Chapter 1

Introduction

1.1 Background study

People have benefited greatly from many conveniences that plastic has brought. However, the waste produced as a result of using plastic products causes significant environmental issues. Microplastics are a new category of environmental contaminant that are generated from primary and secondary plastics and are typically defined as plastic particles with a measurement of smaller than five millimeters (*do* Sul et al., 2013; Farrell and Nelson, 2013; Anderson et al., 2016; Avio et al., 2017). Microplastics (MPs) in the natural environment are divided into primary and secondary microplastics (Sharma and Chatterjee, 2017). Primary microplastics are small particles used in products and microbeads for personal care and health (Duis and Coors, 2016). Personal care product usage contributes to 306.8 ton of MPs entering the environment (Cheung and Fok, 2017). Secondary microplastics (MPs) are caused by deteriorating and weathering of plastic items (Geyer et al., 2017). Disposable plastic packing materials in shipping and synthetic textiles like clothing also contribute to this issue (Napper and Thompson, 2016; Hernandez et al., 2017).

Microplastics (MPs) have been discovered in many different regions, incorporating the ocean (Cozar et al., 2014), lakes (Eriksen et al., 2013; Su et al., 2016), and rivers (Wagner et al., 2014); environmental media, including drinking water and seafood (Oßmann et al., 2018; Berglund et al., 2019); and remote habitats, including the deep sea (*van* Cauwenberghe et al., 2013), ocean trenches (Jamieson et al., 2019), polar zones (Peeken et al., 2018) and distant lakes (Zhang et al., 2016). According to Panebianco et al. (2019), animals like snails have been discovered to microplastics. According to relevant researchers' risk evaluations, microplastics released from various toothpastes have certain features (Ustabasi and Baysal, 2019).

According to Thompson et al. (2004), environmental and human causes might contribute to slow breakdown of plastic materials and creation of microplastics. Over the past few decades, the worldwide manufacture of plastics has expanded due to numerous uses of plastics in a variety of industries and household goods. According to recent estimates, the yearly output of plastics worldwide amounted to about 360 million tons in 2018 (Plastic Europe, 2020). A large portion of this production is used for single-use applications, which is mostly to blame for the significant non-biodegradable solid waste formation. According to Li et al. (2016), about 80% of plastic waste in the ocean originates from land-based sources and the remainder coming from various marine activities. These synthetic solid wastes have a tendency to degrade into minute particles investigated as microplastics in the aquatic environment because of biofouling, physical and mechanical abrasion, and the effects of natural radiations (Anderson et al., 2015; Frias and Nash, 2019).

1.2 Significance of the study

Microplastics and the Patenga Sea Beach are this study's two most crucial components. It gives an indication of the level of plastic pollution in the study area which will be useful information for starting mitigation effort. The study will aid in the development of policies and guidelines to limit plastic contamination and the findings can help in future investigations about microplastics.

1.2.1 Significance of microplastics

Research (Cole et al., 2014; Li et al., 2016; Rochman, 2016; Heidbreder et al., 2019) shows that solid waste release into marine environments has negative impacts, including marine creatures' death. Humans face risks from contaminated seafood (Bergmann et al., 2015; Gray et al., 2018); while sunlight exposure may release greenhouses gases and accelerate climate change (Royer et al., 2018; Heidbreder et al., 2019). Plastics and microplastic trash are nondegradable and slow-degrading, accumulating in different habitats (Browne et al., 2011). Microplastic particle concentrations impact larval fish growth (Eurasian perch, *Perca fluviatilis*) (Lonnstedt and Eklov, 2016) and development, causing harmful effects on their intestines. Microplastic fibers cause more severe intestinal toxicity than trash and microbeads (Qiao et al., 2019). Microplastics can harm the ecological environment and creatures, as numerous studies have shown. Currently, ecological risk assessment and possible risks associated with microplastics have gained attention on a global scale (Schrank et al., 2019; Barboza et al., 2020).

1.2.2 Significance of Patenga Sea Beach

Patenga Sea Beach is located 14 kilometers south of the coastal city of Chattogram, Bangladesh. It is close to the Karnaphuli River mouth (Dey et al., 2017). The Karnaphully River Estuary is crucial to Bangladesh's economy, supporting a significant seaport (Rakib et al., 2022). Almost 800 industries are supported by the river such as tannery factories, textile mills, and fish processing plants, chemical industries, oil refineries and chemical plants (Hossain et al., 2005). Trashes from river contaminate the water of Patenga Sea. Tourists have contaminated seawater near shorelines. These visitors, mostly from lower and middle-income families, leave trash behind and dump it into the open sea without government intervention (Amin, 2019).

Thousands of discovered and undiscovered species of marine and terrestrial flora and fauna previously called it home, but the majority has already gone extinct locally as a result of pressures placed on its marine ecology by tourists (Bashar and Nandy, 2019). Because of its free accessibility and accompanying attractions such as sunrises and sunsets, seafood restaurants, and street-side Burmese markets, Patenga attracts millions of tourists (mostly locals) each year. It is the third most popular beach area in the nation after Cox's Bazar and Kuakata. Its shoreline is an inadequate assembles of beach sand and a few patches of rocks and it is guarded by the Bangladesh Navy (Bashar & Nandy, 2019).

There have been several studies on the regional and seasonal variations of microplastics undertaken in other nations, but relatively few have been found in Bangladesh. In Bangladesh's microplastic research sector, the presence of microplastics in Patenga Sea Beach is also an unexplored topic.

Therefore, there is a pressing need to have a thorough understanding of how microplastics vary in region and different seasons in the marine environment. This will help in the creation of policies aimed at reducing plastics and microplastics pollution. In this study, an attempt has made to estimate the quantity of microplastics present at Chattogram's Patenga Sea Beach.

1.3 Objectives of the study

- To identify the microplastic particles based on their type, color, shape and size.

- To assess the abundance of microplastics in the surface water of the Patenga Sea beach.

- To evaluate the seasonal and spatial variations in the amount of microplastics in the Patenga Sea Beach.

Chapter 2

Review of Literature

2.1 Microplastic in marine environment

Castro et al. (2020) examined the hydrodynamics in the distribution of plastic items in surface waters and beach sediments of the Jurujuba (Guanabara Bay, low and medium hydrodynamic) and Itaipu (marine region, high hydrodynamic) embayment, as well as locations for mussel cultivation and extraction. Eighty three percent of the trash gathered was microplastics, with sediments from beaches having a higher average content (138.41items/kg). The beach sediment samples in Jurujuba showed larger concentrations during the rainy season, but there was no change between the samples of water and beach sediment in numerous embayment during the examined times. The findings imply that the ideal part to comprehend the dynamics of the spread of plastic garbage through time is in the sediments found on beaches.

In the Rockall Trough, Northeast Atlantic Ocean, Courtene-Jones et al. (2017) quantified and characterized microplastic pollution in nearby deep water deeper than 2200 m. Deep sea water was found to have a concentration of microplastic fibers comparable to surface waters despite being thousands of miles distant, at 70.8 particles/m^3. Deep-sea microplastics were visually substantially degraded and had surfaces that were more than twice as large as pristine particles. The discovery of synthetic polymers with densities both higher and lower than seawater and numbers comparable to the upper ocean suggest to processes of vertical re-distribution. Quantification of microplastic pollution in the Rockall Trough and the initial glimpse of marine microplastics are presented in this work. To estimate the pollution amounts of microplastics, vertical mobility, and sequestration, which have the possibility to affect the greatest worldwide ecosystem; further sampling is needed throughout the deep ocean.

Li et al. (2021) used a standard manta net with a mesh size of 330 µm for sampling of surface water to document microplastics in practically various marine ecosystems, incorporating coastal regions, the open ocean, and the deep sea of the Eastern Indian Ocean (EIO) at 36 sites. That current work was the initial to collect comprehensive and comparative baseline data on MPs in that region, incorporating abundance, spatial distribution and features. Abundance of MP ranged from 0.01 to 4.53 items/m^2, with an average concentration of 0.34 ± 0.80 item/m^2. The mean MP concentration in the Bay of Bengal (BoB) was 2.04 ± 2.26 items m^2 and 0.16 ± 0.17 items/m^2. These findings highlight the distribution of MPs' considerable spatial variability. This result demonstrates that pollution of MP in the EIO is the greatest among all the world's oceans, whether in the epeiric sea or the open ocean. Because of the significant intake of land-source plastics and the presence of multiscale recirculation gyres, the BoB will develop into an MP hotspot. These findings are extremely thought-provoking thus MPs need to receive more attention from the EIO.

The first spatial and multi-annual evaluation of surface microplastics in Scotland's seas was carried out by Russell and Webster, (2021) employing a catamaran swimmer body neuston net trawl. Surface samples of sea were collected from 2014 to 2020 and tested for the presence of microplastics. Although approximately 35% of the sample sites had no microplastics, microplastics were found in the surface waters of all Scottish Marine Regions and Offshore Marine Regions. The concentrations on the surface water varied from 0 to 91,128 microplastics. The Clyde (0-77,168 microplastics/ km^2), Forth & Tay (0-83,729 microplastics/km^2), and the Solway (607-91,128 microplastics/km^2) were all shown to be potential hotspots. Nearly 50% of the microplastics that were retrieved were fragments of plastic, which indicate that microplastics in Scotland's oceans are primarily the result of extensive items breaking down. It was impossible to do a trend assessment because the data's varying regional and temporal scopes.

From July 2016 to March 2017, Tsang et al. (2020) looked at the occurrence of microplastics in the seaside environments of Deep Bay, Tolo Harbour, Tsing Yi, and Victoria Harbour in Hong Kong. Tsing Yi had the excessive concentration of MPs in surface water coastal area (17,182 particles/100 m^3). However, there were no appreciable differences in the amount of microplastics (59 to 225 plastic items/kg) in sediments from different sites. Surface waters (53.3% to 98.6%) and sediments (79.1% to 96.8%) both had a predominance of MPs less than 1 mm in size. Surface waters and sediments both included a lot of MPs, both in the form of pellets and fragments. Victoria Harbour and Tsing Yi, where the abundance of MPs was usually larger in the dry season than in the wet season for two continuous years, both showed a similar seasonal pattern of microplastic pollution.

By employing a 330 mm meshed trawling net at 11 locations in the Bohai Sea in August 2016, Zhang et al. (2017) observed the occurrence and placement of microplastics there. After processing, samples of the collected debris were examined for quantity, composition, size, shape, and color. There were 0.33 ± 0.34 particles of microplastic/m^3 on average. The ratio of polypropylene climbed while the percentages of polyethylene and polystyrene declined a plastics size shrank. The majority of the samples were made up of plastic lines, pieces, and films. Various sources of plastics, as well as transport and retention processes connected to wind and the dynamics of the rim current, all could play a role in the accumulation at particular sites.

In the South China Sea's Nansha Islands, Nie et al. (2019) investigated the microplastic that was discovered there. Fifteen water samples from the area of the Nanxun Reef were taken for that study. For surface water samples, the average microplastic content was 1733 items/m^3. Blue microbeads, which made up 76.5% of all the particles found in samples of surface water, were the most prevalent category of microplastics. Microplastics were mostly 0.5 mm in size. The findings suggested that human residential waste and fishery operations may be the main contributors of microplastic pollution in the South China Sea's Nansha Island.

A study on the locations and properties of microplastics in the Maowei Sea's aquaculture water and biota was undertaken by Zhu et al. (2019). Surface water samples from the Maowei Sea were found to contain microplastics varied from 1.2–10.1 particles/l, with the highest concentrations seen in coastal oyster nurseries (10.1 particles/l) and Qinzhou Harbor (8.8–9.5 particles/l). The abundances varied from 2.9 to 4.5 particles/l in water samples. Polyester and rayon made up the majority of the microplastic composition, which inclined to be white in color and fibrous in texture. These findings collectively indicate that the Maowei Sea has high amounts of microplastics. The discovered microplastics contamination in the region’s fishery products introduces a channel for human exposure. The biota and aquaculture water in the mariculture Bay of Maowei Sea are both heavily contaminated with microplastics.

2. 2 Microplastic in estuarine environment

Along the Mandovi-Zuari estuary system of Goa, on the west coast of India, Gupta et al. (2021) noted the large regional and seasonal variation on the quantity of MPs and their various feature. The average MPs abundance was found to be somewhat excessive in the wet season (September) (0.107 particles/m^3) and the sediment (7314 particles/kg) than in the dry season (April) (0.099 particles/m^3 in the water and 4873 particles/kg in the sediment). The estuary system accumulates more land source plastic debris during the wet season as a result of heavy rain and an excessive inflow of freshwater from rivers, which raises the average MPs density in surface water and sediment.

Li et al. (2021) analyzed of microplastics contamination in a South China Sea coastal area of the Pearl River Estuary (PRE) was completed in 2021. According to the findings, there were 1.85 times as many MPs during the rainy season (545.5 particles/m^3) than those of dry season. Offshore, MP regional distribution also varied, with the river, estuary, and sea showing the greatest variation. The river's average MP abundance was 1.17 times greater than the estuary's and 4.65 times greater than the sea environment's. Gray, white, and green MPs were prevalent, and 53.5-73.9% of them were smaller than 0.5 mm. Fibers, granules, pieces, and films were the primary types of MPs. MPs made of polyethylene made up 35.7 to 38.8% of the total. According to a PCA study, the river was a significant source of MP pollution in the coastal waters.

For the first time, Zhang et al. (2019) examined the amounts of microplastic contamination in seven minor estuaries in Shanghai. With a mean abundance of 27.84 ± 11.81 particles /l, the microplastics abundance ranged from 13.53 ± 4.6 to 44.93 ± 9.41 particles/ l. Granules were the most prevalent type among the four forms of microplastics that were identified in the samples (fiber, film, granule, and fragment). Up to 99.5% of microplastics had a diameter of less than 2 mm. The microplastics came in a range of hues, with black predominating. The two main types of microplastic components validated were polypropylene (37.5%) and polyethylene (50%). That investigation revealed serious microplastic pollution in small estuaries; hence, the linked rivers require immediate consciousness for the avoidance of microplastic pollution.

2.3 Microplastics in freshwater environment

Neuston net samples were gathered at 21 locations throughout the time of a 700 nautical mile (1300 km) excursion in July 2012 in the Laurentian Great Lakes of the United States using manta trawl and evaluated for plastic trash, according to Eriksen et al. (2013). Station 20, located downstream of two major cities, had more microplastic particles per km^2 than all other stations put together, despite the fact that the average microplastics abundance was only around 43,000 microplastic particles per km^2. Nearly 20% of particles smaller than 1 mm that were firstly recognized as microplastic by visual inspection were shown to be aluminum silicate from coal ash by Scanning Electron Microscopy (SEM) examination. Numerous microplastic particles were multicolored spheres, which resembled microbeads from commercial products and are likely to be the same size, shape, texture, and composition. These surface samples contained the highest concentrations of microplastics and coal ash, which were probably brought in by local coal-burning power plants and urban wastewater.

Sighicelli et al. (2018) compared various lakes and the shared elements that might have an impact on the presence and distribution of microplastics. Lake Maggiore, Lake Iseo, and Lake Garda are the three subalpine lakes being watched. All of the examined surfaces contained microplastics particles (less than 5 mm in size). On the basis of quantity, shape, and composition, the particles were categorized. The shape distribution revealed that pieces were most common (73.7%). All of the samples under examination have chemical compositions that clearly demonstrate the dominating presence of polyethylene (45%), polystyrene (18%), and polypropylene (15%). The results show significant relationships between the various contributions of direct and diffuse sources to the quantity of microplastics, highlighting the significance of understanding the spatial distribution dynamics of microplastics within a lake system that functions as both source and sink of plastic particles.

In Wuhan, the biggest city in central China, Wang et al. (2017) examined the amounts of microplastics in surface water of 20 urban lakes and urban reaches of the Hanjiang River and the Yangtze River. The tested waters had microplastic concentrations varying from 1660.0 ±639.1 to 8925± 1591 n/m^3, with Bei Lake having the excessive level. In comparison to the majority of the examined lakes, urban portions of the Hanjiang River and the Yangtze River were found to have relatively lower amounts of microplastics. Colored plastic was the most prevalent sort of microplastic in the rivers under study, and fiber was by far the most common structure. In terms of quantity, more than 80% of microplastics were 2 mm in size. This study offered crucial references for better comprehending the amount of microplastic in inland freshwaters.

Surface water was gathered from six sampling sites along five distinct rivers on the Tibet Plateau by Jiang et al. in 2019. With the help of a big flow sampler, samples from surface water were taken. From 483 to 967 items/m^3 of surface water contained microplastics, this was a lot. The results of this analysis revealed a significant amount of tiny, fibrous, translucent microplastics. These findings show that rivers in the Tibet Plateau have affected by microplastics, not only in advanced areas with high levels of human activity but also in isolated areas, where microplastic pollution needs more consciousness.

The Tallo River, the main river in Makassar in eastern Indonesia, was studied by Wicaksono et al. (2021) in order to establish the regional patterns, seasonal fluctuation, and MP features in the water and sediment. Neuston nets were used to gather water samples. MPs were present in the samples, with abundances in water samples varying from 0.74 ± 0.46 to 3.41 ± 0.13 items/m^3. The Tallo River's microplastic abundance increased toward the lower river segment and was higher during the dry season. The most common shapes were fragments (47.80-86.03%) and lines (12.50-47.80%), and the most common colors were blue (19.49-46.15%) and transparent (14.29-38.14%).

In surface water of the Manas River basin, China, Wang et al. (2021) looked into the features of microplastic contamination in the dry (April) and wet (July) seasons. In comparison with July (14 ± 2 items/l), April had a greater average abundance of microplastics (17 ± 4 items/l). This study is significant because it will enable the appropriate agencies to precisely calculate the quantity of microplastic contamination in various seasons. It also has practical implications for comprehension of the peculiarities of the seasonal variation in microplastics in inland freshwater ecosystems. Understanding the origins and sinks of microplastics in inland water environments is important from a practical standpoint.

By using the isolation process of wet peroxide oxidation with inclusion of zinc chloride to water samples taken in March and October 2016, at three sampling sites, Rodrigues et al. (2018) offered fresh insights into the abundances and distribution of microplastics in the Antu River, Portugal. In March, there were 5 to 8.3 mg m^{-3}, or 58 to 193 items/m^3, and in October, there were 5.8 to 51.7 mg/m^3, or 71 to 1265 items /m^3. The highest concentrations were found in the water samples from So Joo da Madeira and Aguincheira. In So Joo da Madeira, foams and fibers were the most prevalent category. This study stresses the significance of rivers as microplastic transportation routes.

2.4 Microplastic pollution in Bangladesh

According to research by Islam et al. (2022), microplastics are pervasive in both the land source and aquatic environments and are thought to pose a severe danger to the biodiversity and ecology. Being one of the most densely populated nations in the world, Bangladesh is concerned about the plastic pollution and microplastics in the fresh, estuarine and marine environments. This paper covers the developments in the study of microplastic separation and characterization, as well as the prevalence and origins of these materials in Bangladesh. The majority of the microplastics found in the country's inland and marine environments come from secondary sources, despite the fact that the government implemented the primary total ban on plastic bags back in 2002. Fibers, which were primarily obtained from textile sources, dominated the microplastics found in Bangladesh. In Bangladesh's marine and freshwater environments, the most prevalent polymers for microplastics were polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), and polyvinyl chloride (PVC). Extensive and in-depth studies are needed to close knowledge gaps and enable comprehensive risk assessments of microplastic pollution on local ecosystems and human health, in addition to the research priorities identified to better understand the eco toxicological effect and fate of microplastics. Effective management of plastic wastes and their recycling are also required to address this issue in the nation.

The investigation on the quantity, distribution, features, and risk appraisal of microplastics in the sediment of the Karnaphuli River Estuary, Bangladesh, was carried out by Rakib et al. (2022). A stereomicroscope was used to count and describe the microplastic particles after they had been removed by density separation from the sediments at 30 stations throughout the estuary. The amount of MPs in the silt taken from the estuary of the Karnaphuli River ranged from 22.29 to 59.5items/kg of dry weight. The mean abundance was excessive on the upstream and left embankment of the estuary, and films (35%), white (19%), and 1-5 mm (30.38%) were the most common shapes, colors, and sizes of MPs, respectively. This study provided fresh information on the presence of MPs in the sediments of the Karnaphuli River Estuary, setting the framework for further study, management, and regulation of microplastic contamination.

Microplastics (MPs) were examined by Siddique et al. in 2023 in 12 salt pans from Bangladesh's southeast to determine their frequency and spatial distribution. In all, 9640 MPs particles totaling between 560 and 1253.33 particles/kg were discovered in the samples that were taken. The concentration of microplastic was highest in the salt pans from South Kutubdia (1253.33 ± 128.58 particles/kg) and North Kutubdia (1026.67 ± 189.03 particles/kg), referring that sites associated to open seawater have higher MP concentrations than sites associated to the sea through channels or creeks. The size range of 300-1500µm was where the greatest percentage of MPs (88%) was found. Black (24%), transparent (17%), and yellow (15%) were the three most prevalent MPs based on color in the samples that were gathered. The two most prevalent morphologies of MPs among the six different types were fibers (43%) and foams (21%). According to this study, MPs have severely contaminated the surface saltwater off Bangladesh's southeast coast. The possibility of MPs in sea salt poses a serious risk to public health, food security, and food safety. The presence of MPs in local sea salts should therefore be continuously monitored.

Al Nahian et al. (2023) examined the form, size, color, and polymeric characterization of microplastics in surface water of the Moheshkhali Channel in Bangladesh as well as their pollution and dispersion. At 12 surface water sample locations, it has been shown that the water is highly contaminated with microplastics. At the same time, 163 particles in the surface water were seen at 12 distinct sampling locations, varying in concentration from 0 to 0.1 particles/m^3. In the Moheshkhali Channel, numerous morphologies, including films, fragments, fiber/lines, foams, and pellets (resins), were seen. This study sheds light on anthropogenic movements and baseline microplastic contamination in Bangladesh's Moheshkhali Channel, aiding in the development of effective supervision and management measures to address such environmental problems.

In Bangladesh, Rakib et al. (2021) carried out research that revealed microplastic contamination in coarse salt that had been processed for human consumption. Eight representative salt pans in the Maheshkhali Channel, which is located throughout the length of the Bay of Bengal and is the largest salt producing region in the nation, were used to gather sea salt samples. All samples contained microplastics, which had mean concentrations ranging from 78 ± 9.33 to 137 ± 21.70 particles/kg, most of which were white and ranged in size from 500 to 1000 m. Fragments (48%) were the most common kind, followed by films (22%), fibers (15%), granules (9%), and lines (9%). These findings help the MP better acknowledge and control this important human disclosure pathway and source of environmental contamination in sea salts in the future.

In the Karnaphuli River Estuary, Bangladesh, Rakib et al. (2023) investigated the spatiotemporal distribution and features of MPs. By pulling a plankton net with a mesh size of 300 m at three river inclines (upstream, midstream, and downstream), MPs abundance was measured. MPs dispersal patterns were also examined. The mean abundance of MPs in water was the higher in April (4.33 ± 2.45 items /m^3) compared to September (3.65 ± 2.54 items/m^3). The maximum abundance of MPs was found downstream (6.60 items/m^3), followed by midstream (3.15 items/m^3), and then upstream (2.22 items/m^3), in that sequence. The majority of MPs particles was white, film-shaped, and varied in size from 1 to 5 mm. To build future mitigation methods, these findings can be used to calculate MPs movement in the freshwater ecosystem of the Karnaphuli River estuary in Bangladesh.

Tajwar et al. (2022) examined the quantity and variety of microplastics (MPs) in the intertidal sediments of St. Martin's Island, Bangladesh. By using the sieving and density separation procedure, MPs were extracted from 12 samples of surficial silt that were collected along the island's coastline. The MPs were visually identified using a stereomicroscope. All samples contained microplastics, primarily white and varied in size from 0.5 to 1 mm, with mean concentrations of 20.8 items/100 g. The greater part of the MPs that were found were fibrous (1 mm), amounting about fifty percent of all the microplastics. The most common varieties were foam, films, fragments, and fibers. Compared to Dakhin Para, locations in Uttar Para have higher microplastic concentrations, which can be attributed to the expansion of unexpected industries, growing tourism, and urbanization. The marine and coastal habitats on St. Martin's Island may be threatened by microplastic pollution. To learn more about the level of microplastic contamination in Bangladesh's southeast coastline region, this paper may be a useful resource.

The possible effects of microplastic pollution in the Cox's Bazar coastal region were investigated by Tajwar et al. (2022). Quantification, type identification, and geographical distribution of the microplastics were carried out using samples that were taken from the Cox's Bazar coastal areas. Every silt examined visually and using a scanning electron microscope (SEM) for identification of restrained microplastic particles (< 5 mm). More than 70% of the microplastics were fibrous (1 mm), making up the majority of the microplastics. The Cox's Bazar beach's Laboni point (111) and Kolatoli (97) areas have the highest concentrations of microplastic. On the other hand, the areas around Himchori (6) and Bardeil (5) exhibit the least amount of microplastic, which is consistent with the expansion of urbanization centered on tourism. The results of this study can assist pinpoint potential microplastic origin that can be used to enhance the coastal environment and offer crucial information for coastal zone management in the Cox's Bazar districts.

In order to assess the prevalence, features, and potential dangers of microplastics, Nur et al. (2022) examined salt samples from five commonly eaten refined and unrefined sea salts of distinct commercial brands that came from 15 salt pans in Bangladesh. In comparison to processed salts, which had an average MP content of 157 ± 34 items/kg, unprocessed salts had an average MP content of 195 ± 56 items/kg. One-way analysis of variance (ANOVA) revealed variations in the average MP numbers in both treated and unprocessed salts that were statistically significant ($p<0.05$). Compared to other countries, the MP levels in this research were two to three times greater. In both instances, transparent, fiber-shaped MPs predominated. The majorities of MPs were smaller than 0.5 mm in size and were present in both processed (62.2%) and untreated (58.2%) salts. Consumers, the salt industry, and policy officials can use these insights to lower MPs levels during use, manufacture and policymaking.

Chapter 3

Materials and Method

3.1 Study Area

One of the most visited beaches in Bangladesh is Patenga Beach, which stretches for kilometers close to where the river Karnaphuli and the Bay of Bengal meet. A significant amount of plastic garbage pollutes coastal seas due to fishing, beach enjoyment, and coastal tourism. The GPS coordinates were recorded in the study area. The coordinates of sampling area were Abir Point (22°14′ 17″ N, 91°47′14″E), Patenga Beach (22°13′56″N, 91°47′21″E), Bay Terminal (22°14′42″N, 91°46′57″E), Char Para (22°14′29″N, 91°47′00″E).

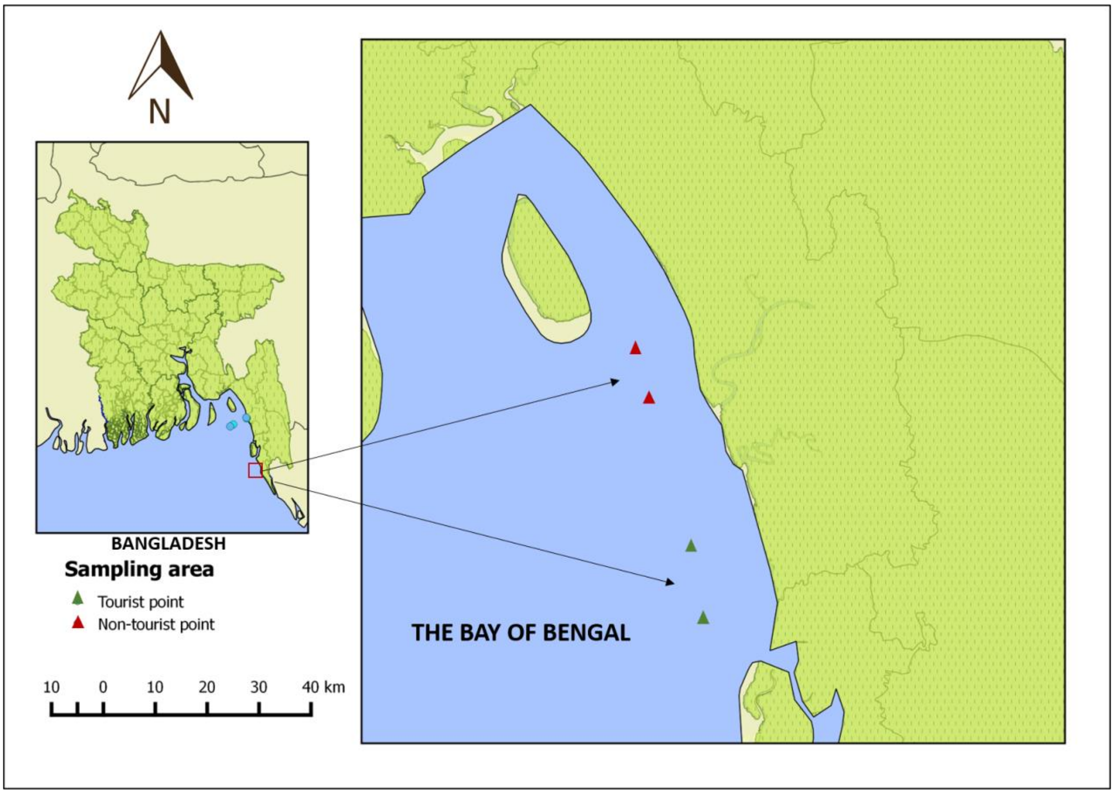

Figure -1: Map of Bangladesh and study area

3.2 Sampling technique

Seasonal sampling was done to gather floating microplastics from the Patenga Sea's surface water from January 2022 to December 2022. Four seasons, including spring, summer, rainy and winter were used to split the entire year. For sample collection, four sites with a total length of around 100m were chosen. Two sites near the crowded beach area were chosen as tourist sites such as Abir Point and Patenga Beach. Another two sites which were far away from tourist area were chosen as non-tourist sites such as Bay terminal and Char para. Two samples were obtained from each site, for a total of eight samples. Manta nets with rectangular openings 20 cm high by 30 cm wide, 80 cm long, 200 µm mesh size with a 20 ×10 cm^2 sampling pot, were used to gather samples. The net was floated on the water's surface after being towed from the margin of the boat. The flowmeter (KC Denmark A/S, DK-8600Silkborg) was mounted at the net opening to enable normalization of filtered water volume; items/m^3 was used as unit quantification for the microplastics abundance in water. Finally, distilled water was utilized to rinse the net on sampling site. The net was cleared of larger plastic bottles and other trash. To prevent airborne plastic contamination, the samples were transferred to a 500 ml jar and the top was immediately sealed. At the start and finish of the towing, GPS coordinates were taken.

3.3 Laboratory analysis

The National Oceanic and Atmospheric Administration's (NOAA) laboratory method was followed in this experiment with some modifications. Laboratory work was conducted immediately after completing the sampling. Laboratory analysis includes following steps:

- Wet sieving and drying
- Wet per oxidation
- Density separation
- Filtration
- Identification

3.3.1 Wet sieving and drying

The whole content of water sample was successively passed through 5 mm and 0.3 mm steel sieve using a wash bottle with distilled water. The particles retained on the 5 mm sieve were removed and disposed, while those on the 0.3 mm sieve were collected in a pre-weighted beaker with a capacity of 500 ml. For 24 hours, or extended if sample dryness was necessary, all beakers were heated in a hot air oven (Binder GmbH: ED115) set at 90°C.

3.3.2 Wet peroxidation

To get rid of the organic matter mixed in with the sample, a wet peroxide oxidation method was used. The 0.3 mm size fraction of the collected materials was placed in a beaker, and 20 ml of an aqueous 0.05 M Fe (II) solution was added, followed by 20 ml of 30% hydrogen peroxide (H_2O_2). Before proceeding on to the next step, the combination was kept to settle on the lab bench for five minutes at room temperature. Adding a magnetic stir bar and covering the beaker with foil paper after applying heat at 75 °C to a hotplate (HSD180). The beaker was separated from the hotplate and kept in the fume hood until the surface begins to bubble with gas. The Beaker received an extra 30 minutes of heating to 75°C. If any natural organic material persisted, it was digested with an additional 20 ml of 30% H_2O_2 and the process was repeated until all the organic matter digested. For each 20 ml of H_2O_2, 6 g of salt (NaCl) was added to increase the density of the aqueous solution. Once more, the liquid was heated to 75°C in order to dissolve the salt.

3.3.3 Density separation

With few modifications, method of Coppock et al. (2017) was followed for the density separation procedure. The following methods for density separation were used:

For this, a density separator composed of PVC pipe was employed. The device was constructed using 50 mm PVC piping and a ball valve, which were fastened to a plate that was 100 (w) x 200 (d) x 480 mm in size (h). For separating the low dense solution from the high dense solution, a ball bulb was placed in the middle of the pipe. As flotation media, zinc chloride ($ZnCl_2$) solution was employed. Each sample received 150 ml of filtered $ZnCl_2$ solution, which was then added before being placed into the density separator. The sample was kept to settle until the supernatant was free of any debris. Undissolved organic residues and inorganic substances collected in the bottom of the density separator, allowing less dense particles to be separated, while a layer of microplastics floated upward. After gently closing the valve, the headspace supernatant was gathered in beakers. The headspace was thoroughly cleansed with distilled water to remove any remaining debris. The subsided remnants from the density separator's base were thrown away. All of the density separator's parts were cleaned with distilled water both before and after each sample was taken.

3.3.4 Filtration

The density separator supernatant was filtered through cellulose nitrite filter paper with a pore size of 0.45 µm and a diameter of 47 mm. After filtering, the filter paper was put in a clean petri dish and viewed under a microscope.

3.3.5 Microplastics type, shape, color, size identification

Microplastics having a length greater than 2 mm were spotted and visually measured. Alternatively, according to Masura et al. (2015), microplastics with a length smaller than 2 mm were discovered and quantified with a stereo microscope (OPTIKA, B-192, Italy) at 40 times magnification. A digital camera (OPTIKA-CB3) that was mounted to the microscope was used to capture the photographs of the microplastics.

The microplastic criteria from Hidalgo-Ruz et al. (2012) were followed to differentiate between microplastic particles and naturally developing particles. Morphological traits like color, shape, surface texture and specific feature that have been previously studied for the purpose of identifying microplastics (Virek et al., 2016). Microplastics were categorized into six groups according to Virek et al. (2016), such as fragment, fiber, film, foam, granule, and pellet. The microplastics shapes and colors were also noted.

3.3.6 Microplastics size measurement

The length of the microplastic was defined as the side of the particle with the longest length (Isobe et al., 2014). The remaining (lower than 2 mm size) particles were measured using Proview digital camera software under an electron microscope by calibrating the stage micrometer scale, only microplastics with a length longer than 2 mm were calculated directly using a ruler scale

3.4 Determination of microplastics abundance

A flow meter was mounted to the subsurface net frame close to the mouth of the net to measure the number of revolutions and account for currents and tides. The flow meter has an accuracy of 0.3 meters per revolution, thus the trawled distance was estimated by multiplying the number of revolutions by 0.3 (XTow m). With the data of Lusher et al. (2014) items per m^3 were measured as follows:-

Items per m^3 = number of items\(XTow*ANet)

XTow= Towed distance

ANet= Net mouth width * depth

3.5 Statistical analysis

The MPs abundance in water was expressed in item/m^3. All statistical analysis was executed using the software program IBM SPSS statistics and Microsoft Excel. Total microplastics abundance variations with sites were analyzed by performing an independent sample t- test. A one way ANOVA was executed to determine the seasonal variations regarding the microplastics abundance. Microsoft Excel was used to analyze percentage data on the type, shape, size and color of microplastics. The statistical significance threshold was set at $p < 0.05$.

Chapter 4

Results

4.1 Microplastics abundance

4.1.1 Variation of microplastics abundance among different sites

Quantitative analysis of the abundance of collected microplastics in the marine environment of the Patenga Sea Beach was analyzed and compared among different sites. Present study conveyed that differences in abundance of MPs of surface water varied with sites (Figure-2). The highest abundance of microplasticss was detected at Patenga Beach (8.53 items/m^3) and lowest abundance of MPs was detected at Bay Terminal (1.83 items/m^3) (Figure-2).

An independent sample t-test was conducted to examine the frequency of variations between tourist and non-tourist area where there was a significant variation existed ($p<0.05$). A slightly higher range of MPs abundance was noticed in tourist area with a mean value 7.60 items/m^3 than non-tourist area where the mean value was 1.94 items/m^3.

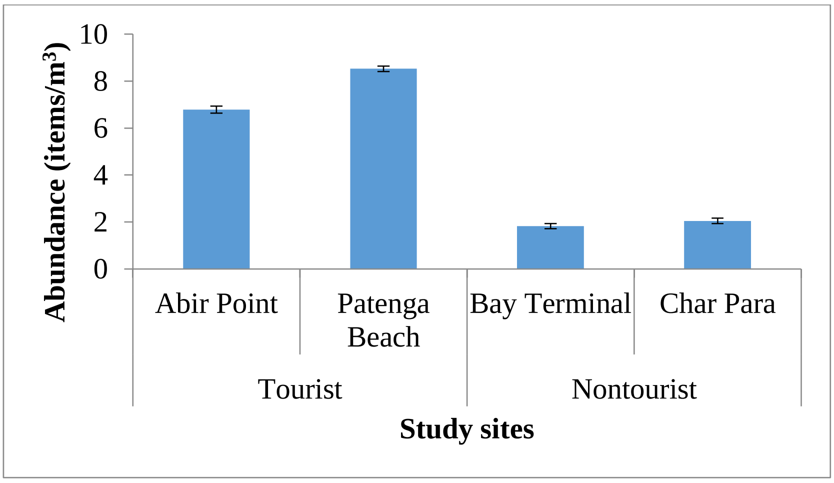

Figure -2: Abundance showing variation of MPs in surface water among different sites

4.1.2 Seasonal variation of microplastics

An analysis of the abundance of micro plastics of Patenga Sea Beach was determined and seasonal variations between sites were compared. This result showed that MPs abundance was higher in spring, summer and rainy seasons of tourist sites compared with non-tourist sites. On the contrary, MPs abundance was higher in winter season of non-tourist site (Figure-3). The abundance of tourist sites varied with seasons (1.23 to 8.05 items/m^3) where spring season (8.05 items/m^3) had the highest abundance and winter season (1.23 items/m^3) had lowest abundance. The abundance of non-tourist sites also varied with season (1.54 to 3.27 items/m^3) where spring (3.27 items/m^3) had highest abundance and summer (1.54 items/m^3) had the lowest abundance (Figure-3).

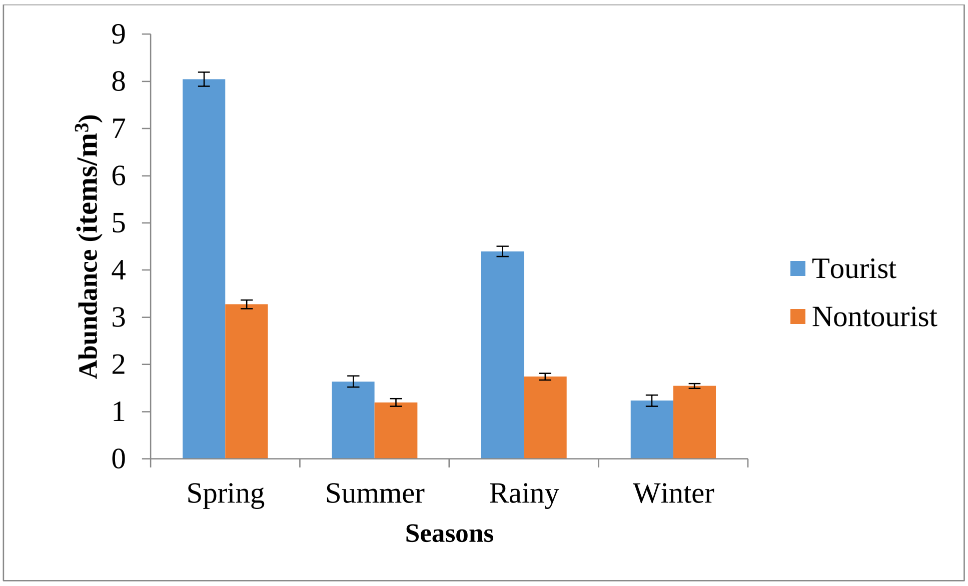

Figure-3: Seasonal variation between sites

The mean variance of MPs abundance among the seasons was determined using a one way ANOVA test. There was a considerable variations noticed among the season regarding the MPs abundance. The abundance of MPs peaked in the spring and greatly differed from the winter and summer season (Figure-4).

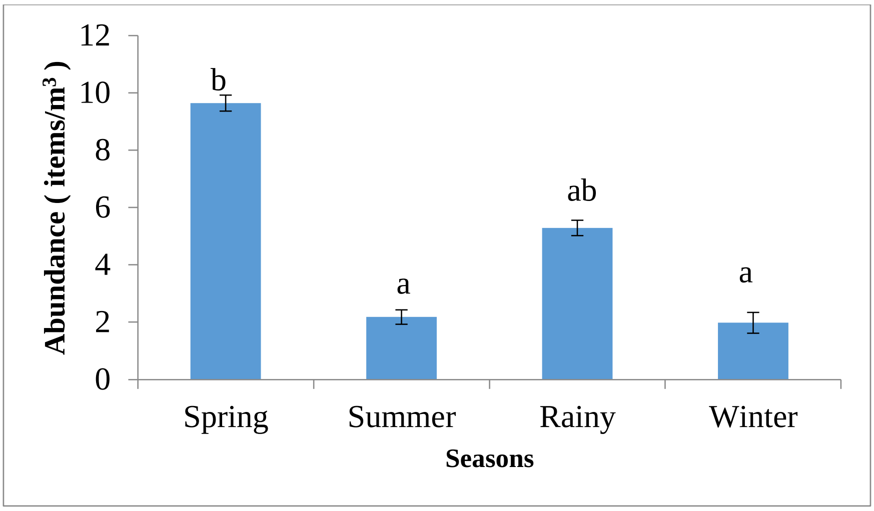

Figure-4: Seasonal variation of MPs

4.2 Microplastics characteristics

4.2.1 Microplastics type

There were six types of MPs identified such as fragment, filament, film, foam, pellet and granule in this study. The results showed that fragments (49.63%) and filaments (40.44%) predominated over the MPs like films (7.35%), pellet (1.10%) and low proportion of foam (0.73%) and granule (0.71%) (Figure-5). Fragment and filament were more dominant types in each site over other types. Film, pellet and granule had lower proportion in different sites comparing fragment and filament. Foam was the least recorded which was only found in Abir Point (Figure-6).

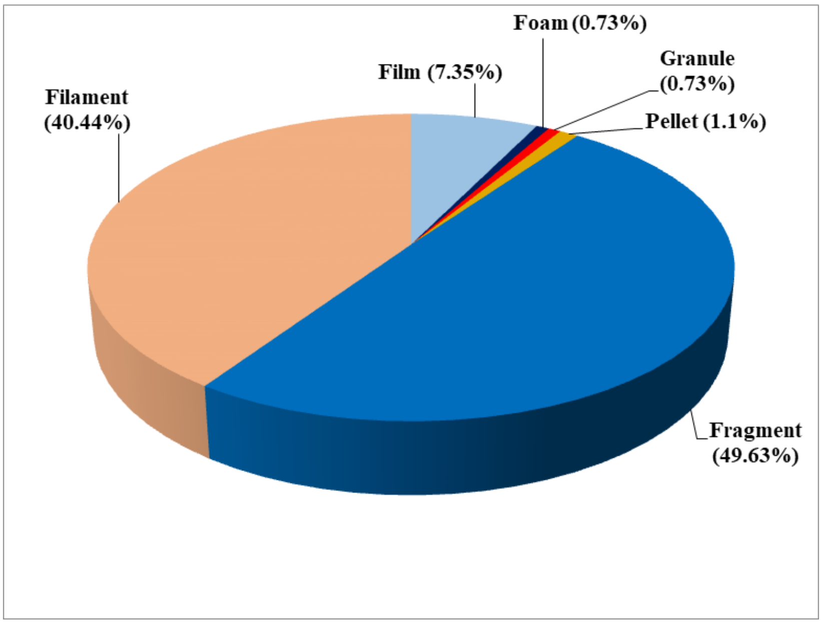

Figure-5: Percentage of identified microplastics types

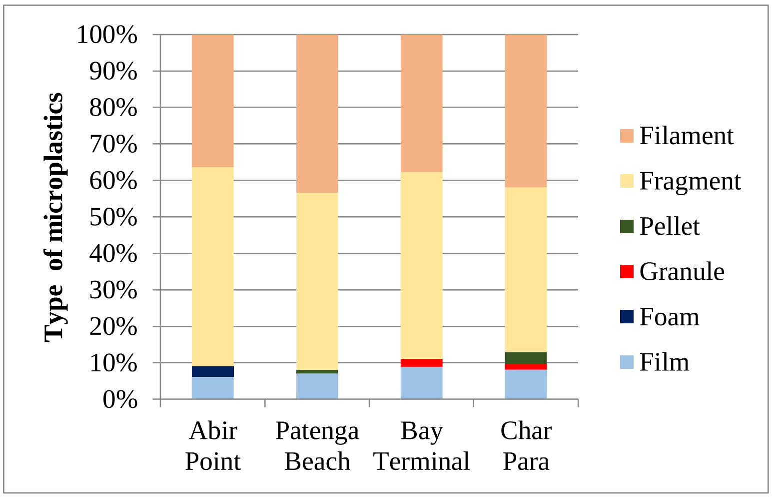

Figure-6: Proportions of identified MPs types

4.2.2 Microplastics color

The eight different group of MPs color were identified in this study in which transparent (40.40%) and red (24.50%) being the more dominant colors, followed by black (12.91%), blue (9.27%), green (8.28%), brown (2.65%), yellow (1.66%) and white (0.33%) (Figure-7). Transparent and red colors were more dominant in three sites. Black, blue, green and brown colors had lower proportion comparing transparent and red. White color was the least recorded which was only found in Char Para (Figure-8).

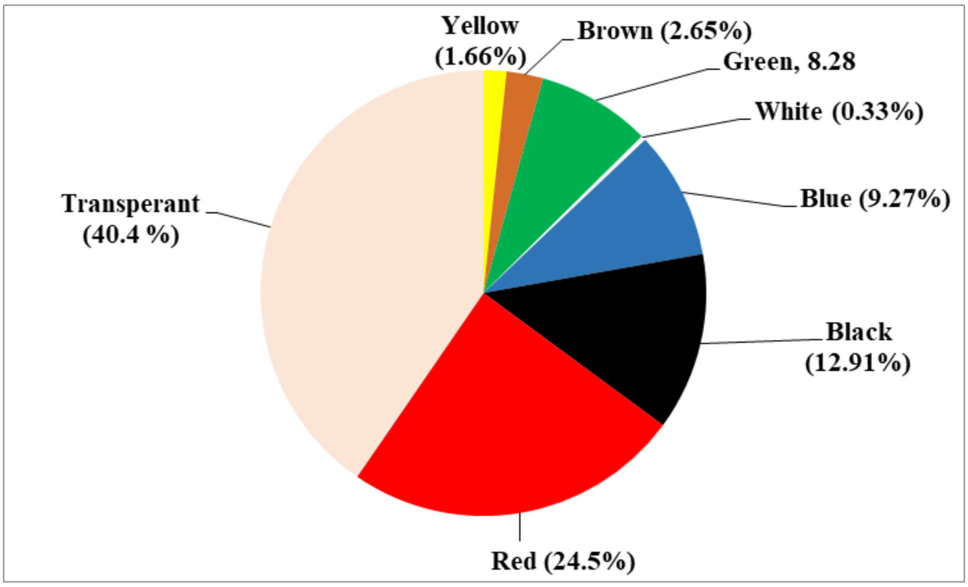

Figure-7: Percentage of identified microplastic color

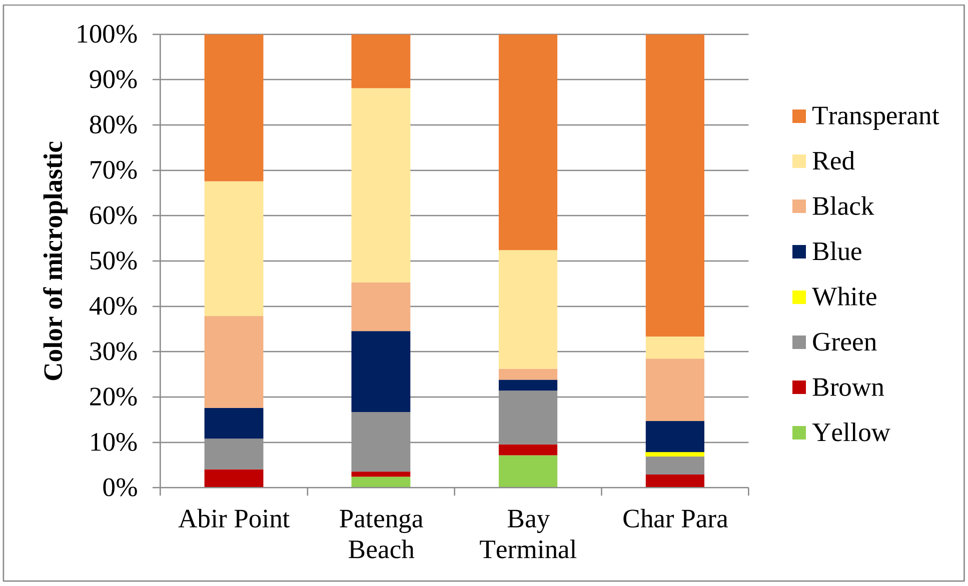

Figure-8: Proportion of the identified MPs color

4.2.3 Microplastics shape

There were six shapes of microplastics identified, such as irregular, elongated, angular, rectangular, round and cylindrical. This result shows that irregular (52.63%) and elongated (37.17%) being the more dominant over angular (4.61%), rectangular (3.95%), round (1.32%), cylindrical (0.33%) (Figure-9). Irregular and elongated shape had higher proportion in each site. Angular, rectangular and round shapes were lower in proportion compared to irregular and elongated shapes. Cylindrical was the least recorded which was only found Patenga Beach (Figure-10).

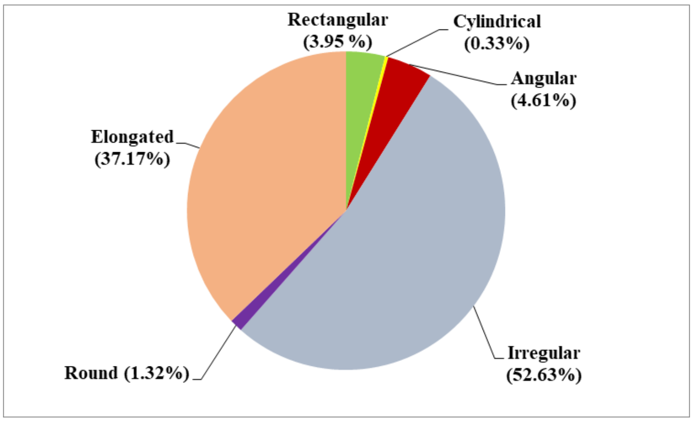

Figure-9: Percentage of identified microplastics shape

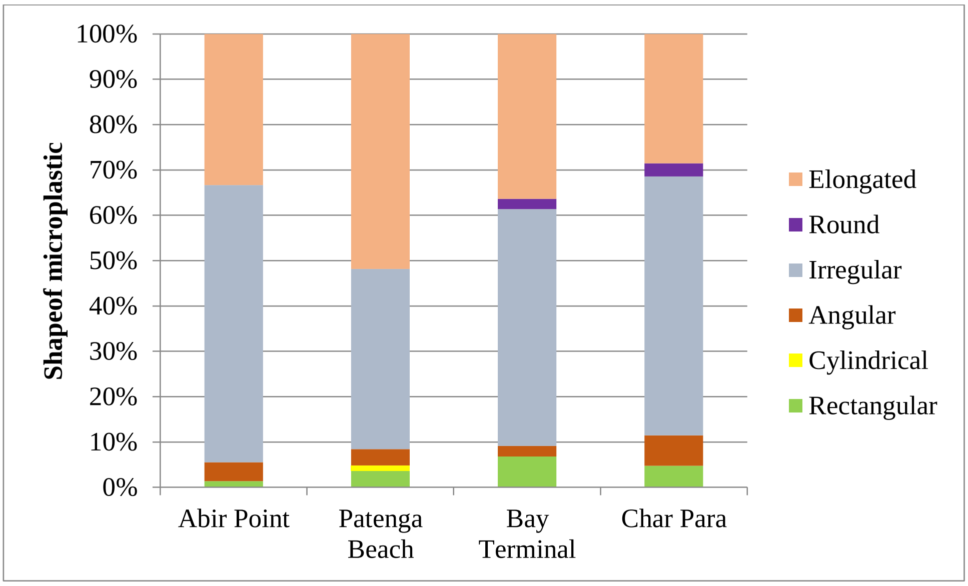

Figure-10: Proportion of identified MPs shape

4.2.4 Microplastics size

This result states that five separate size categories were determined from the identified MPs where 300 µm to < 500 µm (48.50%) and 500 µm to < 1 mm (24.25%) sizes dominated over 1 mm to < 2 mm(9.97%),2 mm to < 3 mm (6.98%), 3 mm to < 5 mm (10.30%) (Figure-11). Comparing to other size classes 100 µm to < 500 µm and 500 µm to < 1 mm had higher proportion in each station (Figure-12).

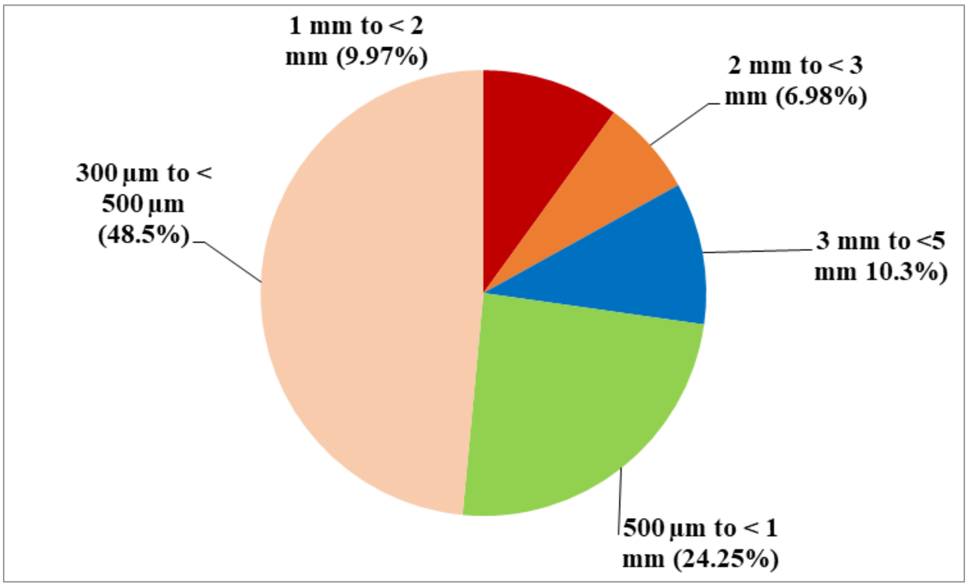

Figure- 11: Percentage of identified microplastic sizes

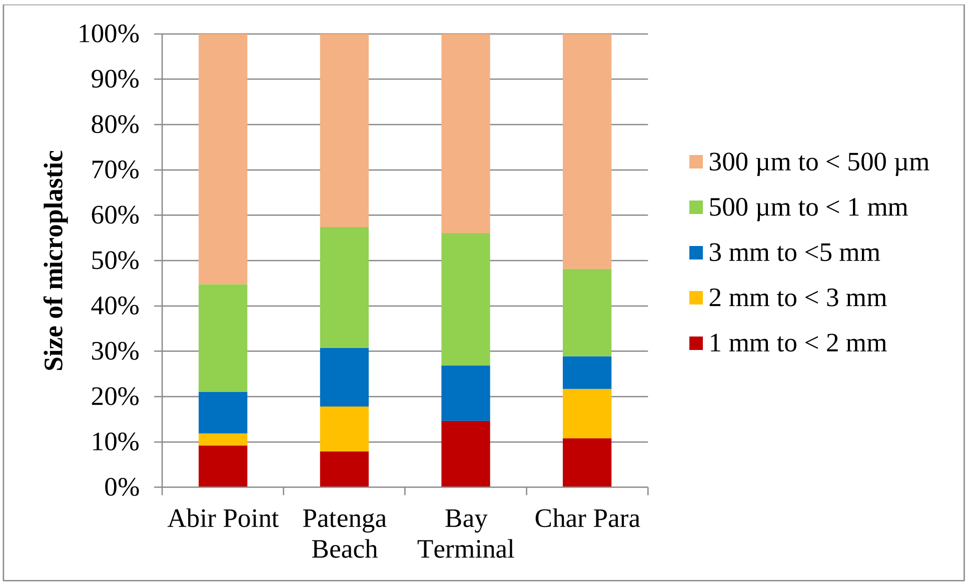

Figure-12: Proportion of identified MPs size

Chapter 5

Discussion

5.1 Variation of microplastics among different sites

In the present study, Patenga Beach had the highest abundance (8.52 item/m^3) among four study sites. Patenga is a well-known tourism destination in Chattogram, Bangladesh. To draw tourists, city vendors sell countless of toys and a variety of culinary products like ice cream, cold drinks, chips, etc. As a result, this study contends that a significant source of plastic waste is thrown out by locals and visitors. As Patenga Beach is the most crowed one among four sites that's why it is the most polluted site according to this study.

On the other hand, lowest microplastics abundance was reported at Bay Terminal (1.83 items/m^3). As Bay Terminal is a non-tourist area which is far from main tourist point, it is less polluted according to this study.

In this study the mean microplastics abundannce of the Patenga Sea Beach (7.60 items/m^3 in tourist site and 1.94 items/m^3 in non-tourist site) has been compared to other aquatic environment. Microplastics are subtantially lesser than other recorded aquatic environment such as 17 items/m^3 in Auckland stream, New Zealand (Dikareva and Simon, 2019), 42 items/m^3 in Bahia Blanka Estuary (Severini et al., 2019) where it is marginally higher than other waterbodies such as 4.33 items/m^3 in the Karnaphuli River Estuary (Rakib et al., 2023) , 0.1 items/m^3 in Moheshkhali channel (Al Nahian et al., 2023), 1.6 items/m^3 in Japanese rivers (Katoka et al., 2019), 0.099 items/m^3 in India Mandovi Zuary Estuary (Gupta et al., 2021), 0.045 items/m^3 in the South China Sea (Cai et al., 2018). As a result, these different MP abundances in surface water show spatial changes that may be attributable to a combination of changing hydrodynamic process, wind motions, and regional human inputs (Gupta et al., 2021).

5.2 Seasonal variations of microplastics

The abundance of microplastics was exceeded in spring, summer and rainy seasons of tourist site compared to non-tourist site. It may be occurred due to increase of tourist visitation in spring and summer seasons. As pollutant from lands enters the sea due to runoff, MPs may become abundant in rainy season as well. On the contrary, only winter season micropollutant was abundant in non-tourist area. The non-tourist area is considered as transportation route to many areas. So, the transportation of people and various products may be increased in winter season.

The mean microplasticss abundance in spring was (9.64 items/m^3) higher compared to summer (2.81 items/m^3), rainy (5.29 items/m^3) season and winter (1.98 items/m^3) had the lowest mean abundance among all season.

The Tallo River has more microplastics during the dry season (2.247 items/m^3) than during the wet season (1.457 items/m^3) (Wicaksono et al., 2021). In China's Maozhou and Yellow Rivers, there is a similar tendency for MPs abundance to increase throughout the time of dry season (Wu et al., 2020; Zhou et al., 2020). These occur from a reduced surface area ratio in water during the dry season, which causes a larger concentration of MPs in the surface water (McNeish et al., 2018).

On the contrary, the MPs abundance in India's Mandovi-Zuari Estuary was higher in the wet season (0.107 items/m^3) compared to the dry season (0.099 items/m^3) (Gupta et al., 2021). Heavy rains in the area, according to Lima et al. (2014), create runoff that permits microplastics from the land to enter the aquatic ecosystem.

5.3 Microplastics type

There were six types of MPs identified such as fragment, filament, film, foam, pellet and granule in this study where fragment, filament and film being more dominant over other types. This result was uniform with studies by Lin et al. (2018), Dikareva and Simon (2019), Radhakrishnan et al. (2021), and Saha et al. (2021). Fragments formed by the breaking of bigger plastic product pieces or the abrasion of industrial raw materials were the most prevalent (Li et al., 2021). Gupta et al. (2021) claimed that this happened as a result of using a wide range of hard plastic products (such as plastic containers and food packaging), local activities (like fishing and floating trash), port activities, transporting commodities, etc.

Filament or fiber was the second dominant types of microplastics found in the present study. Fibers are likely derived from clothing (synthetic textile), through washing activity and are not effectively eliminated by sewage treatment (Browne et al., 2011). These fibers can also come from the fishing sector, airborne deposition, and the footwear and textile industries (Cole et al., 2011; Dris et al., 2018).

The films were made of soft plastic fragment and might be developed from the degeneration of plastic bags, or plastic wrap, single-use plastics, and trash disposed throughout the time of tourist activities (Robin et al., 2020). Single use Styrofoam food container, floating used in ships and boat are commonly considered to be one of the main source of foam microplastics. Pellet and granule are least found MPs type in this study. Typically, pellets are used as a feedstock for making plastic or for air blasting (Eerkes-Medrano et al., 2015). Small plastic granules are typically found in a variety of cleaning and cosmetic products or are created when bigger degradable plastics break down (Fendall and Sewell, 2009; Cole et al., 2011).

5.4 Microplastics color

The eight different groups of MPs color were identified in this study where transparent and red were the dominant among other colors. White color particle were dominant in the Karnaphuli River Estuary according to Rakib et al. (2023).

The microplastics color can help examine their source and rate of deterioration. A common food packaging material, for instance, has transparent color. It can be possible that transparent MPs are linked to transparent food container. Other potential indicators include the photo-oxidation and weathering processes that result in the yellowish color of MPs (Andrady, 2017).

MPs generally contain a synthetic colorant that leaches into the environment, increasing the threat to aquatic life (Rochman, 2015). Fish prefer lighter MP colors like blue, white, and transparent, according to some authors, because they are easier to detect from the brownish hue of the natural environment (Wicaksono et al., 2021).

The color of pigmented MPs may have come from paint and textiles, which frequently employ a variety of colors. Fishes prefer to eat minute pieces of plastic may also depend on the color of the MPs. Fish typically like MPs that are the same color as their prey. For instance, because of their color resemblance to copepod species, which are scad fish's native prey, the scad fish gathered from the South Pacific gyre tend to consume blue MPs (Ory et al., 2017).

5.5 Microplastics shape

There were six shapes of microplastics identified such as irregular, elongated, angular, rectangular, round and cylindrical. This result showed that irregular (52.63%) and elongated (37.17%) being the more dominant over angular (4.61%), rectangular

(3.95%), round (1.32%), cylindrical (0.33%). Similar findings concerning the predominance of filamentous or elongated, irregular-shaped microplastics were found in studies of Bay of Bengal fish and sediment from the beach (Hossain et al., 2019; Hossain et al., 2021).

Physical, chemical, and biological processes all devote to the creation of this texture (Veerasingam et al., 2016; Zhang et al., 2016; Zhao et al., 2018). Particle-particle collisions and saltation result in the formation of MPs with irregular forms, which eventually cause plastic to become embrittled (Corcoran et al., 2009; Zhang et al., 2016). It is vital to acknowledge how MPs weather because disintegrated MPs are more likely to accumulate hazardous contaminants in an estuarine system. The ability of MPs to act as a specific microbial habitat is also improved by weathering (McCormick et al., 2014; Liu et al., 2020).

The least frequent microplastics in our experiment had cylindrical forms. Numerous factors, such as the source of the waste, the breakdown of macroplastics, the nature of the debris, UV-B radiation, the manner that plastics are suspended in water, wind drift, and the rate at which plastics sink, may contribute to these changes in microplastic morphologies (Karthik et al., 2018).

5.6 Microplastics size

This result stated that five separate size categories were determined from the identified MPs where 300 µm to < 500 µm (48.50%) and 500 µm to < 1 mm (24.25%) sizes dominated over 1 mm to < 2 mm (9.97%), 2 mm to < 3 mm (6.98%), 3 mm to < 5 mm (10.30%).

Since smaller particles often have higher adsorption energies than larger ones, the ability of microplastics to adsorb and desorb other pollutants in aquatic environments varies greatly, creating more serious issues with microplastic compound contamination (Coverntton et al., 2019).

Larger microplastics are a sign that they are becoming more prevalent over time and that smaller microplastics may also be becoming more common. According to earlier studies, secondary microplastics constitute a significant environmental source of microplastics. Environmental and anthropogenic causes in particular broke down large-particle plastics and microplastics into smaller microplastics. Small-sized microplastics made up a higher percentage of the total, showing that variables like climate and water volume changes had an impact on how microplastics broke down into smaller particles. As a result, small-sized microplastics were relatively abundant in pollution sources (Wang et al., 2021).

Chapter-6

Conclusion

Microplastic is a current issue in environmental science that is causing concern all around the world including Bangladesh. This investigation has demonstrated that the Patenga Sea Beach's surface water has medium to low levels of microplastics compared to others research. Tourist areas have slightly more MPs than non-tourist areas. The spring season had a significantly greater microplastic concentration than the winter season. The microplastics were mainly composed of fragments, followed by filaments, films, granules, and pellets. The majority of microplastics are considered dangerous because they resemble living species' prey and are often colored. The majority of the microplastics that were found were elongated, irregular in shape, and were of various sizes. There were found to be five different size classes of microplastics, with 300 µm to < 500 µm microplastics being the most common. Overall, the different sizes, shapes, and hues of the microplastics suggest that different physical processes may have been applied to the microplastics in this study site, leading to a diversity of origin of pollution. In this study area, land-based origin such as road runoff, unprocessed wastewater expulsion, tourism, and other anthropogenic trash are convinced to be the main producers of microplastics, with contributions from sea-based origin like fishing and port performance being negligible. Future investigations into the point and nonpoint sources of microplastic contamination will be able to build on these findings. In addition to the current study, more research is required to guarantee that annual variations in the amount of microplastics and their toxicological effects on aquatic life and the ecosystem are taken into account.

Chapter-7

Recommendation

According to the findings of the present study, the following suggestions might be made:

- Microplastic pollution will be needed to address right away because it is a significant global problem. The most effective strategy to eliminate microplastic contamination in the aquatic environment is to stop it at the source.
- Policymakers will be crucial in designing the legislative framework enforced to reinforce mitigation initiatives that lessen plastic waste at the origin and support cleaning of plastic pollution before it poses the greatest threat.
- In order to minimize consumption patterns and littering, it will be essential to monitor pollution at its source and implement public awareness campaigns.
- To meet the rising need for microplastic pollution monitoring at both the national and international levels, new procedures will be developed in addition to existing ones.
- The microplastics concentration and their ramifications on aquatic life, people, and the environment would be studied further.

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Photo Gallery

Plate -1 Manta net

Plate-2 Net towing

Plate-3 Flowmeter

Plate-4 Sample collection

Plate -5 Sieving

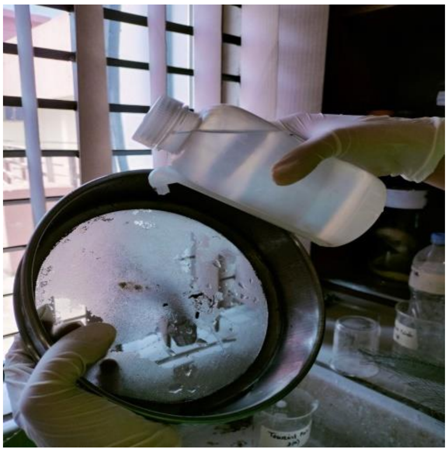

Plate-6 Wet sieving

Plate –7 Drying

Plate-8 Adding H_2O2

Plate-9Heating

Plate-10 Adding $ZnCl_2$

Plate -11 Density separation

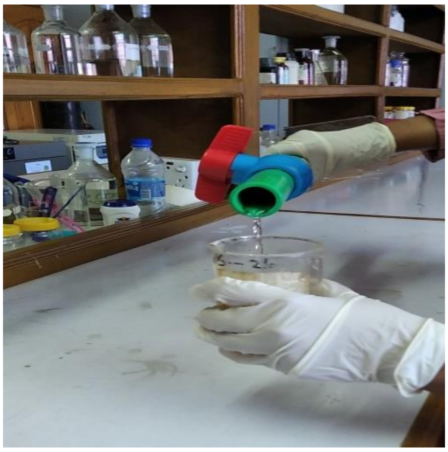

Plate-12Separated sample

Plate –13 Filtration

Plate-14 Identification

Plate-15 Visual identification

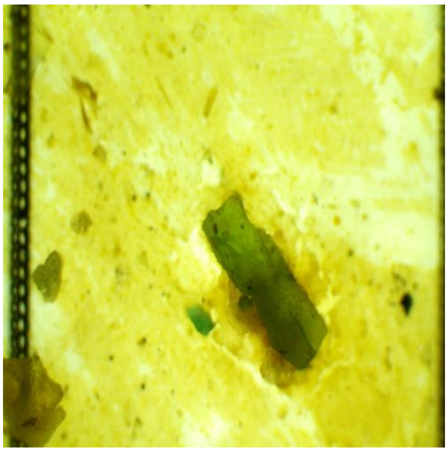

Plate-16 Green rectangular fragment

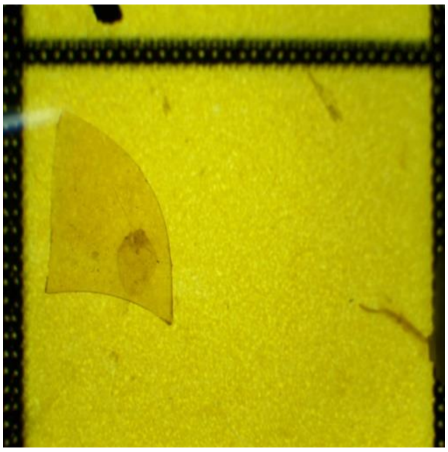

Plate -17 Transparent angular film

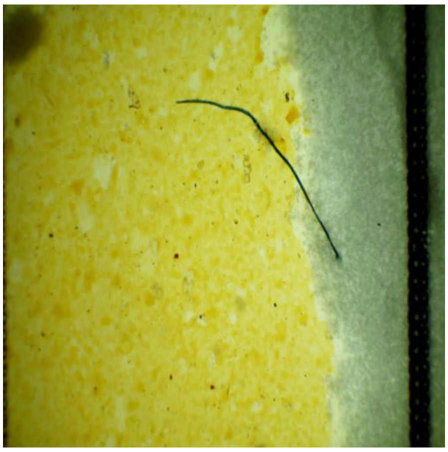

Plate-18 Black elongated filament

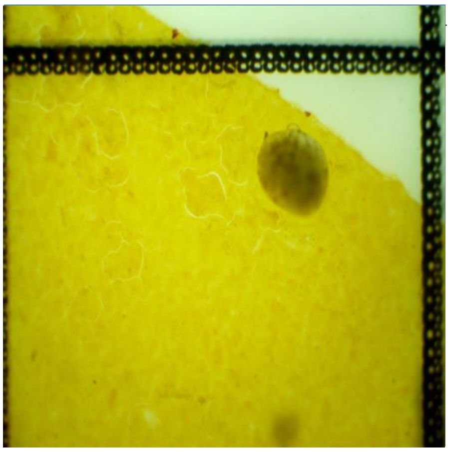

Plate –19 Black round foam

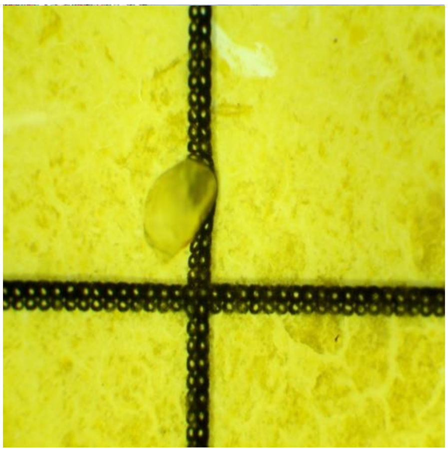

Plate-20 Tansparent irregular Pellet

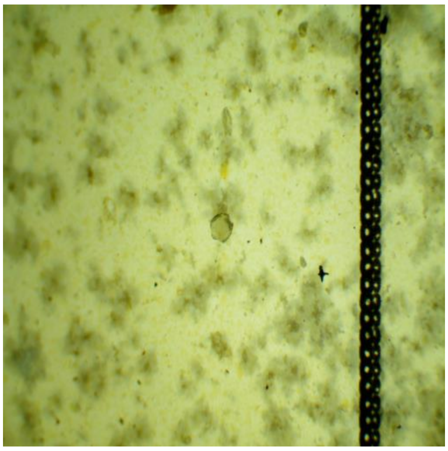

Plate-21 Tnasparent round granule

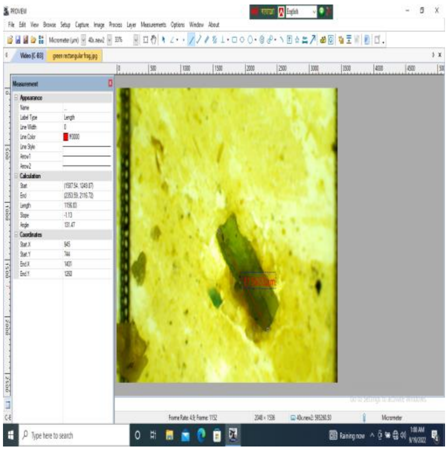

Plate-22 Size measurement