A BASELINE STUDY ON IDENTIFYING AND CHARACTERIZING MICROPLASTICS IN AIR AND RAINWATER OF DHAKA CITY, BANGLADESH

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ABSTRACT

One of the environmental issues at the forefront research in last ten years has been the exponential rise in worry about microplastic (MPs) contamination. Even though the existence of MPs has been proven in every segment of the environment, hardly any research found on the nexus of MPs in atmosphere. Determining the abundance of airborne MPs is substantially important when assessing the danger of human inhalation and drinking rainwater. In this study, MPs in ambient atmosphere of Uttara residential area and rainwater of Hazaribag commercial area were investigated. Air samples were collected in premonsoon season (February 2023) and monsoon season (July 2022) while rainwater samples were collected during pre-monsoon (early rain, April 2022) and monsoon (July 2022) and brought to the laboratory of Khulna University to analyze the abundance, size, shape and color. With seasonal change, rainwater demonstrated a considerable difference in abundance compared to air. For Uttara's atmosphere, concentrations were 52.1 particles/m^3 in premonsoon season and 50.64 particles/m^3 in monsoon season. For pre-monsoon and monsoon, rainfall from Hazaribag contained 124 particles/L and 81 particles/L respectively. MPs between 1000-1500 µm were abundant in air samples while a majority of MPs in rainwater were <500 µm in size, though few particles were even found in the size range of >2500 µm in both cases. Fiber-shaped MPs were most dominant in both air and rainwater. Surprisingly, transparent MPs were mostly abundant in air samples in contrast with rainwater which was dominated by black color MPs. This pioneer investigation confirms the substantial presence of MPs in both air and rainwater of Dhaka city. However, the zone-specific further studies with more samples may draw more robust conclusions in this regard. The findings will encourage environmental scientists and policymakers to control the use of plastic to keep the atmosphere clean for human health.

***Keywords**: Microplastics, Atmosphere, Rainwater, Dhaka city.*

1. INTRODUCTION

Plastic is a type of polymer produced by various reactions using petroleum or natural gas (Cole *et al*., 2011). Since the mass production of plastic began in 1950, plastic has been widely used because of its characteristics of cheapness, lightness, durability and corrosion resistance (Sang *et al*., 2021). There is no uniform microplastic size definition as of yet, but a size range of 1mm to 5 mm is typically allowed (Hidalgo-Ruz *et al*., 2012). Microplastics are generally characterized as solid, water-insoluble polymer particles that are less than 5 mm in size (Bergmann *et al*., 2015) and are pervasive in freshwater and marine habitats.

Around the world, microplastics are frequently found in freshwater and marine ecosystems, such as beaches, saltwater, marine sediments, surface water, and lake or river sediments (Auta *et al*., 2017). In contrast to the extensive study of microplastics in water and soil environments, research on microplastic particles in air (also known as atmospheric microplastics) has only lately gained traction. Many suspended elements are carried over regional or global boundaries via the atmosphere. Microplastics, because of their tiny size along low density, may be easily transferred to air and moved by airflow (Allen *et al*., 2019). Airborne plastic particles may be repeatedly and directly absorbed into the human body, endangering human health as compared to the amount of microplastics in those other ecosystems. The presence of microplastics (MPs) in the environment and various types of seafood has raised concerns about the potential health effects of plastics. Plastics have been found in shellfish and fish purchased from supermarkets and fish markets on several occasions. Up to 11,000 pieces of seafood per person per year are thought to contain MP (Welden *et al*., 2020). According to Anwar *et al.,*(2021), the increased risk of neurological and cognitive abnormalities, cancer, delayed chemotherapy, obesity, early puberty, medicine resistance, adult-onset diabetes, chromosomal issues, and cardiovascular damage are all associated with the use of plastics. Styrene is a component of polystyrene that may be inhaled and is present in the air. It affects the central neurological system, the kidney, blood, stomach, and respiratory systems, as well as is linked to an increased risk of cancer. Vinyl chloride exposure levels can have an impact on the nervous system, damage the liver, and even cause cancer. It is more prevalent in drinking water and modern autos.

Literature reported the presence of airborne microplastics in several cities and shown that airborne microplastics may be transferred to ocean surface air and remote places (Allen *et al*., 2019; Dris *et al*., 2015; Liu *et al*., 2019). Microplastics were first detected in atmospheric fallout by Dris *et al*. (2015), who concluded that atmospheric deposition could be a major source of microplastics in freshwater. Since then, researchers in many cities all over the world have reported on the dispersion features of microplastics in the atmosphere or road dust (Cai *et al*., 2017; Dehghani *et al*., 2017).

Air pollution has always been a problem in Dhaka city. Its air quality often deteriorates throughout the winter and becomes better during the monsoon season. Dhaka has an average $PM_{2.5}$ concentration of 186 micrograms per cubic meter where the acceptable level of $PM_{2.5}$ for outdoor air is 15 micrograms per cubic meter (Kumar *et al*., 2006). The city's air quality begins to rapidly decline as winter approaches as a result of the large release of polluting particles from building projects, dilapidated roadways, brick kilns, packaging and processing industries and other sources. The potential sources of MPs in water in many parts of the world are well studied. Dhaka, despite being one of the most air polluted cities in the world, is still ignored to be studied as the potential sources of MPs in water through precipitation. Numerous plastic industries, garments, packaging industries and dumping of plastics with solid waste are the potential sources of MPs to the atmosphere of Dhaka. Hence, this study aims to identify the contamination of MPs in the rainwater of Dhaka city. There are many plastic production industries, textile industries, and landfilling areas in Dhaka city that produce lots of microplastic which ultimately goes into the atmosphere. According to Begum *et al*.,(2019), the air in Bangladesh is heavily particulate-filled. Studies have previously demonstrated the dangers of particulate matter, but none have provided information on the precise amount of microplastic present. Air pollution grew with industrialization, and since many of those businesses produce goods using polyethylene, there is a chance that the air may get contaminated with microplastics (Rifa *et al.,* 2022). However, a large number of people in Bangladesh rely on rainwater for several tasks around the house, including drinking and the low-cost rainwater harvesting technique was feasible and acceptable to the slum dwellers as the only potential alternative source of safe drinking water in Dhaka city (Islam *et al*., 2011). Prior research on the subject of microplastic contamination of air and rainfall has not been carried out in Dhaka. The goal of this study is to detect microplastic particles in Dhaka, Bangladesh's air and rainfall and to classify them according to their physical characteristics.

2. MATERIALS AND METHOD

2.1 Study Area

Dhaka is the capital and eighth-largest and the fourth-most densely populated city in the world (Nevins *et al.*,2018). Two areas within Dhaka's metropolitan boundaries, air pollution-laden Uttara and plastic production hub Hazaribag were chosen for targeted sampling due to their distinct environmental profiles. Uttara's high population density and reliance on private vehicles contribute to its air pollution burden (Mridha, *et al*., 2011) while Hazaribag's concentration of plastic factories and extensive use of plastic packaging make it a key site to study microplastic contamination.

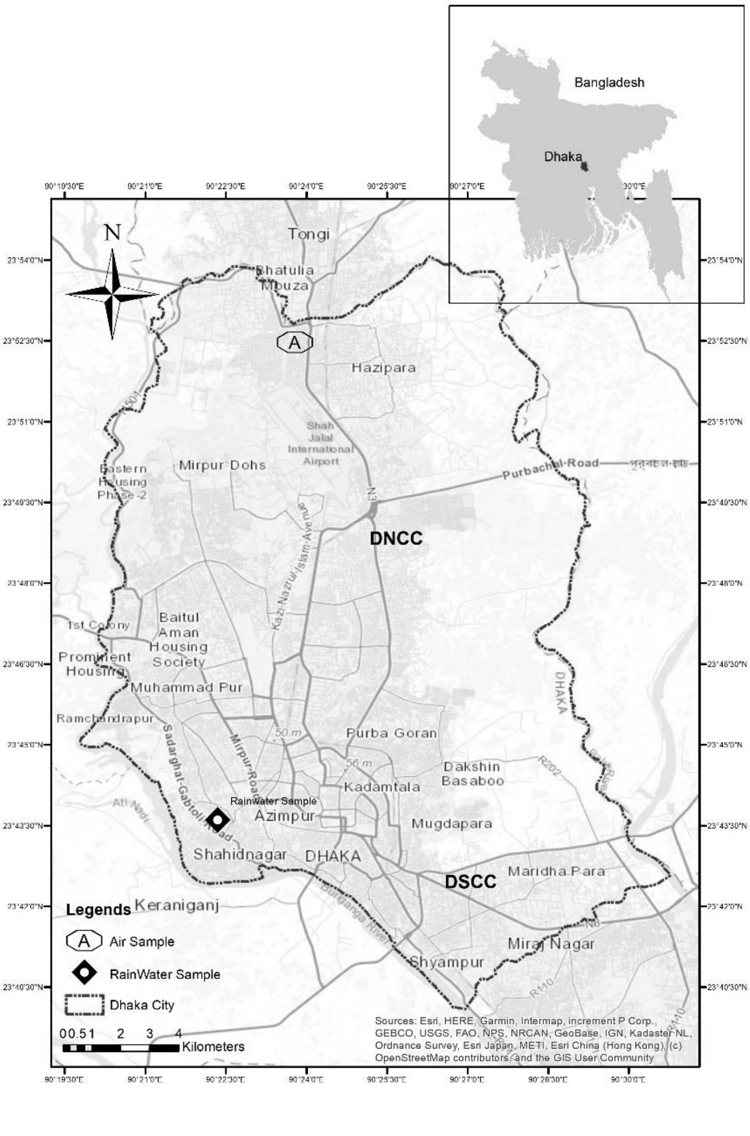

Figure 1: Map of study pointing to sampling locations

2.2 Methodology

There are currently no standard operation protocols (SOP) for microplastic analysis in the environment. This is majorly due to the lack of studies regarding airborne MPs and only a few studies have been published to date (Enyoh *et al*., 2019). An active sampling process with visualization through a microscope will be used for this study.

2.2.1 Sample Collection

The sample collection method was active sample collection. The samples were the particulate matter of air. The PM collection system comprised a low-volume sampler unit and a filter changer with an intake tube and sampling head (inlet) to collect PM from air that will draw through a size-selective inlet and the filter media. Particulates with aerodynamic diameters less than the cut-point of the inlet are collected on the filter media, and here focused on PM (Dris *et al*., 2017). A pump (Tactical Air Sampler MiniVol, TAS-5.0, Oregon, USA) was used to sample 7L/min of air on glass fiber filters (2µm, 47 mm) as per EPA recommendation. Sampled volumes range between 2 and 5 m^3 depending on occupants' presence. The samplings were carried out at a 1.2 m height because it is standardly used to correspond to the breathing height of an adult (Dris *et al.*, 2017). Sampling periods ranged between 12 h to conduct the all period of a day that people spend in their activity. Samples were collected in both the dry season or premonsoon time (February 2023) and the wet season or monsoon season (July 2022). As seasonal variations influence atmospheric pollution, rainwater samples were collected both in pre-monsoon (April 2022) and monsoon (July 2022) period. All samples were collected in glass bottles and the plastic containers were avoided.

2.2.2 Sample Processing and MPs Extraction

To avoid sample contamination from the outside of the bottles, all bottles were rinsed with deionized water after cleaning with detergent. Bottles were allowed to dry in a laminar flow box before being opened. Each sample was mixed by inverting the bottle, and microplastics were extracted using a simple and traditional filtration method, as described by Liebezeit (2013) and Liebezeit (2014), Kosuth *et al*. (2018), Schymanski *et al*. (2018), and Shruti *et al*., (2020). Additional Milli-Q water was used to thoroughly rinse the filtering units. Following that, the sample was vacuum-filtered through a cellulose nitrate filter (0.45 µm pore size, Sartorius AG, Germany). When filters became clogged or blocked, new filters were used to ensure that the remaining volume was adequately served. All filters were carefully transferred to individual new petri dishes (pre-labeled) using metal tweezers and dried at room temperature and stored for future analyses. Air samples were stored carefully for direct observation.

2.2.3 Visual Identification, Particles Quantification, Size and Shape Determination

Filter membranes were examined visually with an IM660 TI Biological Microscope (Imerco GmbH Geesthacht, Germany) and photographed with an AmScope digital camera with Toupview software. A hot needle test was done in case there was any uncertainty. Based on recognizable properties, microplastics were classified as fibers (long, thin lines with a slender shape and equal thickness particles), fragments (a piece of plastic from a bigger plastic item), and film (thin, flat with a soft and malleable texture), granules were ignored because their small shape. The color and shape of the microplastic particles found in the samples were measured using Toupview software.
Various studies divided size into various categories for their convenience and to show the abundance variation (Dris *et al*., 2017; Zhang *et al*., 2020), for easier calculations, the size range in this study was divided into seven categories: 50-250, 250-500, 500-750, 750-1000, 1000-1500, 1500-2500, and larger than 2500µm. MPs smaller than 50µm were ignored to avoid errors in counting. Under the colorful category, puzzling hues are mentioned.

2.2.4 Quality Control and Data Analysis

In advance of every filtration experiment, the membrane filter meant to be used was visually inspected for microplastic-like particles found on them and photographed under a microscope to determine background contamination. Plastic hardware was avoided to ensure clean and efficient beverage analyses, and glass equipment (containers, beakers, sampling barrel, stainless steel sieve, conical flask, glass fiber membrane, vacuum filter, filtering units, and petri dishes) was used after rinsing with filtered deionized water and drying. Filters were carefully wrapped with aluminum foil and combusted at 450◦C for 4h prior to use. The filter screen on the air sampler was cleaned using alcohol and a dry cotton cloth between each sampling collection. To avoid post-collection contamination from airborne MPs, extraction processes were performed in a laminar-flow hood, and all glassware was thoroughly rinsed with distilled water before use. Cotton laboratory coats and single-use nitrile gloves were worn during all procedures. As a result, during the analysis, the microplastic contamination in the air can be overlooked. All samples and equipment were covered with glass petri dishes or aluminum foil after cleaning. Each test was analyzed a minimum of three times to ensure the accuracy and reproducibility of the results. Due to limitations, 12-hour samples were shown in this study and compared to others. The results from visual analysis were presented through charts, tables and graphs using Microsoft Excel software. All statistical analyses were performed with Microsoft Excel software.

3. RESULTS AND DISCUSSION

3.1 Microplastics in Air and Rainwater

MPs were detected in both Air and Rainwater samples from respective locations. 237±6 particles of MPs were detected in the Air of Uttara Area in monsoon season and in premonsoon it was 244±4 particles. In Uttara, the MP concentration of Air did not show a significant difference between in monsoon season (50.64±1.28) particles/m^3) and the premonsoon season (52.1±0.85 particles/m^3) (P >0.01). In the Hazaribag Area, 248 particles of MPs were found in the premonsoon rainwater (mentioned as premonsoon rainwater in figure 2) and 162 particles in the monsoon rainwater (mentioned as premonsoon rainwater in figure 2). The respective concentrations showed a significant difference between premonsoon (124±10 particles/L) and monsoon season (81±8 particles/L) (P <0.01). The particle distribution is shown in Figure 2.

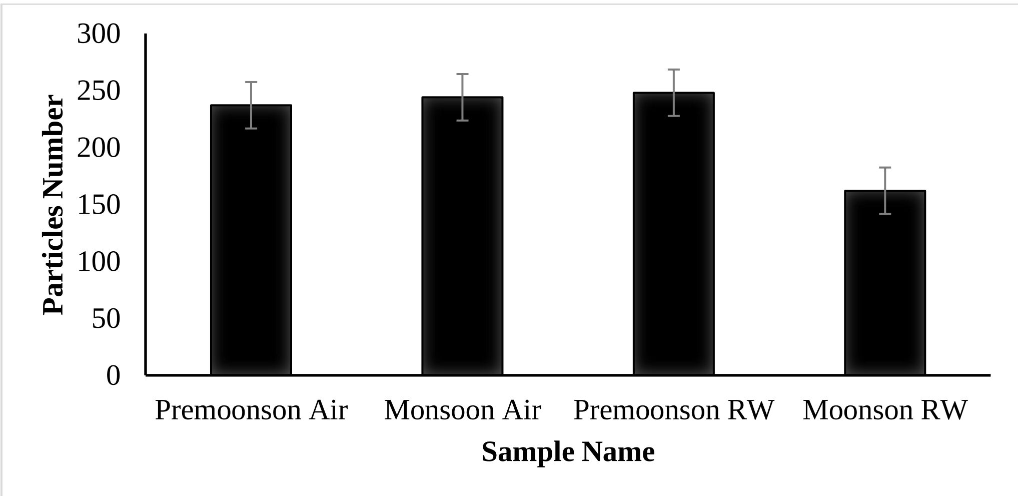

Figure 2: Number of Identified MPs in Sampling Locations with seasonal variation between premonsoon and monsoon season. Particles were highest in Premonsoon RW and lowest in Monsoon RW.

3.2 Physical Properties of Identified Microplastics

On the MPs' physical characteristics, a variation had been observed. MPs' dimensions, forms, and colors as their physical characteristics had been mainly observed. The seven groups' worth of sizes ranged from 50 to 5000 µm. In the air samples, MPs with a size range of 250–500 µm predominated, accounting for 31.93% during the monsoon season and 31.97% during the premonsoon season. However, MPs of

50-250 µm dominated the rainfall samples, accounting for 33.06% during the premonsoon and 40.74% during the monsoon season. Figure 3 shows the MPs in relation to size.

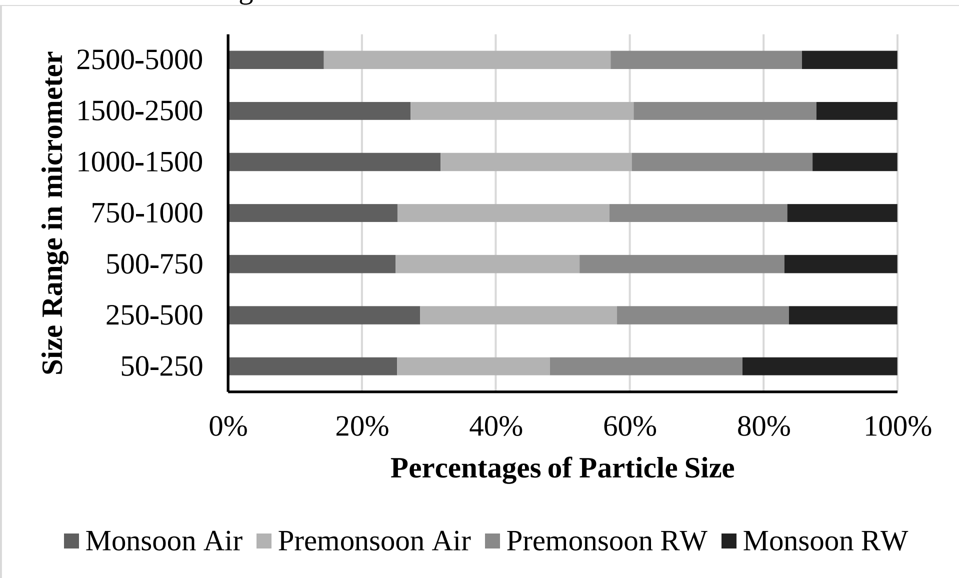

Figure 3: Detected particles of Air and Rainwater Sample of Premonsoon and Monsoon season within size range from 50-5000 into categories from 50-250µ,250-500 µ,500-750µ,1000-1500µ,1500-2500 µ, 2500-5000µ.

Fibers were the major type of MPs found in both types of samples. In each sample fibers were more than 80% percent. Following by fragments were the second type of MPs that had been identified in the study and a few numbers of filaments were also identified. Figure 4 describes the shape percentage below. Fragments were abundant 4-12% on various samples and films were the lowest abundant with about 2-5% on different samples.

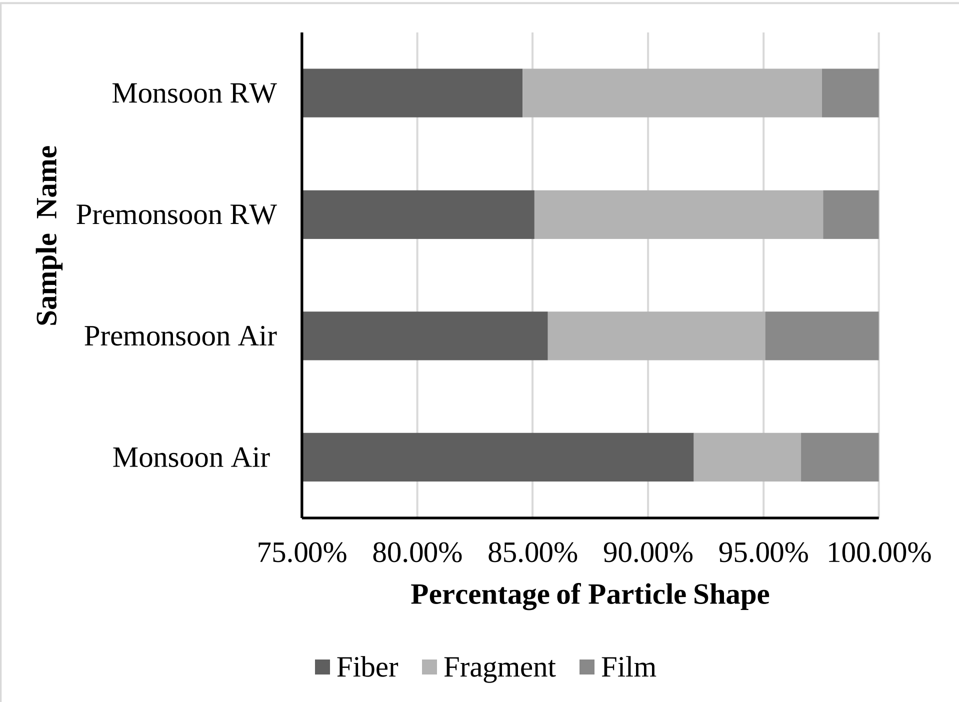

Figure 4: Shape percentages of identified MPs Air and Rainwater Sample of Premonsoon and Monsoon season.

The color profile of the MPs was very colorful. The majority of the MPs in both types of samples contained the transparent or white color. Blue, Red, Yellow, and Green colors were easily defined, other colors that could not defined in the visual observation were mentioned as colorful. Figure 5 shows the color chart of the MPs.

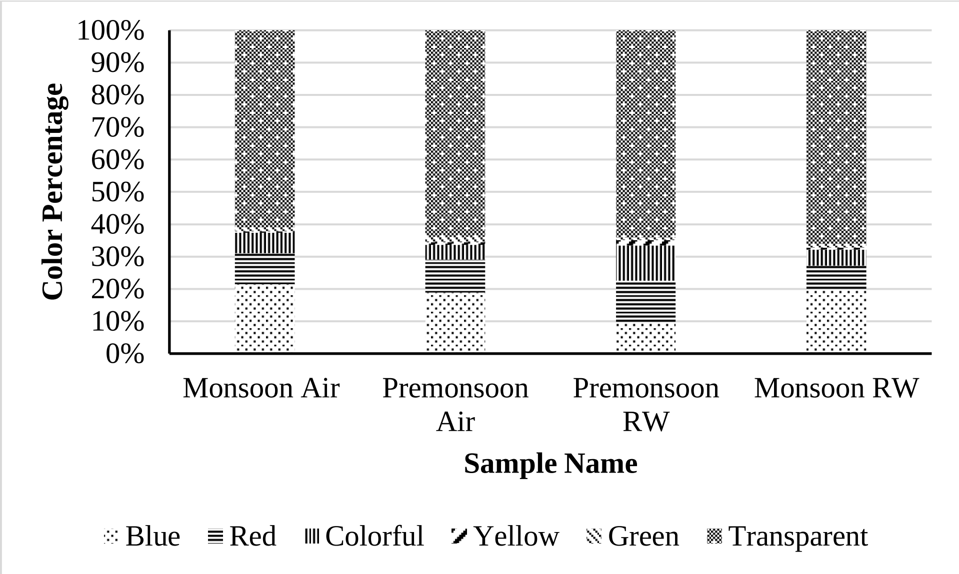

Figure 5: Color distribution of Identified MPs of monsoon and premonsoon season.

More than 60% of the particles were transparent in color. Blue was the second highest abundant color in particles except in premonsoon rainwater. The lowest abundant color was yellow.

3.3 Discussion

Compared to previous research based on particulate matter, microplastics are identified at a higher concentration. In Paris, Dris *et al.* (2015) found 3 particles/m^3, while 1.1/m^3 in Tehran by Abbasi *et al.* (2019). Microplastics are expected to be found in Dhaka city, because of human activity and pollution levels (Afrin *et al.*, 2020). But concentration is surprisingly high compared to other studies around the world (Dris *et al.*, 2017, Do *et al.*, 2023, Abbasi *et al.*, 2019). The higher abundance of MPs could be for some reason as follows: 1) high population which increases the rate of consumption, 2) poor legislation and directive body for waste management (Shimo, 2015), 3) huge number of plastic industries with increasing rate day by day (Shimo, 2015), and 4) lower economic condition of peoples. The structure of fiber and their light weight let them stay longer in atmosphere (Dris *et al.*, 2017). While the shape of fragments, filaments and other shapes have different shapes and greater weight than fiber. The source of fiber could be daily plastic use, secondary degradation, synthetic cloths etc. Dris *et al.* (2017) found fiber more in number in Paris and their source was textile fiber. This could be the same in the abundance of fiber in Dhaka, Bangladesh, as it is one of the most highly populated cities in the world. Studies in France showed a concentration of 1–60 particles/m^3 in indoor & outdoor air and the most common particles were fibers, ranging from 50- 3250 microns (Dris *et al.*, 2017; Dris *et al.*, 2015). Studies by Allen *et al.* (2019) in the West Pacific Ocean and Liu *et al.* (2019) in the Rural Pyrenees mountains, Spain found parallel findings where most of the particles ranged from 20-500 microns. Microplastics have been found in remote areas of the Rocky Mountain Range(Allen *et al.*, 2019). A recent study by Do *et al*. (2023) found 502 particles/L of microplastics in South Korea.

The shape fibers are found extensively in this study as in the other studies. According to Dris *et al.* (2017), fibers are very common due to their structure and lightweight. The concentration of microplastics is far higher than what has been seen in other places worldwide. The main reason it might be feasible is the increased amount of pollution in the immediate area. Dhaka is one of the most highly polluted cities in the world, it even ranked 1st for several times (IQAir, 2023). The daily consumption of plastic in Bangladesh is also high. From daily use and plastic pollution, microplastics may arise and get into the atmosphere. The higher RMG factories may also be a reason for those synthetic materials in the atmosphere.

4. CONCLUSIONS

This study is a baseline study for atmospheric microplastic study in Bangladesh and only aims to find the presence of microplastics in the atmosphere and rainwater. The study findings confirmed the presence of a remarkable number of microplastics in both the air and rainwater of Dhaka city. The percentage of particle size was similar in both types of samples and indicates that they could be easily inhaled but there is still no supporting evidence of that, more extensive study is needed to understand the exposure. The fiber shapes were dominated in both cases with more than 80% abundance and more than 60% of the total particles were transparent Their color along with the shapes showed an expression that they derived from various sources. A better Raman microscopy could tell us about the details of the sources of those microplastics. Further, detailed multidisciplinary investigation is required to understand the real extent of atmospheric microplastic pollution and its consequences on humans along with the environment.

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