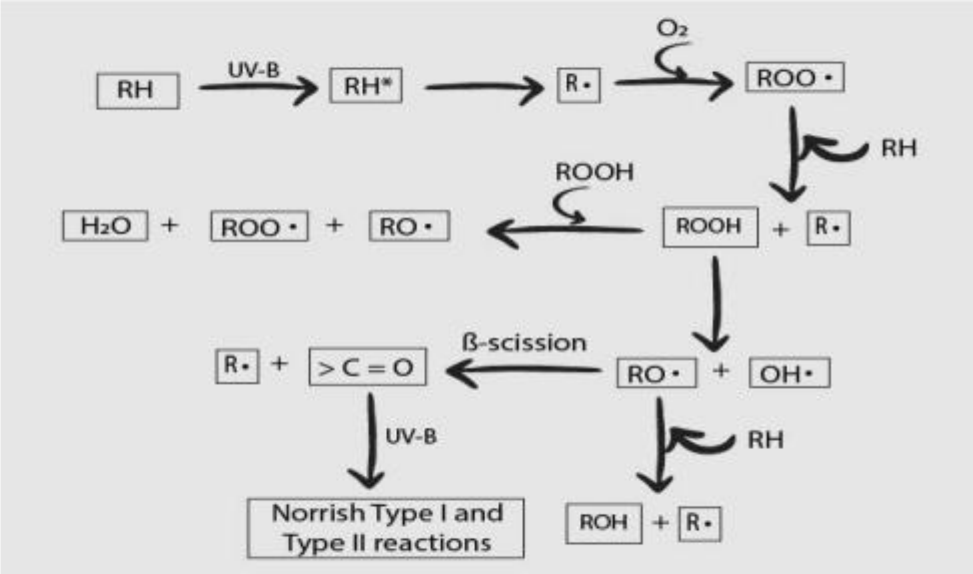

Figure 1 An overview of the photodegradation process of MPs

2.2.3.2 Biodegradation

Microplastic particles will go through biodegradation following considerable photodegradation and fragmentation by waves, wind, and rain (Cassidy & Aminabhavi, 1981; Muthukumar & Veerappapillai, n.d.). Polymers slowly turn into biomass during biodegradation, until they eventually vanish (Andrady, 2011). The characteristics of the polymer, such as its molecular weight, size, shape, and surface area, the type of organism and the nature of its enzyme, the characteristics of the abiotic exposure, such as pH, temperature, moisture, and the type of pretreatment, all have an impact on this process (Ahmed, 2018; Fotopoulou & Karapanagioti, n.d.; Muthukumar & Veerappapillai, n.d.). Exoenzymes released by microorganisms attach to polymer fragments to start the action (Ahmed, 2018). Exoenzymes are responsible for breaking down polymer chains into monomers, dimers, or oligomers (Fotopoulou & Karapanagioti, n.d.). Lightweight molecules with shorter chains like monomers, dimers, or oligomers can easily enter the cytoplasm of bacteria (Muthukumar & Veerappapillai, n.d.). According to Cassidy and Aminabhavi (1981), the assimilated molecules are used by microorganisms to produce energy, new cells, and other metabolic products, with the end result being water, carbon dioxide (in anaerobic conditions), or methane (in anaerobic conditions) (Ahmed, 2018; Muthukumar & Veerappapillai, n.d.).

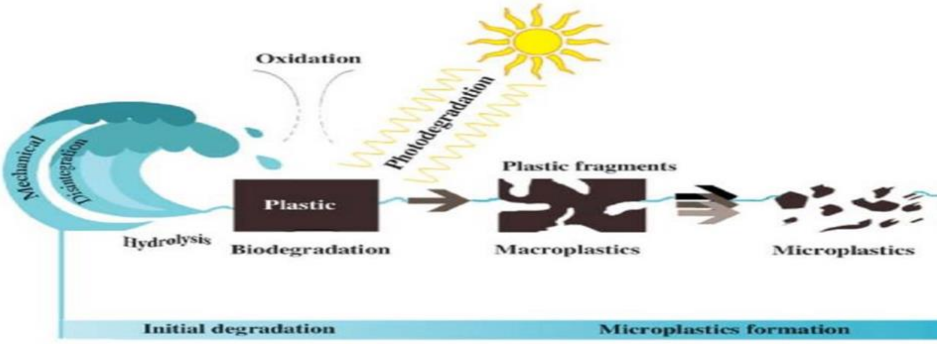

Figure 2 An overview of the degradation process of plastics

2.2.3.3 Pathways of MPs to River Sediment

According to Gong and Xie (2020), microplastics move from one environmental component to another rather than remaining isolated to one. According to Tang et al. (2020), there are three different ways that microplastics can enter the water column: directly through land-based activities, indirectly through treated and untreated wastewater, and directly through water-based activities. In the aquatic environment, land is thought to be the major source of microplastics (Gong & Xie, 2020; Yang et al., 2021). Some microplastics from waste yards, agricultural fields, roads, and other sources move directly into rivers with surface runoff; others travel into the subsurface first and then reach rivers with subsurface runoff (Gong & Xie, 2020; Yang et al., 2021); and the remaining portion enters the sewage system (Waldschläger et al., 2020). Microplastics are released into the river with sewage wastes since the municipality lacks a wastewater treatment facility.

Despite having a high removal effectiveness, the sewer system with a good treatment facility can nevertheless be a significant source of microplastic (Yurtsever, 2019). Similar to how macroplastics can enter rivers with includes industrial wastewater. In order to prevent microplastics from entering the aquatic environment, sludge from wastewater treatment plants can be utilised as a landfill and fertiliser in agricultural fields (Waldschläger et al., 2020). Additionally, certain microplastics are directly released into rivers by activities involving water, such as fishing, navigation, and port operations (Tang et al., 2020). Microplastics with a density larger than water easily sink down and assemble in the benthic sediment in a river with low flow velocity (Nizzetto et al., 2016). In contrast, particles in a river with a high flow velocity will travel with it into a zone of low flow velocity before settling (Nizzetto et al., 2016). Though they often float and end up in the ocean, particles with a density lower than water can be kept in the river sediment by biofouling and agglomeration (Waldschläger et al., 2020). According to Andrady (2011), biofouling is the colonisation of microorganisms on the surface of microplastics. The initial stage of the procedure is the formation of a biofilm on the surface of the microplasi-cs that contains algae, spores, and other dissolved debris and makes it easy for colonising microorganisms to attach (Coyle et al., 2020). When biofouling occurs, the density of the particles tends to rise, allowing the particles to sink when it exceeds the density of water (Coyle et al., 2020). Regardless of density, microplastics smaller than 0.2 mm typically do not end up in river sediment (Nizzetto et al., 2016).

2.3 Microplastics Analysis Methodology

Although several researchers have conducted rescarch on microplastic since two decennaries, standardized methodologies for microplastic analysis have yet to develop (Li et al., 2018; Yang et al., 2021). This paper has reviewed previous studies to overview sample collection.Overall microplastic analysis methodology can be divided into four

Steps: Sample collection, sample preparation, sample extraction and purification &

identification and quantification.

2.3.1 Sample Collection

Though sample collection strategy mostly depends on the objectives of the study, it is expected to collect the maximum possible number of samples in order to gain an accurate and deep understanding of the distribution and quantity of microplastic particles in sediment (Stock et al., 2019).

The methods of microplastic sampling in freshwater column can be –

1. CTD Device: Water samples at depth in the water column are collected using CTD devices, which also measure depth, temperature, conductivity, oxygen, and other parameters simultaneously. At the necessary water depths, the sampling bottles can be sealed from the ship (*Water Column Sampling - NIOZ*, n.d.).
2. Manta Net: Actually, the most popular technique for MP sea surface sampling is the Manta net device. The floating/stabilizing component, the opening mouth, and the net bag are the three primary components of this net, and each of them can be customised. The effectiveness of the sampling and correct quantification of MPs in aquatic environments may depend on these characteristics and the sampling techniques. It is impossible to compare the research because of the use of various mesh sizes, inconsistent trawling time, pace, and distance, and irregular net opening measurements (Pasquier et al., 2022).
3. AVANI trawl : The AVANI trawl, however, can capture microplastics from the sea surface at rates up to 8 knots as it "skis" across the surface using a 335 m net. In general, the manta trawl and DiSalvo neuston net only skim the surface layer while the AVANI trawl, moving vertically in a random manner, collects a "deeper" sample, catching the few plastics that float slightly lower in the water column. This is likely because these trawls only skim the surface layer (Eriksen et al., 2018).

2.3.2 Sample Preparation

To avoid variability in moisture content of water samples, microplastic concentration is suggested to be expressed as dry weight (Van Cauwenberghe et al., 2015). So, residual moisture should be driven off to a constant weight preceding analysis (Yang et al., 2021). Samples can be dried in both oven and air. Interior of oven prevents airborne pollution of sediment sample during the oven drying process(Adomat & Grischek, 2020), but the higher operating temperatures may crack and distort the shape of microplastic(M. Zobkov & Esiukova, 2017). Nevertheless, in some studies, samples are dried at high temperatures by omitting common polymers that are vulnerable to heat distortion(Blair et al. , 2019) or eliminating heat distortion effects from consideration (Amrutha & Warrier, 2020; Rodrigues, 2018). In most of our reviewed studies. drving temperature varies from 40°C to 90°C, and in few studies, samples were heated at high temperature of greater than 70°C. In one study, Samples were dried in air at room temperature, which may prolong drying time, contaminated the sample with airborne pollutants, and may have residual moisture content even after completion of the drying process (Adomat & Grischek, 2020).

2.3.3 Extraction & Purification

2.3.3.1 Filtration

The Su et al. (2016) method was used to extract microplastics from the water sample. Briefly, a cellulose nitrate filter with a 5 mm porosity and a 47 mm diameter was used to filter each water sample (Whatman AE 98). All of the filter residues were removed and poured into a glass beaker that contained hydrogen peroxide (30%, v/v), which was then promptly covered with a watch glass to prevent spills. To thoroughly eliminate biological stuff from the leftovers, the glass breakers were heated on an electric plate at 120 C for around 48 hours. The mixture in the beakers was put onto a 20-mm nylon net filter after standing for 24 hours. After that, the filters were kept for later identification (Dai et al., 2018c). Sieving step can be omitted during microplastic analysis in order to include fine-sized microplastic fractions in the study(Z.Wang et al., 2018) or if there is no visible debris in the sample (Di & Wang, 2018).

2.3.3.2 Digestion

Sample purification or digestion is a pretreatment process for removing organic matter from sediment samples to avoid disruption of accurate extraction and categorization of microplastics (Adomat & Grischek, 2020; Gong & Xie, 2020). Acid, alkaline, enzyme, 10-30% H_2O_2 ,solutions, Fenton's reagent can be used to treat biological samples.

35%H,0, solution is proved to be efficient by some studies to remove organic matter from sediment samples (Nuelle et al., 2014). Moreover, standardization of digestion method is moderately being developed by using H,0, solution at controlled temperature in a specific digestion period (Y. Zhang et al., 2020). H,0, digestion may result in discoloration and size reduction of polymer particles > 1 mm in size (Nuelle et al., 2014). On the contrary, (Hurley et al., 2018) have found no visible changes for most of the polymer types during H_20_2oxidation.

A mixture of H,0, and Ferrous Sulfate (FeSO$_4$7H,0) catalyst, namely Fenton's reagent, can be an alternative to H,0, digestion (Adomat & Grischek, 2020). The reaction rate of Fenton's reagent is more rapid and can more efficiently degrade organic matter that is laborious to remove in traditional H,0, digestion (Hurle y et al., 2018). But pH requirement (3.0-5.0) tor the dissolution of ferrous sul fate and effective digestion of organic matter may degrade some microplastics to a certain degree (Neyens & Baeyens, 2003).

Some studies use acid or alkali for the oxidation of sediment samples. But variability in chemical resistance of different types of microplastic may limit the application of strong acid and alkali digestion (Gong & Xie, 2020). For example, the use of sulfuric acid, nitric acid, or Sodium hydroxide may cause the degradation and melting of microplastic particles (Hurley et al., 2018). On the other hand, low concentration of acid and alkali exhibit low removal erficiency; excess organic compounds may remain in the sediment samples at the end of digestion (Nuelle et al., 2014). Enzyme digestion is another alternative for the extraction of microplastic from organic-rich samples. Like Fenton's reagent digestion, enzyme digestion may require certain pH conditions, which can deteriorate some sensitive microplastics (Adomat & Grischek, 2020). Nevertheless, proteinase-K enzyme digestion can achieve more than 97% removal efficiency without affecting the morphology of microplastics (Cole et al., 2015). The applicability of enzyme digestion is limited to small-volume samples only due to the high expense of enzymes (Hurley et al., 2018). Although enzyme can be used in combination with H,0, to reduce expense of the research, it takes several days to digest organic matters efficiently (Martin G. J. Löder et al., 2017). Thus, none ofour reviewed studies used this technique for the oxidation of sedment samples.

2.3.3.3 Density Separation

As the collected sediment samples are mixed with impurities like inorganic clay, separation or extraction of microplastics must be performed during analysis(Gong & Xie, 2020). All the studies used density separation for microplastic extraction. Using the dissimilarity of density between microplastic and non-microplastic particles is the principle of the density separation method (Gong & Xie, 2020). In this method, saturated or highly dense salt is thoroughly mixed with the sediment sample, which allows the low-density particles like microplastics to float and high-density particles like impurities to settle down (Li et al., 2018). Consequently, microplastics are extracted from the supernatant of the solution.

Saturated NaCl solution is a non-lethal, non-abrasive, and economical material, which makes it the most widely used solution for density separation (Yang et al., 2021). The major drawback of this solution is the low extraction efliciency of high-density microplastics like polyethylene (PE) and polyvinyl chloride (PvC) due to its comparatively low density (1.2 g. cm^{-3})(Amrutha & Warrier, 2020).

Zinc chloride solution ($ZnCI_2$) (density: 1.8g. cm-3) eliminate the limitation of NaCl solution and allows floatation of all types of polymer (Tien et al., 2020). A study found that $ZnCl_2$ Solution can extract microplastics with a high recovery rate of 95.8% (Coppock et al., 2017).Since ZnCl,is a perilous solution, recycling and reusing of this solution should be ensured to circumvent environmental degradation(Li et al., 2018).

2.3.4 Identification & Quantification

ldentification is the most important part of the microplastic analysis and can be performed by visual and/or spectroscopic inspection. The purpose of the visual investigation is to sort out presumed microplastics for further identification based on physical attributes like shape, size, and color (Y. Zhang et al., 2020). Sorting can be done by the naked eye or in assistance with a microscope (Hidalgo-Ruz et al., 2012). Various types of microscopes such as stereoscopic microscope(Jiang et al., 2019; Simon-Sánchez et al., 2019), metallographic microscope (Ding et al., 2019), fluorescence microscope (Wu et al., 2020), light microscope (He et al., 2020), etc. are used during visual inspection. Among them stereoscopic microscope is considered the most used microscope.

2.3.4.1 Visual Inspection

Visual sorting may depend on the examiner's perspective, quality ofmicroscope, and condition of sediment sample (Li et al., 2018). So, this type of inspection is open to bias and may result in the misidentification of microplastics (Yang et al., 2021). It seems difficult to identify particles smaller than 100 um in size, and even veteran operators sometimes confound microplastics with organic particles (Eerkes-Medrano et al., 2015; Hanvey et al., 2017). The accuracy of visual inspection decreases with the decrease of particle size (Gong & Xie, 2020), and the rate of misidentification can be as higher as 70% (Hidalgo-Ruz et al., 2012). For instance, (Horton et al., 2017) analyzed 336 visually identified particles under Raman spectroscopy and found only 1ll particles (33%) chemically identifiable. Selection of plastic particles during visual identification should be based on the following criterion: particles must be free from organic impurities, must have consistency in thickness, and homogeneity in color across its length, transparent or white microplastics must be identified with the help of a fluorescence microscope under high magnification to avoid organic particles (Hidalgo-Ruz et al., 2012). Nevertheless, sometimes irregularity in the edge of colored fiber, bleaching, biological contamination, and design of plastics are taken into deliberation (Simon-Sánchez et al., 2019). It is preferable to examine the microplastics on the filter surface without transferring to any other container to avoid loss (Yang et al., 2021), and the investigation should be performed from the top left to the bottom right to avoid duplicate counting (Simon-Sánchez et al., 2019).

Apart from identification purposes, surface characteristics of microplastics and the effect of ultrasonic cleaning on polymers can be investigated by a Scanning electron microscope (SEMXWu et al., 2020). Microplastics identified from the spectrometric analysis are wrapped with a thin gold or platinum film and then mapped using SEM. As degraded particles are heterogeneous, visual inspection should be repeated at least thrice to avoid inaccuracy (Jundong Wang et al., 2017).

2.3.4.2 Spectromnetric Analysis

Spectrometric analysis is performed in order to investigate the chemical composition of microplastics (Gong & Xie, 2020). Besides, It can be used to assess visual sorting and correct the particle count determined from visual inspection (Constant et al., 2020). The principle of spectrometric analysis is to detect vibration from agitated samples and compare the produced spectra to the known reference spectra (de Souza Machado et al., 2018; Elert et al., 2017: Mai et al., 2018). Fourier transform infrared (FTIR) and Raman spectroscope is the most widely used spectroscope for the analysis of microplastic (Hidalgo-Ruz et al., 2012).

FTIR can function in three modes- Reflection, transmission, and attenuated total reflectarnce(Yang et al., 2021). FTIR is widely operated by attenuated total reflection (ATR), in which particles are individually identified and detected by an ATR tip (Lee & Chae, 2021).

Unlike FTIR spectrometry, wet samples can be analyzed in Raman spectroscopy (RM)(lvlevaet al., 2017). RM offers high spatial resolution so particles less than 20 um-can be easily detected (Gong & Xie, 2020). Moreover, when microscopy is added with RM spectra, it even allows the analysis of submicron particles (<l um) (Imhof et al., 2016). In contrast, RM spectrometry is not fit for the samples that are sensitive towards fluorescence action. So. samples need to be free from additives, pigment, cellular, organic, and inorganic impurities (Gong & Xie, 2020; Yang et al., 2021). Another possible drawback of RM spectroscopy is the misidentification of photodegraded particles (Silva et al., 2018). For example, the spectrum of, which photodegraded PVC illustrates a concurrent depletion of the peak at 693 and 637 cm^{-1} is similar to the characteristics of C-Cl (Lenz et al., 2015). Moreover, chemical mapping using RM spectrometry is a comparatively time-consuming process (Ivleva et al., 2017). In comparison with FTIR it can be concluded that FTIR is more etlicient to identify polar groups of polymer while RM shows better result of identifying non-polar and symmetric bonds (Silva et al., 2018).

Pyrolysis-GC/MS is another alternative for microplastic analysis where the chenmical composition of microplastic is detemined by analyzing themally decomposed products (Nuelle et al., 2014). Since it is a destructive method, it does not determine the amount, shape & size of microplastics (Y.Zhang ct al., 2020). Rather it only provides information about the type and mass fraction of chemical components (Dümichen et al., 2015). In addition, it is not possible to distinguish between polymer subtypes, such as whether the detected particles are low-density or high-density using Pyrolysis-GC/MS (Silva et al., 2018). But it is a quick method and can be the best alternatives for routine 2017). Another possible advantage of Pyrolysis-GC/MS is that it allows the identification ofthe chemical composition of the polymer and its associated additives simultaneously (Fries et

al., 2013). Moreover, This type of analysis omits the requirement of any pretreatment of the Samples (Kusch, 2017). In contrast. Samples with a high amount of impurities and samples With smaller particles (<500um) do not have applicability to Pyrolysis-GC/MS analysıs (T ang et al., 2021). However, only a small volume of samples (5-200 ug) can be analyzed at a time with the machine setup of Pyrolysis-GC/MS -GCMS (Kusch, 2017). Besides, Some polymers may exhibit identical degradation outcomes and lead to the misidentification of polymer types (Gong & Xie, 2020). analysis of microplastics (Dümichen et al.,

2.4 Abundance and Characteristics of MPs

2.4.1 Factors affecting the occurance of MPs in water column

Abundance of microplastics in river water column depends on various factors such as- Population density, level of urbanization, and anthropogenic activity of surrounding area; precipitation, wind intensity, tidal current, river width, flow velocity, season, and microplastics properties. Thus, the concentration of microplastics varies significantly around the globe (Jiang et al., 2019). Since rivers receive household sewage, industrial effluent, and agricultural wastewater, the abundance of microplastics has a positive correlation with population size, urbanization, industrialization, recreational, and other human-induced activities(D. Huang et al., 2020; Nel et al., 2018; Wen et al., 2018; Wu et al., 2020). Though microplastics particles can travel for prolonged distances (Gerolin, 2020), the concentration of microplastics decreases with the distance from the city or industry (Joana C. Prata et al., 2021). However, an effective treatment plant with tertiary technology can eliminate 98% of microplastics pollutants from effluent and prevent WWTP from being a potential source of microplastics(Lin et al., 2018). Low flow velocity promotes sedimentation of microplastics and thus is negatively correlated with the microplastic concentration in sediment (Tien et al., 2020). This correlation results in low microplastics accumulation during the rainy season(Wu et al., 2020) and high microplastics abundance in comprehensive portion of the river (D. Huang et al., 2020). Subsequently, higher microplastics accumulation is observed during winter than summer due to the decrease in flow rate (Nel et al., 2018; Schmid et al., 2020). Again, Extensive rainfall incorporated with high wind intensity and intense wave action associates the entrance of microplastics from sediment to the water column and reduces microplastics concentration in sediment (Amrutha & Warrier, 2020). In contrast, there is evidence of increase in microplastics abundance after a typhoon both in water column and sediment(Jun Wang et al., 2019). Accumulation of microplastics in water column also depends on microplastics properties like density and surface to volume ratio(Wu et al., 2020). High surface to volume ratio and low density enables polymer to remain in the water as suspension, whereas low surface to volume ratio and high density promotes deposition of polymer in the riverbed(Lin et al., 2018; Liu et al., 2021; Wu et al., 2020). Though microplastics particles can travel for prolonged distances (Gerolin, 2020), the concentration of microplastics decreases with the distance from the city or industry (Joana C. Prata et al., 2021). For example, (Jiang et al., 2019) found comparatively high amount of microplastics in the sediment near Lhasa, the capital of the Tibet Autonomous region, high in population and tourist attraction. On the contrary, (Z.Wang et al., 2018) observed an exception of this trend in the sediments of a river network in eastern China, where concentrations of microplastics in the sampling sites near the highly populated region were slightly lower than the average value of all sites.

2.4.2 Characteristics of MPs

An overview of Microplastics characteristics is summarized in Table A1.

2.4.2.1 Shape

Fibre is a secondary microplastic, cylindrical in shane, and whose length is significantly higher than its width (D. Huang et al.. 2020: Ngo et al.. 2019), It usually originates from synthetic Clothes during the washing and manufacturing process of textile goods, fishing nets, rop Sacks (Amrutha & Warrier. 2020: Ngo et al 2019- Vang et al. 2021). Fibers produced from fishing activity can be defined as lines (Dioses-Salinas et al.,, 2020). Pellet is a primary microplastic which is spherical or elliptical in shape and usually derived from personal products such as cosmetics, toothpaste, etc. (D. Huang et al., 2020; Kutralam-Muniasamy et al., 2020; Ngo et al., 2019). Film is a thin, pliable polymer, whereas foam is a soft, light microplastic (Wu et al., 2020). Microplastics with iregular shapes and definite thicknesses are categorized as fragments (D. Huang et al., 2020). Continuous exposure of large plastic debris to erosion, wear, and UV light may produce fragments (Yang et al., 2021). However, Film, foam, and fragments can originate from wrapping or packaging materials, Supermarket bags, milk boxes, tires, pavement materials during the mechanical wearing or chemical degradation process (Kutralam-Muniasamy et al., 2020; Ngo et al., 2019; W. Wang et al., 2017). Foam is also derived from the insulating material of buildings (W. Wang et al., 2 017)

Interaction with various organisms depends on the shape of microplastics (Kutralam-Muniasamy et al., 2020). The irregular and angular shape of fragments provide a suitable Surface for the attachment of microorganisms which accelerates the sedimnentation process and increases the removal efficiency of fragments in WwTP(Ngo et al., 2019). However, this phenomenon can severely affect the tissue of microorganisms in the natural environment (Kutralam-Muniasamy et al., 2020). On the other hand, smooth surface and significantly higher length to width ratio galvanize fibers to escape from WWTP and cause less histopathological damage to microorganisms (Kutralam-Muniasamy et al., 2020; Ngo et al., 2019). Fiber is found to be the predominant shape of microplastic in river sediment in most of our reviewed studies (Jiang et al., 2019; Liu et al., 2021; Tien et al., 2020). However, in the Nakdong River, South Korea, fragments was detected as the most abundant shape and contributed to almost 84% of the total microplastics, which trend is similar to some other studies (Constant et al., 2020; Eo, 2019; Rodrigues, 2018). In Shanghai, China, the most dominant shape was spheres and accounted for 88.98% of the total number of microplastics observed(Peng et al., 2018). In Pearl river catchment, China, and Brisbane river, Australia, the most common shape of microplastics were sheets and films, respectively (Fan et al., 2019; He et al., 2020).

2.4.2.2 Size

The probability of being ingested and he pathway of microplastics largely depend on its size (Amrutha & Warrier, 2020; Yang et al., 2021). Due to high specific surface area, biofouling is more likely to occur in small-size microplastics that fasten their deposition in the river bed (Liu et al., 2021; Z. Wang et al., 2018). So, larger microplastics can migrate longer distances compare to smaller ones. In addition, larger microplastics pose more threat to the environment as it is less likely to be biodegraded, prevails longer time in the environment and eventually converts into small-sized microplastics and nano-plastics (Kutralam-Muniasamy et al., 2020). But smaller particles are more bioavailable to benthic organisms and can be transmitted to the terrestrial food web (Dioses-Salinas et al., 2020). Diferent studies have detected microplastics of various size ranges, but small size microplastics were dominant in all studies, which indicates high level of weathering and fragmentation of their initial product (Feng et al., 2020; D. Huang et al., 2020). For example, in the rivers of the Tibet Plateau, 70% of the total microplastics were found to be less than Imm(Jiang et al., 2019). A similar trend was observed in the middle-lower Yangtze river basin, where microplastics ranges from 0.25-Imm were the most abundant (Su et al., 2018). However, in the Wen-Rui Tang River, microplastics ranges from 20-300 um were predominant and contributed to 84.6% of the total microplastics (Z. Wang et al., 2018).

2.4.2.3 Colour

Since the color of microplastics can be bleached out during the sample preparation and even in the natural environment during the photodegradation process, careful approach is required to identify the source of microplastics based on color (Fan et al., 2019; Yang et al., 2021). Furthermore, during sample extraction and purification process, some microplastics can be eroded and result in the underestimation of transparent microplastics during identification (He et al., 2020). Microplastics are recommended to classify into four colors - Colorless or transparent, black, white, and colored (Yang et al., 2021). However, some studies have also sub-grouped the colored microplastics into yellow, green, blue, red, etc. categories (Jiang et al., 2019; Wen et al., 2018). In most of our reviewed studies, transparent microplastics were found to be predominant. For example, transparent microplastics contributed to 45.69% of the total number of microplastics in the Tibetan

Plateau(Feng et al., 2020). However, white particles were also found to be the most abundant in some studies. For instance, the contribution of white spheres in Shanghai, China were almost 90% (Peng et al., 2018). In contrast, yellow particles were most dominant in the Pearl River and accounted for 36.2% of the entire microplastics (Lin et al., 2018).

2.4.2.4 Chemical Composition

Chemical composition is one of the most fundamental characteristics of microplastics (Y. Zhang et al., 2020). At present more than 30 types of microplastic polymers have been identified in different studies (Ngo et al., 2019). Among them Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Poly(ethylene-propylene) Copolymer, Polyethylene, Terephthalate (PET), Polyester (PES), Polyvinylchloride (PVC), Vinyl Acetate Copolymer (VCVAC), Polyamide (PA), Cellulose, etc. are noteworthy. PP, PE, and PET usually originate from packaging material, plastic bags, containers, agricultural films, conduits, cords, automobiles, and domestic accessories, etc. (Kutralam-Muniasamy et al., 2020; Liu et al. 2021: Tien et al., 2020). On the contrary, fabrics, lines and furniture fillers, etc. are the potential source of PA and PES (Tien et al., 2020).

Biofouling on the surface of PE and PP that influenced them to sink in the river bed may be the potential cause of this (D. Huang et al., 2020). Other than PP and PE, polymer types varied considerably in different studies. For example, PES (33%) and PA(24%) were predominant in the Yangtze River basin and Ebro river sediment, respectively. (Su et al., 2018)

2.5 Research on the detection and assessment of microplastics pollution in Bangladesh

In July 2022, "microplastic Bangladesh", "microplastics in Bangladesh", “microplastic pollution in Bangladesh", "micro debris", or “micro plastic fragments" were used as keywords to find out research on microplastics pollution in Bangladesh from Web of Science,

Science Direct, and Google Scholar. A total of 18 studies were found. The existing studies on microplastics pollution in Bangladesh was divided into six broad groups based on regions of analysis and sample types: 1) Coastal sediment/water, 2) Urban water, sediment and fish, 3) Estuary sediment/water, 4) Marine/freshwater fish and shrimp species, 5) Salt farms/edible salts, and 6) Ship breaking yard soil. The relationships between results from different studies, sampling method, separation technique, characterization process, abundances and characteristics of microplastics have been summarized in Table 1.

Table 1 Study area and corresponding river basinsNumber of articles found in online search

Databases	Objectives	Major Findings
Google Scholar	examining the connections between sediment and water pollution from microplastics. (Dai et al., 2018)	1.Different types of microplastics were predominately found in the saltwater and sediment of the Bohai Sea. 2. The sediment and deeper water levels had less fibres than the surface water. 3. In contrast to its surface waters, the Baohai Sea's deeper waters acquired significant levels of microplastics. 4. Fibre, which made up roughly 75%-96.4% of all microplastics found in the soil and saltwater found in the Bohai Sea, was the most prevalent type.. 5. However, compared to surface water, the proportion of fibres in sediment and deeper water layers was decreased.

		6. The sizes of the microplastics varied The size-fraction below 300 micrometres grew in proportion with depth in the water column. This is most likely owing to the small microplastics' fast biofouling because of their larger specific surface area. 7. With a mean of 2.2 pieces L-1, the microplastic abundance ranged from 0.4 to 5.2 pieces L-1. 8. Spatial variation in the amount of microplastics was found in the research region. 9. Between 5 and 15 metres in depth in the Bohai Sea, a higher concentration of microplastics was found. 10. The microplastic polymers included cellulose, polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET), and polypropylene (PP) are examples of common plastics. (Dai et al., 2018)

Google Scholar	They have launched a new tool to help people better grasp what happens to MPs in water environments and how they migrate, as well as the need to know about MP monitoring in all key aquatic habitats. 2. For the MPs' inquiry into the water column, a tool that can collect water in multiple cubic metre volumes from designated water strata down to a depth of 100 metres was constructed. (Zobkov et al., 2019)	1. There was a distinct stratification of MPs at each site that was tested. 2. The thermohaline, near-bottom, and subsurface layers had higher concentrations of MP than the middle layers did. 3. MPs had a varied distribution, and their remains can be found above the ocean's surface and in the coastal seas.. 4. The vast majority of deep net tows at depths more than 25 m contained plastic, which was dispersed vertically within the mixed layer as opposed to being surface-trapped.. 5. It was discovered that smaller MPs were more common in the water column. 6. A self-priming pump that can take water from a particular stratum is the foundation of the PLEX. 7. It is not necessary for the pump to have a particular waterproof certification because it is used on the ship's deck.. 8. The technology can subjugate suspended water that is many cubic metres in volume from various strata down to a depth of 100 metres. 9. This study highlights the impact of a vertical density stratification on the distribution of MPs concentrations in the Baltic Sea water column by explaining the instrument operating concept and testing outcomes. 10. MPs concentration on the station could be shown to be vertically stratified, with the subsurface and intermediate strata having the highest fibre contents.

		11. In comparison to the other stations, Station A has the fewest fragments. 12. The level of film concentration was comparable to what was seen at other locations. 13. Based on their morphological characteristics, a total of 122 microplastic specimens were selected, with fibres being the most common kind of MPs. Of these, 44 were accurately identified using Raman spectroscopy. (Zobkov et al., 2019)
Google Scholar	1. Using a specific procedure for water sample, extraction, and plastic debris detection is strongly encouraged. 2. In order to protect the marine environment, management strategies that reduce plastic waste at the source, as well as reduce plastic usage, increase recycling, and improve disposal facilities, must be promoted and put into action. (Supuran et al., 2019)	1. This analysis explains the concentration, origin, distribution, and composition of MP in the Mediterranean Sea's water column and sea surface. According to the research, there were distinct geographical variations in the distribution and makeup of MP particles across the sub-basins of the Mediterranean. 2. Since there is no recognised sampling method, the identification and quantification levels of floating MPs cannot be compared. Variations in extraction and detection methods, replication rates, tools, and mesh sizes are mostly to blame for this. (Supuran et al., 2019)
Google Scholar	Both primary and secondary sources can produce microplastic that ends up in the marine environment. Primary microplastic is produced in incredibly tiny proportions. Physical, chemical, and biological processes that lead to the	1. Other sizes were rare, with the majority of the plastic microlitter collected from the ocean falling between the diameters of 0.1 and 2.5 mm.. 2. The quantity

	fragmentation of the initial plastic piece cause secondary microplastic to be created over time from the breakdown of bigger plastic debris.. (Güven et al., 2017)	samples of surface water contained between 16 339 and 520 213 microplastic particles per km2. 3. A total of 1822 microplastic particles were found in fish stomach and intestines. 4. Only a small portion of the total was made up of nylon (2.7%), rubber (0.8%), and different plastics (5.5%), whereas fibres (70%) and hard plastic (20.8%) made up the majority of ingested particles. 5. The most prevalent colour of plastic was blue. 6. Of the fish examined, 34% had microplastic in their guts. 7. The average amount of microplastic particles discovered in the guts of fish was 1.80. In the intestines of 41% of all fish, microplastic was discovered with an average of 1.81 particles per fish. 771 specimens, or 58% of the total sample, had microplastic in their stomachs or intestines, with an average of 2.36 pieces per fish. 8. Microplastic was present in all species and families with sample sizes of at least two people. The stomach or intestines may contain between 1 and 35 particles. Although smaller particles as little as 9 mm were also discovered, the average diameter of the swallowed microplastic particles ranged from 656 to 803 mm. 9. The amount of microplastic that different fish species ingested was not at all correlated with their trophic status. Pelagic fish absorbed more microplastic than demersal species. Fish that absorbed more microplastic particles often originated from regions with higher saltwater and substrate particle counts. (Güven et al., 2017)

CHAPTER 3: Methodology

General

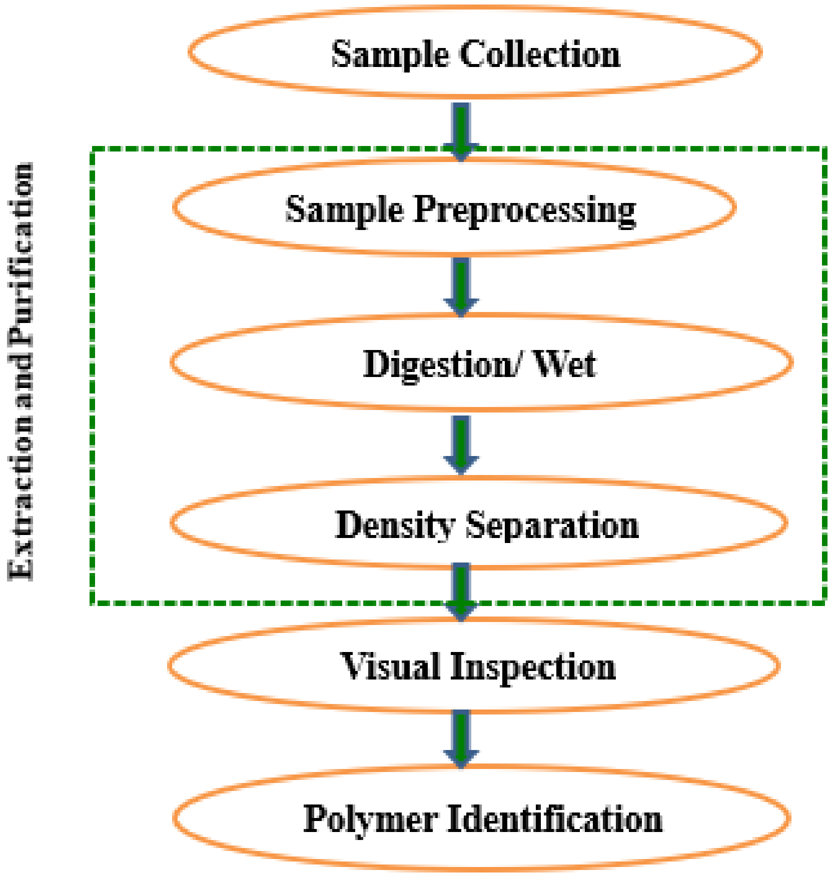

Figure 3 Extraction and purification of MPs

These are the steps that are followed in the whole process sequently.The methodology is adopted from NOAA and some changes are made according the lab situation.

3.1 Study area and Selection of sampling points

This investigation was carried out along the Buriganga, Turag, and Balu rivers in the outskirts of Dhaka. These freshwater streams measured BR, 23 km; TR, 36 km; and BaR, 15 km in length. The rivers' subbasins were created using a digital elevation model using Esri's ArcGIS 10.8

software. Catchment areas for the BR, TR, and BaR subbasins are 251, 50, 290, 56, and 463, 88 km2 respectively.

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In consideration of the land use patterns and pollution sources, 28 sampling points from the rivers BR (n = 11), TR (n = 14), and BaR (n = 3) were chosen (Fig. 1).

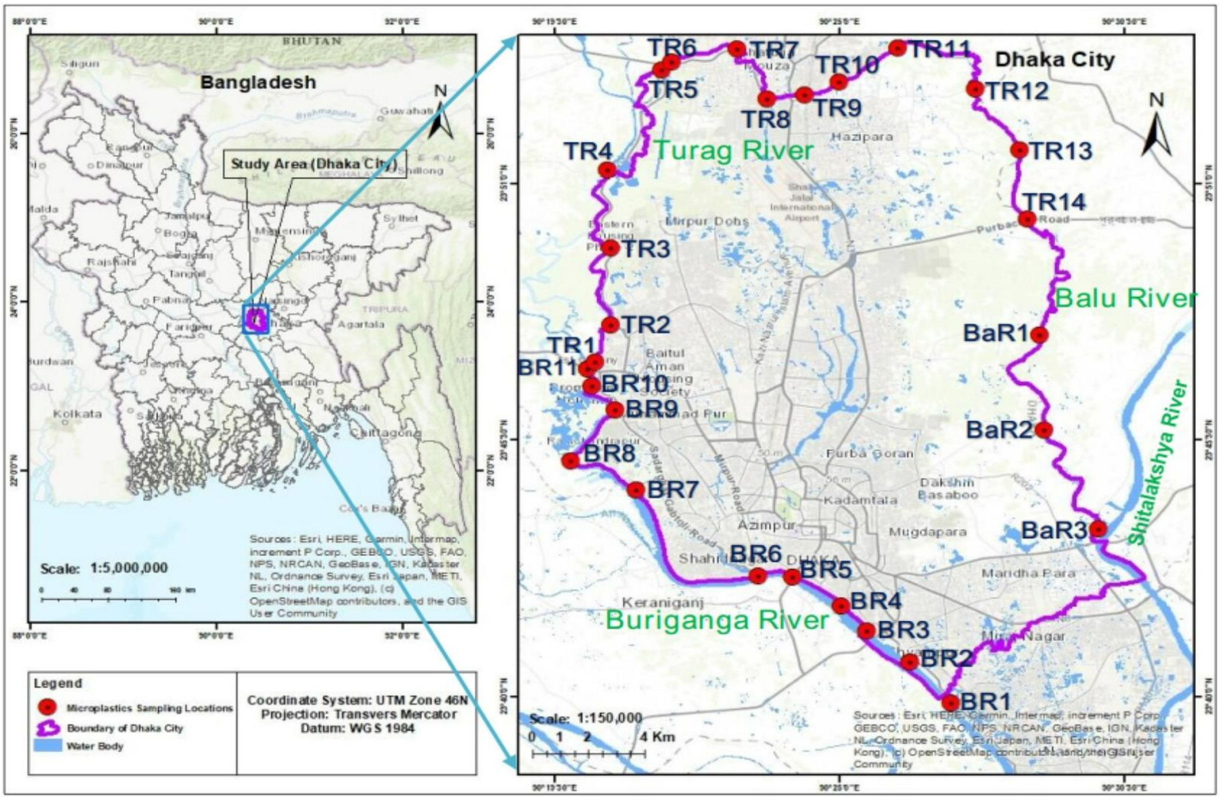

Figure 4 Study area and riverbed sediment sampling locations of the peripheral rivers of Dhaka city

Instead of considering length or catchment area, sampling stations were chosen based on pollution sources and land-use trends. Despite being the largest basin of the three, the Balu River was only used for three sampling stations. The sample stations in Buriganga and Turag (TR and ToC) were 11 and 14, respectively. Information about land-use characteristics and pollution sources was taken from Google Earth and the USGS (Figure 1). Figure 1 shows that Balu Basin had completely reversed aspects in terms of land use characteristics from Buriganga Basin, which was primarily urbanized and influenced by point sources. Both point (urban) and non-point (agricultural and green fields) sources are included in the Turag Basin. Table 2 contains more information on the study area.

Table 2 Study area and corresponding river basinsNumber of articles found in online search

SI. No.	River	Assigned ID	GPS Coordinates	Key Features/Remarks	Source Type
01	Buriganga	BR1	23.664859° N, 90.452726° E	Downstream of Pagla STP (Commercial & Industrial Area)	Point
02	Buriganga	BR2	23.679284° N, 90.439381° E	Upstream of Pagla STP (Commercial & Industrial Area)	Point
03	Buriganga	BR3	23.690331° N, 90.425369° E	Faridabadh Residential Area, Buriganga Bridge near Fatullah, Postogola Govt. Modern Flour Mill	Point
04	Buriganga	BR4	23.699379° N, 90.417263° E	Down Stream of Sadar Ghat, Sluice gate near Buriganga River, Farash-Ganj Bridge	Point
05	Buriganga	BR5	23.709795° N, 90.401527° E	Commercial area, Sawari Ghat, Babu Bazar, Sir Salimullah Medical College	Point
06	Buriganga	BR6	23.710026° N, 90.390533° E	Downstream of Sultanganj Residential & Commercial area, Kamrangi char	Point
07	Buriganga	BR7	23.740877° N,	Boshila Residential Area, Bangladesh eye trust Hospital	Point

SI. No.	River	Assigned ID	GPS Coordinates	Key Features/Remarks	Source Type
			90.351158° E		
08	Buriganga	BR8	23.751012° N, 90.330164° E	Boshila Residential Area, Brick Firm	Point
09	Buriganga	BR9	23.769175° N, 90.344659° E	Residential Area: Baitul Aman Housing Society, Sunibir Housing	Point
10	Buriganga	BR10	23.777804° N, 90.337171° E	Mixed Area: Downstream of Gabtoli Sweeper Colony, BIWTA Landing station	Both
11	Buriganga	BR11	23.783858° N, 90.335702° E	Mixed Area: Gabtoli Cattle Market, Amin Bazar landing station, Gabtoli Bridge (Mix Zone Area)	Point
12	Turag	TR1	23.786274° N, 90.338190° E	Mixed Area: Golaptak mix zone Area, Boro Bazar, Boro Bazar Ghat	Both
13	Turag	TR2	23.799784° N, 90.343166° E	Residential & Homestead Plants area: Turag City , Bangladesh national Zoo, BIWTA, Landing Station , Diabari Boat Yard	Both
14	Turag	TR3	23.826958° N, 90.342968° E	Residential and Planted Garden: Eastern Housing, Botanical Garden, Tamanna Family Park, S4 Sluice Gate	Both
15	Turag	TR4	23.854818° N, 90.341898° E	Downstream of Rajuk Residential area (Effect of Ashulia Industrial Area).	Both

SI. No.	River	Assigned ID	GPS Coordinates	Key Features/Remarks	Source Type
16	Turag	TR5	23.890476° N, 90.359335° E	Ashulia Ferry Ghat, Ashulia Landing station, Ashulia Bus Stop (Effect of Ashulia Industrial Area)	Both
17	Turag	TR6	23.893522° N, 90.362811° E	Industrial & Residential Area (Jamaldia, Tongi)	Both
18	Turag	TR7	23.898066° N, 90.383805° E	Industrial & residential Area, kathaldia Ghat, Greenland hospital	Both
19	Turag	TR8	23.880292° N, 90.393299° E	Industrial, Residential and Hospital Area: Abdullah Sluice Gate, Shaheed Mansur Ali Medical college & Hospital, Tongi Bishwa Ejtema Mydan, Near Uttara Sector 11	Point
20	Turag	TR9	23.881708° N, 90.405556° E	Mixed Zone: Tongi Bridge, Sawdagar Stone Mill, Arichpur	Point
21	Turag	TR10	23.886367° N, 90.416720° E	Effect of Industrial Area, Tongi Nodi Bondor	Point
22	Turag	TR11	23.898398° N, 90.435431° E	Effect of Industrial Area, Radix Garments	Both
23	Turag	TR12	23.861912° N, 90.474911° E	Agricultural land & Open Plot for Future Development	Non-Point
24	Turag	TR13	23.837315° N, 90.477250° E	Effect due to construction work of 300 ft Purbachal Road: Boalia Bridge, Balu River, Purbachal Express Highway	Both

SI. No.	River	Assigned ID	GPS Coordinates	Key Features/Remarks	Source Type
25	Turag	TR14	23.796113° N, 90.481048° E	Beraaid Residential Area, Agar Para Mosjid, A K H Rahmatullah Stadium,	Both
26	Balu	BaR1	23.762079° N, 90.482599° E	Open Area for Future Development, Rampura Khal,	Both
27	Balu	BaR2	23.727584° N, 90.500133° E	Mixed: Demra Residential Area, Chanpara Bus Stand, Chanpara Bazar	Point
28	Balu	BaR3	23.718460° N, 90.499591° E	Confluence of Shitalakshya & Balu River, Karim Jute Mill	Both

Table 3 The study also includes Dhanmondi lake (3km) covering 8 sampling points that is shown in the table below:

Sl. No.	Lake	Assigned ID	GPS Coordinates	Key Features/Remarks	Source Type
1	Dhanmondi Lake	DhL1	23.7388120°, 90.3761879°	Surrounded by Shopping mall	Point
2	Dhanmondi Lake	DhL2	23.7427379°, 90.3776409°	Clean Residential area	Both
3	Dhanmondi Lake	DhL3	23.7433130°, 90.3764380°	Surrounded by Shopping mall	Non-Point
4	Dhanmondi Lake	DhL4	23.7449380°, 90.3773130°	Effect of restaurant	Both

5	Dhanmondi Lake	DhL5	23.7463129°, 90.3775632°	Effect of public toilet	Both
6	Dhanmondi Lake	DhL6	23.7471879°, 90.3779380°	Ghat area	Both
7	Dhanmondi Lake	DhL7	23.7495629°, 90.3779380°	Clean Residential area	Point
8	Dhanmondi Lake	DhL8	23.7506870°, 90.3768132°	Beside park area	Both

3.2 Sample Collection and Preparation

Figure 5 Sample Collection with Grab Sampler

Each sampling point's water column yielded about 1 Litre of water, which was taken. Here, we took some water samples using a 1 L glass container. The samples were collected during monsoon season. The sampling date for Buriganga river was 27 May, 2022 ; for Turag and Balu river was 1 April, 2023 ; for Dhanmondi lake was 13 November, 2022.To prevent contamination and provide quality standards, samples were kept at room temperature in glass jars.

3.3 Sample processing and extraction of MPs

3.3.1 Filtration

Figure 6 Filter paper & Ongoing filtration

Modified NOAA methods was adopted for the laboratory analysis of the sediment sample [23]. Necessary adjustment in the standard NOAA methods was made based on the existing literature in Frias et al. [24], Kabir et al. [25], and Li et al. [26]. For primary extraction, filtration is done to trap microplastic particles and to separate impurities like clay and silt.Here sieving is avoided because the particles floating water were very finer. A vaccume filter is used to pass water through its filter paper where particles greater than 5 mm got removed as microplastics are typically categorized as anything less than 5 mm. Then the filtrated water was throne and particles were initially collected in filter paper. The filter papers were dried in an oven at 65°C for approximately 24 h to avoid the influence of humidity.

3.3.2 Wet Per-Oxydation (WPO)

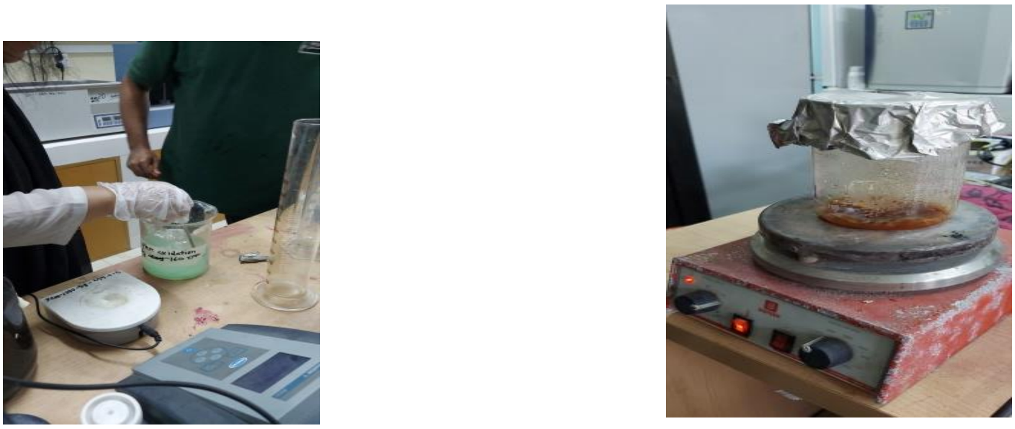

Figure 7 Mixing iron solution & Bubbles in hotplate

Samples can contain many organic particles along microplastics.In order to prevent interference with correct extraction and classification of microplastics, sample purification or digestion is a pretreatment technique that removes organic debris from samples (Adomat & Grischek, 2020; Gong & Xie, 2020). Here, water column samples were treated using Fenton's reagent.Wet Peroxidation was performed using Fenton's reagent, a mixture of 20-mL $FeSO_4.7H_2O$ solution and 20 mL of 30% H_2O_2 solution. First, 20 mL of aqueous 0.05M Fe (II) solution and 20 mL of 30% hydrogen peroxide were added to the beaker containing the isolated particles.. The mixture was cooked at 65°C on a hotplate following 10 minutes of keeping it at room temperature. Once a gas bubble was visible on the beaker's surface, it was removed from the hotplate. After the liquid stopped boiling, it was heated for a further 30 minutes. If overflow reaction shows, distilled water will lessen the reaction.These actions would be repeated until no organic matter was left to be seen.

3.3.3 Density Separatio

Figure 8 Separation after 12 hours, Collected MPs after 3 times & Separation

Before analysis, the sample must be separated or extracted since the collected sediment samples are combined with contaminants like inorganic clay (Gong & Xie, 2020).The density separation approach works on the basis that microplastic and non-microplastic particles have different densities (Gong & Xie, 2020). This method allows low-density particles like microplastics to float and high-density particles like contaminants to settle down because saturated or highly dense salt is extensively mixed with the sediment sample (Li et al., 2018). As a result, the solution's top layer is used to extract microplastics. For density separation, ZnCl2 solution was made adding 972g ZnCL2 to 1L water.Then particles from filter paper were collected and combined with 500 mL of aqueous ZnCl2 solution. The mixture was vigorously stirred with a spatula and allowed to settle for the night. Again the extracted particles were confirmed to be in the required size range by passing the supernatant through vacuum filtration, it was then put into a beaker for storage. The step would be repeated for three times for thorough removal of inorganic particles. Then in an oven, the filter papers with removed particles were heated to 65°C and dried.

3.3.4 Visual Inspection and Microscopic View

Figure 9 Microscope

The purpose of visual investigation is to sort out presumed microplastics for further identification based on physical attributes like shape, size, and color (Y. Zhang et al., 2020). Sorting can be done by the naked eye or in assistance with a microscope (Hidalgo-Ruz et al., 2012). Here,extracted MP particles were visually inspected under a Stereo Zoom microscope (SLX-3, Optika, Italy) with standard magnifications from 7× to 45× and categorized based on their size, shape, and color (Witte et al.,2014; Hidalgo-Ruz et al., 2012). A digital camera (C–B5, Optika, Italy)was incorporated into the microscope, and the particle size was directly measured using Optika Proview digital camera software. To prevent loss, identifying the microplastics is directly done on the filter surface (Yang et al., 2021), and the research should be carried out from top left to bottom right to prevent double counting (Simon-Sánchez et al., 2019).

3.3.5 Spectrometric Analysis (FTIR)

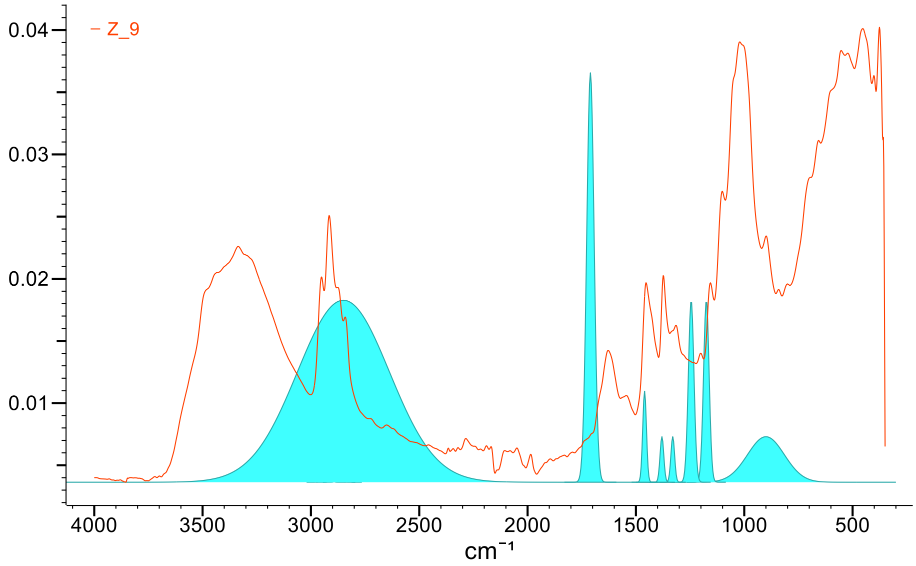

Figure 10 FTIR Analysis

The chemical makeup of microplastics is investigated via spectrometric analysis (Gong & Xie, 2020). Additionally, according to Constant et al. (2020), it may be used to evaluate visual sorting and adjust the particle count based on visual examination. The basic idea behind spectrometric analysis is to use agitated samples to detect vibration and then compare the resulting spectra to established reference spectra (Li et al., 2018). The most used spectroscope for the examination of microplastic is the Fourier transform infrared (FTIR) and Raman spectroscope (Hidalgo-Ruz et al., 2012).Here, Fourier transform infrared spectroscopy (FTIR Spectrum Two, PerkinElmer C110303, UK) with Attenuated Total Reflection (PerkinElmer UATR Two) was used to analyze the polymer composition of all separated particles. The spectrum information was gathered using PerkinElmer Spectrum 10 Spectroscopy Software. Each MP measurement was preceded by background scans. With infrared wavenumbers ranging from 4000 cm-1 to 400 cm-1, each MP particle, with sizes ranging from 0.1 mm to 5 mm, was individually scanned. Ten accumulated scans were then taken to provide spectra with a resolution of 16 cm-1. In order to determine the different kinds of polymers, the obtained FTIR spectra were compared with Wiley's KnowItAll Spectral Libraries 2021.

3.3.6 Quality Control

To ensure quality control measures, the experimental protocols established by Masura et al. (2015) were followed. The sediment samples were dried in an oven at a temperature (65°C) to prevent any MP deformation or degradation. To avoid external contamination, all plastic tools and instruments were purposefully avoided, and metal and glassware were used instead. During the analysis, cotton clothing and nitrile gloves were also used. Before usage, deionized water was used to rinse all of the equipment three times. To assess potential contamination from the experimental procedures, three blank samples of pure water were examined concurrently. The blank samples had no MP particles that were detected in the lab. Glass petridishes were used to store the extracted MPs.

3.3.7 PLI Assesments of MPs

Based on the models employed in the literature (Enyoh et al., 2021; Kabir et al., 2021; Rakib et al., 2022; Ranjani et al., 2021; Zhang et al., 2020b), the ecological risk of MP contamination in each river was evaluated in terms of the PLI. This evaluation employed the PLI formulas proposed by Tomlinson et al. (1980) and the polymer hazard scores Sj (Lithner et al., 2011). The benefit of this model is that it takes into account both the combined effects of several pollutants as well as the environmental impact of individual contaminants in specific places (Peng et al., 2018). The ratio of the MP abundance at station i (Ci) to the minimal background MP abundance from the literature (C0) was used to calculate the pollution load index for each sampling station (PLIi). This study provided the MP concentration at each sampling site (Ci).

The lowest MP abundance found in this study was selected as the background concentration (C0), given there is no information on the background concentration of MPs in rivers in the literature. The pollution load index (PLIriver) of the rivers was then determined by multiplying all of their PLIi by n.

Here, PLIi = Ci / C0

$$PLI_{river} = \sqrt[n]{PLI_1 \times PLI_2 \times \ldots\ldots\ldots \times PLI_n}$$

Here, the letters i and n stand for a sampling station and the number of stations in each river, respectively. Once PLI>1, the sampling station is regarded as being MPs-polluted (Tomlinson et al., 1980).

CHAPTER 4: CHAPTER FOUR: RESULTS and DISCUSSION

4.1 Characteristics of MPs

4.1.1 Mass Concentration and Abundance

At every sampling site in the three nearby rivers and lake inside of Dhaka, MPs were visible. MPs in the river sediment varied with sampling location, and the abundance of MPs varied from 6 to 52 items per Litre of water column. Urbanization is to blame for this difference in MP abundance (Ma et al., 2022). The total number of MPs was 1261 items among the total 36 sampling locations . The average and median MP abundance of three riveres were 27.46 items/L and 27 items/L respectively. Same findings for Dhanmondi lake was 25.875 items/L and 26.5 item/l.The highest abundance of MPs was exhibited in BR (Mean: 25.9 items/L ; median: 22 items/L), followed by TR (Mean: 26.14 items/L; median: 26.5 items/L) and BaR (Mean: 39.33 items/L; median: 44 items/L).

Table 3 Abundance & Mass concentration

Location	Abundance (n/L)	Mass Concentration (mg/ L)
BR1	44	44.52
BR2	32	38.21
BR3	37	42.63
BR4	22	20.24
BR5	19	22.42
BR6	15	18.11
BR7	15	22.84
BR8	22	30.12
BR9	20	23.41
BR10	26	31.26
BR11	33	57.44
TR1	6	10.65

TR2	18	17.78
TR3	9	11.64
TR4	52	50.12
TR5	10	11.88
TR6	34	23.67
TR7	35	24.78
TR8	36	25.89
TR9	26	19.78
TR10	46	45.26
TR11	10	11.78
TR12	32	22.46
TR13	25	57.44
TR14	27	19.65
BaR1	22	20.34
BaR2	52	48.31
BaR3	44	40.12

Table 4 Three Peripheral Rivers

Location	**Abundance (n/L)**	**Mass Concentration (mg/ L)**
DhL1	40	44.41
DhL2	23	28.56
DhL3	35	40.02
DhL4	24	28.38
DhL5	31	38.94
DhL6	29	34.43
DhL7	17	18.87
DhL8	8	9.98

Dhanmondi Lake

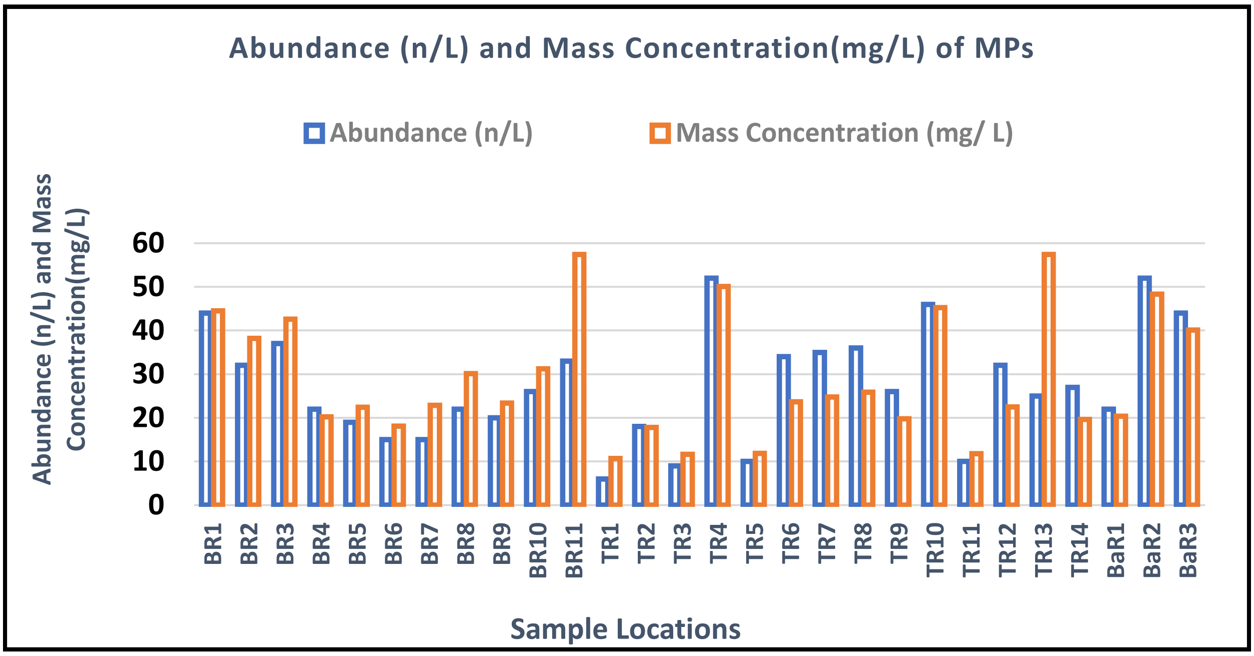

Figure 11 Abundance (n/L) and Mass Concentration(mg/L) of MPs of three peripheral rivers

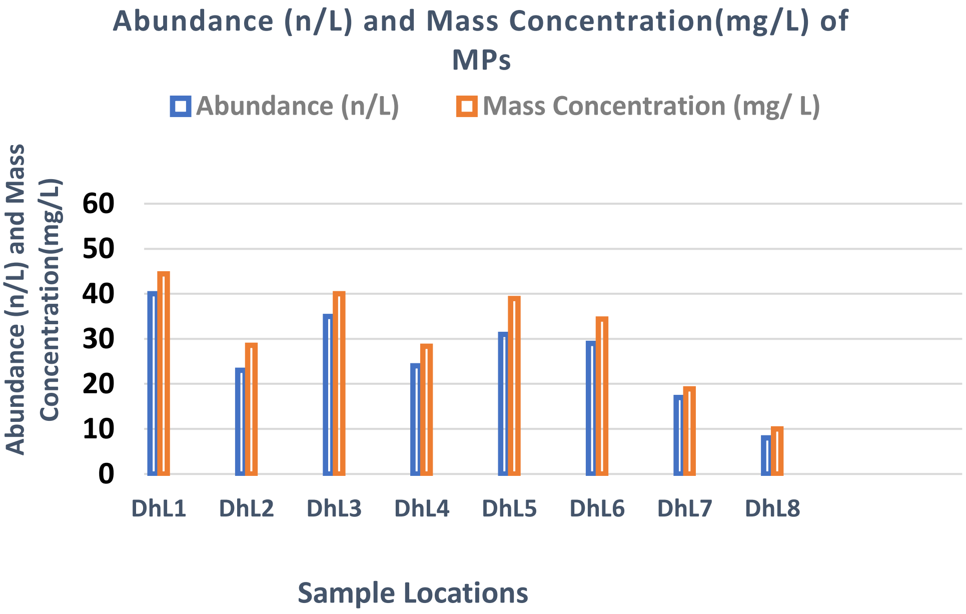

Figure 12 Abundance (n/L) and Mass Concentration(mg/L) of MPs of Dhanmondi lake

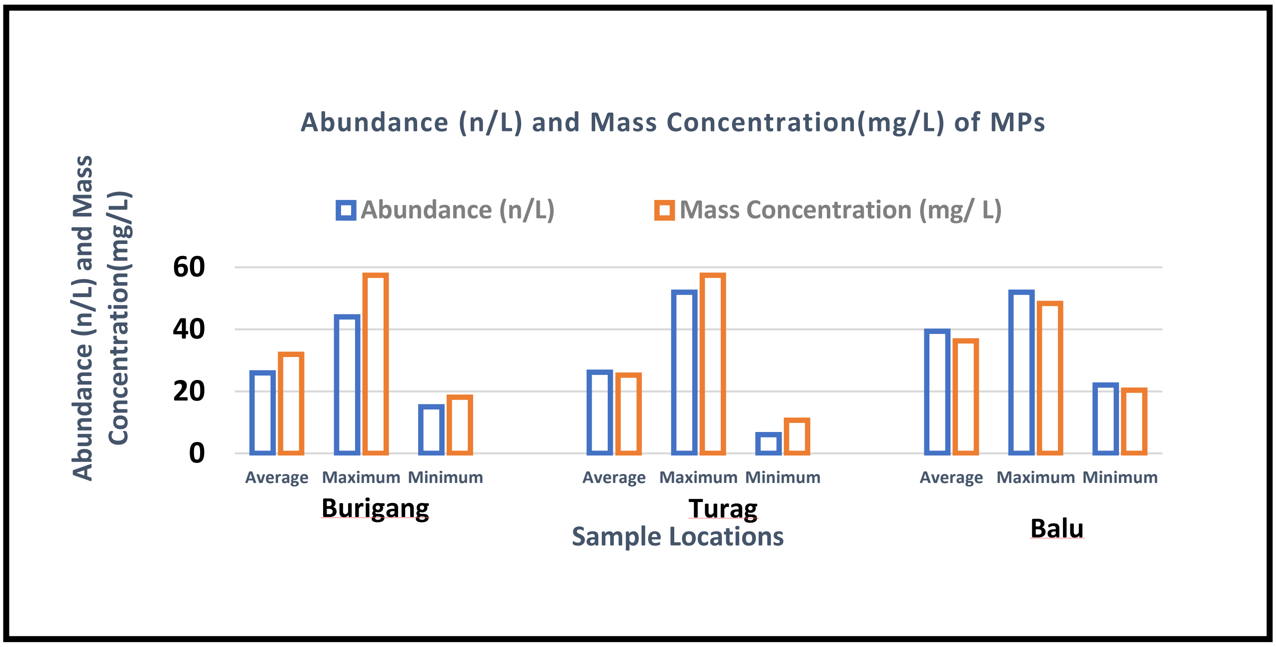

Figure 13 Average,Maximum and Minimum of Abundance (n/L) and Mass Concentration(mg/L) of MPs of three

The highest number of MP particles in rivers, 52 items/L, were detected at sampling locations TR4 and BaR2. The lowest number of MP particles were found at sampling location TR1; where the majority of the land is grassland and vacant lots for future development, had the lowest concentration of MP particles. For the lake, the highest number of MP particles were 40 items/L at sampling location DhL1 and lowest number of particles were 8 items/L at sampling location DhL8. Fig 1 and fig 2 show abundance (n/L) and mass Concentration(mg/L) of MPs of three perpherial rivers and Dhanmondi lake.Fig 3 shows the stastical comparison of three rivers.

4.1.2 Shapes

Three Perpheral rivers

Table 5

Rivers	**MPs**	**Count (n/L)**
	Fibre	286

Buriganga	Film	0
	Fragment	0
Turag	Fibre	364
	Film	1
	Fragment	1
Balu	Fibre	118
	Film	0
	Fragment	0

Dhanmondi lake

Table 6

MPs	Count
Fibre	205
Film	2
Fragment	0

Three shapes—film, fragment, and fiber—could be identified among the MP particles that were seen. The proportion of each shape was comparable among the three rivers and lake in terms of dispersion. The primary sources of film-shaped MPs are packaging materials and plastic waste, and the primary sources of fragment-shaped MPs are the breakdown of plastic products and plastic trash; the majority of fiber types come from textile-washing industries (Salvador Cesa et al., 2017; Zhang et al., 2017). Consequently, the fact that MPs had film, fragment, and fiber morphologies suggests that they primarily came from plastic debris and the effluent of denim washing companies in Dhaka.The majority of the materials were fibers in rivers (99.74%), followed by films (0.26%) and no fragments at all.

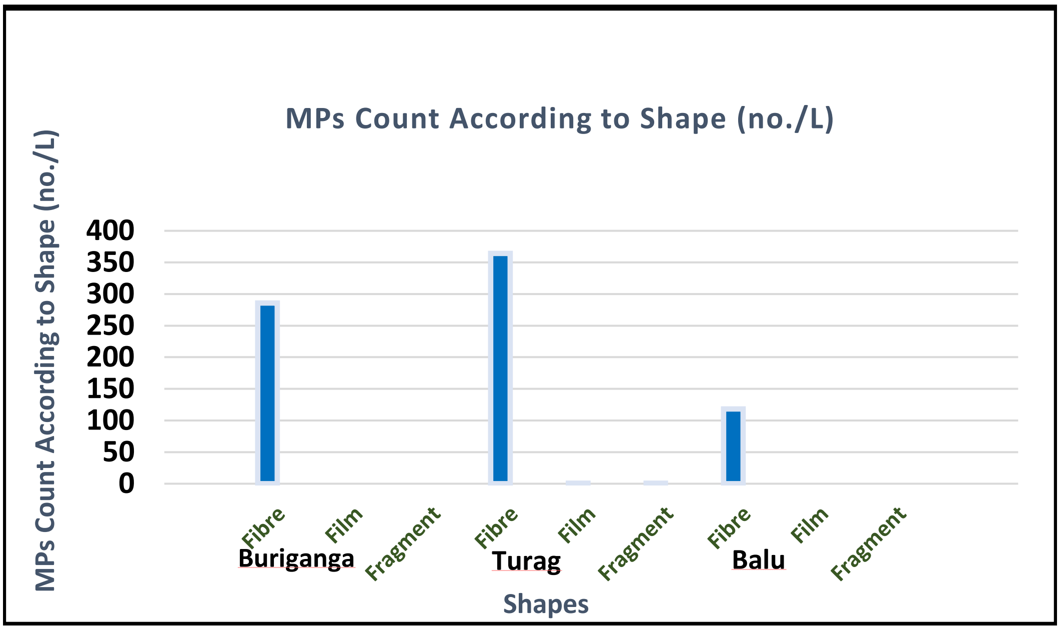

Figure 14 MPs Count According to Shape (no./L) of three peripheral rivers

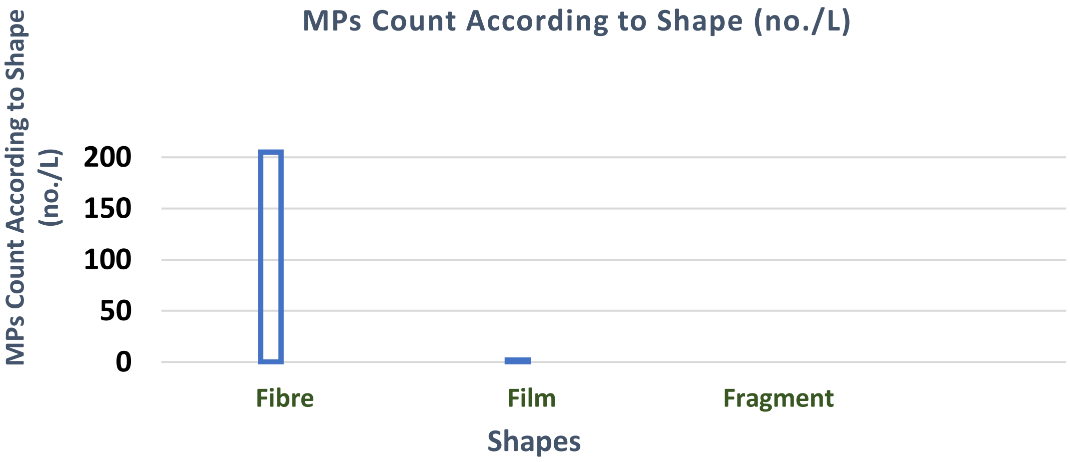

Figure 15 MPs Count According to Shape (no./L) of Dhanmondi Lake

Fig19 and fig20 shows the count of microplastics of three peripheral rivers and Dhanmondi lake according to shape . For Dhanmondi lake , The majority of the materials were fibers in rivers (99.03%), followed by films (0.97%) and again no fragments at all.Fig4 and fig5 show MPs Count according to shape (no./L) of three peripheral rivers and Dhanmondi lake.

4.1.3 Size

Three peripheral rivers

Table 7

Rivers	Size range(mm)	Abundance (n/L)
Buriganga	0-1 mm	24
	1-2 mm	104
	2-3 mm	85
	3-4 mm	44
	4-5 mm	1
Turag	0-1 mm	119
	1-2 mm	160
	2-3 mm	58
	3-4 mm	19
	4-5 mm	10
Balu	0-1 mm	18
	1-2 mm	59
	2-3 mm	21
	3-4 mm	12
	4-5 mm	5

Dhanmondi lake

Table 8

Size Range (mm)	DhL1	DhL2	DhL3	DhL4	DhL5	DhL6	DhL7	DhL8
0-1.0	3	1	4	1	4	4	5	0
1.0-2.0	18	12	17	11	19	18	11	6
2.0-3.0	12	5	10	8	4	6	1	2
3.0-4.0	7	5	4	2	2	0	0	0
4.0-5.0	0	0	0	2	2	1	0	0

MPs of various sizes were present in all water column samples.The size ranges for the extracted MP particles were 0.1-0.3 mm, 0.3-0.5 mm, 0.5-1 mm, 1-2 mm, and 2-5 mm. For three peripheral rivers, The highest proportions were found in the size category 1-2 mm (42%), followed by 2-3 mm (21.32%), 0-1 mm (20.93%), 3-4 mm (9.75%), and 4-5 mm (2.08%), had the largest proportions**. For Dhanmondi Lake,** The highest proportions were found in the size category 1-2 mm (54.1%), followed by 2-3 mm (23.18%), 0-1 mm (10.63%), 3-4 mm (9.66%), and 4-5 mm (2.42%), had the largest proportions.

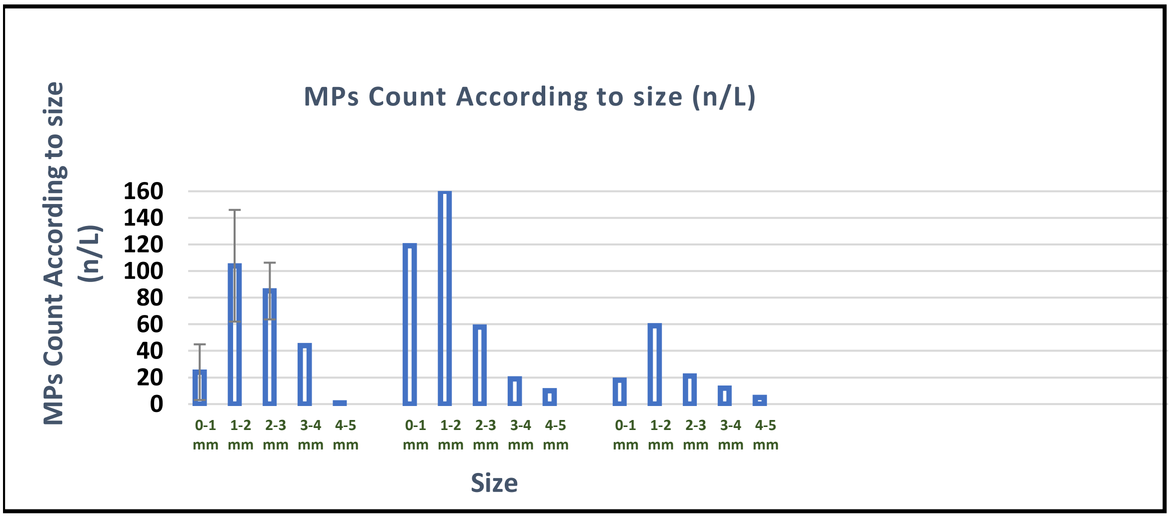

Figure 16 MPs Count According to size (n/) for three peripheral rivers

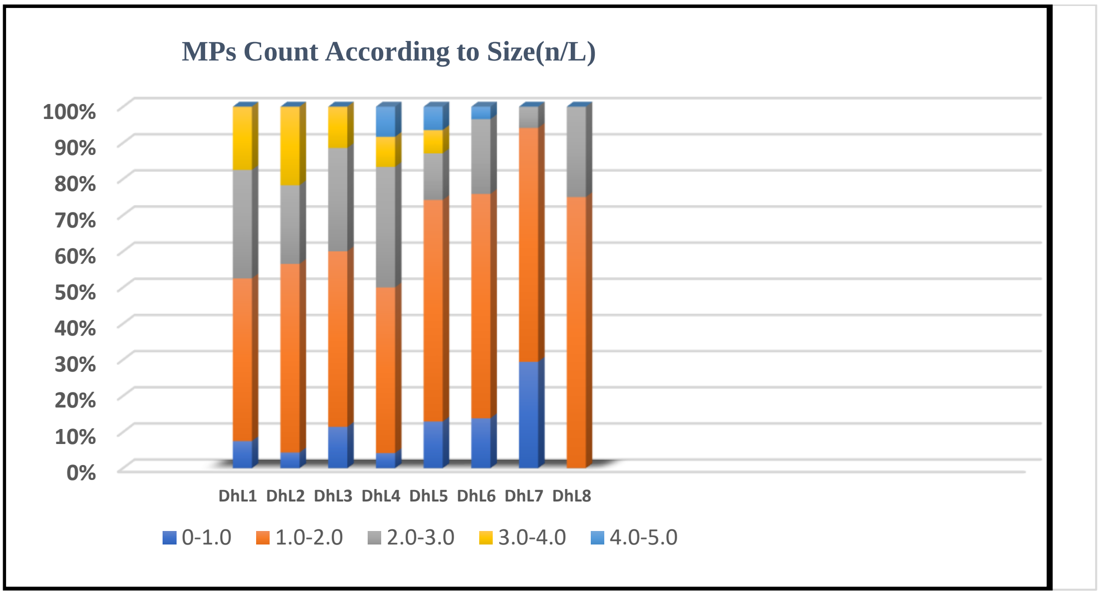

Figure 17 MPs Count According to size (n/L) for Dhanmondi Lake

According to the investigation's findings, the water column often contained more large MPs than small MPs. Additionally, prior research (Islam et al., 2022; Mu et al., 2019; Zhang et al., 2020a) revealed a higher proportion of big MPs. According to the predominately large MPs, biofilms may settle before they undergo deep weathering as a result of the rapid biofilm production caused by excessive nutrient levels in water and poor hydrodynamics (K. Zhang et al., 2017). Large MPs can, however, travel great distances and contaminate places that are far away (Browne et al., 2010). Additionally, over time, biodegradation and other environmental processes break down large MPs into smaller ones, and smaller MPs are more dangerous than larger ones (Lei et al., 2018).Here, fig6 and fig7 show MPs Count According to size (n/L) for three peripheral rivers and Dhanmondi Lake.

4.1.4 Colours

Table 9

River	Colour	Count(n/L)
	Black	155

Buriganga	Red	30
	Blue	16
	Green	4
	Yellow	2
	White	0

Table 10

River	Colour	Count (n/L)
Turag	Black	284
	Red	52
	Blue	16
	Green	4
	Yellow	4
	White	0

Table 11

River	Colour	Count (n/L)
Balu	Black	81
	Red	22
	Blue	10
	Green	5
	Yellow	0
	White	0

Table 12

Lake	Colour	Count(n/L)
Dhan-mondi lake	Black	155
	Red	30
	Blue	16
	Green	4
	Yellow	2
	White	0

Different colored MPs that had been extracted were seen. In all three peripheral rivers, the majority of MPs were black (54.09%), followed by red (31.13%), blue (19.41%), green (11.57%), and yellow (2.56%). When diverse colored home plastic consumption goods are produced and dumped into the aquatic environment, the plastic cutting, remolding, and washing industries produce a considerable amount of these colorful MPs. On the banks of the nearby rivers in the city of Dhaka, the majority of these plastic manufacturers are located. Small plastic pieces and debris from the plastics industry that are dumped into rivers because to poor waste management may result in the creation of colorful MPs. Aquatic species may be misled by these vivid MPs and incorrectly consume them as food (Kabir et al., 2020; Wright et al., 2013). Fish may unintentionally swallow colorful MPs while engaging in routine feeding behaviors.

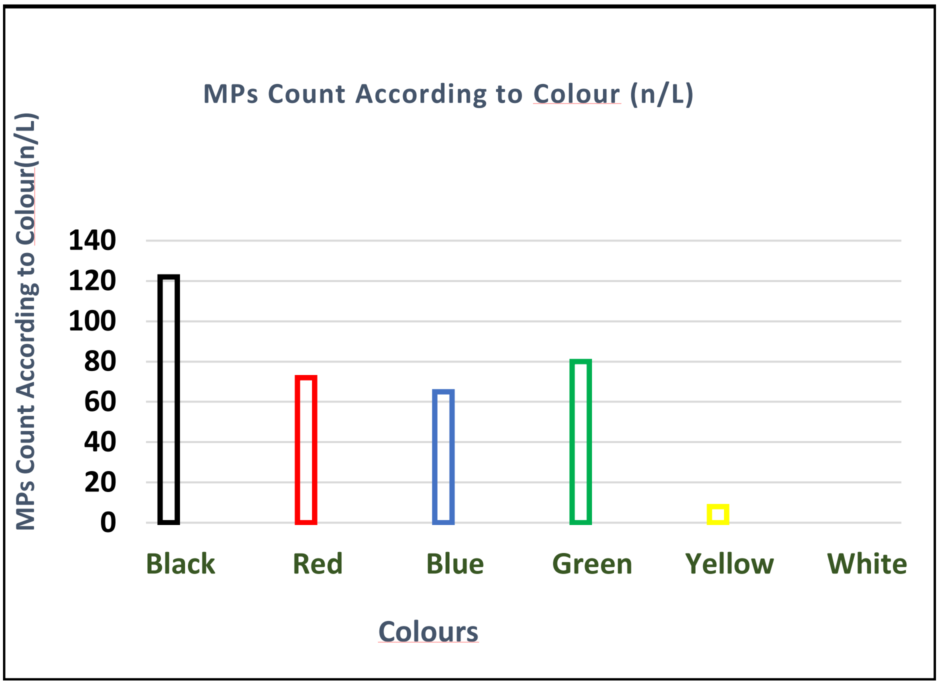

Figure 18 MPs Count According to Colour (n/L) of Buriganga river

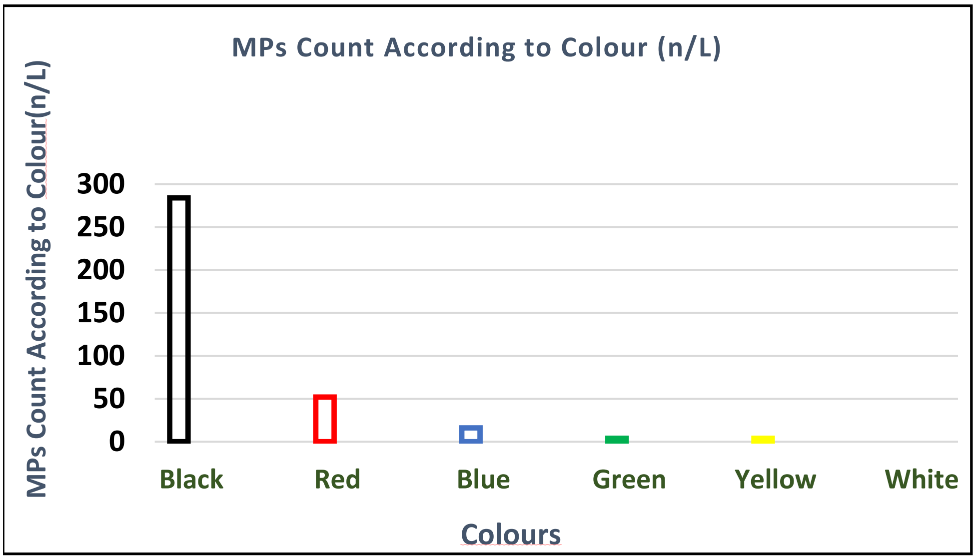

Figure 19 MPs Count According to Colour (n/L) of Turag river

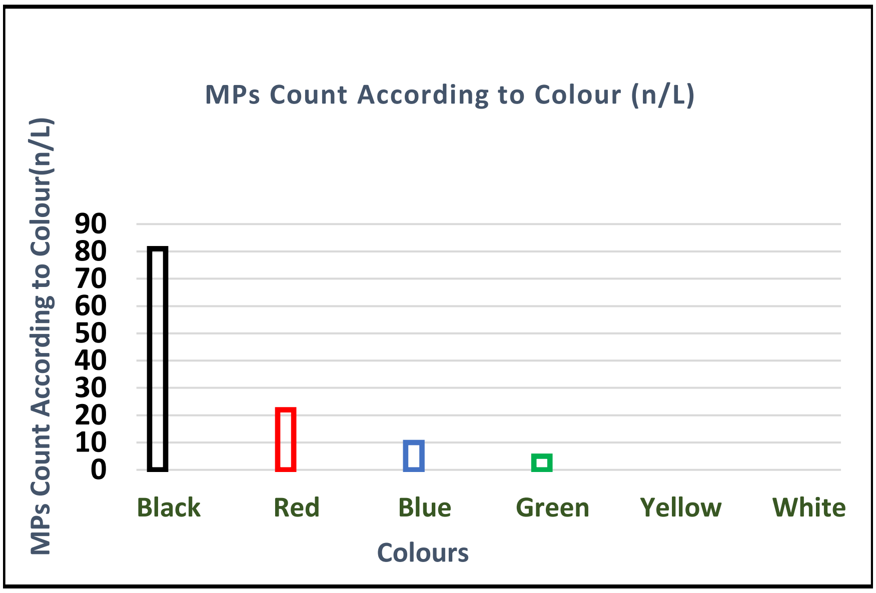

Figure 20 MPs Count According to Colour (n/L) of Balu river

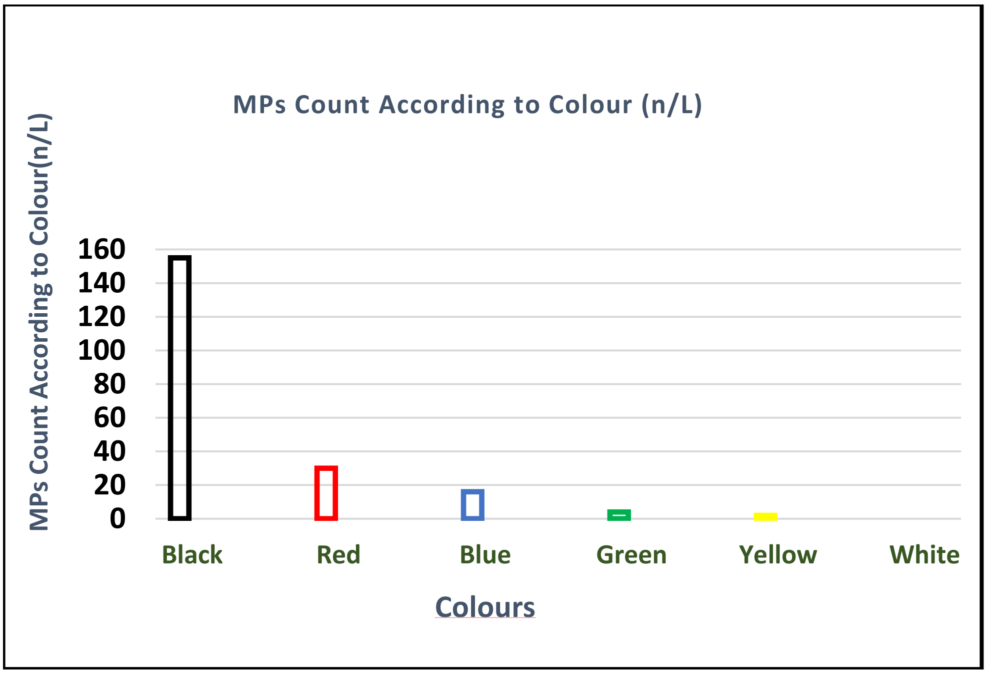

Figure 21 MPs Count According to Colour (n/L) of Dhanmondi Lake

For Dhanmondi Lake, the majority of MPs were black (74.88%), followed by red (14.5%), blue (7.73%), green (1.93%), and yellow (0.97%). In both cases, black fibres are the most in count. The reason of getting mostly black fibres from water column can be decaying rubber gaskets or washers in the plumbing.Fig10 and fig11 show MPs Count According to Colour (n/L) of three peripheral rivers and Dhanmondi Lake.

Comparison can be done among the worldwide results and our studies. Following is the table of results of different rivers of different findings and the variation can be seen.

Table 13 Global microplastic pollution in comparison with this study

Study Areas	Abundance (n/kg) (d.w.)	Concentration (mg/kg)	References
Buriganga River, Bangaldesh	$65 - 534^{r}$, 165.45 ± 127.87^{m}	$55.38 - 430.65^{r}$	This study
Turag River, Bangladesh	$46 - 178^{r}$, 142.43 ± 37.32^{m}	$13.56 - 203.23^{r}$	This study
Balu River, Bangladesh	$60 - 196^{r}$, 152.33 ± 68.16^{m}	$45.19 - 109.83^{r}$	This study
Karnaphuli River, Bangladesh	$22.29 - 59.5^{r}$		[21]
Brisbane River, Australia	$10 - 520^{r}$	$0.18 - 129.20^{r}$	[30]
Ayaragi River, Japan	$24 - 608^{r}$	$3.94 - 282.45^{r}$	[25]
Daliao River, China	$100 - 467^{r}$, 237 ± 129^{m}		[32]
Amazon Rivers, Brazil	$417 - 8178^{r}$		[33]
Antuã River, Portugal	$18 - 629^{r}$	$2.6 - 71.7^{r}$	[34]
Atoyac River Basin, Mexico	$33.33 - 400^{r}$		[35]
Yushan River, China	$30 - 70^{r}$, 44 ± 18^{m}	$3.5 - 53^{r}$, 30.5 ± 23^{m}	[36]
St. Lawrence River, North America	$65 - 7562^{r}$, 832 ± 150^{m}		[37]
Tisza River, Central Europe	3177 ± 1970^{m}		[38]

r- indicates range (Min to Max)

m- indicates mean value

4.1.5 FTIR

Table 14

Location	PP	PE	PET	PVA	PS	PVC	Nylon6	PPS	PUR	EP	ABS	PVT	PVB	PVP	PVF	PTT
B1	P	P	A	A	P	P	A	P	A	A	P	A	P	A	A	A
B2	P	A	A	A	P	P	A	A	A	A	P	P	P	P	P	A
B3	A	P	A	A	P	A	A	A	P	A	A	A	A	A	A	P
B4	A	A	A	A	A	P	A	A	P	A	A	P	A	A	A	A
B5	A	A	A	A	A	P	A	A	P	A	A	A	A	A	A	A
B6	A	A	A	A	A	P	P	A	P	A	A	A	A	A	A	A
B7	P	A	P	A	P	P	A	A	P	A	A	P	A	A	P	A
B8	P	P	A	A	P	P	A	A	A	A	P	A	A	A	P	A
B9	P	P	A	A	A	P	A	A	P	A	P	A	A	A	A	A
B10	P	P	A	P	A	A	A	A	P	A	P	A	A	A	A	A
B11	P	A	A	P	A	A	A	A	A	A	P	A	A	A	P	A
T1	P	P	A	A	P	P	A	A	P	A	P	A	A	A	A	A
T2	P	P	A	A	A	P	A	A	A	A	P	P	A	A	P	A
T3	P	A	A	P	P	P	A	A	P	A	P	A	A	A	A	A
T4	P	P	A	A	P	A	A	A	P	P	P	A	A	A	A	A
T5	P	P	A	A	A	P	A	A	P	A	P	P	A	A	A	A
T6	P	A	A	P	A	P	A	A	P	A	P	A	A	A	P	A
T7	P	P	A	A	P	P	A	A	P	P	P	A	A	A	A	A
T8	P	A	A	P	A	A	A	A	P	P	P	A	A	A	A	A
T9	P	P	A	P	A	P	A	A	P	A	P	A	A	A	A	A
T10	P	A	A	A	P	P	P	A	P	A	P	A	A	A	A	A
T11	P	P	A	P	A	A	A	A	A	P	P	P	A	A	A	A
T12	A	A	P	A	P	P	A	A	P	P	P	A	A	A	A	A
T13	P	P	A	P	A	P	A	A	P	A	P	A	A	A	A	A

T14	P	P	A	A	A	A	P	A	P	A	P	A	A	A	P	A
Ba1	P	A	A	A	P	A	A	A	A	A	P	A	A	A	A	A
Ba2	A	P	A	P	A	P	A	A	A	A	A	A	A	A	A	A
Ba3	P	P	A	A	P	A	A	A	P		P	A	A	A	A	A
Location	PP	PE	PET	PVA	PS	PVC	Nylon6	PPS	PUR	EP	ABS	PVT	PVB	PVP	PVF	PTT
DhL1	P	P	A	P	A	P	A	A	A	A	P	A	A	A	A	A
DhL2	P	P	A	A	A	A	A	A	P	A	P	A	A	A	A	A
DhL3	A	A	A	A	P	P	A	A	A	A	P	A	A	A	A	A
DhL4	P	P	A	A	A	P	A	A	P	P	P	A	A	A	A	A
DhL5	P	P	A	A	A	A	A	A	A	P	P	A	A	A	A	A
DhL6	P	P	A	A	A	P	A	A	A	P	P	A	A	A	A	A
DhL7	P	P	A	A	A	A	A	A	A	A	P	A	A	A	A	A
DhL8	P	P	A	A	A	A	A	A	P	A	P	A	A	A	A	A

FTIR analysis was used to determine the various types of polymers.These polymers' presence suggests that Dhaka city's widely used plastic bags and packaging materials were the main sources of microplastics. At all sampling sites, PE, PP, and PET were the predominant polymers that were found. PUR was found in all rivers among the non-dominant polymers, however ABS, EP, and PPS were not found in the Balu River. PVA, PVC, and ABS were discovered as fragments and films, whereas PE and PP were seen as fragments, films, and fiber forms. PET was recognized as fibers and pieces. The supplemental information includes descriptions of the MP polymers' observed forms.

4.1.6 Pollution Load Index (PLI) of MPs

PLI was calculated using the minimum MP abundance (C0 = 6 items/L) discovered in this investigation as the background level of MPs. For three peripheral rivers, PLI of Buriganga, Turag and Balu are following 4.07, 3.64 and 6.15. PLI values greater than 1 were present at every sampling site, indicating that MPs had contaminated every site (Tomlinson et al., 1980). This result arises from the fact that the pollution load index (PLI) value and the number of MPs are directly correlated. Thus, the more value of PLI the higher degree of pollution it means. So, according to the degree of pollution , Balu river is in the highest followed by Buriganga and Turag river.

CHAPTER 5: CONCLUSION & RECOMMENDATIONS

5.1 Introduction

Microfibers have undergone chemical processing, dyeing, or additional treatments that, according to studies, put aquatic species at risk at all trophic levels and throughout the food chain. Our findings encourage efforts to comprehend the effects on aquatic life and human health, as well as to develop strategies to reduce, prevent, and remediate anthropogenic microfibre contamination in our public freshwater and marine rivers (Miller et al., 2017c).

To mention, little is known about the occurrence of MPs in the aquatic system of Banglades.all of the existing research articles focused on marine or beach samples (Banik et al., Rahman et al., 2020). Therefore, this study is the first comprehensive investigation of river sediment of the peripheral urban river systems, which assessed the ecological risk due to Ms pollution of Dhaka city. In this study, baseline information on the abundance, characteristics, and spatial distribution of microplastics in the sediment of Buriganga, Turag, and Balu rivers and Dhanmondi lake were investigated and the probable land use sources were identified and understood their influence on MPs pollution. Another major aim of this study was ecological risk assessment of MPs through multiple indices. As a part of the study oxidation and weathering effect of MPs were observed. This Chapter presents the major conclusions from the study; it also presents presents the limitations of the study and recommendation for future studies.

5.2 Conclusions

Additionally, the sources of MPs in Dhanmondi Lake are based on nearby families, the MP sources in the Buriganga, Turag, and Balu River are intimately tied to industrial operations. Therefore, we advise concentrating on the management of industrial and agricultural wastes. Assessing the dangers of microplastic contamination needs more effort (Ding et al., 2019d). We contend that routine human activity is the primary source of microplastics. The solution to the microplastic problem lies in improving the wastewater and solid waste treatment facilities. However, more study is still needed to determine the frequency of microplastic contamination at various locations and during various times of the year (Jiang et al., 2019). To conserve the maritime environment, management techniques must be encouraged and put into practise. These include minimising the amount of plastic used, encouraging recycling, and upgrading dumping facilities (Supuran et al., 2019b).

From the top of the water column to the bottom, the shapes and sizes of the microplastic particles likewise vary. Diverse biological consequences on marine species living in various water strata could come from this. Therefore, it is important to pay more attention to the threats to the ecosystem posed by microplastic pollution across the entire water column (Dai et al., 2018b).

The riverine and lake samples were predominated by fibre-shaped, black- colored, and larger-sized (1-5 mm) MPs. At all sampling sites, PE, PP, and PET were the predominant polymers that were found. PUR was found in all rivers among the non-dominant polymers, however ABS, EP, and PPS were not found in the Balu River .Most of the identified MP polymers were high was the most abundant density, which facilitated deposition to river and lake water column which are likely to cause toxic effects on ecosystems.

Overall, pollution load and ecological risk indices revealed that all the sampling sites were polluted with MPs and posed low-medium to very high-level risks to the ecosystems. High ecological risk depended on abundances and toxicity of MP. Land-use behavior such as urban locality, industrial effluent, and agricultural runoff might release a higher abundance of MPs and toxic polymers. However, the anthropogenic activities, especially continuous disposal of untreated wastewater from various industries, urban and agrochemical outflows and direct dumping of mismanaged waste into the water bodies, influenced MP pollution in the river and lake.

5.3 Limitations of the Study

There are still understanding gaps regarding MPs pollution and its impacts in aquatic systems, particularly in freshwater systems, despite the growing concern about these issues. This work offers fresh perspectives on the distribution and quantity of MPs in the water column (Rodrigues et al., 2018). Not more than 20 studies are conducted regarding MPs in marine sediment, river sediment, water column, fish etc (Saifullah et al., 2022), (Haque et al., 2023)), (Rakib et al., 2022)

In conclusion, for the first time, we have shown microplastic abundance and vertical distribution in the water column of the Buriganga, Turag, and Balu rivers, as well as Dhanmondi lake. This study also serves as a reminder that surface water surveys are far from adequate for assessing the level of microplastic contamination in a water body (Dai et al., 2018b).

The influences of population density on MPs abundance could not be identified due tounavailability of e-Stat population vector data in Bangladesh for each square of mesh. Baseline concentration is required to calculate pollution load index. However, due to lackof available background data in similar environments, the lowest MPs abundance obtained in this study was taken as the baseline concentration. This limitation will be overcome for further studies since this study will set a baseline data for the abundance, characteristics, and spatial distribution of microplastics in the water column around Dhaka city.

5.4 Recommendations for Future Research

The abundance and quantification of microplastics pollution is an important issue that requires scientific research and effective strategies for mitigation. Here are some recommendations and future references for addressing this problem:

1. Research and Monitoring:

- Encourage and support comprehensive research on microplastics pollution to better understand its sources, distribution, and impacts on ecosystems and human health.

- Develop standardized methodologies for sampling, extraction, and analysis of microplastics in different environmental compartments (e.g., water, soil, air) to ensure consistency and comparability of data.

- Establish long-term monitoring programs to track the abundance and trends of microplastics pollution in various regions and ecosystems.

2. Regulatory Measures:

- Implement and enforce regulations to reduce the production and release of microplastics into the environment, focusing on key sources such as plastic manufacturing, packaging, and single-use plastics.

- Promote the development and use of eco-friendly alternatives to plastic materials and products.

- Encourage the adoption of wastewater treatment technologies that can effectively remove microplastics before the effluent is released into the environment.

3. Public Awareness and Education:

- Raise public awareness about the issue of microplastics pollution and its potential ecological and health impacts.

- Educate individuals, communities, and industries about sustainable plastic use, proper waste management, and recycling practices to minimize the input of plastic waste into the environment.

- Support educational programs that highlight the importance of reducing, reusing, and recycling plastic materials.

4. International Cooperation and Collaboration:

- Foster international collaboration among governments, research institutions, and organizations to share knowledge, data, and best practices in addressing microplastics pollution.

- Establish global initiatives and partnerships to coordinate efforts in research, monitoring, policy development, and technological innovation to tackle this issue on a larger scale.

Future References:

1. Continued Research: Conduct further research to explore the impacts of microplastics on ecosystems and human health, including potential toxicity, bioaccumulation, and ecological interactions.
2. Technological Advancements: Support the development of advanced techniques and technologies for the detection, quantification, and characterization of microplastics, including remote sensing, spectroscopy, and automated monitoring systems.
3. Policy Development: Advocate for the integration of microplastics pollution into national and international policy frameworks, such as plastic waste management strategies, marine protection policies, and circular economy initiatives.
4. Industry Responsibility: Encourage industries to take responsibility for reducing plastic waste and developing sustainable practices throughout their supply chains, including product design, manufacturing processes, and end-of-life management.
5. Consumer Behavior: Promote conscious consumer choices, such as purchasing products with minimal plastic packaging, supporting eco-friendly brands, and reducing personal plastic consumption through lifestyle changes.

By implementing these recommendations and staying informed about future advancements, we can work towards mitigating microplastics pollution and safeguarding our environment for future generations.

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Appendix

Table 15 An overview of abundance and characteristics of MPs

No	Study Area	Abundance	Size	Shape	Chemical Composition	Color	Ref
1	Rivers of the Tibet Plateau	range: 50+7 item/kg to 195+64items/kg	<1mm - 70%	Fiber -53.8% to 80.6% and Pellets or Fragments-rest	Polyethylene terephthalate (PET)- most abundant.	Transparent-30% to 50%, Black- 18% to 30%, White-4% to 10%, Red-6% to 18%, Blue-3% to 32% and Green- 0 to 8%	(Jiang et al., 2019)
2	Nakdong River, South Korea	mean: 1971 particles/kg dry weight	<300 µm -81%	Fragments - 84%, Fibers - 15% and Spheres (1%).	PP-24.8%, PE-24.8%, PES-5.5%, PVC-5.4%,PS 5.3%, Acrylic -4.6%, Polydimethylsiloxane-4.5%, PU-3.9%, Poly(acrylate-styrene)-3.7%, Poly(lauryl acrylate) -3.6% and others <3%		(Eo, 2019)
3	Middle-Lower Yangtze River Basin	range: 15 to 160 items/kg	10.25-1 mm-Most abundant	Fiber Fragment>Film>Pellet	Polyester-33%, Polypropylene- 19% and Polyethylene-9%	Transparent and blue items- Most abundant	(Su et al., 2018)
4	Amazon rivers, Brazil	range: 417 to 8178 particles/kg of dry weight (particles 0.063-5mm) and 0 to 5725 particles/kg of dry weight(particles 0.063-1 mm)	0-1mm: 3 to 70%, 1- 2mm: 23 to 72%, 2- 3mm: 5 to 28%, 3-4mm: 0 to 7%, 4-5mm: 0 to 11%				(Gerolin, 2020)

5	Xiangjiang River	range: 270.17 +48.23 items/kg to 866.5937.96 items/kg	<0.5mm: 21% to 52%, 0.5-1mm: 12% to 29%, 2-3mm: 5% to 12%, 3-4mm: 3% to 12% and 4-5mm: 2 to 40%	Fragment-50.82%, Fiber-28.15%,Film-18.14% and Foam<10%	PET-14.71%, PP- 13.24%, PE-19.12%, PA-10.29%, PS- 19.41%, PVC-7.35%, Non- plastic-5.88%	Transparent-16% to 50%, White-4 to 40%, Red- 2 to 32%, Blue- 4% to 23%, Green-4% to 23% and Yellow-0 to 8%	(Wen et al., 2018)
6	Têt river, perpigan, France	mean: 258 + 259 item/ kg		Fragments - 54.8%, Fibers -19.5%, Foams-13.0%, Films -7.0% and Beads -5.7%	Fibers: Non-plastic- 40%; Fragments: PE- 45%, PP-23%; Films: PE-29%, PP-35%; Foams: PS-50% and Beads: PE- 100%		(Constant et al., 2020)
7	Ebro River, spain	range: 1491 ± 272 particles/kg dry weight to 2899+718 particles/kg dry weight	<50 µm: 2.5%, 50- 100µm: 4%, 100- 200µm: 11.5%, 200-500µm: 30%, 500- 1000µm: 18%, 1000-2000µm: 18%, 2000- 3000µm: 9% and >3000µm: 7%	Fiber Fragment Fi Im>Foam	Polyamide-24%, Polyethylene- 16%, Poly(methyl methacrylate)(acrylic)-12%, Polyester- 12%, Polypropylene-8% and Polyacrylate- 4%	Colour-58%, Transparent-20%, Black-10% and White-2%	(Simon-Sánchez et al., 2019)
8	Wei River,china	range: 360 to 1320 items/kg	<0.5 mm: 40.8% to 68.8%, 0.5-1mm: 8.35% to 24.2%	Fiber-42.25% to 53.20%, Film- 23.9% to 31.8%, Fragment-10.2% to 20.3%, Pellet 5.6% - 16.1%, Foam-0.7% to 3.5%			(Ding et al., 2019)
9	Tibetan Plateau	range: 20-160 items/kg ;mean: 60.8+25.06 items/kg	20-50 µm-25.83%,50- 100 µm: 31.79%, 500 -1000µm 11.26% and >>1000 µm - 4.65%	Fiber-42.38%, Fragment-25.16%, Film-11.92%, Sphere-11.26% and Foam 9.27%	PP-32.45%, PE 28.48%, PS 15.23% and PET 13.24%	Transparent-45.69%, white-18.54%, black and blue-15.23% and others-20.53%	(Feng et al., 2020)

10	Antua River, Portugal	range: 18 to 629 items/kg dry weight	Fragments-43.6% (most) and Pellets- 1.2% (lowest)		PE-29.4%, PP-29.4%, PS-8.8%, PET-8.8%, Others-29.4	Colour(blue,green)>White Black >Transparent	(Rodrigue s, 2018)
11	Brisbane River sediments, Australia	range: 10 to 520 items/kg	PE: <1mm: 22%, 1- 2mm: 20%, 2-3mm: 21%, 3-4mm:19% and 4-5mm:18%; PA: 2- 3mm: 4% and 3- 12%, 1-2mm: 23%, 2- 3mm: 20%, 3-4mm:96%;PP: <1mm:4mm:13% and 4-5mm:32%; Others: <1mm: 28%, 1-2mm: 50% and 2-3mm: 22%	Film Fragment>Fiber	PE-70%, PA-12% and PP-10%	White - Most abundant	(He et al., 2020)
12	Wen-Rui Tang River, southeast china	mean: 32947+15342 items/kg	20-300 µm :84.6%, 300-5000 um: 15.4%	Fragment-45.9%, Foamp-29.5%, Pellets- 12.8% and Fibers-11.7%	PE,PP.PES,PS-Most abundant		(Z. Wang et al., 2018)
13	Maozhou River, china	range: 35+ 15 to 560 ± 70 item/kg sediments in April; 25 ± 5 to 360±90 item/kg sediment in October	0.1-1mm: 47.5% to 72.9%	Fragment-89.4%, Foam-6.7%, Fiber- 2.3%, Film- 1.6%	PE-45%, PS-34.5% and PP-12.5%	Transparent-38%, White-28%	(Wu et al., 2020)
14	Haihe River	range: 1346 to 11917 items/kg dry weight (dw) average: 4980+ 2462 items/kg dw	500-1000 µm: 26.5+12.8% (range: 3.7-50.9%), 200-500 um:24.7±14.3% (range: 1.9-71.5%) and 1000-2000 um:23.7 12.7% (range: 1.4-70.4%)	Fibers-70.9% Fragments-15.8%, Lines- 5.7%, Films- 4.2% Pellets- 3.3%	PE-49.3% (LDPE- 90.7% and HDPE-9.3%), PP-32.9%, poly(ethylene-propylene) copolymer-6.4%, PS- 5.9% and cellulose-5.5%	Black-47.1%. Green-22.3%, Red-17%, Transparent-7.4%, White-6.2%	(Liu et al., 2021)

15	Fengshan River	range: 508 to 3,987 items/kg	Small size: 67% to 96%	Fiber - 61% to 93%	Epoxy resin- 17%, Phenolic resin - 13%, PET-17%, PE- 8%, PVOH- 8%, PI- 7%, PS- 6% and PTFE- 6%		(Tien et al., 2020)