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Microplastics in the Atmospheric Deposited Dust Collected from Different Traffic Intersections in Dhaka City

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Abstract

Plastic particles less than 5 mm in size, known as microplastics, can infiltrate the environment from a variety of sources. This study aimed to assess the presence of microplastics (MPs) in the atmosphere at fifteen major traffic intersections in the greater Dhaka city from July to August 2022.The deposition rate (DP) of MPs was calculated and the observed DPs value ranged from 1.11×10^6 MPs/m^2/day to 5.78×10^6 MPs/m^2/day with a portion of microplastics exhibiting fluorescence activity. Fourier Transform Infrared (FTIR) spectroscopy was used to analyze the functional groups present in microplastics. The identified polymer compositions of MPs were polyethylene (PE), Nylon-6 and natural polymers (cellulose and rubber). The current study highlights the data and knowledge gaps on the atmospheric transport of microplastics and their impact to the deterioration of overall urban air quality.

Keywords: Microplastic, traffic intersections, deposition rate, fluorescence activity

I. Introduction

Microplastics are fragments of larger plastic items that are between 1 mm and 5 mm along their longest dimension[1]. They can be intentionally manufactured as primary microplastics, or they can be secondary microplastics[2]. Microplastics are made up of particles with various morphologies, such as fiber, fragment, spherical, film, and foam[3], as well as variations in color and surface porosity[4]. Along with a variety of additives, MPs also adsorb hydrophobic organic contaminants (HOCs), which include polycyclic aromatic hydrocarbons (PAHs), dichlorodiphenyltrichloroethane (DDT), and polychlorinated biphenyls (PCBs),[4-6] and thus imply potentially different toxicity[7]. The surface of MPs contains pores and cracks which give them a better adhesive character due to the degradations[8]. Some MPs such as polyethylene terephthalate (PET) or polyamide (PA) show natural fluorescence which makes them easier to detect under a fluorescence microscope[9].

MPs are introduced through synthetically manufactured beads found in personal care products or cleaning agents[10-12]. Diverse polymers were discovered in marine matrices from the urban site, implying that MP sources are diverse in densely populated and industrialized areas[13]. MPs are harmful as they may enter the human food chain while consumption of seafood and terrestrial food products, potentially causing human health effects[5,14]. Several studies have reported inhalation of plastic fibers and particles, particularly in exposed workers, which is frequently associated with dyspnea produced by airway and interstitial inflammatory reactions[5,15-16]. Airborne microplastics are a recently discovered pollutant in the atmosphere that scientists, non-governmental organizations, and the media are currently concerned about[17]. Due to their much larger size than other air pollutants such as $PM_{2.5}$ and aerosols, MPs are given less importance when it comes to atmospheric pollution. $PM_{2.5}$ can act as a carrier for airborne MPs[18], and areas with high traffic densities have an abundance of $PM_{2.5}$[19].

A study found out that people may inject up to 4.16×10^4 particles per year from deposited indoor MPs, and this exposure to airborne MPs may result from its deposition in open meals during the nighttime hours[20]. MPs are easily transported by air for less than 100 km and are influenced by polymer shape/form, population, and thus anthropogenic activities, which also influence their deposition rate[21]. Few studies have interfered with the idea that wind is a transportation medium for MPs[22]. In high-traffic urban areas MPs in the 0.1-0.5 mm size range were predominantly tyre wear particles entering and spreading in the atmospheric air[23]. Therefore, investigating the atmospheric prevalence of MPs is essential. Some studies have recently reported the presence of MP in the atmosphere or atmospheric fallouts[16,24-25].

As far as we know, the airborne microplastic in the traffic intersection (outdoor environment) of Dhaka city has not been studied till date. We targeted major traffic intersections (15 sites) for the quantification and characterization of the microplastic which focuses on the atmospheric MPs in the traffic intersections, deposition rate

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of microplastics (MPs), and characterization of the deposited microplastics using fluorescence microscopy and Fourier Transform Infrared spectroscopy (FTIR).

II. Methodology

Sampling Sites

For collecting the deposition of microplastics, we selected fifteen traffic intersections in Dhaka city, Bangladesh (Fig. 1). The locations were chosen in a way so that the sites are spread out well and cover the densely populated part as much as possible. The sampling was carried out from July to August 2022 for 15 consecutive days. Site description has given in Table-1.

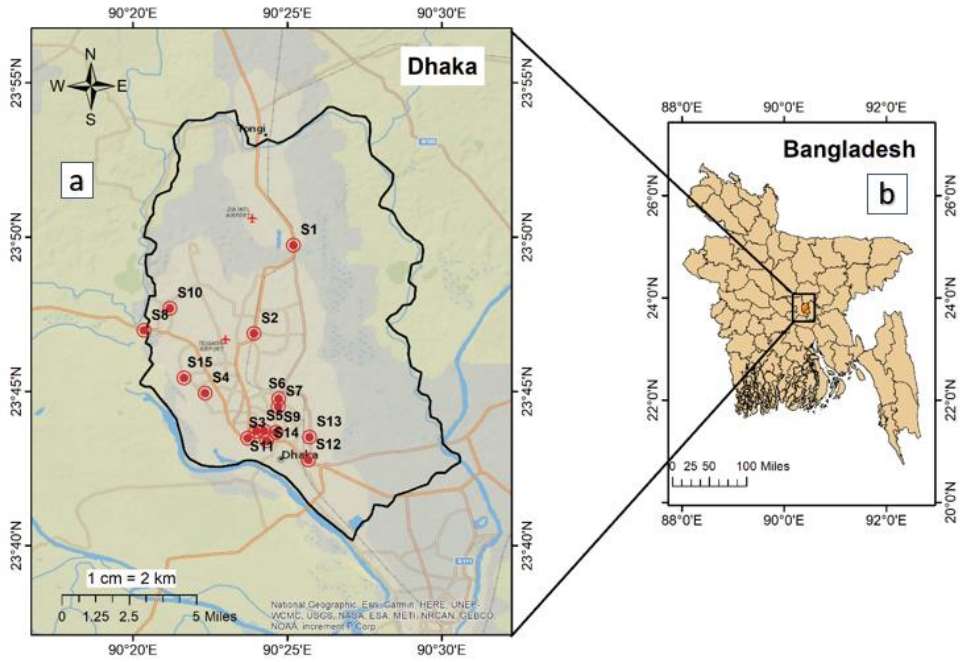

Fig 1.a. The sampling sites at the traffic intersectionsin Dhaka city; b. Map of Bangladesh (Source: Google)

Table 1. Locations and characteristics of the sampling sites at different traffic intersections in Dhaka

Sample No.	Locations	Latitude, Longitude	Height from the Ground (ft)	Buildings and Shops (appr. 50 ft away)
S-01	Khilkhet Bus Stop	23°49'43.8"N 90°25'12.2"E	6.0	No
S-02	Amtoli Mohakhali	23°46'51.8"N 90°23'55.5"E	7.5	Yes
S-03	Bakshi Bazar Corner, BUET	23°43'28.2"N 90°23'43.7"E	4.0	Yes
S-04	Dhanmondi -12	23°44'56.0"N 90°22'20.6"E	6.0	Yes
S-05	Old High Court Corner	23°43'42.2"N 90°24'15.2"E	4.0	No
S-06	Malibag	23°44'44.7"N 90°24'43.7"E	4.0	Yes
S-07	Shantinagar	23°44'29.6"N 90°24'42.9"E	4.0	Yes
S-08	Gabtoli	23°46'58.0"N 90°20'22.1"E	3.0	Yes
S-09	Gulshan	23°43'39.5"N 90°24'38.3"E	4.5	Yes
S-10	Mirpur -1	23°47'40.8"N 90°21'12.4"E	4.0	Yes
S-11	Doel Chattor, Dhaka University	23°43'41.8"N 90°23'59.9"E	7.0	No
S-12	Sayedabad	23°42'46.0"N 90°25'41.4"E	5.0	No
S-13	TT Para Bus Stop	23°43'30.4"N 90°25'43.3"E	7.0	No
S-14	Banga Bazar, Gulistan	23°43'23.2"N 90°24'20.0"E	7.0	No
S-15	Mohammadpur Bus Stop	23°45'25.6"N 90°21'39.7"E	6.0	Yes

Sampling Procedure

The deposited dusts were collected in a glass petri dish of 100 mm diameter. The dishes were cleaned and rinsed with distilled deionized (DI) water. The dishes were then dried in an electric oven (JP Selecta, DIGITHEAT, Spain). To collect samples, the petri dishes were placed face-up at about 5 ft height from the ground in the open environment having rain protection at each location. The lid was kept away in aluminum foil over the sampling duration. After fifteen days of sampling, the lid was put back on and the dishes were covered again using aluminum foil. Necessary precautions were taken during the transportation of the samples.

Sample Extraction

The samples were extracted using the vacuum filtration process. The samples consisted of deposited dust, MPs, and particles. The deposited dusts were extracted from the Petri dishes using distilled water. A glass rod was used to gently scrub the glass wall for the removal of particles stucked to the glass. The washings were filtered using quartz fiber filter papers of pore size 0.4 micron and diameter of 75 mm (Pall Life Sciences, 2500 QATUP, Germany). A Büchner funnel attached to a vacuum pump was used for this process. The dishes were washed multiple times to ensure the complete removal of particles. Then the filter papers were driedin an electric oven. After drying the samples were ready for analysis. MPs were selected as representatives from several samples in the instance of polymer characterization in order to determine the composition of the polymer based on their appearance. A tweezer was used to move the particles, and an Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectrophotometer (IR Prestige-21, Shimadzu, Japan) was used to capture FTIR spectra. In absorbance mode, the infrared signal was recorded between 4000 and 600 cm^{-1}. In order to determine the polymer material, the spectra of microplastics were also compared with the library and the suggestion was obtained by the Spectra Gryph software[26].

Visual Observation with Stereomicroscope

The Euromex Holland, NZ.1902P stereomicroscope, equipped with a 10-megapixel camera (CMEX-10PRO), was used to observe the particles on the filter papers. The particles were subjected to analysis at 15x magnification. Each filter paper was observed in 20 distinct regions of the filter paper (8.35×6.40 mm^2) chosen randomly to detect microplastics (MPs). The deposition rates of MPs for each location, D_r ($\times 10^3$ MPs/m^2/day) were calculated using the following formula[27]:

$$D_r = n \times \frac{A_f}{A_o \times A_p} \times 10^3 \times \frac{1}{d} \quad (1)$$

Here, "n" represents the quantity of MP particles within the observed area (A_o) of the filter paper, "d" signifies the sampling duration in days, and "A_f" and "A_p" denote the dimensions of the filter paper and petri dish areas in mm^2, respectively.

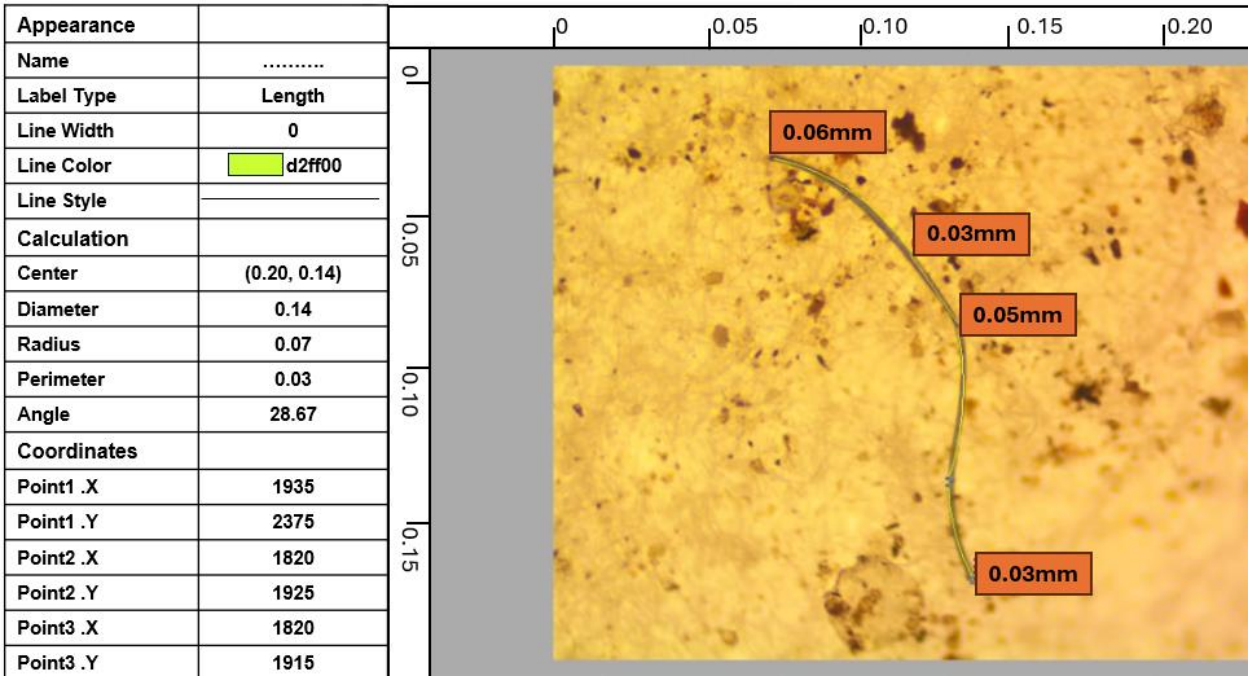

Fig 2. Typical image with scaling by the Euromex Holland, NZ.1902P stereomicroscope.

Quality assurance

Carefully minimizing cross-contamination, plastic materials were replaced with glass equipment that was thoroughly washed with DI water before each analysis. Glassware remained covered using aluminum foil when not in use. Work surfaces were cleansed using an ethanol solution, and efforts were made to reduce airflow by keeping ventilators, windows, and air-conditioning closed[28]. For handling samples, Petri dishes were enveloped in aluminum foil and then transported. Quartz fiber filters were stored likewise and exposed only during analysis.

III. Results and Discussion

Observation of MPs Under Fluorescence Microscope:

The deposited MPs were predominantly microfibers, with relatively few fragments. Although there were many textile microfibers among the fibers, semi-transparent and intense red colored filaments and fragments were prominent (Fig. 3). An innumerable number of filaments and fragments are generated from large plastic material degradation like household plasticware waste, decanted bottle and landfill. Most of the MPs were of three colors- black, red, and blue. Green and yellow fibers were also observed. Microplastic fibers measured and were found to be in the range of 1 to 1000 μm. Two blanks contained 3 and 7 MPs which is negligible compared to actual samples.

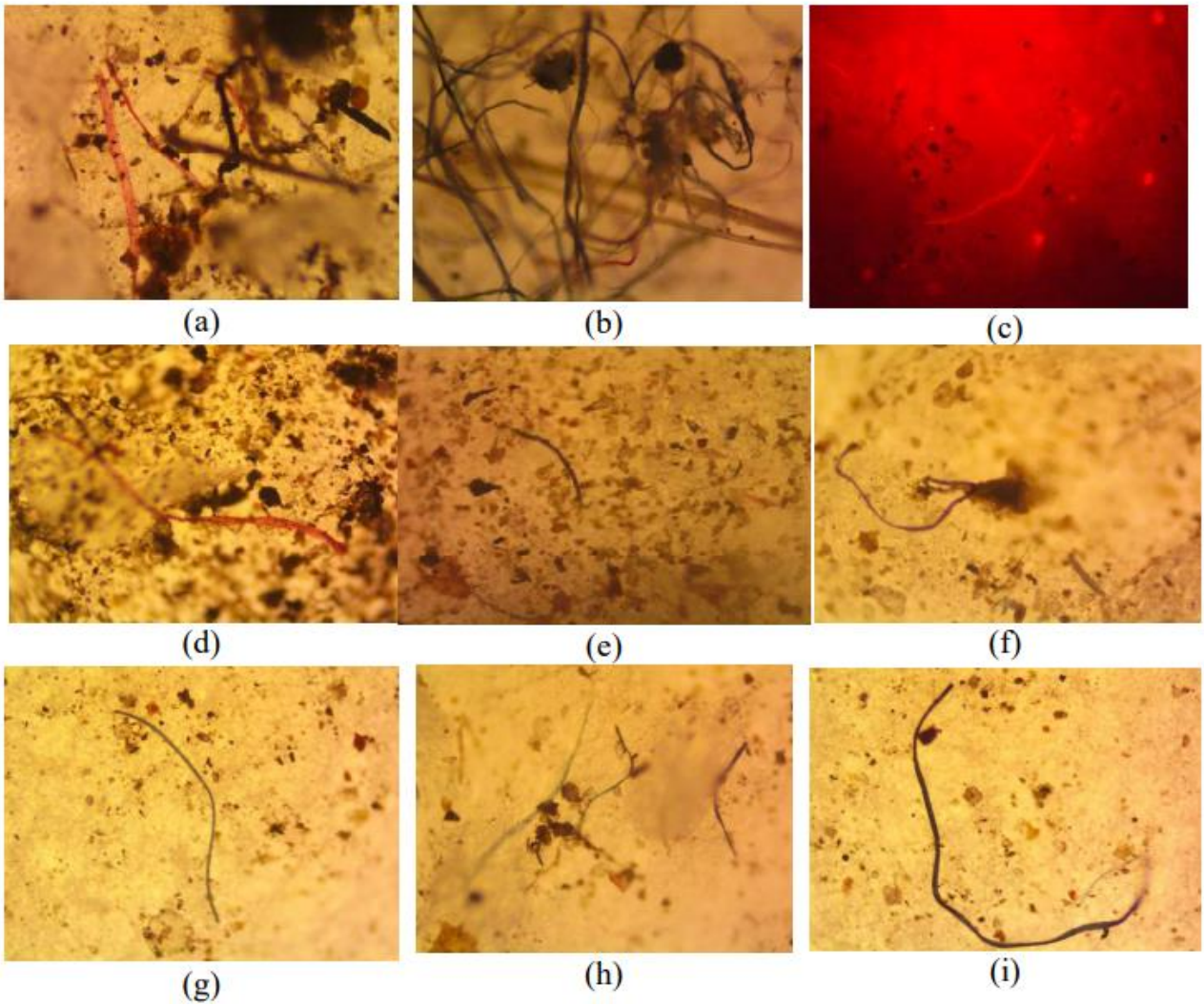

Fig 3. Observation of microplastics under fluorescence microscope: (a) Filaments and fibers, (b) Agglomeration of fibers (natural and synthetic fibers), (c) Fluorescence activity of microplastic, (d) Red Colored MP fiber, (e) Black fiber, (f) Fiber attached with organic substance, (g) Green fiber, (h) Fibers attached with sand particles, and (i) large fiber (black).

Deposition rates of MPs

The deposition rates of microplastics were estimated in the range of 1.11×10^6-5.78×10^6 MPs/m^2/day. The average value of the deposition rate was 3.43×10^6 MPs/m^2/day. The lowest deposition rate was found in Khilkhet Bus Stop which belonged to low crowd area. No buildings and shops were observed within the 50 ft distance of this site. The region with the least amount of crowding, Khilkhet Bus Stop, had the lowest deposition rate. Within 50 feet of this location, there were no visible buildings or stores. In contrast, the greatest one is recorded in Shantinagar, an area encircled by restaurants and residential structures following to high number of vehicles. Furthermore, abrasive emissions from moving cars may be a special source of microplastic contamination in roadside dust[29].

Although there is no safe limit for MPs yet, the obtained deposition rate is considerably higher than similar studies conducted in other countries. For example, deposition rates in the range of 4.8×10^6 to 14.4×10^6 MPs/m^2/day was found in intercity bus terminal, Sakarya, Turkey[30]. In Humber region of U.K., average deposition rate was $3.617x10^6$ MP/m^2 /day in the roadside dust[31].

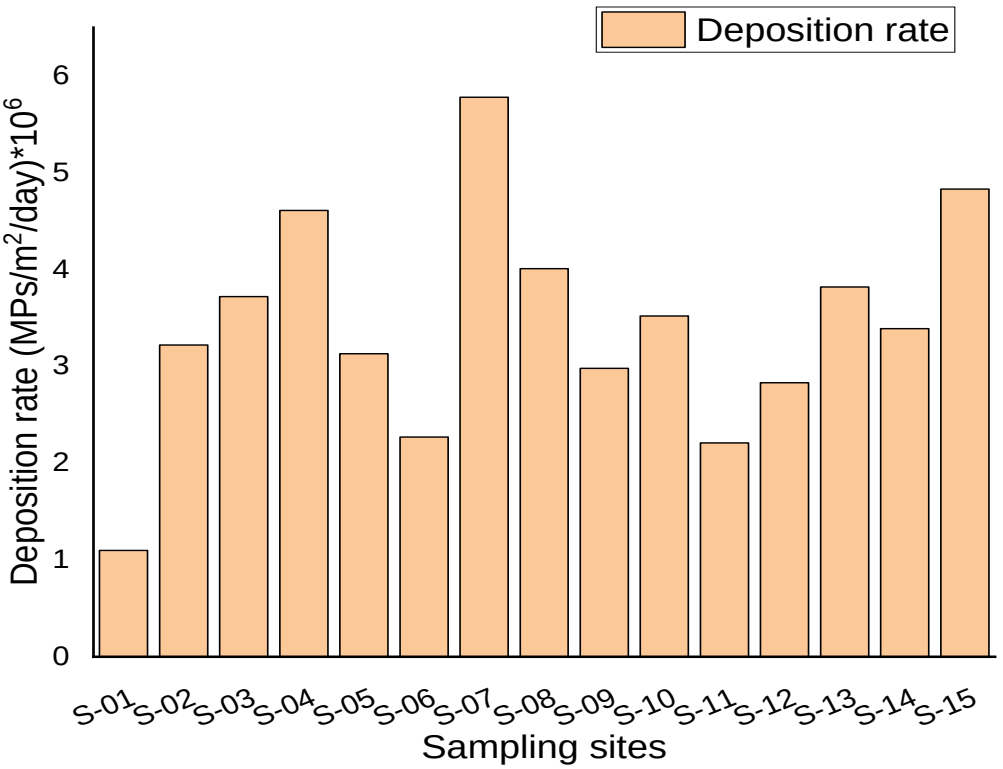

Fig. 4. Deposition rate of the microplastic samples in the collected fifteen traffic intersections in Dhaka city.

ATR FTIR -Polymer Type Analysis

The FTIR spectra of the different MPs and possible bond vibration are given below (Fig. 5 and Table 2). The IR spectra of microplastics may not be sufficient to provide a conclusive result due to degradation, the small size of microplastics, and the presence of fillers. However, IR spectra information combined with other analyses may be useful for characterization. Alternatively, a micro-FTIR may be more appropriate for detecting polymer composition. The IR signal was acquired in absorbance mode in the range 4000 - 600 cm^{-1}. In order to determine the polymer material, the spectra of microplastics were also compared with the library and the suggestion was obtained by the Spectra Gryph software[26]. The identified polymers are Polyethylene (PE), Nylon-6 and natural polymers (cellulose and rubber). The polymers undergo contamination and degradation, as well as frequent mixing with various additives, which may change their physical characteristics[32]. As a result, the spectra may differ and shift from the uncontaminated polymer's considerably[33].

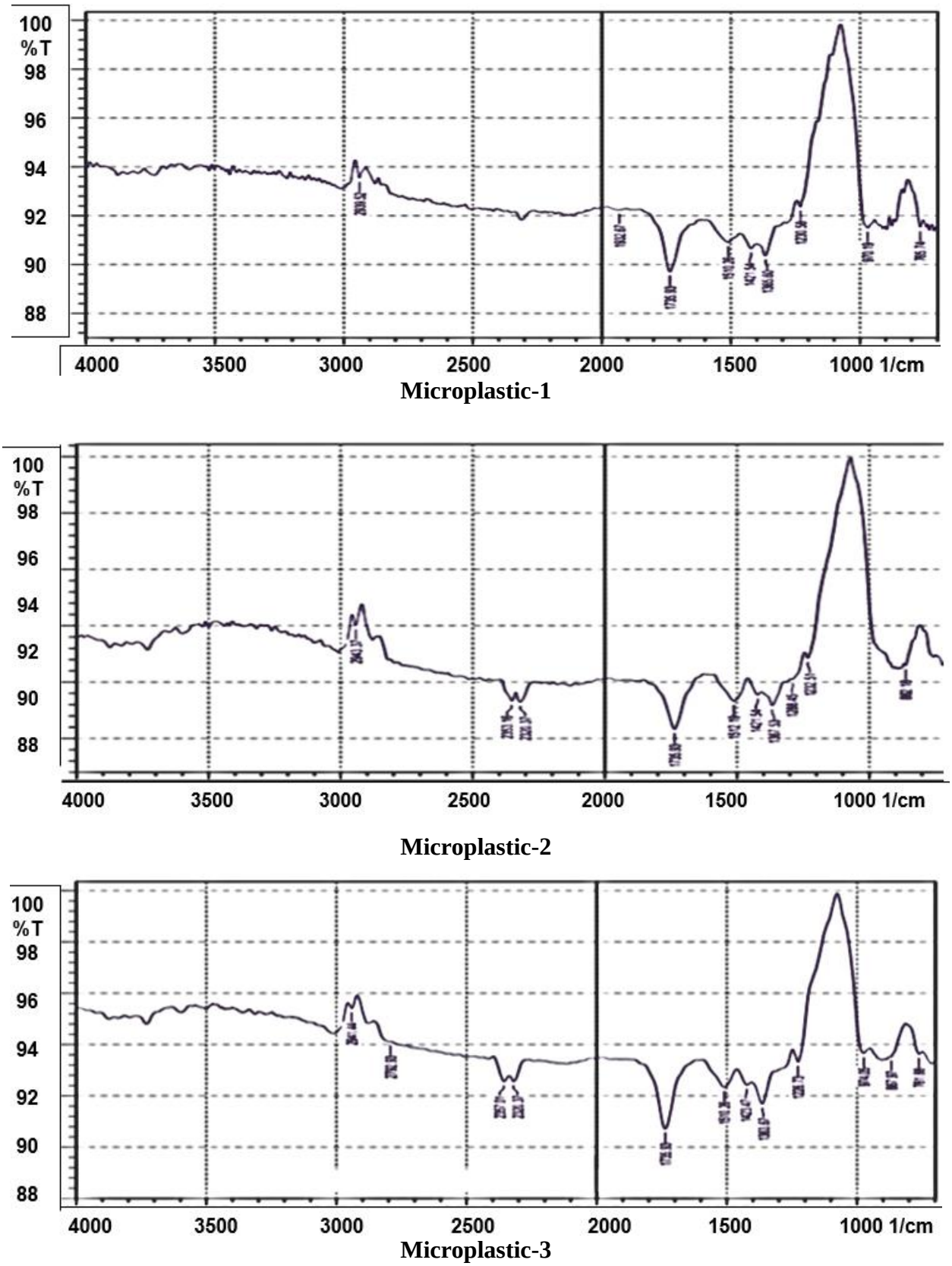

Fig. 5. Spectra of microplastics with probable band assignments.

Table 2. Band assignment for the spectrum of microplastic-1, 2 and 3

Microplastic-1		Microplastic-2		Microplastic-3	
Wavenumber (1/cm)	**Tentative Band Assignment**	**Wavenumber (1/cm)**	**Tentative Band Assignment**	**Wavenumber (1/cm)**	**Tentative Band Assignment**
2939	sp^2 C-H	2943	sp^2 C-H	2941	sp^2 C-H
1735	C=O	2353, 2320	O=C=O	2357, 2320	O=C=O
1510	N-O	1735	C=O	1735	C=O
1421, 1365	C-H bending	1512	N-O		
970	C=C bending	862	C=C		

Conclusion

The purpose of this study was to find out the presence of microplastic from the deposited dust in traffic intersections using a fluorescence microscope and characterize the microplastics using FTIR analysis in the greater Dhaka city. It was observed that the average deposition rate was 3.43×10^6 MPs/m^2/day, which is quite similar to the deposition rates observed in studies conducted in other locations. The majority of the microplastics discovered were microfibers, principally filament strands and beads. The deposition rates were influenced by air movement, neighboring homes and shops, human activity and traffic. The deposition included polyethylene (PE), nylon-6, and natural fibers (cellulose and rubber). This study successfully identified the presence of microplastics in the traffic intersections. However, additional systematic investigations are necessary to comprehend the complex interplay between airborne microplastic concentration and various environmental factors.

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