ABUNDANCE AND CHARACTERISTICS OF MICROPLASTICS IN URBAN CANALS: A CASE STUDY IN DHAKA CITY

By

Fahad Rahman (190051237)

Mohammed Fahamidun Nabi (190051246)

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APPROVAL

The paper titled "Abundance and characteristics of microplastics in urban canals: A case study in Dhaka city" Fahad Rahman (190051237) and Mohammed Fahamidun Nabi (190051246) submitted by has been accepted as partial attainment of the requisite for the degree, Bachelor of Science in Civil Engineering.

Supervisor

_____

Prof. Dr. Md. Rezaul Karim

Professor

Department of Civil and Environmental Engineering (CEE) Islamic

University of Technology (IUT)

Board Bazar, Gazipur, Bangladesh.

DECLARATION OF CANDIDATE

We hereby declare that the undergraduate research work reported in this thesis titled "Abundance and characteristics of microplastics in urban canals: A case study in Dhaka city", has been performed by us under the supervision of Professor Dr. Md. Rezaul Karim and this work has not been submitted elsewhere for any purpose (except for publication).

Fahad Rahman	Mohammed Fahamidun Nabi
Student ID: 190051237	Student ID: 190051246

Supervisor

Prof. Dr. Md. Rezaul Karim

Professor

Department of Civil and Environmental Engineering (CEE) Islamic

University of Technology (IUT)

Board Bazar, Gazipur, Bangladesh.

DEDICATION

*WE WOULD LIKE TO DEDICATE THIS THESIS WORK TO OUR **PARENTS AND FAMILY**. WE WANT TO SHOW OUR GRATITUDE FOR THEIR CONTINUOUS SUPPORT THROUGHOUT OUR LIFE.*

WE ALSO WANT TO EXPRESS UTMOST RESPECT FOR OUR THESIS SUPERVISOR PROFESSOR DR. MD. REZAUL KARIM.

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ABSTRACT

Microplastic pollution is an emerging global environmental challenge with significant implications for aquatic ecosystems and human health. This study focuses on the urban canals of Dhaka city, Bangladesh, where the abundance and characteristics of microplastics remain largely unexplored. The research problem lies in the lack of comprehensive data on how urban canals contribute to microplastic pollution in peripheral rivers, thereby exacerbating ecological risks. Prior studies have primarily concentrated on larger water bodies, leaving a critical gap in understanding the role of smaller canals as conduits for microplastics.

The main objectives of this research were to investigate the occurrence and characteristics of microplastics in urban canals of Dhaka, evaluate the environmental and ecological risks associated with microplastic pollution, and assess the loading of microplastics into connected peripheral rivers. These objectives aim to bridge the knowledge gap and provide actionable insights for policymakers to devise effective plastic waste management strategies.

The research adopted a systematic design encompassing field sampling, laboratory analysis, and data interpretation. Five canals—Kallayanpur, Norail, Gobindapur, Digun, and Abdullahpur—were selected for their strategic connections to the Balu, Buriganga, and Turag rivers. Sampling was conducted during the dry season to ensure higher microplastic concentrations, with water and sediment samples collected from urban areas, connecting channels, and canal-river junctions. Laboratory methodologies included vacuum pump filtration for water samples, oven drying for sediment samples, density separation using zinc chloride solutions, and visual and spectroscopic

analysis for microplastic identification and quantification. Quality assurance measures adhered to NOAA guidelines to ensure reliability and minimize contamination.

The findings revealed that microplastics were present in all sampled canals, with higher concentrations observed in sediment samples compared to water samples. The average concentration in water samples ranged from 13 to 185 items per liter, while sediment samples exhibited 81 to 594 items per kilogram. Among the canals, Digun recorded the highest microplastic concentration in water samples due to industrial discharges, whereas Abdullahpur had the highest sediment concentrations, attributed to stagnant flow and water retention. The dominant microplastic shapes included fibers (55% in water and 22.99% in sediment), films (18.62% in water and 43.1% in sediment), and fragments. Microplastics predominantly ranged in size from 0.1 millimeters to 1 millimeter, with transparent particles accounting for the largest proportion. These findings highlight significant spatial variability influenced by land use and human activities.

The study concludes that urban canals in Dhaka serve as critical pathways for microplastics, facilitating their transfer to peripheral rivers and contributing to broader environmental pollution. The implications underscore the urgent need for targeted waste management policies, improved industrial effluent treatment, and public awareness campaigns to mitigate microplastic pollution. Future research should explore seasonal variations, microplastic weathering processes, and their combined ecological impacts, while assessing the risks to human health and biodiversity.

This study provides a foundational framework for addressing microplastic pollution in urban waterways, offering insights for environmental management in rapidly urbanizing regions worldwide.

Chapter 1 INTRODUCTION

1.1 Background

Microplastic pollution has emerged as a significant environmental concern globally, affecting aquatic ecosystems and human health. Studies from various global regions, including urban areas of Thailand (Jiwarungrueangkul et al., 2021) and China (J. Chen et al., 2022), highlight similar patterns of microplastic pollution in canals. For instance, research in urban canals of Thailand (Eamrat et al., 2022) revealed high concentrations of polypropylene (PP) and polyethylene (PE) microplastics, predominantly in the form of fibers and films. In Lima, Peru, irrigation canals showed significant microplastic contamination, with secondary microplastics being the most prevalent due to the fragmentation of larger plastic debris (Canchari & Iannacone Oliver, 2022).

Microplastic pollution in Dhaka city primarily originates from domestic waste, industrial effluents, and urban runoff. The textile and dyeing industries are the major contributors, releasing microplastics into rivers and canals without proper treatment of wastewater. (Mercy et al., 2023) Inappropriate waste disposal by slum dwellers and urban populations further accelerates plastic pollution, leading to the degradation of plastics in rivers like Buriganga, Turag, and the connected canals. Additionally, stormwater mixed with domestic sewage significantly affects the catchment areas of canals. As a result, this long-term mismanagement of waste dumping sites causes a significant microplastic accumulation in the canals.

In the riverbed sediments of Dhaka city, microplastic pollution ranged between 46 to 534 items/kg of dry sediment, with film and fragment shapes being the most dominant, and white, transparent are the most common colors (Islam et al., 2023). In the Turag River, the microplastic abundance

reached (29.00±10.68) particles/100L in surface water and (86.00±12.17) particles/kg in sediment (Hossain et al., 2022), the mean concentration of MPs was found to be 36,000 ± 32 MPs/m^3 (Parvin et al., 2022). The city canals are directly connected with these peripheral rivers. The MPs in canals may contribute these significant MPs of the rivers. However, no data is available regarding MPs abundance and loading of MPs into the surrounding river system.

1.2 Objectives

This study aims to address this gap by conducting field sampling and laboratory analysis for comprehensive understanding of MPs' abundance, characteristics and types within five canals (Digun, Kallayanpur, Gobindapur, Norail, Abdullahpur) connecting the peripheral rivers of Dhaka city. This study will help in understanding the MPs loading to the rivers and the associated ecological risks of the environment.

The study aims to-

i. To investigate the occurrence and characteristics of microplastics in urban canals of

Dhaka city.

ii. To evaluate the environmental and ecological risks associated with MPs pollution in the canals.

iii. Assessment of the microplastics loading to the connected peripheral rivers of Dhaka city.

1.3 Scope of the study

Understanding the MPs of the urban canals in Dhaka city, associated environmental and ecological risks and contribution of the urban canals in MPs pollution of the surrounding river system of

Dhaka City. This comprehensive study could be useful for the policymakers and stakeholders to develop the policy for effective plastic waste management for safeguard of rivers from MPs pollution.

1.4 Organization of the Thesis

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 aquatic and terrestrial ecosystem, its impact on the overall environment and the means to mitigate the adverse effects.

Chapter Three presents the methodology followed in this research. It includes details of the sampling and analysis of microplastics in different samples, and it describes in detail the laboratory experiments carried out for the quantification and characterization of microplastics.

Chapter Four presents' abundances and mass concentration of microplastics, and the results of the laboratory experiments for the characterization (shape, size and color) of Microplastics.

Chapter Five presents result, conclusion and recommendations for future research on Microplastic in Bangladesh.

Chapter 2 LITERATURE REVIEW

2.1 Introduction

This literature review emphasizes on the loading of microplastics from urban canals to the rivers lying at the outskirts of Dhaka. For a comparative analysis, sediment and water samples were collected. This study investigates the following study gaps:

1. Studies regarding MPs in urban canals are yet to be addressed in completion.
2. The source of MPs pollution can be directed from the urban areas.
3. Propagation of microplastics can be determined by the flow from canals to rivers

Microplastics (<5 mm, including nanoplastics <0.1 microns) originate from the fragmentation of larger plastic debris or direct environmental emissions(de Souza Machado et al., 2018). Microplastics can adsorb harmful pollutants from their surroundings, acting as transport vectors, while simultaneously leaching chemical additives into the environment(Issac & Kandasubramanian, n.d.). Microplastics vary in color and density based on polymer type and are generally categorized by their origins as primary or secondary(Issac & Kandasubramanian, n.d.). The understanding of human and environmental risks posed by chemicals in diverse plastic products remains limited. Most chemicals used in producing plastic polymers are derived from non-renewable crude oil, with many classified as hazardous(Lithner et al., 2011). Microplastics from various primary sources follow intricate transport pathways in the environment, eventually reaching the oceans and adding to their pollution(Sharma et al., 2024).

There have been no studies regarding the MPs contamination in the canals of Bangladesh. Although there are studies regarding the MPs in surface water bodies, the propagation of MPs from urban areas will clarify the sources and sinks of MPs from human habitation to the

environment. Although MP pollution is a serious concern, the focus of research has been on larger waterbodies such as rivers and lakes whereas small streams provide a medium between urban areas and drainage networks(Dikareva & Simon, 2019). Investigations in urban environments confirm the presence of microplastics in sewage, freshwater, and atmospheric fallout, offering insights into their types and size distributions(Dris et al., 2015). One important way that microplastics enter the marine environment is through riverine transport(Besseling et al., 2017). Microplastics were measured upstream and downstream of treatment plants in various catchments with differing characteristics, revealing that all contributed to an increase in microplastics in rivers(Kay et al., 2018). Likewise, sludge application on land is thought to be a significant contributor to environmental microplastic (MP) pollution(X. Li et al., 2018). Because of the buildup of microplastics and the presence of dangerous particles, areas close to aquaculture farms are regarded as hotspots for microplastic contamination(P. Xu et al., 2018). Microplastics are unevenly distributed in space, with higher concentrations close to drainage canal entry and a downward trend throughout the lake from north to south which is evident in the study of Lake Ulansuhai(Z. Wang et al., 2019). These results demonstrate the need for greater attention to microplastic contamination by showing that rivers in the Tibet Plateau have been contaminated by microplastics, impacting both remote and developed places with considerable human activity(Jiang et al., 2019). This variance in microplastic abundance seen across lakes from around the globe is a sign of variations in watershed conditions, lake activities, particularly fishing, the size ranges of microplastics examined, and sample and processing techniques(Egessa et al., 2020). A study shows that the Chao Phraya River near the Tha Prachan area has high concentrations of microplastics in both its water and sediment. For this reason, both sediment and water samples were the primary target of this investigation(Ta et al., 2020). While there was no clear trend in the

water samples, the quantity varied throughout the sampling locations: silt levels dropped along the river's path. A barrier that traps sediments and reduces tidal influence in the river's upstream sections could account for this variation(Scherer et al., 2020). While there was no clear trend in the water samples, the quantity varied throughout the sampling locations: silt levels dropped along the river's path. A barrier that traps sediments and reduces tidal influence in the river's upstream sections could account for this variation(Wu et al., 2020).

2.2 Transport from urban areas to rivers

Numerous criteria need to be taken into account in order to evaluate the presence, trajectory, and movement of microplastics (MPs) and forecast the areas where they will accumulate. These include the physical and chemical characteristics of MPs, wind impacts, oceanic tides, water flow dynamics, environmental weathering rates, and human activity(Darabi et al., n.d.). Plastic garbage is transported into river systems by surface runoff from upstream land usage, which connects terrestrial sources to aquatic habitats(Darabi et al., n.d.). Freshwater ecosystems in the hydrosphere alternate between MP transport (like rivers) and deposition (like lakes), with flow rate being found to be a crucial determinant of MP movement and destiny(Petersen & Hubbart, 2021). Reduced flow velocities in a lake along the River Tame encouraged the deposition of fine sediments and microplastics, resulting in the most notable shift in microplastic abundance(Tibbetts et al., 2018). Stormwater events, rainwater drainage, flooding, and wind can gather and carry microplastics (MPs) dispersed or generated on land into freshwater ecosystems(Bellasi et al., 2020). Whereas rivers and streams serve as MP transport paths, lakes and areas with lower flow velocities usually serve as MP sinks(Tibbetts et al., 2018). Evidently, there is significant MPs pollution in the rivers of Dhaka(Islam et al., 2023). In Dhaka city, Bangladesh, canals act as conduits, transporting urban waste, including microplastics (MPs), from densely populated areas to peripheral river systems,

contributing significantly to MP pollution in these aquatic environments. While heavier particles may settle to the riverbed or be caught by natural obstacles, buoyant microplastics are mostly carried by the flow of rivers(Lebreton et al., 2018). Since the particles can travel great distances on wind(Gasperi et al., 2018), they can also get to far-off places like lakes(Battulga et al., 2019). The movement of microplastics is irregular and greatly varies based on their physical attributes (size, density, and shape), the surrounding environment, and the particular ecosystems they live in(Waldschläger et al., 2020).

2.3 Sources and pathways of microplastics

Microplastic (MP) sources are categorized as primary, produced at sizes smaller than 5 mm, and secondary, resulting from the environmental degradation of larger plastics, with their entry into ecosystems occurring through point or diffuse pathways(Waldschläger et al., 2020). Two important variables affecting microplastic pollution are population density and the surrounding waste disposal environment((Gong & Xie, 2020)). Areas near industrial sources and coastal locations near populated areas are especially affected by microplastic contamination(Gong & Xie, 2020).

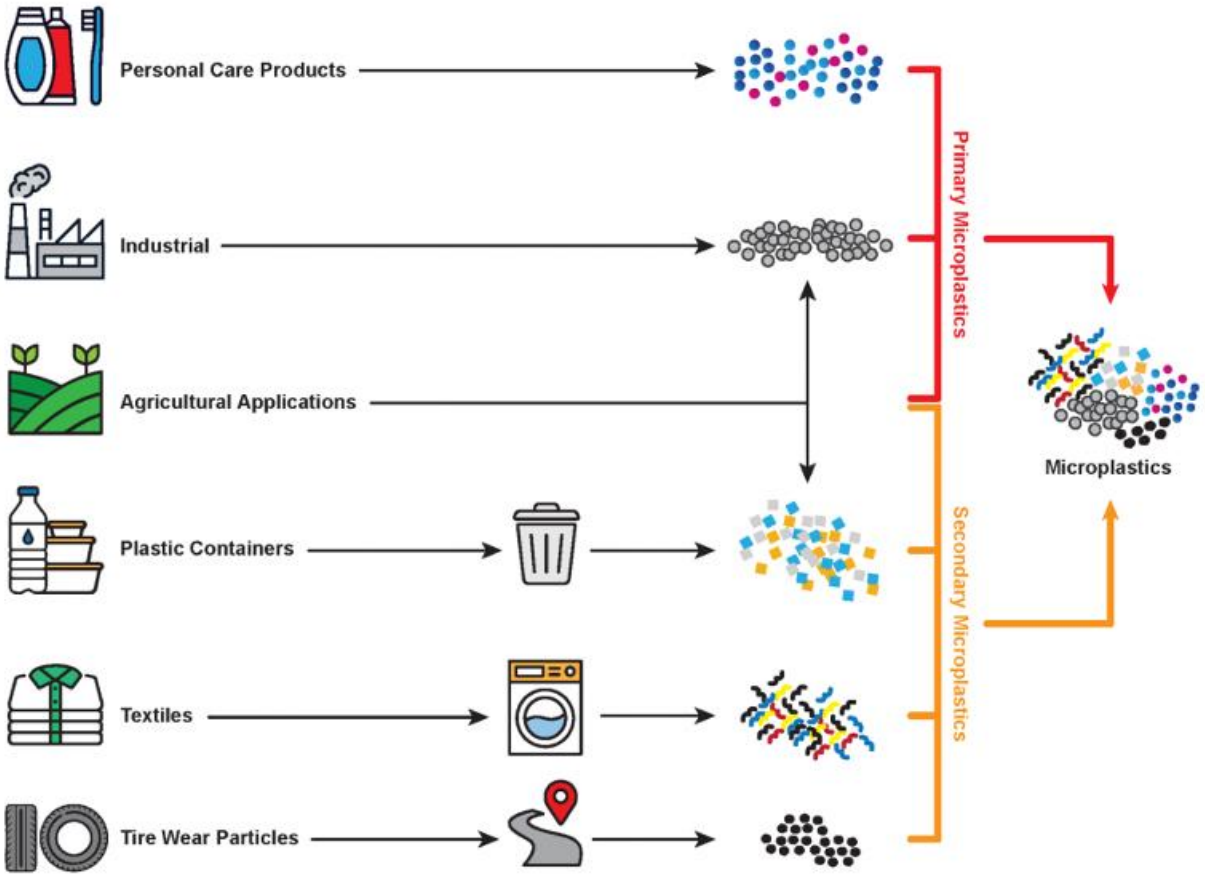


Figure 1: Sources of Primary Microplastics(2 Environmental Distribution, Fate, and Transport, n.d.)

2.3.1 Primary sources

Primary microplastics are tiny plastic particles designed for industrial and commercial use, entering the environment through manufacturing spills, product use, and waste streams, including examples like nurdles, fertilizer pellets, and microbeads in personal care products such as facial cleansers and toothpaste(2 Environmental Distribution, Fate, and Transport, n.d.). Additionally, raw materials used for the fabrication of plastic products, such as plastic resin pellets, flakes, plastic powder, and fluff, can also become significant sources of primary microplastics due to accidental loss during transport and runoff from processing facilities(Duis & Coors, 2016). Primary

microplastics are commonly acknowledged to have been purposely created to tiny proportions, with emphasis on "intentional production" and "artificial generation"(J. Song et al., 2024). Polyethylene microbeads used as exfoliants in cosmetics have a wide size range, with mean diameters between 164 and 327 μm, and it is estimated that between 4594 and 94,500 microbeads could be released in a single use(Napper et al., 2015). The processes by which primary microplastics from various sources infiltrate aquatic habitats are complicated, with little available data(T. Wang et al., 2019). Approximately 1500 tons/year of microplastics from personal care products (PCPs) escape from wastewater treatment plants (WWTPs), contributing to a total global emission of up to 1.2×10^4 tons/year, with up to 3.00×10^5 tons accumulated over the last 50 years (1970–2019)(Derraik, n.d.; Gregory, 2009). Wear and tear from tyres contribute to microplastics in the environment, with emissions ranging from 0.23 to 4.7 kg/year per capita (global average of 0.81 kg/year), predominantly from car tyres (100%) compared to other sources like airplane tyres (2%), artificial turf (12-50%), brake wear (8%), and road markings (5%)(Jan Kole et al., 2017). Primary microplastics are also manufactured for use in airblasting technology(Derraik, n.d.; Gregory, 2009). In 2015, mainland China generated 737.29 Gg of primary microplastic waste, with one-sixth entering the aquatic environment. Tire dust and synthetic fiber accounted for majority of the garbage, which was influenced by population and economic development, resulting in approximately 538 g of microplastic per person(Shen et al., 2020).

2.3.2 Secondary Sources

Secondary microplastics are smaller particles that are inadvertently created when larger plastic fragments break down due to physical, chemical, and biological processes(J. Song et al., 2024). All conventional plastic that has ever been released into the environment is thought to still be

unmineralized, either as whole objects or in pieces, with the exception of materials that have been burned(Thompson et al., 2005). When subjected to environmental factors, larger plastic materials on land and in the ocean gradually decomposes into tiny particles, which are known as microplastics(Anderson et al., 2016). Fragmentation occurs through a combination of physical, chemical, and biological processes that compromise the structural integrity of macroplastic waste(Cole et al., 2011). The construction industry uses a considerable amount of plastic products, such as pipes, cladding, and insulating materials, which can be lost to the environment due to carelessness or incorrect storage, with expanded polystyrene (styrofoam) often being transported away from construction sites by drifting and surface runoff(Battulga et al., 2019; Waldschläger et al., 2020). Sewage contaminated by synthetic fibers from washing clothes is a significant source of microplastics, with the highest release observed from washing woven polyester fabrics(De Falco et al., 2018). Littering leads to the fragmentation of discarded macroplastics into secondary microplastics, contributing to environmental pollution(Waldschläger et al., 2020). The key-ways that plastic enters the environment are through general littering, inappropriate trash disposa l, and poorly maintained landfill sites(Duis & Coors, 2016). Various factors can cause plastic debris to break down into secondary microplastics, with some research suggesting that the intense UV radiation on the Tibetan Plateau may accelerate this process(Jiang et al., 2019). Secondary microplastics can also be generated by building supplies like insulation and pipes, as well as athletic equipment like goal nets and artificial grass(Waldschläger et al., 2020). In some regions, majority of the MPs are generated through the breakdown of larger plastic items(Dikareva & Simon, 2019).

2.4 Degradation of plastics in aquatic and terrestrial environment:

MPs go through different degradation mechanism(Auta et al., 2018; Duan et al., 2021; D. He et al., 2018; Iñiguez et al., 2018). Moreover, the weathering processes are influenced by the physicochemical properties of microplastics (MPs) such as size, structure, and crystallinity, as well as environmental conditions like oxygen levels, water, temperature, and biofilms(Z. Chen et al., 2020; Mei et al., 2020; Tian et al., 2019; Turgay et al., 2019; C. Wang et al., 2020). In other words, degradation involves the oxidation or hydrolysis of plastics, leading to a loss of structural stability and a reduction in molecular weight(Andrady, 2011; Chamas et al., 2020). In this literature review, due to the velocity and discharge differences of urban canals with respect to larger surface waterbodies, mechanical breakdown along with photodegradation and biodegradation.

2.4.1 Mechanical Degradation

Plastics can break down into smaller fragments while interacting with soil particles through adsorption and desorption(Chae & An, 2018). When microplastics scrape against sediments, pebbles, waves, and tides in water, they undergo mechanical breakdown. Human activity can also cause this to happen on land(D. He et al., 2018). Aged microplastics become stiffer, altering their mechanical properties(Luo et al., 2020). The quantity of fragmented polymer particles generated through UV exposure and mechanical abrasion increased as the particle size decreased across all polymer types(Y. K. Song et al., 2017). It can be concluded that the generation of MPs in the environment will speed up under prolonged UV ray exposure and mechanical wear(Duan et al., 2021).

2.4.2 Photo Degradation

Photodegradation refers to the degradation of a photodegradable molecule caused by the absorption of photons, particularly from sunlight (infrared radiation, visible light, ultraviolet light), though other electromagnetic radiation can also cause it(Yousif & Haddad, 2013)Photo-degradation is the primary weathering process for the majority of MPs(Duan et al., 2021). Aged microplastics exhibit a rougher surface, lower glass transition temperature, and higher surface stiffness(Luo et al., 2020). UV-B radiation reaching Earth (wavelength 290-400 nm) has an energy range of 72-97 Kcal/mol, sufficient to disintegrate most chemical bonds, except a few like N-H, O-H, and C-H bonds(Aminabhavi, 1981). Sunlight application on polymers triggers a chemical chain reaction, removing a hydrogen atom (H•) from an excited polymer molecule (RH) and producing a free polymer radical (R•)(Chamas et al., 2020).

Initiation:

$$RH \overset{UV-B}{\rightarrow} RH^*$$

$$RH* \rightarrow R\bullet + H\bullet$$

The polymer radical (R•) combines with oxygen (O_2) to form a peroxy radical (ROO•), which reacts with an adjacent polymer molecule (RH), extracts a hydrogen atom (H•), and produces a new polymer radical (R•) and a hydroperoxide (ROOH) group(Rånby, 1993).

Propagation:

$R\bullet + O_2 \rightarrow ROO\bullet$

$$ROO\bullet + RH \rightarrow ROOH + R\bullet$$

$$ROOH \rightarrow RO\bullet + OH\bullet$$

$$2ROOH \rightarrow RO\bullet + ROO\bullet + H2O$$

$$RO\bullet + RH \rightarrow ROH + R\bullet$$

Hydroperoxide (ROOH) is susceptible to changes when exposed to light(Yousif & Haddad, 2013). "ROOH breaks down into alkoxy (RO•) and hydroxyl radical (OH•), each generating a new polymer radical (R•), continuing photodegradation through chain propagation(Chamas et al., 2020).

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

Termination:

ROO• + ROO•→ ROOR + O_2

$$R\bullet + R\bullet \rightarrow R - R$$

$$ROO\bullet + R\bullet \rightarrow ROOR$$

β-scission of the alkoxy radical (RO•) forms oxidized groups like carboxyl and carbonyl, promoting further chain scission by photolysis of carbonyl functional groups (C=O)(Aminabhavi, 1981; Yousif & Haddad, 2013). Carbonyl photolysis progresses through either Norrish Type I or Norrish Type II reactions(Rånby, 1993). Norrish Type I reaction refers to photochemically induced homolysis of a carbonyl group into two free radical intermediates, while Norrish Type II involves light-induced intramolecular extraction of a γ-hydrogen, producing alkene and enol or enabling cyclization of carbonyl compounds to cyclobutanols(Chamas et al., 2020).

As the key role of radiation is to introduce chain initiation reaction, further degradation can proceed at moderate temperature without any exposure to sunlight (Andrady, 2011). Photodegradation and

thermal degradation are indistinguishable under usual conditions, but without UV radiation, a minimum temperature of 100°C is required to initiate the thermal degradation of Polyethylene (PE)(Chamas et al., 2020). An overview of the photodegradation process shown in Figure

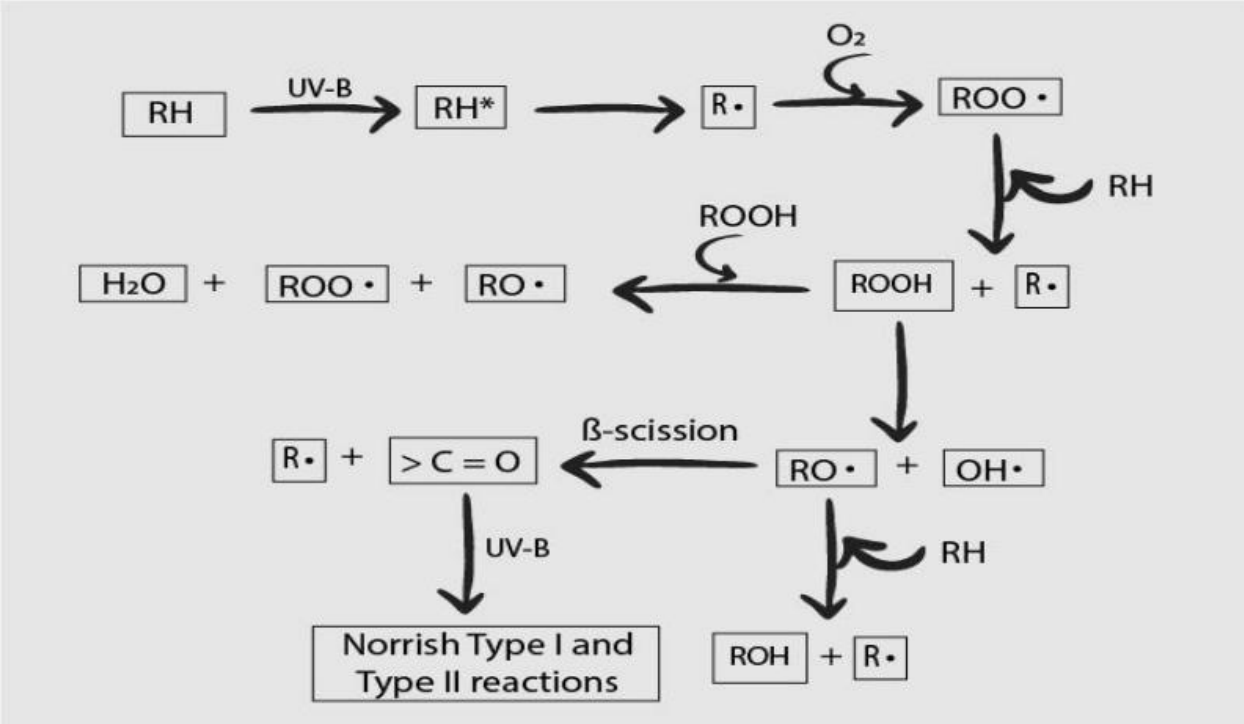


Figure 2: Overview of photodegradation of MPs.

2.4.3 Biodegradation

The main processes for the biological weathering of microplastics (MPs) include microbial breakdown and biological ingestion and digestion(Duan et al., 2021). Bacteria can alter the appearance of MPs as well as their functional group structures and characteristics(Yuan et al., 2020). Biodegradation slowly transforms polymers into biomass through disintegration(Andrady, 2011). Polymer properties like molecular mass, size, shape etc. along with types of organisms and abiotic factors affect process of biodegradation(Ahmed et al., 2018). The process of biodegradation starts when the exoenzymes secreted by microbes gets attached to the plastic particles(Ahmed et al., 2018). Bacteria has the capability to efficiently degrade MPs present in wastewater including

PETase (PET hydrolase) and MHETase (mono-2 hydroxyethyl terephthalate hydrolase)(Ali et al., 2024). Enzymes of algae can generate a layer on the plastic particles speeding up the biodegradation and fragmentation process. Some species of algae can genetically transform themselves to secrete polymer-degrading enzymes(Ali et al., 2024).

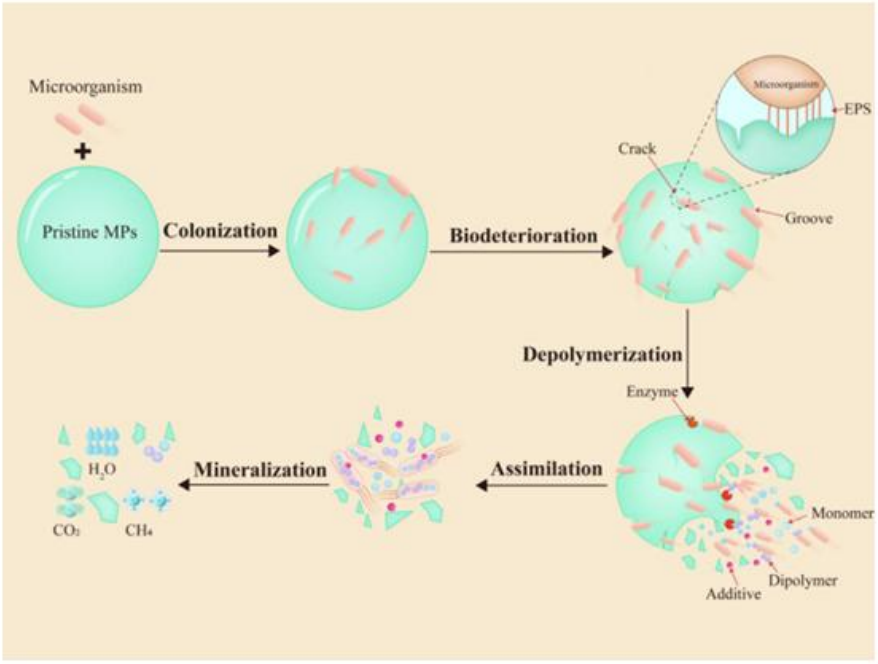


Figure 3: Biodegradation of MPs (Duan et al., 2021)

2.5 Pathways of MPs to the canal

Microplastics move between different environmental elements rather than staying in one place(Gong & Xie, 2020). Microplastics can find their way into the environment through various routes. These include: a) plastic waste directly discharged into water bodies by daily human use, b) release of microplastics through both treated and untreated wastewater by sewage treatment plants, and c) discharge from water-based activities such as navigation, fisheries, and other water operation industries(Tang et al., 2021). Land is a major contributor to microplastics in aquatic

environments(Gong & Xie, 2020; Tang et al., 2021). Microplastics from waste yards, agricultural fields, roads, and other sources can enter water bodies directly through surface runoff, or they might travel underground before emerging through subsurface runoff ((Gong & Xie, 2020; Tang et al., 2021)), while the remaining portion enters the sewage system(Waldschläger et al., 2020). Even with high removal efficiency, a properly functioning sewer system can still be a significant source of microplastics ((Yurtsever, 2019)). Moreover, Microplastics can enter the environment through industrial wastewater. Research indicates that a single secondary wastewater treatment plant can release up to 23 billion microplastics per year (Murphy et al., 2016). Wastewater treatment sludge, often used as landfill or fertilizer in agricultural fields, can introduce microplastics into aquatic environments through wind and rain ((Waldschläger et al., 2020)). Additionally, some microplastics are directly released into water bodies through activities such as navigation, fisheries, and port operations ((Tang et al., 2021)).

2.6 Microplastics Analysis Methodology

There are studies regarding MPs but standardized methodologies for analysis have not been developed yet(J. Li et al., 2018; Yang et al., 2021). This paper reviewed previous studies to overview sample collection, preparation and analysis of microplastics in sediments and water-columns.

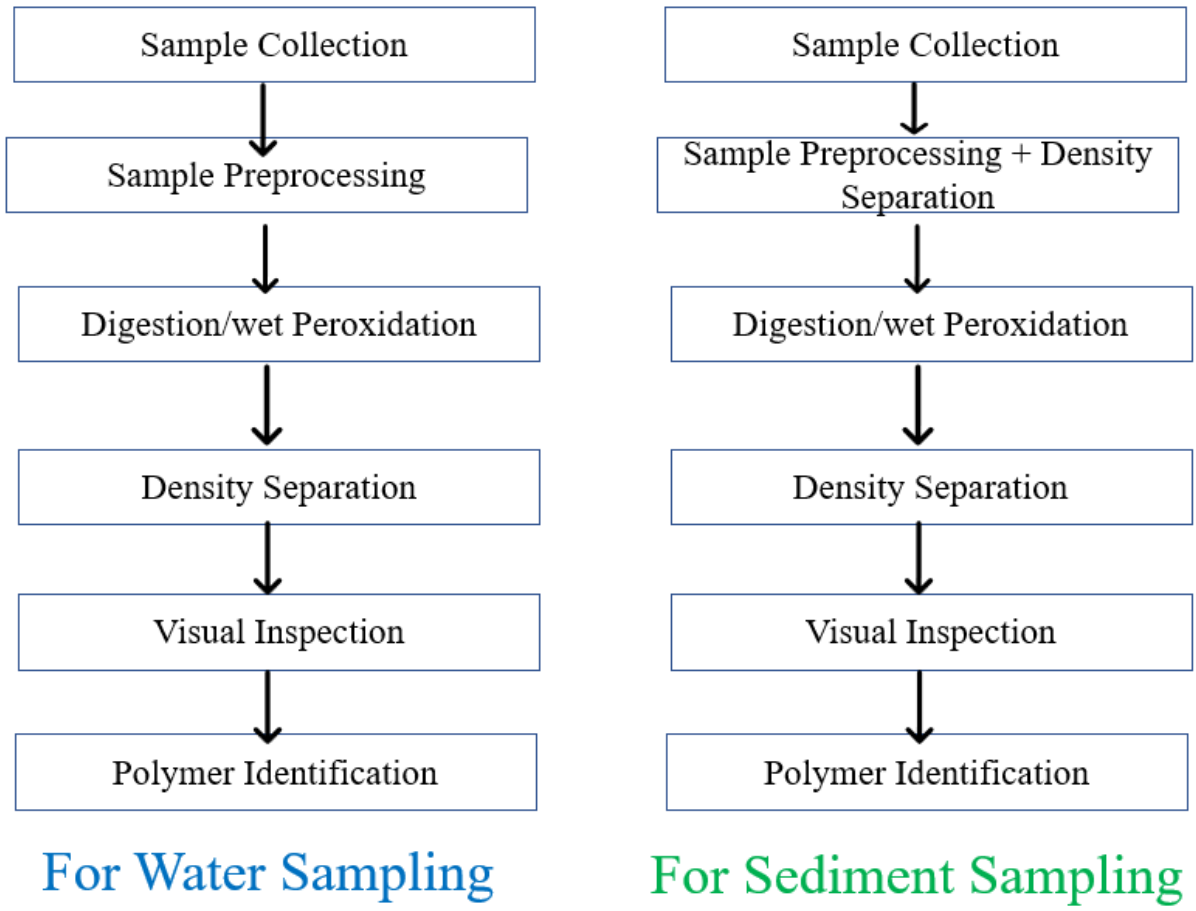


Figure 4: Flowchart of MPs Analysis for water and Sediment samples.

2.6.1 Sample Collection

To obtain a precise understanding of MPs contamination, it is important to collect as many samples as possible(Stock et al., 2019). MP sampling in sea surface, water column, and sediment can be classified into three methods (Hidalgo-Ruz et al., 2012):

1. Selective Sampling: This method is conducted through visual monitoring(Gong & Xie, 2020) and the microplastics are directly picked up from the samples. This process is feasible for samples containing considerably larger MPs (1-5mm in size)(Yang et al., 2021)

2. Volume-reduced Sampling: Here, the portion of the sample required for further analysis is preserved to decrease the volume of the bulk sample(Silva et al., 2018).
3. Bulk Sampling: The total sample is to be collected(Silva et al., 2018).

Shoreline sampling is a rapid and economical choice since it offers a comparatively bigger region for collection. However, because the riverbed is less impacted by human and natural activity, riverbed sampling produces a sample that is less disturbed(Adomat & Grischek, 2021). The decision between riverbed and coastline sampling is mostly based on the goals of the study, the accessibility of data collection equipment, and professional advice(Adomat & Grischek, 2021). Sampling depth is to be defined for higher precision(Prata et al., 2019). Usually, the mean concentration of MPs is higher in the upper 1-5cm sample than the deeper 10cm sample(Besley et al., 2017). For reducing external MPs contamination, equipment made of plastic should be avoided(Adomat & Grischek, 2021).

2.6.2 Sample Preparation

To avoid the external variable of moisture content, the dried states of sediment samples and water samples were considered in accordance with a previous study (Van Cauwenberghe et al., 2015). Therefore, the residual moisture content should be reduced to attain a constant dried weight(Yang et al., 2021). Samples can be either over-dried or air-dried. Oven drying prevents external airborne contamination(Adomat & Grischek, 2021) but higher temperatures may distort the shape of microplastics(Zobkov & Esiukova, 2017). The drying temperatures in most of the research we looked at were between 40°C and 90°C, with several studies heating samples to temperatures above 70°C. In one case, samples were allowed to air dry at ambient temperature, which could have prolonged the drying period, allowed airborne contaminants to contaminate the samples, and left moisture behind even after the drying procedure was finished(Adomat & Grischek, 2021).

2.7 Sieving

An initial extraction technique called sieving involves passing sediment samples through sieves with varying aperture sizes to eliminate contaminants like clay and silt-sized particles and capture microplastic particles(Gong & Xie, 2020). There are two types of sieving namely wet and dry sieving. Dry sieving is not efficient for particles finer than 40 microns whereas wet sieving can sustain for particles finer than 20 microns. However, in wet sieving, MP particles with low-density might get discarded(Adomat & Grischek, 2021).

2.7.1 Digestion

A pretreatment procedure called sample purification or digestion is intended to eliminate organic materials from sediment samples, guaranteeing precise extraction and interference-free microplastic categorization.(Adomat & Grischek, 2021; Gong & Xie, 2020). From our review, we found that 10-30% H_2O_2 solution, Fenton's reagent mixed with acid, alkaline or enzymes are used to treat biological samples.

35% H_2O_2 solution has been proved to be effective for removal of organic matter(Nuelle et al., 2014). Although H_2O_2 digestion may result in discoloration and destruction of MPs(Nuelle et al., 2014), there have also been evidences that no visible changes were present after the usage of H_2O_2(Lusher, n.d.).

An alternative to the process of H_2O_2 oxidation is the use of the mixture of H_2O_2 with Ferrous Sulphate ($FeSO_4.7H_2O$) also known as Fenton's reagent(Adomat & Grischek, 2021). Fenton's reagent is more effective in destroying organic particles than the traditional H_2O_2 digestion(Hurley et al., 2018).

Enzyme digestion is another process of MPs-processing where the organic content is high. However, enzymes are costly and thus, this process is limited to samples of smaller volumes(Hurley et al., 2018). Additionally, the mixture of H_2O_2 and enzymes takes multiple days to destroy the organic particles(Löder et al., 2017). Due to the cost and time constraints, the studies we reviewed did not use this technique for digestion.

2.7.2 Density Separation

Density separation is done to differentiate impure particles and MPs during analysis(Gong & Xie, 2020). All the studies regarding MPs analysis had this step. The difference in densities of MPs and non-MPs particles is the working principle of this chemical process(Gong & Xie, 2020). Sediment samples require 2-step density separation whereas, water samples require 1-step density separation with dense salt solutions(Marine Debris Program, 2015).

NaCl solutions are widely used for density separation for various feasible factors like low-cost, safety and non-abrasive properties(Yang et al., 2021). The main issue of this solution is the low efficiency of collection of dense MPs like PVC (Poly Vinyl Chloride) for the low density of the solution (1.2 g/cm^3)(Amrutha & Warrier, 2020).

The most effective and economical method of separating digested organic particles and micropla stics is density separation using ZnCl2(Rodrigues et al., 2020). $ZnCl_2$ (density: 1.8 g/cm^3) allows the separation of all MPs polymers(Tien et al., 2020). As $ZnCl_2$ is a harmful solution, reusing and recycling of this solution must be ensured to avoid further pollution(J. Li et al., 2018).

2.7.3 Identification and Quantification

Identification of MPs is the most important part of MPs analysis. Visual inspection and spectroscopic inspection ensure accurate analysis of MPs. Sorting of MPs is carried out by the

naked eye or with a microscope(Hidalgo-Ruz et al., 2012). Among the types of microscopes, our study indicates that stereoscopic microscope is the most used.

2.7.4 Visual Inspection

Although visual sorting is the widely used process to identify MPs, it may not provide precise information about MPs(J. Li et al., 2018). As visual inspection depends on the operators' perspective, it may result in the misidentification of MPs(Yang et al., 2021). Smaller sizes of MPs may provide with inaccurate results(Gong & Xie, 2020) and errors can be as much as 70%(Hidalgo-Ruz et al., 2012).

The following standards should serve as a reference when choosing plastic particles for visual identification: they should be devoid of organic contaminants, have a constant thickness, and retain a consistent color over their whole length. To differentiate transparent or white microplastics from organic particles, a fluorescence microscope at high magnification should be used(Hidalgo-Ruz et al., 2012). To avoid extra losses, examining the filter surface without relocating is recommended(Yang et al., 2021). To avoid double counting, the investigation should be initiated from top left to bottom right(Simon-Sánchez et al., 2019). In addition to identification, a scanning electron microscope (SEM) is used to examine the surface properties of microplastics and the impact of ultrasonic cleaning on polymers(Wu et al., 2020). For SEM analysis, the MPs are coated with thin gold or platinum. Due to the heterogeneity of the degraded MPs particles, visual inspection should be repeated at least three times to avoid inaccuracy(J. Wang et al., 2017).

2.7.5 Spectrometric analysis

To determine the chemical constituents of MPs, spectrometric analysis is done(Gong & Xie, 2020). The accuracy of visual sorting can be determined from spectrometric analysis(Constant et al.,

2020). Detecting vibrations from samples and comparing the resulting spectra to pre-established reference spectra is the fundamental idea behind spectrometric analysis(de Souza Machado et al., 2018; Elert et al., 2017; Mai et al., 2018). FTIR (Fourier Transform InfraRed) and Raman spectroscopy are widely used for determining MPs composition(Hidalgo-Ruz et al., 2012). FTIR can be operated in 3 modes: Reflection, transmission and attenuated total reflection (ATR)(Yang et al., 2021), among which ATR is widely used as particles are separately detected and identified by an ATR tip(Lee & Chae, 2021). The database and high signal to noise ratio are the main reasons for attraction of this feature(Yang et al., 2021). The condition for using transmission mode is the ability of infrared light to penetrate through samples, which is not applicable for dark, opaque and thick samples(Gong & Xie, 2020). The method of reflection allows the analysis of particles which are dense and opaque. However, the particles must be regular-shaped or else the scattering of light will provide inexplicable results(Harrison et al., 2012). Addition of focal plane array (FPA) to FTIR spectroscopy enables analysis of individual particles within a defined grid area using precision linear mechanism that facilitates 3 degrees of freedom for movement(Lee & Chae, 2021). FPA detector can detect particles that are 20 microns or larger and deliver detailed information on the polymer type, shape, and size of each individual particle(Löder et al., 2015; J. L. Xu et al., 2019). To prevent in FPA-FTIR analysis, the organic impurities in samples should be removed(Y. Chen et al., 2020). FTIR analysis is time-efficient, effective and can identify the degree of weathering of MPs without fluorescence(Gong & Xie, 2020). However, FTIR analysis is sensitive towards moisture(J. Li et al., 2018). Most of the previous studies used FTIR for spectroscopic analysis.

Raman spectroscopy can analyze wet samples(Ivleva et al., 2017). RM spectroscopy can detect particles less than 20microns due to high spatial resolution(Gong & Xie, 2020). Samples should

be free from additives, pigments, organic and inorganic impurities(Gong & Xie, 2020; Yang et al., 2021). Chemical mapping utilizing RM spectroscopy is a time-consuming process(Ivleva et al., 2017).

2.8 Abundance and Characteristics of MPs

Factors affecting the occurrence of MPs in canal's water and sediment

The abundance of microplastics in the environment is influenced by various factors, including population density, urbanization levels, and anthropogenic activities in the surrounding area. Additionally, elements such as precipitation, wind intensity, tidal currents, waterway width, flow velocity, season, and the properties of microplastics play a role. Consequently, the concentration of microplastics varies significantly across different regions(Jiang et al., 2019). Microplastic particles are capable of traveling long distances ((Gerolin et al., 2020)); however, their concentration diminishes as the distance from urban or industrial areas increases(Prata et al., 2021). Low flow velocity encourages the sedimentation of microplastics, whereas high flow velocity enhances their mobilization in aquatic environments (B. He et al., 2020).This relationship leads to lower microplastic accumulation during the rainy season ((Wu et al., 2020). Consequently, microplastic accumulation is higher in winter than in summer due to reduced flow rates(Nel et al., 2018; Schmid et al., 2021) .Furthermore, heavy rainfall combined with strong winds and intense wave action can move microplastics from sediment into the water column, decreasing their concentration in the sediment (Amrutha & Warrier, 2020). A study in the Maozhou river showed that microplastic concentrations in sediment during the dry season were 10 to 200 items per kg higher than in the wet season. However, (B. He et al., 2020)observed higher microplastic

concentrations during the wet season in some locations. Additionally, there is evidence of increased microplastic abundance in both the water column and sediment following a typhoon (T. Wang et al., 2019). The accumulation of microplastics in sediment is also influenced by their properties, such as density and surface-to-volume ratio (Wu et al., 2020). Polymers with a high surface-to-volume ratio and low density tend to stay suspended in the water column, while those with a low surface-to-volume ratio and high density are more likely to settle and deposit in the sediment (Liu et al., 2021; Wu et al., 2020).

2.9 Characteristics of MPs

Microplastics can be categorized based on the following characteristics- Shape, size, color, and chemical composition (Fred-Ahmadu et al., 2020).

2.9.1 Shape

The shape of microplastics is influenced by various factors such as their source, the process of deterioration, and the duration they are retained in the environment (Yang et al., 2021). Common shapes of microplastics include fibers, films, pellets, foams, and fragments (Ding et al., 2019; Huang et al., 2021; Wu et al., 2020). Some studies have also categorized microplastics into additional shapes like sheets, spheres (or beads), and lines (Constant et al., 2020; Fan et al., 2019; Feng et al., 2020)

Fibers, which are secondary microplastics, are cylindrical with a length significantly greater than their width (Huang et al., 2021; Ngo et al., 2019). They often originate from synthetic clothing during washing, the manufacturing of textile goods, fishing nets, ropes, and sacks (Amrutha & Warrier, 2020; Ngo et al., 2019; Yang et al., 2021). Fibers from fishing activities are sometimes referred to as lines (Dioses-Salinas et al., 2020). Pellets, primary microplastics, are spherical or

elliptical and commonly found in personal care products like cosmetics and toothpaste (Huang et al., 2021; Kutralam-Muniasamy et al., 2020; Ngo et al., 2019). Films are thin, flexible polymers, while foams are soft, lightweight microplastics (Wu et al., 2020). Irregularly shaped microplastics with specific thicknesses are known as fragments (Huang et al., 2021). Large plastic debris can fragment due to continuous exposure to erosion, wear, and UV light (Yang et al., 2021). Films, foams, and fragments can originate from packaging materials, supermarket bags, milk cartons, tires, and pavement materials during mechanical wear or chemical degradation (Kutralam-Muniasamy et al., 2020; Ngo et al., 2019; W. Wang et al., 2017). Foams also come from building insulation materials (W. Wang et al., 2017).

The interaction of microplastics with organisms varies depending on their shape (Kutralam-Muniasamy et al., 2020). Irregular, angular fragments provide suitable surfaces for microorganism attachment, which accelerates sedimentation and increases removal efficiency in wastewater treatment plants (WWTP) (Ngo et al., 2019). However, this can harm microorganism tissues in natural environments (Kutralam-Muniasamy et al., 2020) In contrast, smooth-surfaced fibers with a high length-to-width ratio are more likely to escape WWTP and cause less damage to microorganisms (Kutralam-Muniasamy et al., 2020; Ngo et al., 2019).

Fibers are the predominant shape of microplastics in river sediment, as seen in most reviewed studies (Jiang et al., 2019; Liu et al., 2021; Tien et al., 2020). However, fragments were the most abundant in the Nakdong River, South Korea, making up nearly 84% of total microplastics, a trend observed in other studies (Constant et al., 2020; Eo et al., 2019; Rodrigues et al., 2020). In Shanghai, China, spheres were the dominant shape, accounting for 88.98% of observed microplastics (Peng et al., 2018). Sheets and films were the most common shapes in the Pearl River catchment, China, and Brisbane River, Australia, respectively (Fan et al., 2019; B. He et al., 2020).

2.9.2 Size

The likelihood of microplastics being ingested and their pathways are predominantly influenced by their size (Amrutha & Warrier, 2020; Yang et al., 2021). Due to their high specific surface area, smaller microplastics are more prone to biofouling, leading to their deposition in riverbeds (Liu et al., 2021; W. Wang et al., 2017). As a result, larger microplastics tend to travel further distances compared to smaller ones. Additionally, larger microplastics pose a greater environmental threat as they are less biodegradable, persist longer in the environment, and eventually break down into smaller microplastics and nano-plastics (Kutralam-Muniasamy et al., 2020). However, smaller particles are more bioavailable to benthic organisms and can enter the terrestrial food web ((Dioses-Salinas et al., 2020)). Various studies have identified microplastics of different sizes, but smaller microplastics were predominant in all studies, indicating a high level of weathering and fragmentation from their initial state ((Feng et al., 2020; Huang et al., 2021)). For instance, in the rivers of the Tibet Plateau, 70% of microplastics were found to be smaller than 1mm ((Jiang et al., 2019). Conversely, in the Wen-Rui Tang River, microplastics ranging from 20-300 μm were predominant, making up 84.6% of the total microplastics (W. Wang et al., 2017).

2.9.3 Color

Colored microplastics are more prone to being mistaken for food and consumed by organisms ((Eo et al., 2019; B. He et al., 2020; Wu et al., 2020)). Furthermore, similar to shape, color can indicate the original sources of microplastics (Eo et al., 2019; Yang et al., 2021). For instance, transparent microplastics typically come from plastic bags, bottles, cups, fishing nets, and other disposable plastic items (Di & Wang, 2018; Kutralam-Muniasamy et al., 2020). Conversely, fabrics, packaging materials, cosmetics, and various colored consumer products can be potential sources of colored microplastics (Di & Wang, 2018; B. He et al., 2020; Yang et al., 2021)). Since the color

of microplastics can fade during sample preparation and even in the natural environment due to photodegradation, a careful approach is needed to identify the sources based on color (Fan et al., 2019; Yang et al., 2021). Additionally, during the sample extraction and purification process, some microplastics can be eroded, leading to the underestimation of transparent microplastics during identification (He et al., 2020) It is recommended to classify microplastics into four colors – colorless or transparent, black, white, and colored (Yang et al., 2021). However, some studies have further divided colored microplastics into categories such as yellow, green, blue, red, etc(Jiang et al., 2019; Wen et al., 2018). In most of our reviewed studies, transparent microplastics were found to be predominant. For example, in the Tibetan Plateau, transparent microplastics made up 45.69% of the total microplastics (Feng et al., 2020). However, white particles were also the most abundant in some studies. For instance, in Shanghai, China, white spheres accounted for almost 90% (Peng et al., 2018). In contrast, yellow particles were the most dominant in the Pearl River, constituting 36.2% of the total microplastics (Lin et al., 2018).

2.9.4 Chemical Composition

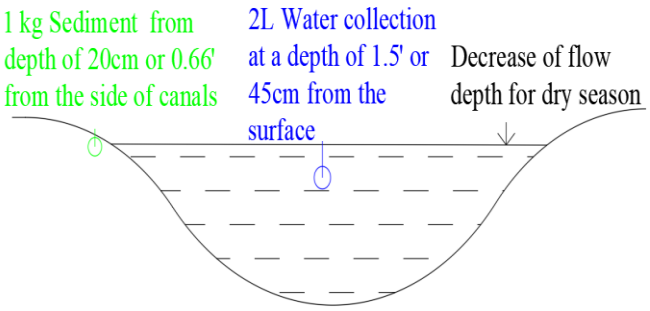
Chemical composition is a crucial characteristic of microplastics (Zhang et al., 2020). Over 30 types of microplastic polymers have been identified in various studies (Ngo et al., 2019). Notable among these are Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Poly(ethylene-propylene) Copolymer, Polyethylene Terephthalate (PET), Polyester (PES), Polyvinylchloride (PVC), Vinyl Acetate Copolymer (VC/VAC), Polyamide (PA), and Cellulose. PP, PE, and PET typically originate from packaging materials, plastic bags, containers, agricultural films, conduits, cords, automobiles, and household items (Kutralam-Muniasamy et al., 2020; Liu et al., 2021; Tien et al., 2020). Conversely, fabrics, lines, and furniture fillers are potential sources of PA and PES (Tien et al., 2020).

The floatation and sedimentation of polymers in aquatic environments are significantly influenced by their chemical composition (Ngo et al., 2019). High-density polymers are more likely to settle in sediments, resulting in higher concentrations in sediments than in water (Eo et al., 2019). Despite their low density, PE and/or PP were identified as the most abundant polymer types in most reviewed studies. For instance, in the sediment of the Haihe River, PE and PP accounted for 49.3% and 32.9% of total microplastics, respectively (Liu et al., 2021). Additionally, PP (38%) was the dominant polymer type observed downstream in the West River, followed by PE (27%), PS (16%), PVC (6%), and PET (4%) (Huang et al., 2021). Biofouling on the surfaces of PE and PP, causing them to sink to the riverbed, may explain this observation (Huang et al., 2021). Aside from PP and PE, the types of polymers varied significantly across different studies. For example, PES (33%) and PA (24%) were predominant in the Yangtze River basin and Ebro River sediment, respectively (Y. Su et al., 2019).

Chapter 3 METHODOLGY

3.1 Sampling

To determine the loading of microplastics from canals to rivers, 5 canals of Dhaka city were selected which had junctions with the 3 rivers bordering Dhaka: Balu, Buriganga and Turag. From each of the 5 canals, 3 locations were used as sampling sites: the urban area from which the canals initiated, the connecting channel of the canal to the river and the junction of the respective canal and river. From the canals, 1 liter water sample and 1 kg sediment sample were extracted using glass jars to prevent contamination. As the amount of microplastics is higher in dry season than the wet season(Jiwarungrueangkul et al., 2021), the sampling was done during the peak dry season within the month of January 2024.



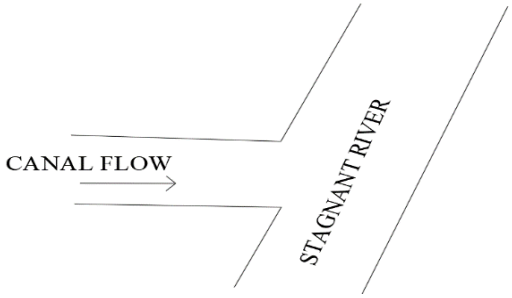


Figure 5: Loading of MPs from urban canals to stagnant river and sample collection points

Table 1. Details of sampling locations

CANALS	Water sample ID	Sediment Sample ID	Relative Location	Co-ordinates
KALLAYANPUR	KW-1	KS-1	Canal River Junction	23° 46' 19.15" N, 90° 20' 32.93" E
	KW-2	KS-2	Connecting channel	23° 46' 19.72" N, 90° 20' 35.85" E
	KW-3	KS-3	Urban area	23° 46' 20.58" N, 90° 20' 39.49" E
NORAIL	NW-1	NS-1	Canal River Junction	23° 45' 40.9" N, 90° 28' 56.9" E
	NW-2	NS-2	Connecting channel	23° 45' 36.2" N, 90° 28' 36" E
	NW-3	NS-3	Urban area	23° 45' 39.3" N, 90° 28' 0.6" E
GOBINDAPUR	GW-1	GS-1	Canal River Junction	23°51'26.89" N, 90°28'26.48" E
	GW-2	GS-2	Connecting channel	23°51'23.10" N, 90°28'17.22" E
	GW-3	GS-3	Urban area	23°51'19.13" N, 90°28'8.05" E
DIGUN	DIW-1	DIS-1	Canal River Junction	23°49'39.30" N, 90°20'31.54" E
	DIW-2	DIS-2	Connecting channel	23°49'46.09" N, 90°20'37.58"E
	DIW-3	DIS-3	Urban area	23°49'46.63" N, 90°20'45.62" E
ABDULLAHPUR	AW-1	AS-1	Canal River Junction	23°52'49.85" N, 90°23'35.20" E
	AW-2	AS-2	Connecting channel	23°52'41.89" N, 90°23'12.54" E
	AW-3	AS-3	Urban area	23°52'32.11" N, 90°22'50.47" E

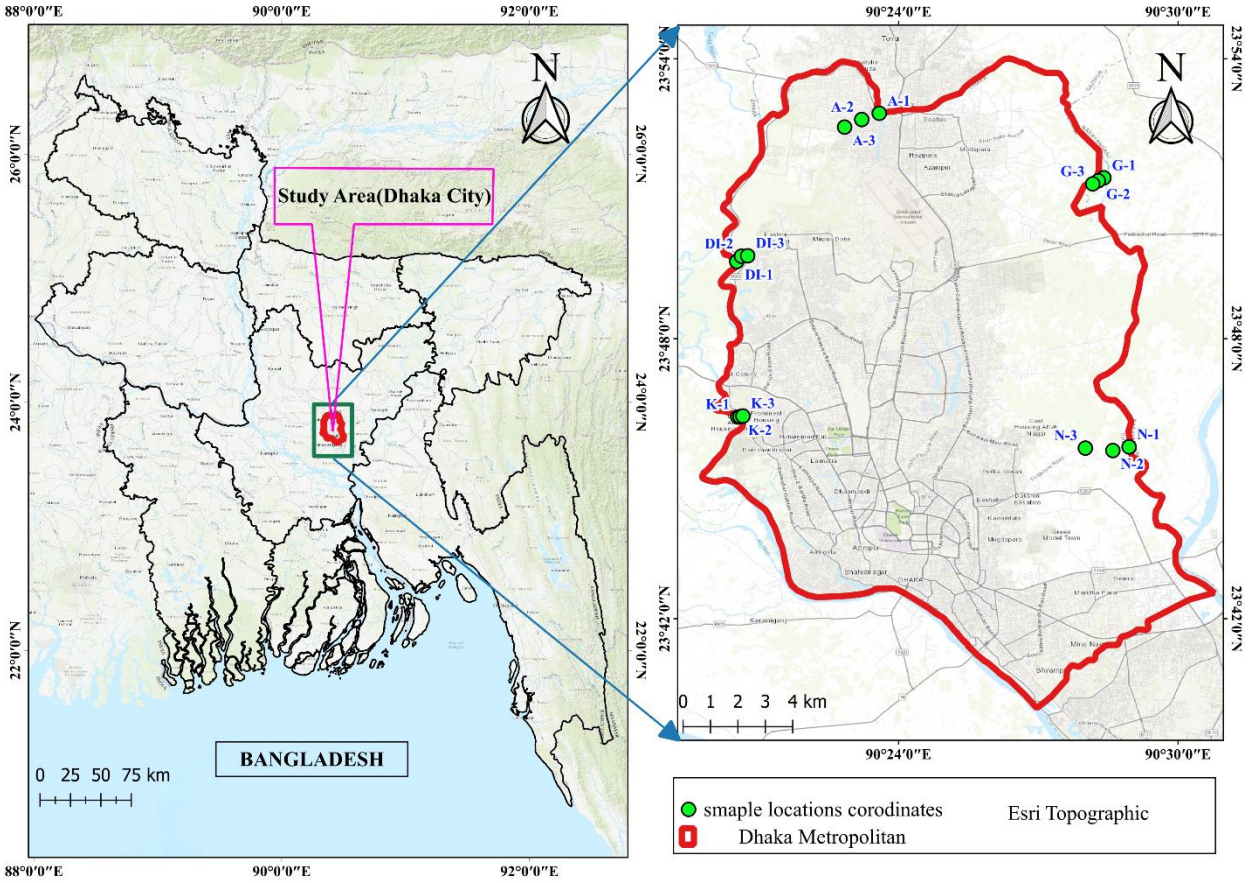


Figure 6: locations of sampling

3.2 Water and Sediment Sample Preparation and Extraction

The general processes were adjusted in accordance with the lab settings following the NOAA guidelines for water samples(Marine Debris Program, 2015). Instead of wet-sieving, vacuum pump filtration was carried out using filter papers to extract the suspended particles in the water samples. After this process, the filter papers were dried out under room temperature for 2-3 days to eliminate the moisture content present in those samples. Although the use of heat oven would have been faster, some microplastics show a tendency to melt below 60 °C(Munno et al., 2018). The suspended particles were collected with caution to avoid further losses.

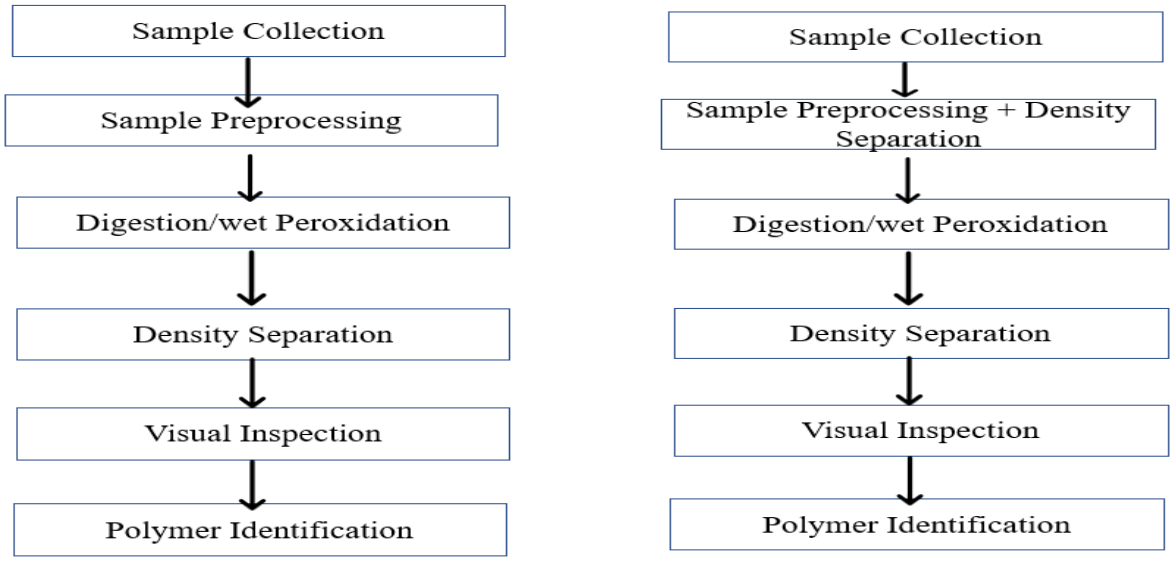


Figure 7: Flowchart of Water and Sediment Sample processing

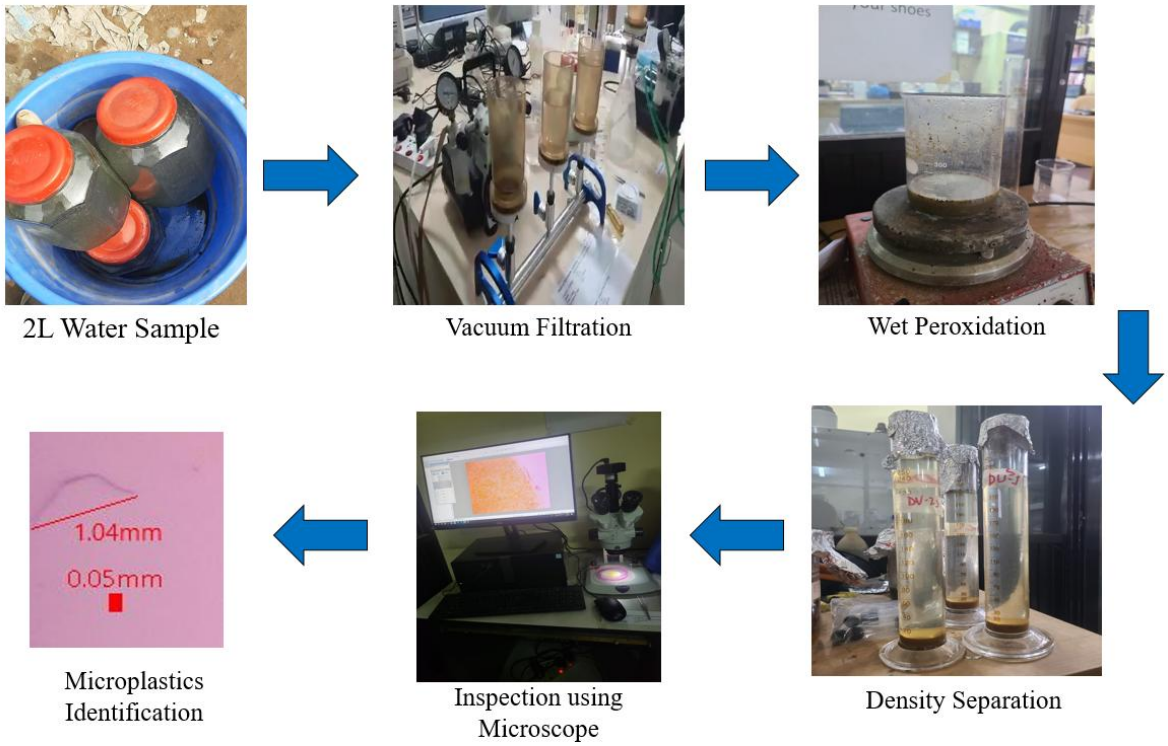


Figure 8: Water sample processing in lab

To remove the moisture content, the sediment samples were dried in an oven at 60°C for about 24 hours. The dried sediment particles were screened using 5mm sieve and those retained on 0.15mm sieve were collected for the primary density separation. 500mL $ZnCl_2$ was added to 500g of the soil sample which allowed the heavier particles to settle down and microplastics to float as supernatant along other organic particles. To avoid the contamination of nano-plastics, the floating liquid phase was filtered using a 0.01mm sieve after a 24-hour period.

For removing the organic particles collected with microplastics, the process of wet peroxidation/digestion was used to destroy the organic contents of the water sample(Zobkov et al., 2020). According to NOAA guidelines, Iron solution (Fe-II) of 0.05M was made by dissolving 7.5g $FeSO_4$ along with 3mL concentrated H_2SO_4 in 500mL distilled water(Marine Debris Program, 2015). Collected water samples were digested using 20mL Fe-II solution and 20mL H_2O_2. Though NOAA guidelines dictate the applied peroxidation temperature to be 75°C(Marine Debris Program, 2015), for reducing losses of microplastics through melting or dissolving, the temperature was kept below 60°C(Munno et al., 2018). As soon as the reaction turned violent, the heat-resistant beaker was removed from the stove till it returned to slower reaction rates. Following this reaction, the solution was heated for 30 minutes and in some cases, distill water was applied to slow down the reactions which had the chances of overflowing from the beaker. 20mL H_2O_2 was added after 30minutes. This step was done repeatedly until no organic matter was present.

Density separation through the usage of $ZnCl_2$ is the most efficient and cost-effective way of separating digested organic particles and microplastics(Rodrigues et al., 2020). To ensure sustainable and effective usage of $ZnCl_2$, the required amount of $ZnCl_2$ was recycled three times whereas, it can be used 5 times to maintain recovery efficiency above 95%(Rodrigues et al., 2020).

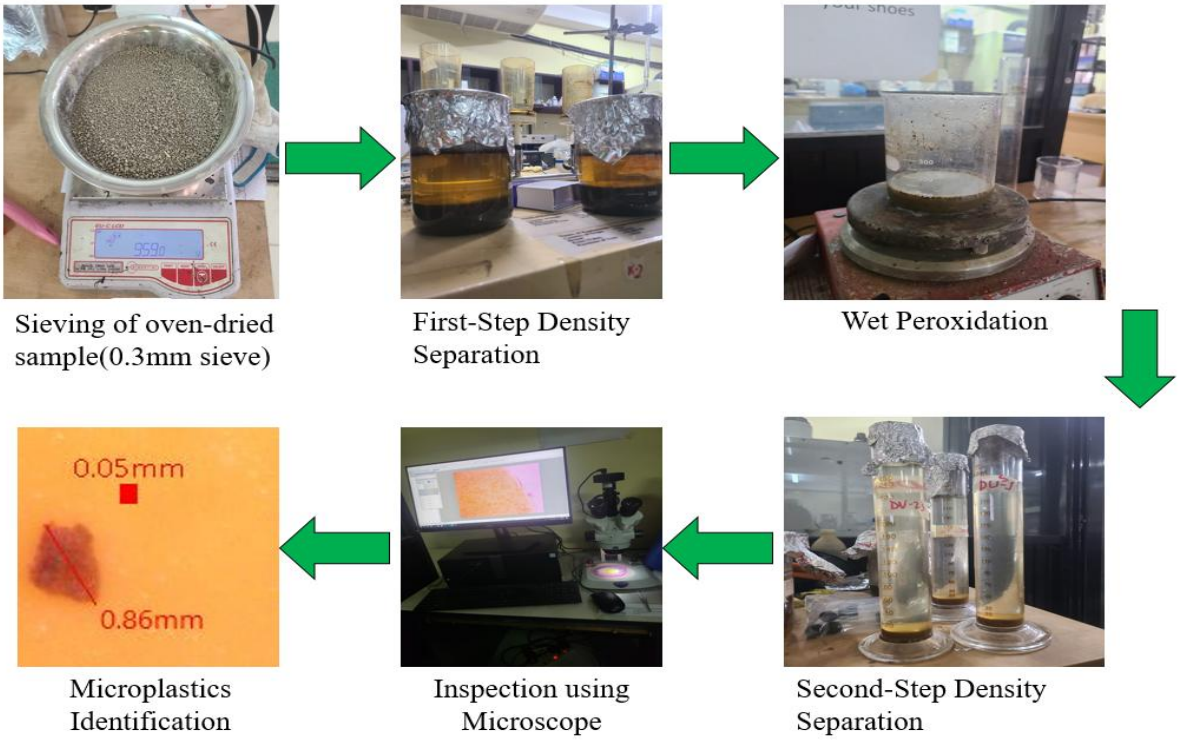


Figure 9: Sediment sample processing in lab

3.3 Identification & Quantification

Visual inspection is one of the most prominent methods of identifying and quantifying microplastics(Prata et al., 2019). To avoid mistakes in identifying and counting microplastics, standardized criteria are to be followed(Hidalgo-Ruz et al., 2012). Referring to previous studies, size, shape and color of microplastics can be determined using stereomicroscope(Zhang et al., 2020). The stereo zoom microscope SLX-3, Optika, Italy was used which had the standard magnifications from 7x to 45x. A digital camera (C-B5, Optika, Italy) was adjusted within the microscope along with the Proview digital camera software.

3.4 Quality Assurance and Control

Along with following the procedures set by Marine Debris Program, 2015, the water and sediment samples were digested at a temperature lower than 65 °C. Additionally, sediment samples underwent drying at 60°C for extended periods of up to 2 days. Non-plastic items and equipment were used to prevent external plastic contamination. The equipment were rinsed with de-ionized water before and after use.

3.5 Risk Assessments of MPs

The Pollution Load Index or PLI is linked to the abundance of microplastics(Tomlinson et al., 1980). Besides this, the polymeric risk indices will be calculated from the scores determined by (Lithner et al., 2011) in accordance with the chemical toxicity coefficient for plastics polymers. PHI or Polymeric Hazard Index identifies the ecological damage caused by the toxicity of polymers by linking the concentration and chemical composition of the polymers(P. Xu et al., 2018). The ecological risk index (ERI) can be determined multiplying PLI and PHI(Islam et al., 2023). Using toxicity response factor, concentration factor, percent composition and hazard score derived form previous studies (Lithner et al., 2011), the Potential Ecological Risk Index or PERI can be determined which assesses the single and combined polymer hazard(Guo et al., 2024; Peng et al., 2018).

Chapter 4 RESULTS AND DISCUSSION

4.1 Abundance

MPs were detected in all the peripheral canals across Dhaka city. However, there were lesser MPs in water samples than the sediment samples. This difference in number is present for other studies regarding surface water (Scherer et al., 2020). The location-wise variation of MPs depends on the urbanization(J. Li et al., 2021).

The concentration of MPs ranged between 13-185 items per liter of the water samples. The overall mean and median MPs quantities amounted to 64.067 ± 47.6257 items/liter and 49 items/liter, respectively. The Digun canal exhibited the highest concentration of MPs (Mean: 105 ± 76.74 items/liter, Median: 98) followed by Gobindapur (Mean: 70 ± 68.44 items/liter, Median: 42), Kallyanpur (Mean: 58.33 ± 9.61 items/liter, Median: 60) and Abdullahpur (Mean: 49.67 ± 23 items/liter, Median: 49). The least amount of microplastics were present in the water sample of Norail canal (Mean: 37.33 ± 26.16 items/liter, Median: 34).

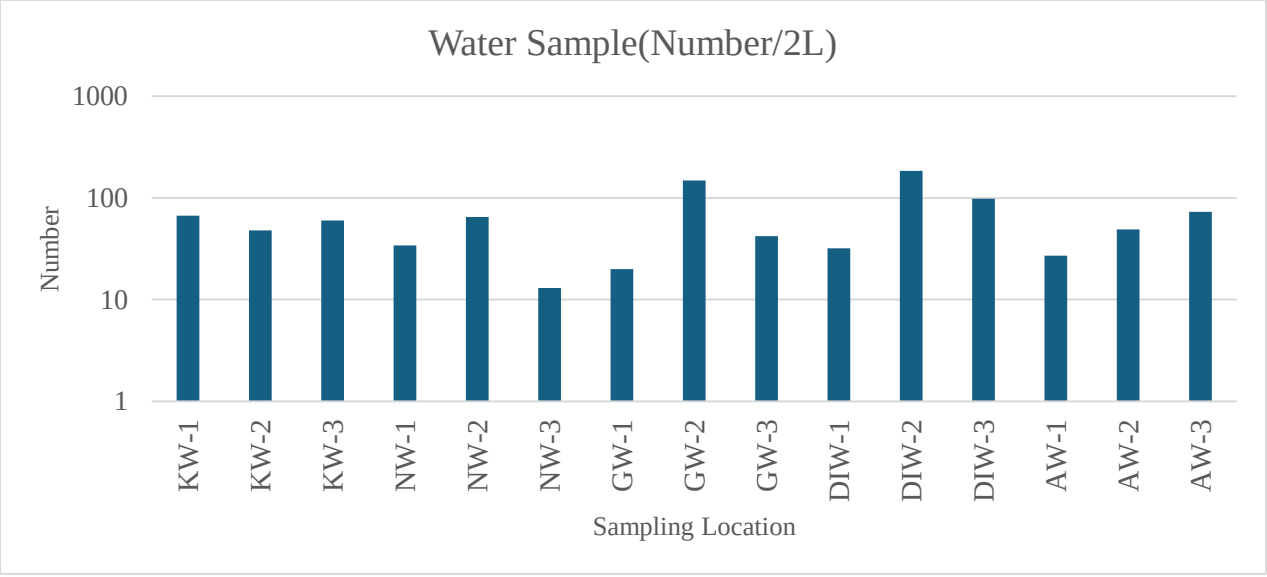


Figure 10: Concentration of MPs in water samples per Liter

The concentration of MPs in sediment samples ranged from 81-594 items per kilogram(kg). The overall mean and median quantities of MPs were 241.8±190.76 items/kg and 110 items/kg, respectively. Abdullahpur canal exhibited the highest concentration of MPs (Mean: 420 ± 272.46 items/liter, Median: 560) followed by Kallyanpur (Mean: 341 ± 214.525 items/liter, Median: 426), Digun (Mean: 225.67 ± 131.67 items/liter, Median: 241) and Abdullahpur (Mean: 49.67 ± 23 items/liter, Median: 560). The least amount of MPs were present in Norail canal (Mean: 95.67 ± 14.04 items/liter, Median: 97).

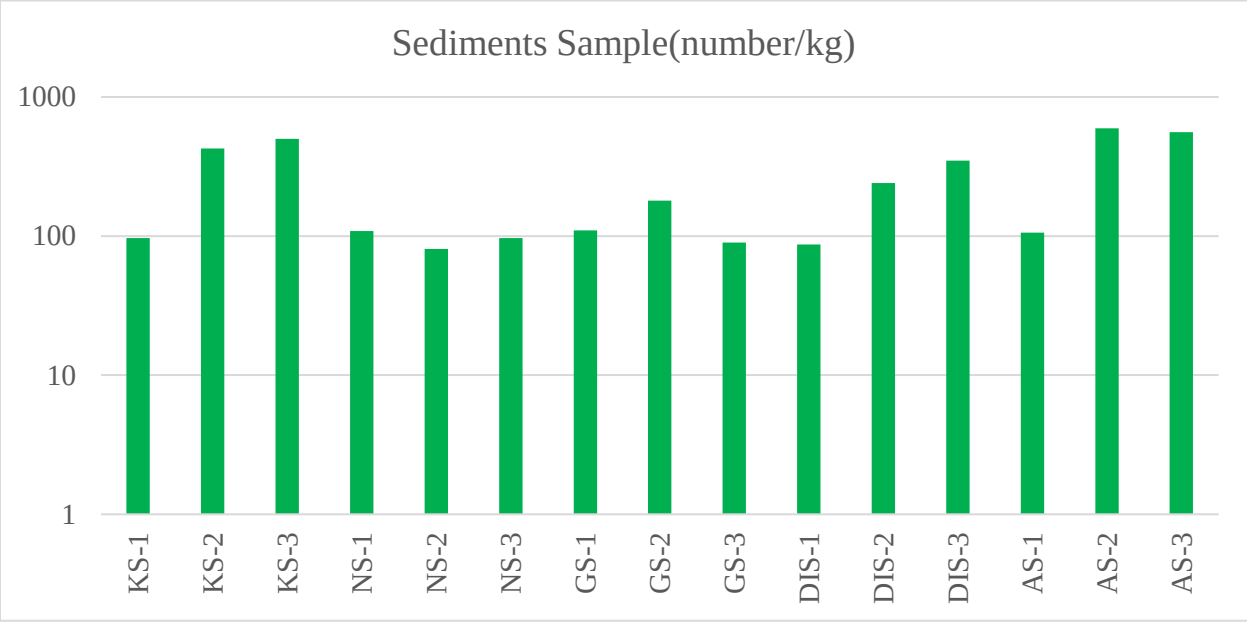


Figure 11: Concentration of MPs in sediment samples per Kg

When comparing sediment and water samples, the Norail canal exhibited the lowest concentration of microplastics, likely due to its remote and rural location, which minimizes exposure to urban and industrial waste sources. In contrast, the Digun canal, serving as a discharge point for industrial waste, recorded the highest microplastic concentration in water samples. Meanwhile, the Abdullahpur canal showed the highest microplastic abundance in sediment samples, attributed to its low flow velocity and water stagnation, which allowed more MPs to settle on the sediment

surface. These findings highlight notable spatial variations influenced by the areas' land uses and human activities.

4.2 Shapes

The shapes of MPs were categorized in 3 shapes: fiber, film and fragment. The percentage of fibers was the highest in the water samples like the previous studies (Fatema et al., 2023; Y. Li et al., 2020, 2021; L. Su et al., 2016) which accounted for 55% of the total composition. Fragments and films added up to 26.46% and 18.62% respectively. The highest percentage of fibers were present in NW1 sample.

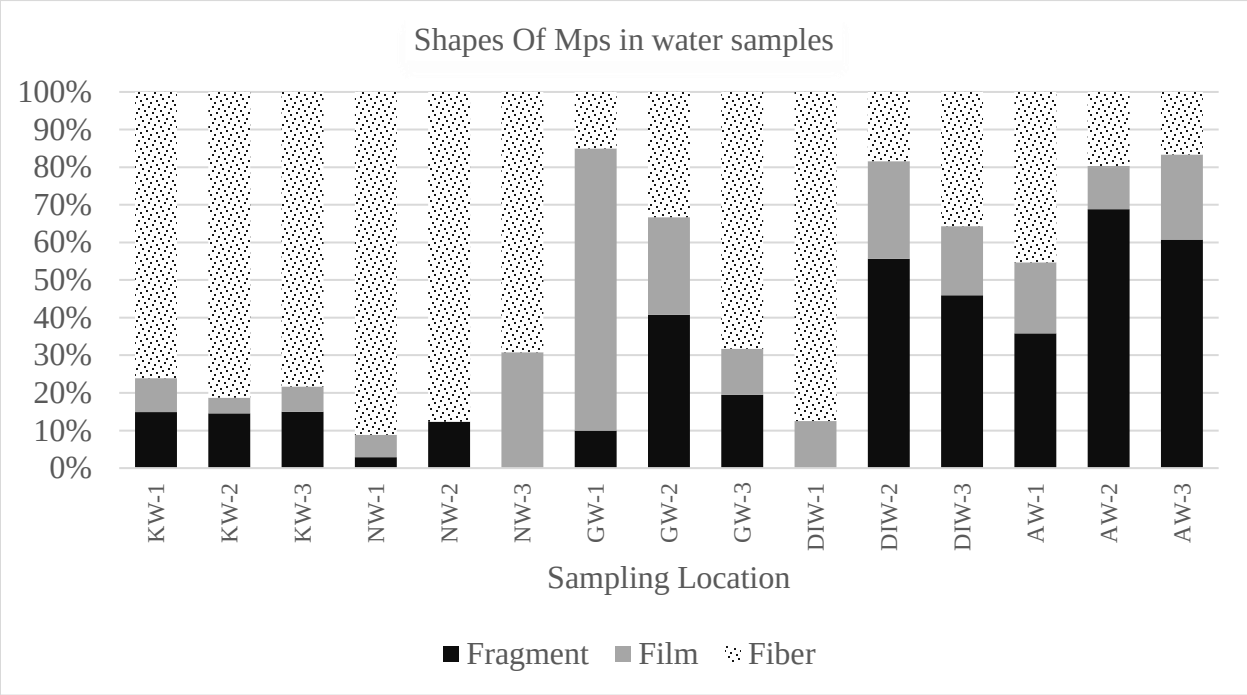


Figure 12: Percentage of Shapes of MPs in water samples

In sediment samples, film microplastics were the dominating shape being around 43.1% which is evident in previous studies(Islam et al., 2023; Niu et al., 2021; Rao et al., 2020; Q. Xu et al., 2020). Fragment and fiber microplastics comprised 33.93% and 22.99% of the total composition. The highest composition of film was present in the sample Di1S.

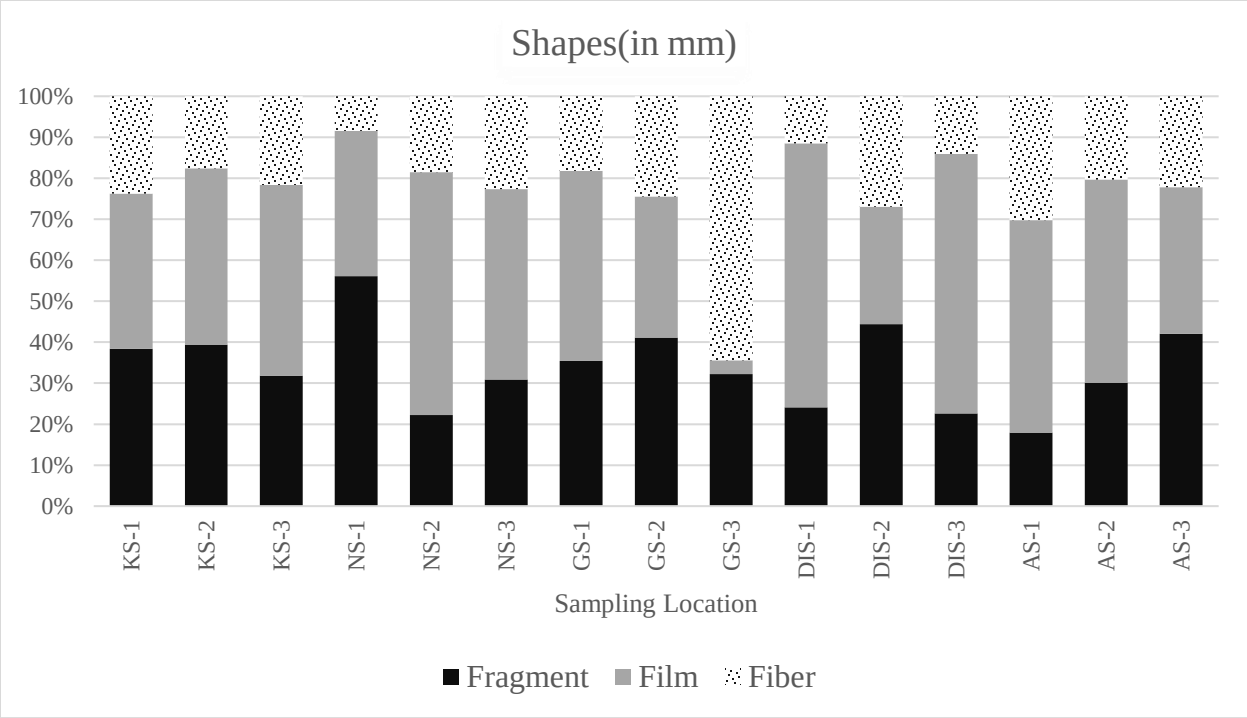


Figure 13: Percentage of Shapes of MPs in Sediment samples

4.3 Size

Both the water samples and sediment samples were contaminated with MPs of various sizes. The extracted MPs were categorized into five size ranges: 0.1–0.3 mm, 0.3–0.5 mm, 0.5–1mm, 1–2 mm, and 2–5 mm.

In the water samples, the highest proportion was found in the 0.5 – 1mm size category (29.9%) followed by 1 - 2 mm (23.3%), 0.1-0.3 mm (21.09%), 0.3 – 0.5 mm (14.18%) and 2-5mm (11.63%).

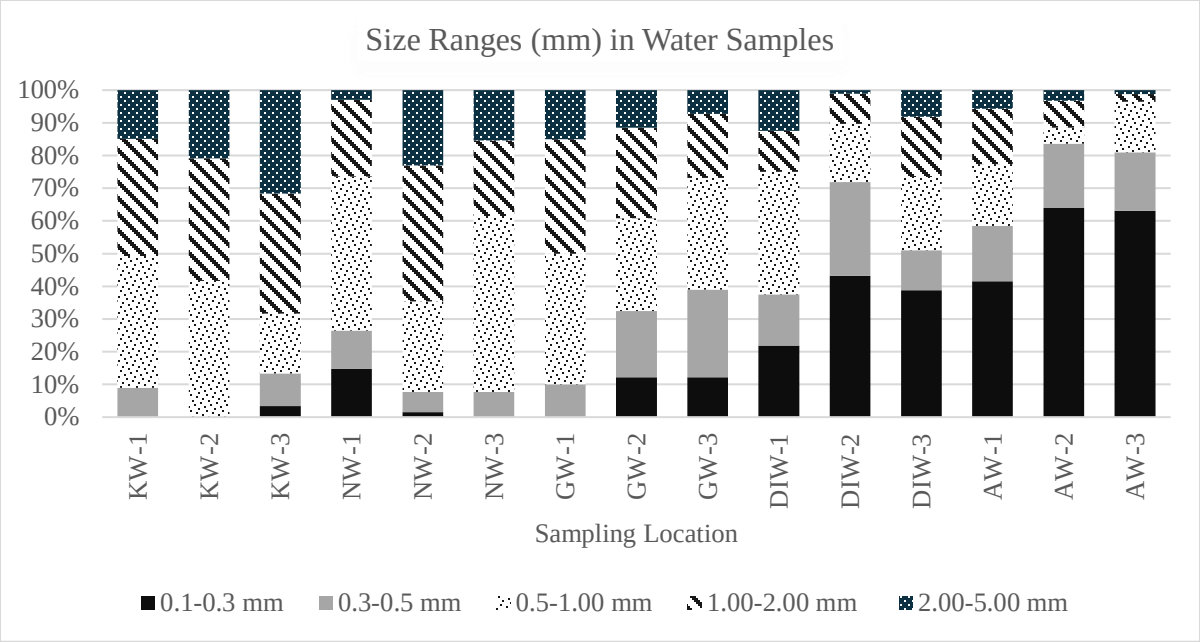


Figure 14: Percentage of Size ranges (in mm) of Water samples

In the sediment samples, the largest proportion was found in the 0.5 – 1mm size category (35.64%) followed by 1 - 2 mm (21.99%), 0.3 – 0.5mm (20.75%), 0.1-0.3mm (11.44%) and 2-5mm (10.17%).

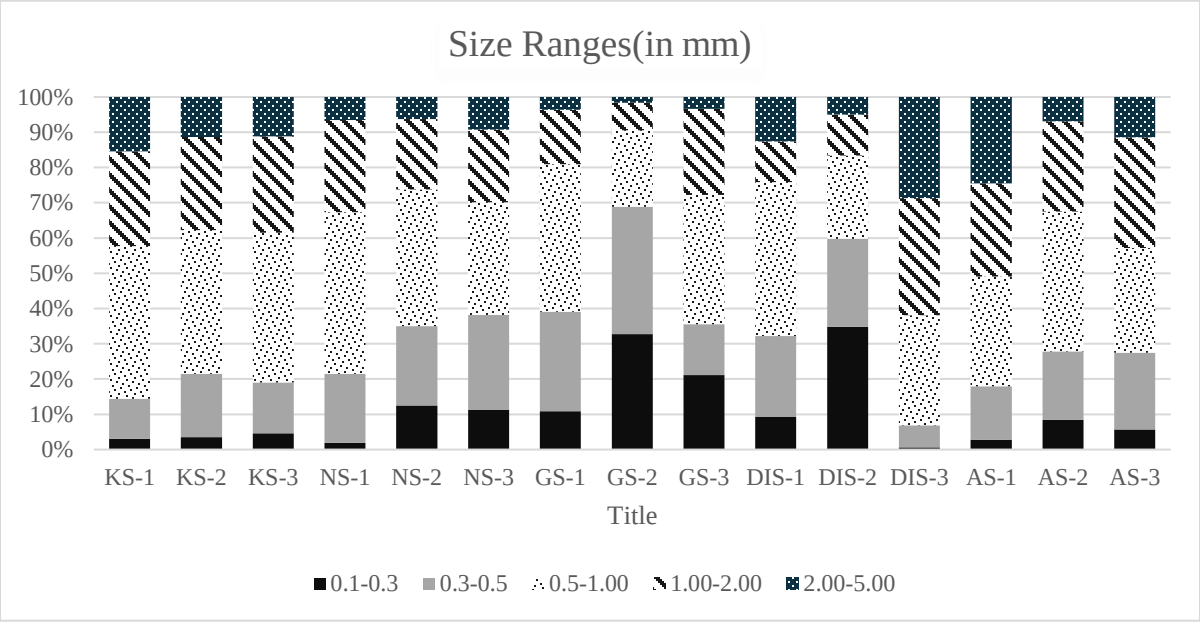


Figure 15: Percentage of Size ranges (in mm) of Sediment samples

A comparison of small microplastics (0.1–1 mm) and larger microplastics (1–5 mm) indicated that small microplastics predominated in both water and sediment samples, comprising of 65.17% and 67.84%, respectively. In natural environments, microplastics (MPs) frequently fragment due to various environmental factors, leading to a substantial increase in the abundance of small-sized MPs (Egessa et al., 2020). Gravitational forces, buoyancy, and drag forces are all influenced by the size of MPs, which play a critical role in determining their behavior in the environment (Shamskhany et al., 2021). These factors affect the dispersal of microplastics (MPs) within the water column and their accumulation in sediment. Small-sized MPs, in particular, tend to sink more quickly when subjected to biofouling (Besseling et al., 2017; Du et al., 2021).

4.4 Color

The extracted microplastics (MPs) were observed in a variety of colors. In the water sample, transparent MPs (28.54%) were the highest in percentage, followed by green(23.74%), red(19.42%), black(11.75%), white(11.51%), blue(5.04%).

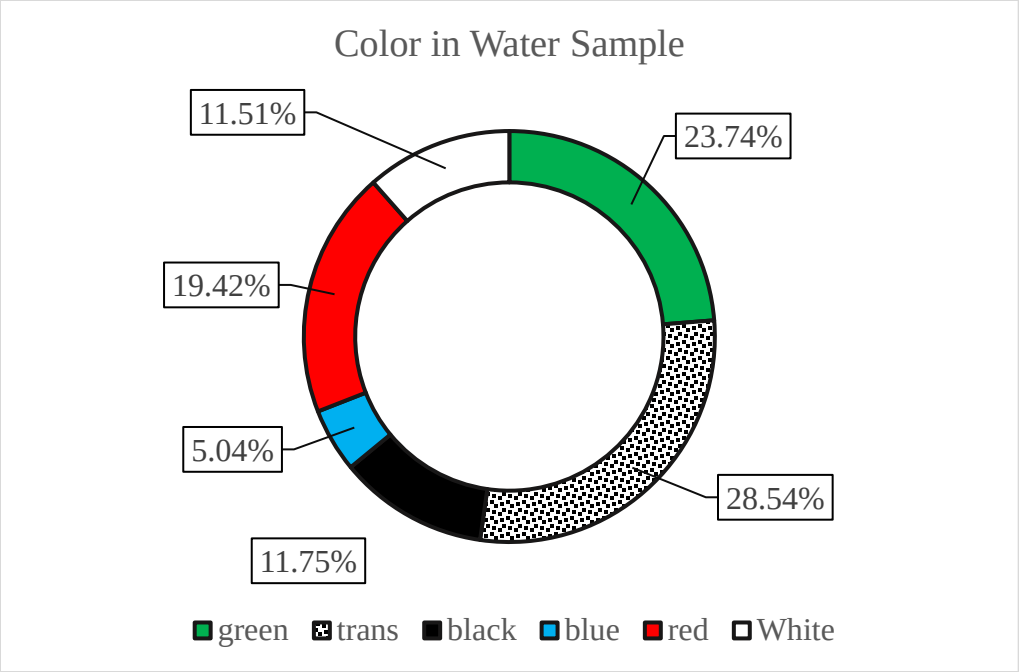


Figure 16: Percentage of Colors in MPs of Water samples

In the sediment sample, transparent MPs (28.7%) were the highest in percentage, followed by white (21.62%), red (15.99%), blue (15.99%), green (10.73%), black (6.98%).

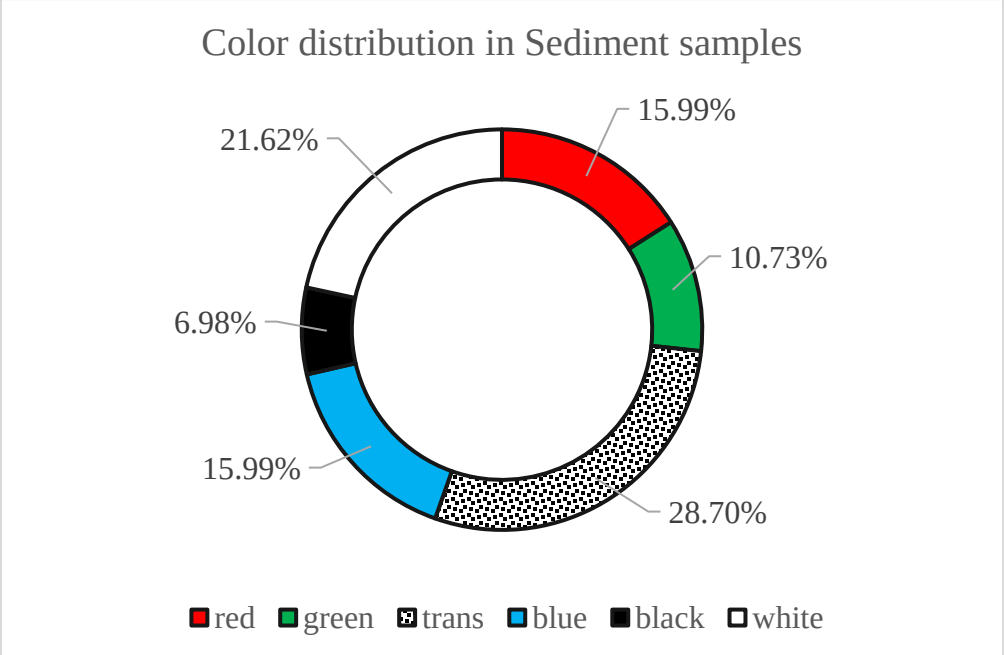


Figure 17: Percentage of Colors in MPs of Sediment samples

The color of microplastics in water and sediment samples was determined through visual observation, with transparent microplastics constituting a significant portion of all the samples which is similar to previous studies (Eamrat et al., 2022; Islam et al., 2023; Jiang et al., 2019; Y. Li et al., 2021; Wu et al., 2020). The higher proportion of transparent microplastics may result from weathering and the fading effects of light and hydraulic processes (Ren et al., 2020).

Chapter 5 CONCLUSION

5.1 Conclusion

According to the study, a number of reasons contribute to the significant abundance of microplastics (MPs) in urban canals. Commercial operations along the canal lines are a major source of MP contamination, most likely as a result of intensive human activity and inappropriate waste disposal. By adding more pollutants to the rivers, industrial development in the surrounding communities makes the problem worse. Additionally, different flow characteristics were noted: slower flow in rivers allowed for larger accumulation in some regions, whereas relatively fast flow in canals facilitated the transfer of MPs.

5.2 Limitations:

i. This study faced temporal limitations due to the necessity of waiting for a couple of months to collect samples during the dry season. Samples collected in the dry season provide more precise and reliable results compared to those collected in the wet season, as the environmental conditions during the dry season are more stable and conducive for our analysis.

ii. Owing to limited resources and time, the FTIR analysis and SEM imaging remain in progress.

5.3 Recommendations for Future Research

i. During the collection of water and sediment samples, the velocity and flow rate should be determined to calculate the loading of MPs from human habitats to the environment.
ii. Further studies regarding canals in Dhaka should be conducted.
iii. Seasonal variations in MPs abundance, concentration, and characteristics in canals water and sediments around Dhaka require investigation.
iv. Detailed studies on MPs weathering and metal contamination are recommended due to their role in ecosystem toxicity.
v. Further research is needed to assess the impacts of MPs pollution on habitats, and human health.

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