Chapter One
Introduction

1.1 Background

The word 'plastic' was initially used in the 1630s to describe a component that could be molded or sculpted. 'Plastic' derives from the Greek term '*plastikos*', which means anything that is suitable for molding. In 1909, the modern use of 'plastic' was first introduced by Leo Hendrick. Nowadays, plastic is a very common term that defines a vast collection of resources (Crawford et al., 2016).

Plastic is a broad term that refers to synthetic or semi-synthetic organic polymers that are long-lasting, adaptable, corrosion resistant, lightweight, low cost to produce, and created through the process of polymerization. Because of these properties, plastics have become a popular material for everyday use. Annual global plastic production has now reached up to 359 million tons in 2018 (Li et al., 2021a). Due to the adaptability of plastic in everyday products, it is anticipated that worldwide plastic production will double by 2025 (Lestari et al., 2021). It is one of the world's most widely utilized materials. They are strewn throughout the world and may be found in nearly every product category. Because of their low charge, many plastic objects have been apparent as disposable. Based on their classification, plastics can be classified as microplastics, nano plastics, mesoplastics, or mega plastics. Some types of plastics such as polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET) cover about 75-90% of global plastic demand (Li et al., 2016).

The term "microplastics" was introduced by Professor Richard Thompson in 2004 (Thompson, 2018). Weathering, water current, photodegradation, and biodegradation mechanisms can fragment and break down plastics in the environment (Thushari et al., 2020). Plastic particles with a diameter of less than 5 mm are known as microplastics. Wind and water currents can transport microplastics to every part of the globe.

Microplastics are frequently divided into primary microplastics and secondary microplastics based on their source. Raw materials needed for the manufacture of different types of plastic products such as virgin synthetic pellets, scrubbers, nurdles, and microbeads used in cosmetics, exfoliating cleansers, and personal care products are considered the primary microplastics. The usage of personal care products has resulted in the discharge of 306.8 tons of microplastic beads into nature (Li et al., 2021a). Secondary microplastic is mainly produced by the weathering and breakdown of synthetic compounds (meso and macro plastics), which are not managed properly or disposed of recklessly and undergo mechanical, oxidative, or biological processes (Thompson et al., 2004). For example, the shipping sector generates a lot of disposable plastic (bags and strings) due to the massive use of packaging materials (Geyer et al., 2017). Secondary microplastics are also derived from synthetic textiles that have been used daily and friction of automobile tires with the earth. The larger particles are degraded towards successively smaller plastic fragments which are eventually invisible to us (Cole et al., 2011).

1.2 Problem Statement

Karnaphuli river is one of the largest and most important water bodies in the Chattogram region. It originated in the Lushai Hills of Mizoram state situated in Northeastern India. Many industrial units are established adjacent to the bank of the Karnaphuli river such as Kalurghat, Sagarika, Anwara, and Nasirabad industrial zone (Hossain et al., 2005) including textile mills, tanneries, jute mills, fertilizer industries, pulp, and paper mills, oil refiners, soap factories, steel, and iron mills, greatly depend on Karnaphuli river for the production processes and equipment needs (Uddin et al., 2019). Industries that use the river water, discharge the wastes into the river without any treatment. The main port city of Bangladesh has a population of about 5.2 million without any modern waste treatment management system.

Microplastics in the river water affect the environment. A large amount of these pollutants is being absorbed in the food chain, which causes an imbalance in the ecosystem. Besides, serious illnesses in humans can be caused by using untreated polluted water. Microplastics are ingested by fish and consumption of these fish can cause bioaccumulation. This contamination will cost the environment and human health by resulting in cardiac arrest, diabetes, cancer, and kidney failure in the human body.

Recently there have been a lot of global movements to ban synthetic products containing microplastics. The United States enacted governmental regulations to ban microplastics. Other countries such as Canada, Australia, and the United Kingdom are also taking measures against plastic pollution. Bangladesh's government banned single-use plastic bags in 2002 but most of industries are producing plastic-wrapped products.

According to the World Bank, in the last 15 years, Bangladesh's annual per capita plastic consumption in urban areas tripled from 3 kg in 2005 to 9 kg in 2020, on top of that the COVID-19 pandemic has worsened plastic pollution with increased use of personal protective equipment (PPE). Microplastics cannot be removed from daily life activities within a few days or months. Public awareness should be created among people and taking this issue into consideration, sustainable management of plastic will be crucial for Bangladesh to tackle the increasing microplastic pollution.

1.3 Significance of the study

Due to the frequent presence in the environment, microplastics are nowadays a rising topic of concern worldwide. Over the last decade, microplastic pollution has paid attention due to the ubiquitous existence. Developing the significant management plans and protective actions at regional as well as universal aspects, scientific knowledge on spatiotemporal pattern and abundance of microplastic is crucial. Plastic pollution in the aquatic environment have become a key concern due to the excessive abundance and hostile significance to aquatic organisms and human health. Identification and quantification of plastic pollutants are required for applying the mitigation strategies and waste management activities.

The outcomes of this study provide basic criteria of microplastics that will help in further studies for mitigation and observation of plastic particles. Besides, this study provides data (size, shape, color, and type) of synthetic particles that will help to improve the ecological process and prosper in human health.

1.4 Objectives

The research goal is to determine the occurrence and distribution of microplastic in Kalurghat of Karnaphuli river. This study will also help in determining the seasonal variation of synthetic particles due to discharge of the industrial and municipal wastes. This study will also help the fisheries scientists, environmental scientists, ecologists as well as policymakers to take necessary actions to protect sea belt environment.

1.4.1 Specific objectives

- To identify and quantify several types of microplastics in the Kalurghat area of Karnaphuli river
- To determine the seasonal variation of microplastics in the study area

Chapter Two
Review of Literature

Literature review is a significant guideline for a particular topic. The previous information related to this study is essential to conduct any research. For this purpose, some previously conducted research is reviewed here. The following information has been reviewed in favor of the present study.

Over the past few years, microplastic debris has become a major problem in both freshwater and marine ecosystems. Understanding the harmful effects of microplastics on human and animals has increased recently. In early 1970s, large number of plastic pellets stimulated research interest in the North Atlantic Ocean with the impact of plastics on aquatic organisms (Carpenter et al.,1972). Since then, microplastics have detected in most of the larger waterbodies including rivers, lakes, ponds, streams even in polar regions (Auta et al., 2017).

2.1 Global microplastics distribution in the marine environment

Auta et al. (2017) showed distribution and different pathways of microplastics in marine environment that are caused by the action of wind, current, and wave through the rivers, drainage system, runoff from wastewater treatment plants. The dispersion of microplastics generally happens in surface waters, sediments and water columns of North America, Asia, Europe, and Africa (Auta et al., 2017). They also reported the negative impacts of microplastics on environment. According to Lusher (2015), plastic particles have been found in almost every habitat in the world. Microplastic fragments has been estimated to range between 0 and 11.5 particles/m^3 and 0 and 1.31 particles/m^3 on the surface and sub surface areas of South and Southwest of Svalbard, Norway, and Arctic waters respectively, where discussed the interaction of marine biota and microplastics and entrance of plastic particles into food chain and food web (Lusher, 2015).

Saliu et al. (2018) conducted research on microplastic in the Faafu Atoll, Maldives, Indian Ocean across 12 sampling stations and found that microplastics are growing threat for oceans that affects the ancient areas of Indian Ocean. They surveyed the contamination of microplastics in Faafu Atoll (Indian Ocean) over twelve sampling stations around the reef rim. They detected 0.32 $\pm$ 0.15 particles/m^3 and 22.8 $\pm$ 10.5 particles/m^2 in the surface water and beach sediment respectively.

Song et al. (2015) evaluated the abundance of microplastics in the surface microlayer in Jinhae Bay situated in the Southern coast of Korea. In this study, microplastics have divided into paint resin fragments and polymer type. The abundance of paint resin particles 94 ± 68 particles/L, and polymer particles 88 ± 68 particles/L was found. Fragmented plastics such as paint resin particles consists about 75% of total, there also spherules 14%, fibers 5.8%, polystyrene 4.6%, sheets 1.6%. Alkyd and poly(acrylate/styrene) respectively 35% and 16% were dominant generally derived from ship paint resin. The availability of microplastics was significantly higher in Jinhae Bay than along the East coast of Geoje. They also found abundance of floating microplastics in the surface water was reported the highest around the world (Song et al., 2015). In another study, Li et al. (2021) showed relative abundance of microplastic during rainy and dry seasons in a coastal area of the Pearl River Estuary (PRE) of the South China Sea and they found 1.85-fold higher abundance of microplastics in rainy season (545.5 particles/m^3) compared to the dry season (294.6 particles/m^3).

2.2 Microplastic pollution in freshwater

The overwhelming precedence of study conducted to microplastics on marine environment. In comparison, a few research provide record for availability of plastic particles in freshwater. It is significant to determine freshwater microplastic emissions to the world's ocean. In addition, study about plastics from most contaminated and larger rivers are very occasional. Even if many of the plastic polluted rivers situated in Asia, only 14% of the study performed in continent (Blettler et al., 2018).

Xiong et al. (2021) conducted a study in aquaculture ponds for fish, crayfish, and crab, along with the natural lake near the Honghu lake in China. The microplastic abundances in the aquaculture ponds were ranged from 87 items/m^3 to 750 items/m^3 and 117 items/m^3 to 533 items/m^3 in the lake, and the fragments and fibers were high in amount in ponds and lakes. They also found a positive correlation between the presence of smaller microplastics with the presence of fragments.

Another study of Earn et al. (2021) found high levels of plastic pollution in shoreline of the Great Lakes. They worked on the shape and size of a particle if there is any change in impacts with the shape and size and their finding was more affects are caused by the smaller particles.

Sruthy and Ramasamy (2017) worked on Vembanad Lake (Ramsar site) in India and collected samples from ten sites and extracted microplastics through density separation. They found microplastics from all the samples, indicating the vast distribution of microplastic in freshwater. The amount of microplastics estimated in the range of 96-496 particles/m^2 with a mean abundance of 252.80 ± 25.76 particles/m^2.

Xiong et al. (2018) detected microplastic pollution in China's largest lake – Qinghai Lake, and found small particles were largely distributed in the surface water of the lake and these small particles were accumulated due to the breakdown microplastics. They also reported film and fiber were predominant in the lake water samples.

Hu et al. (2020) conducted research to report the abundance and nature (shape and color) of microplastics in Dongting Lake and its surrounding rivers. They found fiber was most abundant in the surface water of Dongting Lake and most of the microplastics are transparent in color.

2.3 Sources and pathways of microplastics

Microplastics can be discharged into the environment in several ways, as primary microplastics can be broken down to form secondary microplastics. Some the secondary microplastic sources can be mismanaged waste from industries (litter), deliberate release (illegal dumping), or unintentional losses (e.g., ghost fishing and loss of shipping cargo) (Boucher et al., 2017), with the spread out of different sources and pathways for microplastics. Hossain et al. (2022) showed that Bay of Bengal is receiving about 61.3×10^9 microplastics particles per day. The disposal of littering and improper waste management, for instance, loss in the chain of garbage dumping, industrial messes, or discharge from landfills are major avenues for the release of waste consumption goods (Lechner and Ramler, 2015).

Ribeiro et al. (2019) worked on micro and nano plastics, and associted contaminants. They showed the accumulation of plastic fragments in different organisms including humans.

Sarker et al. (2022) aimed to identify the transfer of microplastics through the trophic level in a marine environment. They sampled individuals of different species from June 2021 to December 2021. They found marine organisms in the Sundarbans mangrove forest are contaminated with microplastics with an abundance of samples varied between 0.56 $\pm$ 0.25 items/individual. The maximum amount found in predators was 5.5$\pm$1.21 items/individual. The highest abundance of microplastics was reported in quaternary consumers (4.17 items/individual).

Model-based assessments have done by the H2020 project CLAIM (Cleaning Litter by developing and applying Innovation Methods) to enhance our knowledge of sources and pathways of microplastics (Murawski and She, 2020). They developed a 3D modelling tool on weathering process of microplastics. They performed multi years studies (2013-2018) to evaluate the accumulation zone and seasonal drift pattern.

2.4 Extraction of microplastics

Huang et al. (2022) studied the adsorption mechanisms and focused on the extraction of microplastics by developing two modified kaolin called Fe-Kaolin and Co/Mn-kaolin. The adsorption capacity was about 22.00mg/g for Co/Mn-kaolin and 13.68 mg/g for Fe-kaolin. For a low-cost and environmentally friendly removal of microplastics, this experiment was very beneficial.

Claessens et al. (2013) proposed a new strategy for the extraction of microplastics from sediment and tissue. Elutriation was done to reduce the sample's volume. Then density separation was done with high-density NaI solution. In the case of fibers and granules an increase of 23% and 39% was recorded.

Prata et al. (2019) separated microplastics from water and sediment with two steps of separation: a) reducing sample volume using nets during collection followed by sieving; b) an isolation step through filtration and density separation. Density separation with NaCl is recommended by NOAA (Masura et al., 2015) and the MSFD technical subgroup (Hanke et al., 2013).

2.5 Microplastic related works in Bangladesh

Microplastic pollution is a rising phenomenon in our country as people are not conscious of the harmful impacts of microplastics. Polyethylene, polymethyl, polypropylene, polylactic acid, and terephthalate are very much common in our waterbodies. Rahman et al. (2020) investigated the generation and distribution of microplastics in about a 36 km beach at Cox's Bazar, Bangladesh. They used Fourier-transform infrared spectroscopy to identify the plastic particles. The mean abundance they found was 8.1 ± 2.9 particles/kg. This study shows a higher amount of microplastics in places with tourists compared to places with little or no tourist activity.

In another research, Tajwar et al. (2022) performed quantification, identification, and spatial distribution of different types of microplastics in Cox's Bazar coastal regions. The most abundant microplastics were found to be fibrous. This research also reported that the highest microplastic concentration was found in the regions of Laboni point and Kolatoli in Cox's Bazar beach. They also recorded lowest abundance of microplastics in Himchori and Bardeil areas. The predominant type of microplastic was fiber followed by films, fragments, and foams. At the same time, another study surveyed the presence of microplastics in the coastal areas of Saint Martin Island. Research found microplastic pollution in beach sediment was 3166 particles/kg and the most abundant type of microplastic was a fragment in Saint Martin Island (Al Nahian et al., 2022). They also found expanded polystyrene, foam, filaments, fragments, fibers, paint flakes etc.

Another study was performed in five selected waterbodies of Dhaka city. The study was aimed at the generation and quantification of microplastics. The determination of plastic particles was done by wet sieving, followed by wet peroxidation using Hydrogen peroxide (H_2O_2) to digest organic substances. Sodium chloride (NaCl) solution was used in density separation. The five stations were reported that varied from 0.49% in Dhanmondi Lake to 9.48% in Turag River. The study also discussed the possible sources of microplastics (Shadia et al., 2020).

According to Islam et al. (2022), the abundance of microplastics in the Buriganga river was found 4.33 ± 0.58 to 43.67 ± 0.58 items/L in the sediment. They studied the occurrence and nature of microplastics in the surface water of Buriganga river. They also found fragments were predominant in the surface water and sediment with the proportion of 72.7% and 85.5%, respectively. Microplastics were found in all the samples they collected from the river. They added that recycling and molding industries were the main sources of microplastics in the surface water.

Chapter Three
Materials and Methods

3.1 Study Area

Karnaphuli river has the second largest estuary in Bangladesh. The length of Karnaphuli river is about 270 km flowing through Chattogram Hill Tracts terminating into the Bay of Bengal. Due to seasonal wind flow and rainfall, an abundance of microplastics in the Karnaphuli river changes. The Indian monsoon causes cyclical variations in the Karnaphuli river environmental characteristics (Alam et al., 2012). The research was conducted at Kalurghat in the river Karnaphuli, Chattogram (Figure 1). Samples were taken from six points. Four samples (1a, 1b, 3a, 3b) were taken from two sides of the river and another two samples (2a, 2b) were taken from the middle of the river within a 500m area of this site. GPS coordinates were taken at both beginning and ending point of the towing (Table 1)

This area was chosen as it is highly polluted by industrial pollution. This site is also used for fishing purposes by local people, which is another reason for high plastic pollution.

Table 1. GPS coordinates of the study area

Point name	Latitude	Longitude
1a	22º23'42.0" N	91º53'25.4" E
1b	22º23'16.6" N	91º53'14.3" E
2a	22º23'42.3" N	91º53'19.1" E
2b	22 º23'17.9" N	91º53'04.7" E
3a	22º23'46.8" N	91º53'14.1" E
3b	22º23'22.0" N	91º52'59.2" E

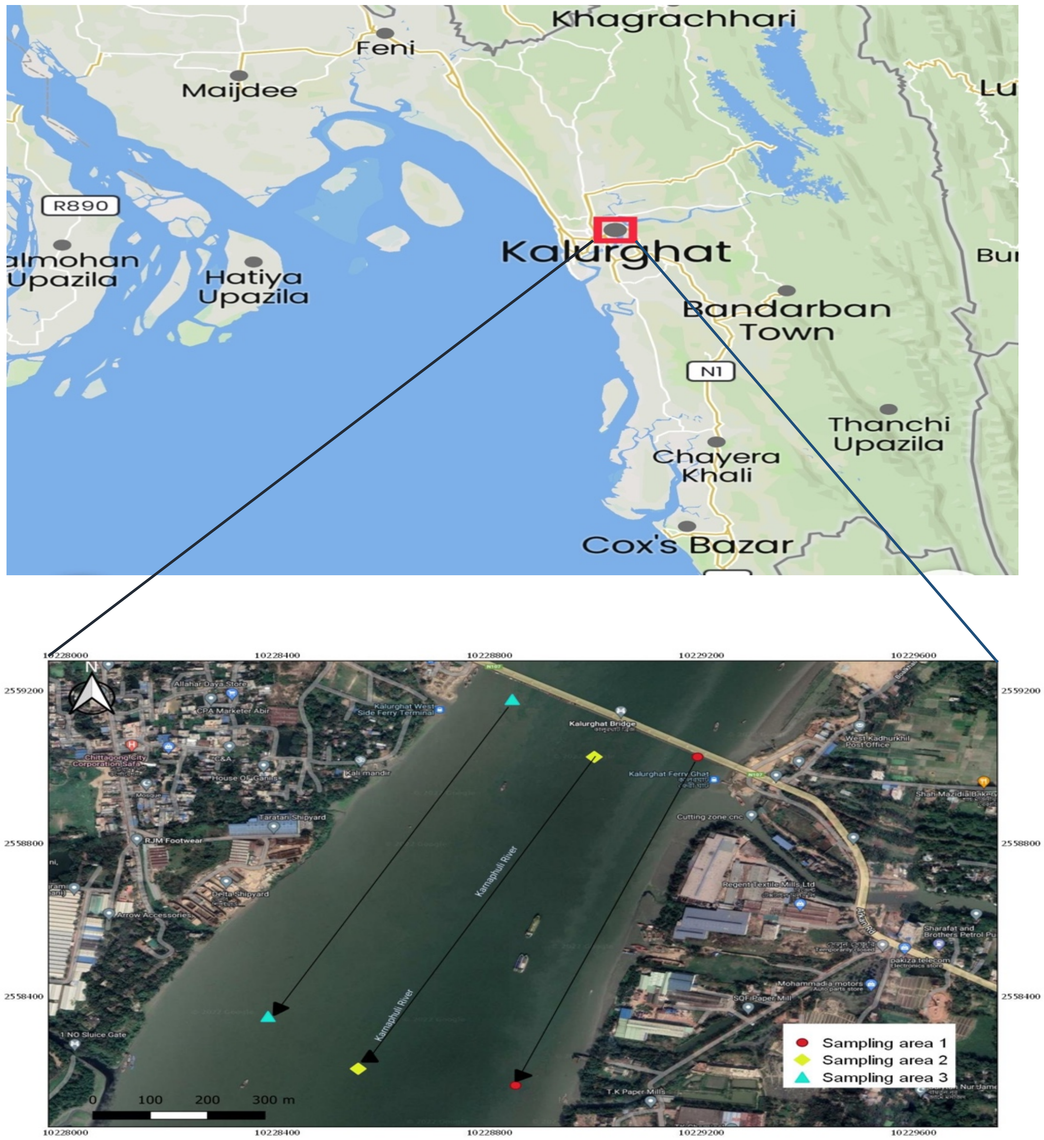

Figure 1. Map of the research area

3.2 Sample Collection

Floating microplastic samples were collected from the surface water of Kalurghat point of the Karnaphuli river from July 2021 and it was continued every month till February 2022. The 200 µm surface net with a 20×10 cm^2 collecting pot known as the Manta net was used to collect water samples. The net had a rectangular opening of 20 cm height by 20 cm width and 80 cm length. The net was towed from the side of the boat and floated on the water surface. The Manta net was towed horizontally at the surface for a 500 m area. In the end, the net was lifted and flushed with natural river water on site so that all samples entered the sample collector located at the bottom of the net. Larger size plastics and other wastes were removed from the net. The samples in the collector were transferred to a 500-ml jar and immediately the lid was closed to avoid airborne plastic contamination.

3.3 Apparatus and Materials:

- Manta net
- Collection jar
- Distilled water
- GPS coordinates

3.4 Solutions:

a. Iron (II) solution (0.05M)

b. 7.5 g of $FeSO_4.7H_2O$ was added with 500 ml of distilled water, then 3 ml of conc. sulfuric acid (H_2SO_4) was added to the solution.

c. Zinc chloride ($ZnCl_2$) solution
500 g of $ZnCl_2$ was added to 1000 ml of distilled water to make a 1.5 g/cm^3 density solution.

3.5 Laboratory Analysis

To extract and quantify microplastics, National Oceanic and Atmospheric Administration (NOAA) is one of the most popular protocols in aquatic environments (Masura et al., 2015). The laboratory procedure of the (NOAA) was followed in this study with some modifications to improve the efficiency of this method. Laboratory work was conducted immediately after completing the sampling. This step had some phases including:

- Wet sieving and drying
- Wet peroxidation
- Density separation
- Filtration
- Identification

3.5.1 Wet sieving and drying

- Samples were poured through a stacked arrangement of 5.6 mm and 0.3 mm stainless steel mesh sieves. Samples were rinsed with a spray bottle of distilled water to transfer all residual solids to the sieves. It was ensured all material had been well washed, drained, and sorted.
- Materials reserved on a 5 mm sieve were discarded and materials retained on a 0.3 mm sieve was collected in a 500 ml weighted beaker as the purpose was to conduct a study with microplastics.
- After that, all beakers were kept in a hot air oven (Binder GmbH: ED 115) at 90^{o} C for 24 hours or longer if required to dry the sample.

3.5.2 Wet peroxidation

- Wet per oxidation is the oxidation of dissolved or suspended materials in water using hydrogen peroxide (H_2O_2) as the oxidizer.
- To remove the organic material mixed in the sample, a wet peroxide oxidation process was conducted.
- 20 mL of aqueous 0.05 M Fe (II) solution was added to the beaker containing the 0.3 mm size fraction of collected solids.
- Then 20 mL of 30% hydrogen peroxide (H_2O_2) was added.
- The mixture was kept at room temperature for five minutes prior to proceeding to the next step.
- A magnetic stir bar was added to the beaker and covered with foil paper.
- Heat was applied at 75^{o} C on a hotplate (HSD 180). The beaker was removed from the hotplate when gas bubbles were observed at the surface and placed in the fume hood until boiling subsides.
- Then the beaker was given heat to 75^{o} C for an additional 30 minutes.
- If natural organic material was still visible, again 20 ml of 30% H_2O_2 was added to dissolve it. This process was done repeatedly until no natural organic material was visible.
- 6 g of salt (NaCl) per 20 ml of sample was added to increase the density of the aqueous solution (5 M NaCl).

- Again, heat was given to 75^{o} C until the salt dissolves.

3.5.3 Density separation

- Density separation is a process of separating components heavier than water from components that are lighter than water.
- The process of density separation was followed by Coppock et al. (2017) with some modifications.
- A density separator made of PVC pipe with 1-foot length and 5 cm width were used for density separation.
- Zinc chloride ($ZnCl_2$) solution was used as flotation media.
- 150 ml of filtered $ZnCl_2$ was added to each sample and then poured into the density separator and kept at room temperature for 24 hours.
- A layer of microplastics floated upwards and organic residues with inorganic matters gathered at the bottom of the density separator.
- Then the valve was carefully closed and the supernatant in the headspace was collected in beakers.
- The headspace was rinsed thoroughly with distilled water to recover any remaining particles.
- The subsided residues from the bottom of the density separator were discarded.

3.5.4 Filtration

The supernatant collected from the density separator was filtered through the vacuum pump filter machine (Rocker 300). A cellulose nitrate filter paper of 0.45 μm and 47 mm diameter was used for filtration. Then the filter paper was placed in a clean petri dish and observed under an electronic microscope (OPTIKA, B-192, Italy).

3.5.5 Identification

- Plastic particles larger than 2 mm were observed and measured with the naked eye.
- Those particles smaller than 2 mm were identified with an electronic microscope (OPTIKA, B-192, Italy).

- 40× magnification was applied for the quantification and identification of microplastics according to Masura et al. (2015).
- The images of microplastics were taken using a high-resolution camera (OPTIKA-CB3).
- Microplastics on the filter papers were identified mainly according to their morphological characteristics (such as color, surface structure, and shape) and detailed criteria described by previous studies (Viršek et al., 2016). They were divided into six categories: fragment, fiber, granule, film, pellet, and foam. Shapes and colors of the microplastics were also recorded.

3.6 Measurement of Size

The length of a microplastic is mainly the longest edge of the particle (Isobe et al., 2014). Larger particles (> 2mm) were measured with a measuring scale and particles less than 2 mm were measured by an electron microscope with Proview digital camera software.

3.7 Determination of Microplastic Abundance

By following the protocol of Viršek et al. (2016), microplastic abundance was calculated. Here, net width = 30 cm = 0.3 m, Sampling length = 500 m,

Total area = (0.3×500) m^2 = 150 m^2 = 0.00015 km^2

Microplastic abundance in per km^2 = Number of particles counted / Total area

3.8 Statistical analysis

Statistical analyses were performed by using the IBM SPSS statistics 26 software. To analyze the percentage data on the type, shape, size, and color of microplastics, Microsoft Excel was used. Microplastic abundance in different months and type variation throughout the sampling were analyzed with one-way ANOVA. Tukey multiple comparison test was used to find a significant difference at a 95% confidence interval. Microplastic type variation and total microplastic abundance variation in the rainy and dry seasons were analyzed by independent sample t test and Levene's test was used to check the equality of variance. Analyzed values were expressed as $\pm$ SE.

Chapter Four

Results

4.1 Abundance of Microplastics

4.1.1 Monthly variation of total microplastics abundance

Qualitative analysis of microplastics from Kalurghat was determined and compared among different months. One-way ANOVA analysis stated a significant difference (P<0.05) was found in July and January. Other months did not show significant difference. Highest abundance of microplastics was found in the month of July with mean abundance of 47222 $\pm$ 9229 particles per km^2 and the lowest amount of microplastics was found in January, and the mean abundance was 22963 $\pm$ 3685 particles per km^2 (Figure 2).

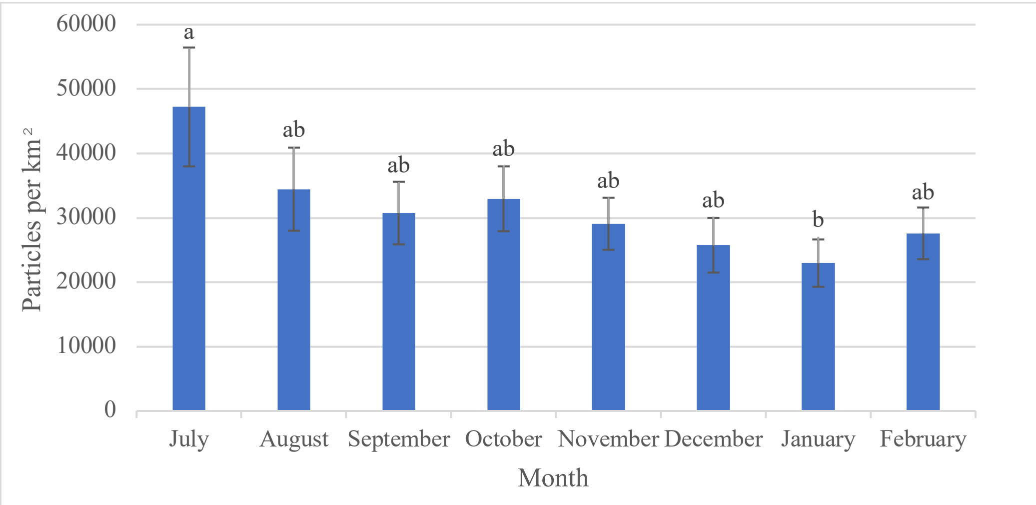

Figure 2. Monthly variation of total microplastic abundance (particles per km^2) in Kalurghat Station. Values with different letters indicate significant differences among different months.

4.1.2 Seasonal variation of total microplastic abundance

Independent sample t-test was performed between the rainy season (July to October) and the dry seasons (November to February) to assess the significant difference in abundance of microplastics. There was a significant difference between rainy and dry seasons. The presence of microplastics was comparatively higher in the rainy season (36343 $\pm$ 3323 particles per km^2) than in the dry season (26343 $\pm$ 1988 particles per km^2) (Figure 3); $P<0.001$, $t(286) = 2.582$.

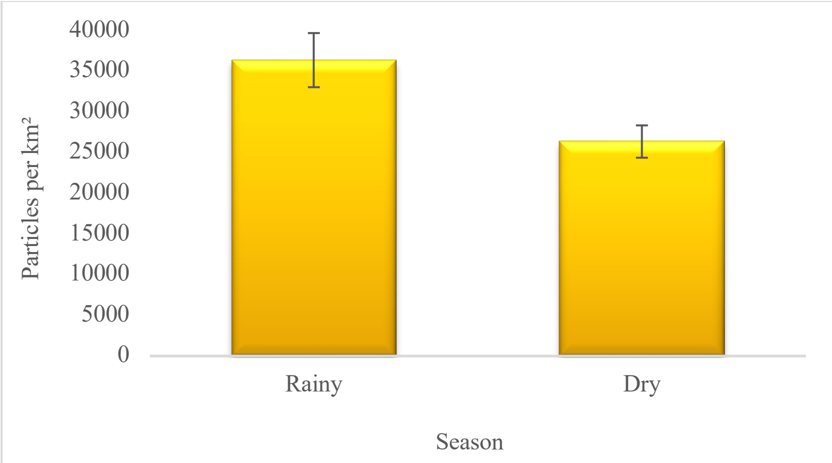

Figure 3. Seasonal variation of total microplastic abundance (particles per km^2) in Kalurghat Station. The standard error is shown in different seasons.

4.1.3 Microplastic abundance variation by type

Six different types of microplastics (fragment, filament, film, foam, pellet, and granule) were identified, and four of them showed significant differences ($P<0.05$), where filament was found significantly higher. There was no significant difference found between fragment and foam. The result also revealed that granule and pellets were significantly lower and there was no significant difference between them (Table 2).

Table 2. Abundance of different types of microplastics (filament, film, fragment, foam, granule, pellet). Values with different letters indicate significant differences ($P<0.05$) among different types of microplastics

Microplastic type	Mean abundance (particles per km^2)
Filament	67500±4729[a]
Film	47500±6471[b]
Fragment	28889±2474[c]
Foam	30278±2807[c]
Granule	7917±1234[d]
Pellet	5972±1195[d]

4.1.4 Seasonal variations of microplastic abundance by type

An Independent sample t-test was performed, and the study shows a significant difference in microplastic type between the rainy and dry seasons. The most abundant type of microplastic was filament in both rainy season (70277 ± 5075 particles per km^2) and in dry season (64722 ± 4854 particles per km^2). The lowest number of pellets was found in both rainy and dry season; t (46) = 2.32, P< 0.01.

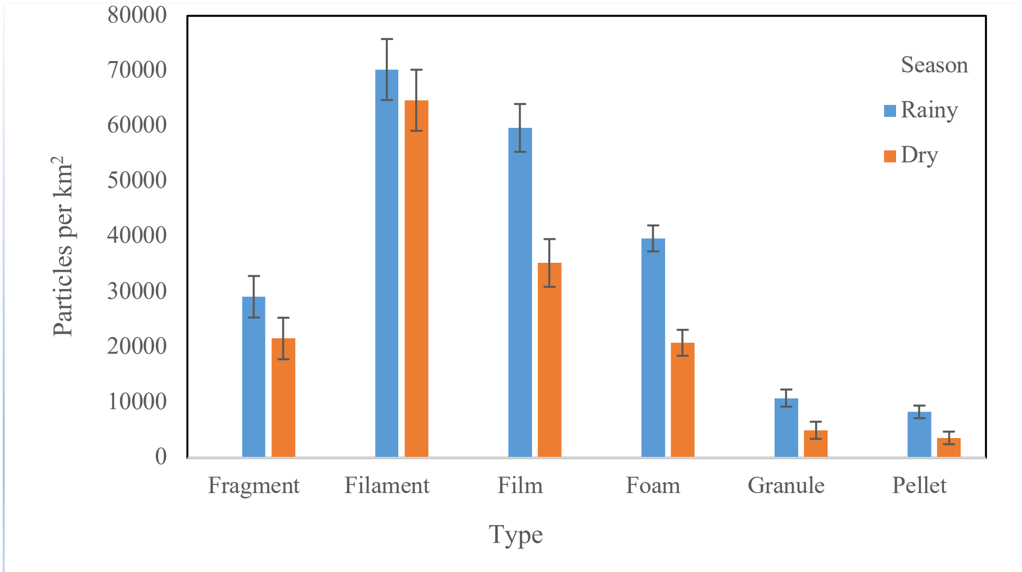

Figure 4. Microplastic abundance variations by type in two seasons. The standard error is shown among different types of microplastics in different seasons.

4.2 Characteristics of Microplastics

4.2.1 Types of Microplastics

In this investigation, six major types of microplastics were elucidated, such as fragments, filaments, film, foam, granules, and pellets. Among these types, filaments were most abundant (35.89%), followed by the film (25.26%), fragment (15.36%), foam (16.10%), granule (4.21%), and pellet (3.18%) (Figure 5). The abundance of the particle filament was comparatively higher in both rainy (32.23%) and dry (40.95%) seasons (Figure 6 and 7). The proportion of foam in rainy season was 18.22% and 13.18% in dry season. The percentage of film was 27.39% in rainy season and 22.32% in dry season. Foam and film were moderate in rainy and dry seasons. Pellets were found in very minor proportion 3.82% in the rainy season and 2.28% in the dry season.

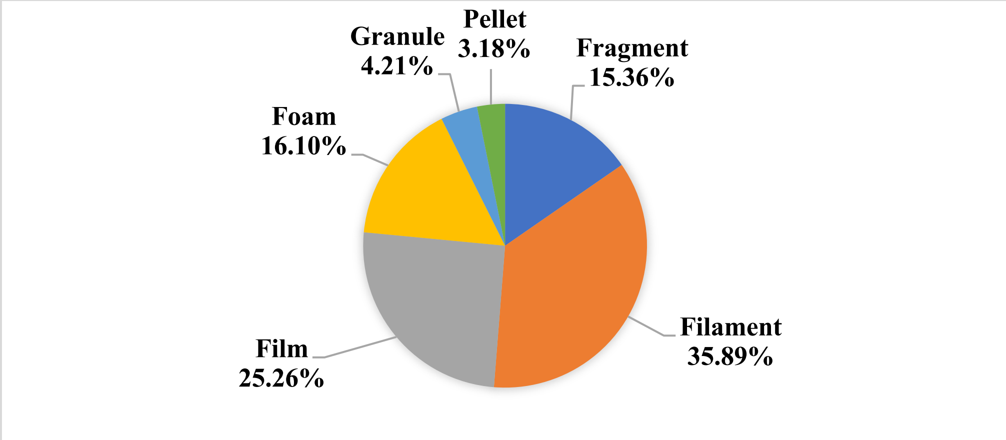

Figure 5. Percentage of microplastics according to type (total percentage)

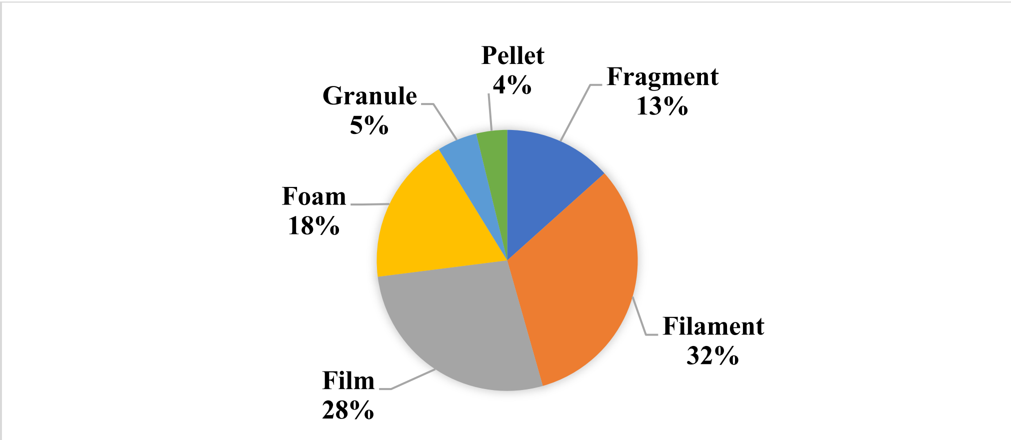

Figure 6. Percentage of 6 types of microplastics in rainy season

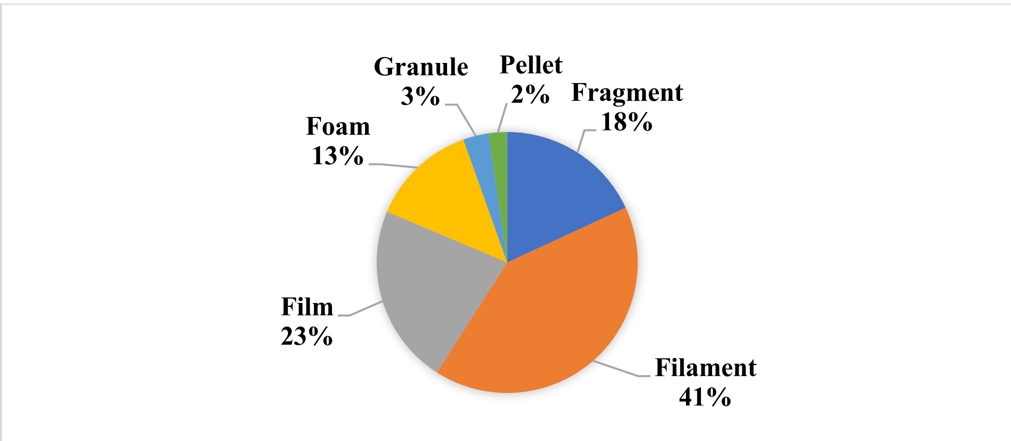

Figure 7. Percentage of 6 types of microplastics in dry season

4.2.2 Colors of Microplastics

The identified microplastics were divided into several groups of colors where brown (18%) was the most available, followed by green (15%), black (14%), red (13%), transparent (13%), white (11%), pink (6%), blue (6%), yellow (3%), orange (1%) (Figure 8). Brown color microplastics were the most abundant both in rainy (19%) (Figure 9) and dry season (17%) (Figure 10). The microplastics of orange color were least abundant during the rainy season (1%) and in dry season the percentage was 0%.

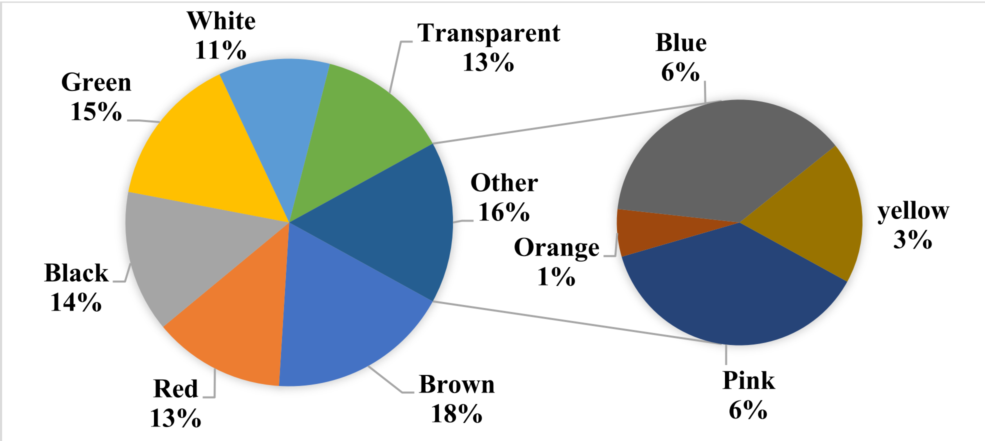

Figure 8. Overall percentage of different color microplastics

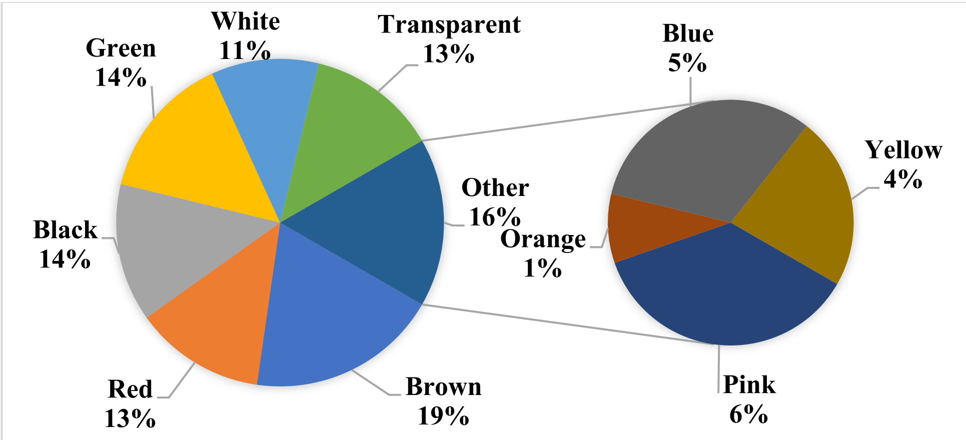

Figure 9. Percentage of different color microplastics in rainy season

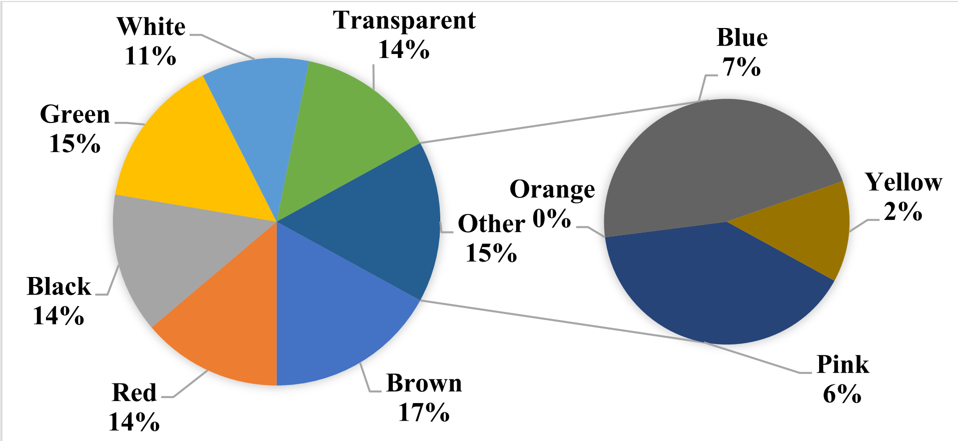

Figure 10. Percentage of different color microplastics in dry season

4.2.3 Shapes of Microplastics

The identified microplastics were round, elongated, rectangular, cylindrical, angular, and irregular in shape. The most abundant type was elongated which was about 39.64% on average (Figure 11). The presence of elongated shapes was 37.30% in the rainy season (Figure 12) and 42.71% in the dry season (Figure 13). The abundance of irregular and round shaped particles was almost similar in the rainy season (20.63% and 20.63%), and in the dry season (18.75% and 17.71%). The least prevalent shape was cylindrical, and the abundance was 3.13% in both seasons.

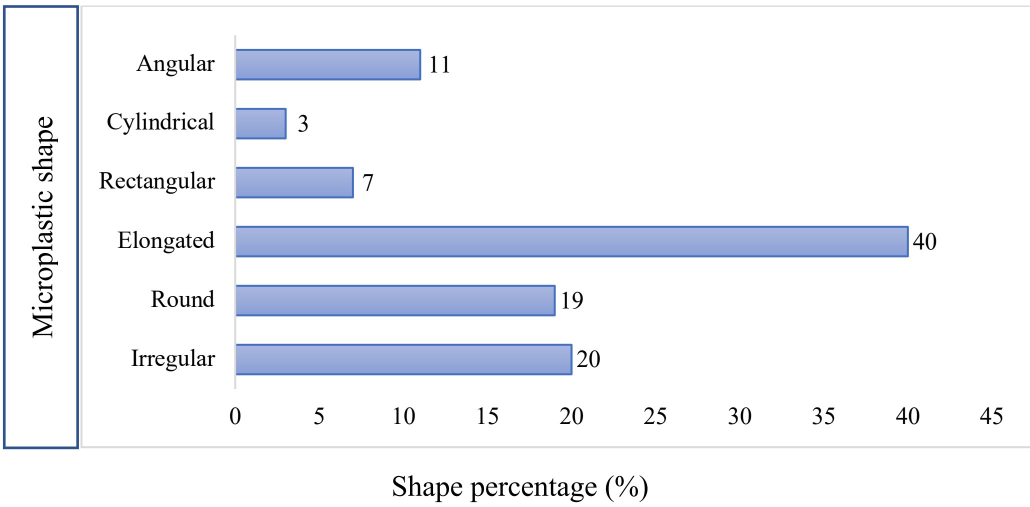

Figure 11. Percentage of different shape microplastics (total percentage)

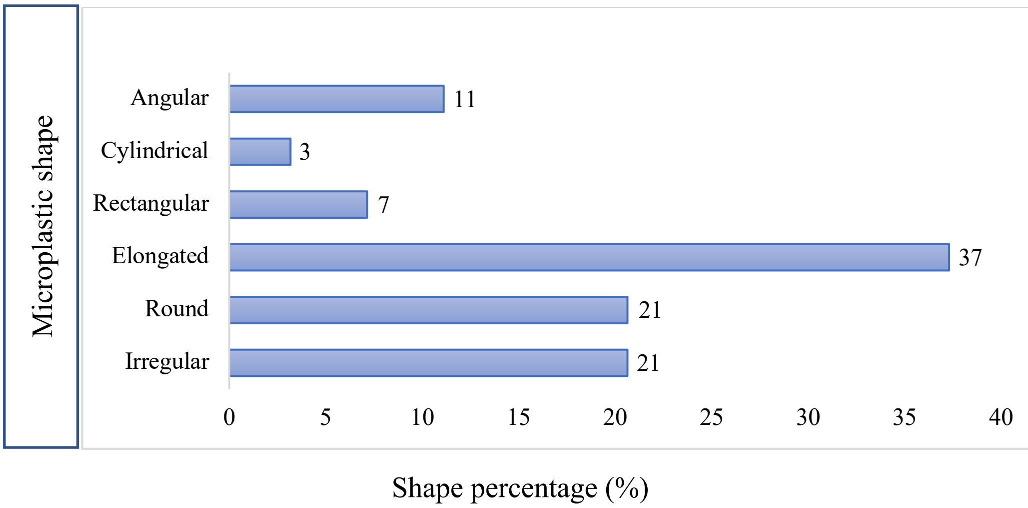

Figure 12. Percentage of different shape microplastics in rainy season

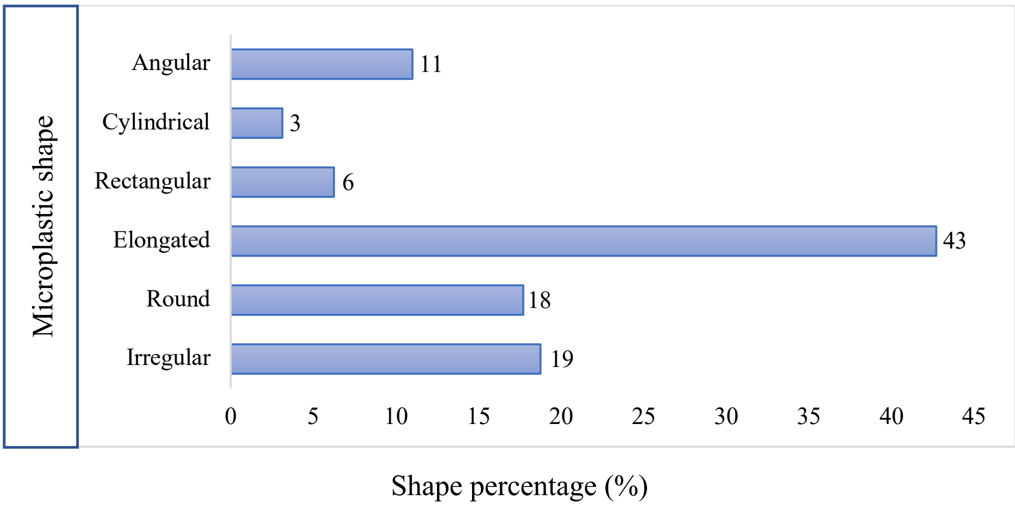

Figure 13. Percentage of different shape microplastics in dry season

4.2.4 Sizes of Microplastics

The observed microplastics were classified into 5 distinct size classes such as 300 µm to < 500 µm, 500 µm to < 1mm, 1 mm to < 2 mm, 2 mm to < 3 mm, 3 mm to < 5 mm. The major proportion of particles was found in the range of 500 µm to <1 mm with 31.58%, followed by 1 mm to < 2 mm (23.68%), 300 µm to < 500 µm (21.93%), 3 mm to < 5 mm (11.4%) and 2 mm to < 3 mm (11.4%) (Figure 14). The presence of particles belonging to the class 500 µm to < 1 mm was highest both in the rainy season (33.33%) (Figure 15) and dry season (29.17%) (Figure 16).

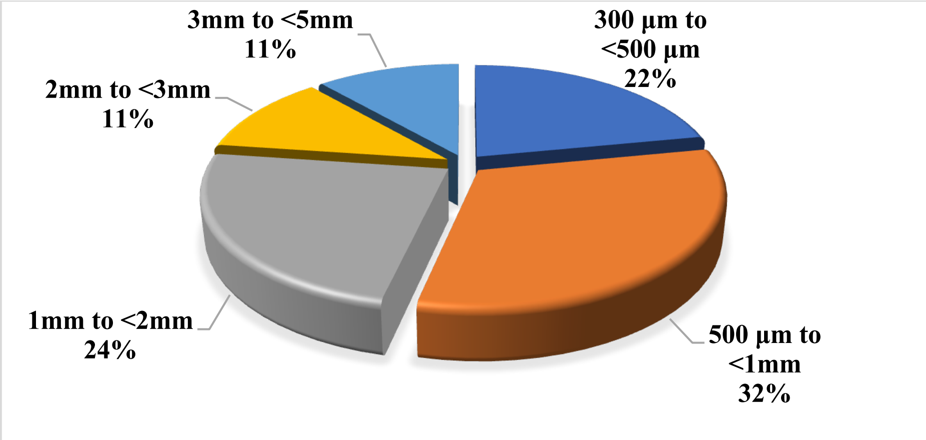

Figure 14. Percentage of different size microplastics (total percentage)

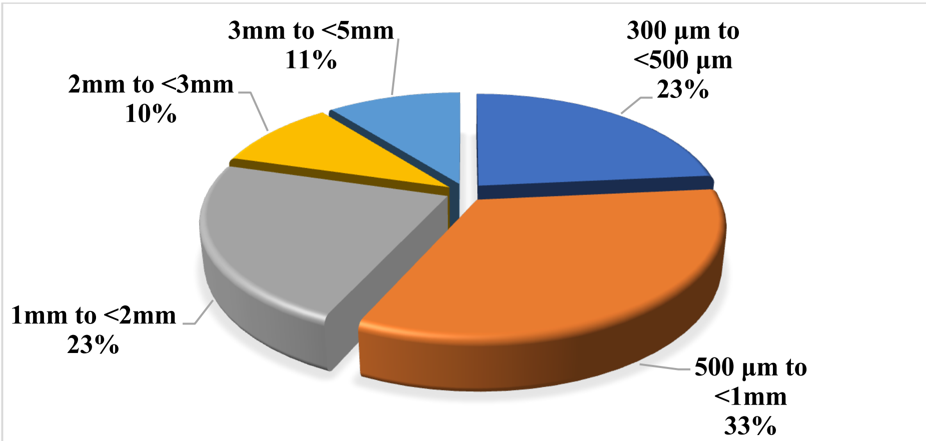

Figure 15. Percentage of different size microplastics in rainy season

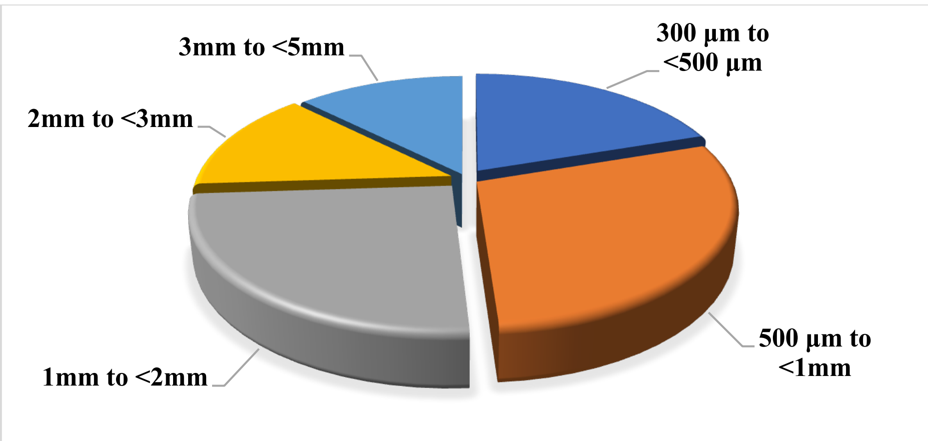

Figure 16. Percentage of different size microplastics in dry season

Chapter Five
Discussion

Karnaphuli river system is one of the most important estuaries in the Chattogram division beside the Bay of Bengal. This river system is considered the lifeline of our economic wheel. Report says, about 4000 ships and 10000 registered and unregistered vessels regularly ply this system (Rakib et al., 2022). Besides, including fertilizer industries, shipbreaking industries, and oil refineries there are more than 1000 small- and large-scale industries situated in the surrounding area (Rakib et al., 2022). During dredging, Chattogram Port Authority had found a layer of 2-7m polythene recently.

The successive monitoring carried out for 8 months resulted in the monthly comparison of microplastic distribution. During the month of July 2021, concentration of microplastics was the highest (47222 particles per km^2) over the eight months. July is the month with the most rainfall in Chattogram with 414mm of precipitation (rain falls for 30.1 days). This kind of heavy rainfall can cause excessive runoff that is connected to the highest level of plastic pollution found in the month of July 2021. Similarly, during the month of January, the least abundance of microplastic particles is found (22963 particles per km^2) as January is the month with the least rainfall. In January, the precipitation is only 5mm only and rain falls for 1.8 days.

The collection, identification, and classification of microplastics was performed over eight month of period and compared among different water bodies. In this study, the occurrence of microplastic in the surface water of Karnaphuli river was 22963-47222 particles/km^2, with the highest abundance in the month of July (47222 particles per km^2) and lowest abundance in the month of January (22963 particles per km^2). This study found a higher abundance compared to Lake Victoria Sites in the vicinity of river inflows ranging from 2834 to 20840 particles per km^2 (Egessa et al., 2020). Another study in the Persian Gulf showed microplastic density ranging from 1.5×10^3 to 4.6×10^4 particles per km^2 with a mean density of 1.8×10^4 particles per km^2 (Kor & Mehdinia, 2020), which shows lower abundance of microplastics compared to Kalurghat of Karnaphuli river. Besides, comparing with the Yangtze River, this study shows lower abundance of microplastics.

According to (Xiong et al., 2019), the abundance of microplastics in the Yangtze River ranges from 1.95×10^5 particles per km^2 to 9×10^5 particles per km^2. Variation is found because of geography, environmental issues, human activities, hydrology, and meteorological circumstances.

Particularly, rivers are the major pathways of plastic pollution due to human activities (Guerranti et al., 2017). In this work, freshwater microplastic samples were collected from the Kalurghat station of Karnaphuli River in Chattogram. The most abundant type of microplastic was filament, followed by film, fragment, foam, granule, and pellet. The filament is mainly a secondary microplastic that is formed by the physical, chemical, and biological degradation of macroplastics such as synthetic textiles and plastic waste (Laskar and Kumar, 2019). The highest abundance of filament is caused due to performing fishing with nets and clothing or any type of textiles (Fiore et al., 2022).

According to Patti et al. (2020), the result found 49% of filamentous microplastics from 22 sample sites. In another study, they recorded 8 ± 2.82 particles per 100g with a majority of filament and fragments in collected samples (Bonyadi et al., 2022). Another study in the Renhuai basin of the Chishui river of China, they found filaments as the most abundant microplastic, and the proportion was 59.4% (Li et al., 2021b).

In the collected samples ten different colors of plastic particles, were observed. Results showed that brown particles were the most dominant both in the rainy and dry seasons. Other moderate particles were green (15%), black (14%), red (13%), transparent (13%), and white (11%). A major source of brown microplastics might be plastic materials such as bags, wrap or package extensively used in daily necessaries. Many of the colorful plastic particles, generally films and filaments could lose their color after throwing into the water. Aquatic organisms are more likely to swallow colorful microplastics than transparent microplastics (Yin et al., 2019). In another study, they found 26% of yellow and brown microplastics (Marti et al., 2020). Longer exposure time in nature may cause fragmentation and discoloration of plastic particles.

Most of the particles found in the samples are secondary plastics that are derived from the breakdown of synthetic debris. The reduction of the structural integrity of synthetic debris is caused by weathering and fragmentation of primary particles. In this study, we found elongated microplastics (synthetic fibers) as the most dominant shape. One of the major sources of a higher abundance of elongated fibers is the release of fiber fragments from garments and industries during washing, drying, filtration and protective clothing (Periyasamy et al., 2022). In another study in Cox's Bazar, they have found fibers as the most dominant particles comprising about 53% (Hossain et al., 2021). The emission of elongated fibers is also caused by landfilling, road marking, and other sources like fishing nets. Small-scale, commercial, and recreational fishing and vessels are directly distributing plastic particles in the water. These elongated particles (fiber fragments) can be ingested by fish and any other aquatic organisms and can hamper their metabolic activities (Ziajahromi et al., 2018). Fiber fragments can cause human exposure through the ingestion of seafood, drinking water, table salt, etc. (Galloway, 2015). Not only the plastics but also the chemicals within the plastic particles are being transferred through the food web and food chain (Tanaka et al., 2013).

In the classification of size ranges of microplastics, there were 5 size ranges in this study. Microplastics less than 1mm accounted for more than 50% of all samples. Most of the microplastics were in the range between 500 µm to 1mm (31.58%). This result was found both in the rainy and dry seasons. According to Bian et al. (2022), microplastic particles smaller than 1mm comprises more than 80% of all samples. This result is mostly consistent with previous studies such as Japan's small-scale freshwater (74.56%) (Kabir et al., 2021) and China's Yangtze River (63%) (Zhou et al., 2021).

Chapter Six

Conclusions

Microplastics are already regarded as a serious issue in aquatic ecosystems that can bring constant and undetectable problems to the environment. Although plastic pollution is considered a major hazard nowadays, experiments on microplastics are limited in Bangladesh. This study found a correlation between microplastic abundance and seasons. During the rainy season, the abundance of microplastics was higher compared to the dry season because of heavy rainfall in the rainy season. The highest concentration of microplastics has been found in the month of the highest rainfall. The proportion of filamentous particles was higher than another type of microplastics. Besides, most of the plastic particles were elongated and irregular in shape and divided into a range of sizes. As the study found smaller size microplastics in higher amount, so the chance of bioaccumulation is very high as they have been ingested by fish, plankton, mammals, and aquatic birds. Areas that are particularly close to industries, factories, and land-based pollution sources (such as Kalurghat), they are more susceptible for microplastics pollution, and because of that our aquatic species are more vulnerable to exposure. That's why the input of plastics into the ecosystem should be minimized, and more studies are required in this sector to give the overview of microplastics abundance in different locations, and their impact on aquatic life.

Chapter Seven
Recommendations

Numerous microplastics approaches can prevent the dissemination of plastic trash at the origin, despite the reality is these plastic particles are ubiquitous. Some recommendations are given below:

- Sources should be identified, and they will be maintained at the source. This can be the most effective way of mitigating the direct mixing of microplastics into the water.
- Public concern about the harmfulness of microplastics should be created.
- Many countries have taken several policies for reducing the exposure of microplastics in the environment. Developing a regulatory framework for mitigating microplastics can help in minimizing the long-term hazards caused by plastic particles.
- Eco-friendly and sustainable clothing made from natural fiber materials like cotton, hemp, silk, wool, and other organic fibers might be chosen instead of synthetic fibers.
- When a plastic product eventually degrades, secondary microplastics have generated that end up in the environment. So, it's very important to minimize the use of single-use plastics by using fabric bags, using paper instead of plastic bags, and recycling plastic water bottles.
- Heating food or water in plastic containers is harmful as this may release more microplastics. Likewise, if hot water or food is kept in plastic dishes or using a plastic spatula can cause exposure to microplastics. In this case, wooden or glassware might be great alternatives.
- Isolation and development of genetically modified plastivore bacteria.
- Reducing the consumption of shellfish such as mollusks, shrimps, crabs, and mussels would be helpful in reducing the chance of bioaccumulation of microplastics.
- Production of bioplastics from fish byproducts such as skin, scales, fins, etc.