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Distribution, Potential Sources, and Health Risk of Microplastics (MPs) in Street Dust during and after COVID-19 Lockdown in Bangladesh

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Abstract: The advent of the COVID-19 era has ushered in significant changes to both the environment and daily life. During the COVID-19 lockdown, a unique opportunity emerged to improve environmental quality and mitigate certain impacts on the planet. The distribution and health risks of microplastics (MPs) in the street dust of Dhaka city, Bangladesh during and after COVID-19 lockdowns were examined in this study. The study covered sites selected based on land usage, including an industrial area (IA), commercial area (CA), public facilities area (PFA), and residential area (RA). The particles in the dust samples were analyzed using a fluorescent microscope and attenuated total reflectance Fourier-transform infrared spectroscopy. The results show that the maximum number of MP particles/g of street dust sample was recorded from industrial areas (17.33 MP particles/g) and the minimum was recorded from residential areas (13.99 MP particles/g) without lockdown. The trends in the MPs were as follows: without lockdown > partial lockdown > complete lockdown. Risk analysis showed that the MPs in dust pose low non-carcinogenic risk to inhabitants of the study area and across lockdown periods. Principal component analysis showed that during the partial lockdown period, comparable sources were detected for the cellulose/low-density polyethylene (LDPE)/high-density polyethylene (HDPE), polychloroprene (PCP)/polyethylene terephthalate (PET)/polypropylene (PP)/polyacrylamide (PAA)/nylon, and polyethylene (PE)/polydimethylsiloxane (PDMS)/polyvinyl alcohol (PVA)/fiber groups of MPs, but various sources were discovered during the complete and without lockdown periods. The results further showed that all MP types would pose no non-carcinogenic or carcinogenic risks in dust from all land-use areas. However, the highest risks were obtained from inhaling dust. The study shows that human activities have a significant impact on the generation and distribution of MPs in the environment. The changes in MP type distribution during lockdown suggest that reducing human activities, such as traffic and industrial activity, can lead to a decrease in the quantity of MPs generated and released into the environment.

Keywords: street dust; MPs; urban-land-use category; lockdown; source identification; carcinogenic; Dhaka

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1. Introduction

Bangladesh is the most polluted country, and the second most polluted city is Dhaka, as reported in the 2019 Global Air Quality Report [1]. Furthermore, the city has the poorest air quality according to the air quality index (AQI); the Department of the Environment (DoE) recently issued a public warning on air pollution [1]. According to the DoE notice, automobiles, the burning of biomass, traditional brick kilns located inside and surrounding the city, street dust, soil dust, and particulate matter are the main contributors to air pollution in Dhaka. The negative effects of air pollution in Bangladesh are severe and provide a substantial risk to the ecology, human health, and economic development [2]. It is an effect of civilizational advancement and the price of advancement [3]. Brick kilns, dust from streets and building sites, defective automobiles (notably diesel-powered ones), and harmful emissions from industry are the main causes of air pollution in the nation [4].

In recent years, street dust has become a significant source of air pollution, which has caused grave worries for the atmosphere. It has dangerous elements, such heavy metals, polycyclic aromatic hydrocarbons (PAHs), microplastics, and others, that come from a variety of sources, such as traffic, home and commercial emissions, and plant debris. The likelihood that airborne dust particles would harm human health directly correlates with their size, with smaller particles posing the highest dangers [5]. These particles can be as small as 1 μm and thus enter the circulation through the lower respiratory tract, endangering internal organs and resulting in cardiovascular problems. Additionally, microplastics in street dust have a higher adsorption rate due to their larger specific area, which is typically associated with smaller particle size. This means that high concentrations of microplastics are found in smaller particles, such as those adhering to children's hands or retained by the skin [6]. Street dust containing plastics particles ($\geq$700 nm) can enter the respiratory system, circulate in the bloodstream [7], and attach to proteins or become ionized in different organs and cells, causing a range of diseases [8]. Microplastics further act as carriers of chemicals and pollutants and can be found in air, soil, and water, posing a threat to both the environment and human health [9]. The increasing population, associated motorization, and industrial emissions in Bangladesh have led to high concentrations of these pollutants, making them a serious environmental health hazard that affects the population.

The SARS-CoV-2 virus generated the COVID-19 pandemic, which has led to worldwide disease transmission. Originating in Wuhan City, China in December 2019, the outbreak quickly spread globally, leading many countries to adopt non-therapeutic measures, such as travel bans, remote work, and social distancing, to prevent further transmission [10]. In Bangladesh, the first COVID-19 case was reported on 7 March 2020, and a nationwide lockdown was implemented from 26 March to 30 May 2020. Subsequent partial and complete lockdowns were enforced from 5 to 11 April 2021, and 14 to 28 April 2021, respectively. It is expected that such measures would lead to improved air quality due to reduced emissions of anthropogenic particles [11]. During the partial lockdown, public transport was limited to 50% capacity, inter-district vehicular movement was restricted, educational and government institutions operated at 50% capacity, and gatherings were prohibited. Complete lockdown measures included the closure of all transport services, government and private offices, factories, and industries, and a ban on unnecessary movement and gatherings.

In a number of environments, it is acknowledged that human activity is the primary source of environmental pollution [12]. Natural resources have been depleted globally due to the excessive rate of urbanization and industrialization, leaving little time to plan for their repair [13]. A crucial part of the COVID-19 shutdown has been identified as natural repair as per various studies [14,15]. Since the COVID-19 shutdown, which almost eliminated industrial activity and vehicle travel in several nations, there has been a significant reduction in air and water pollution globally [16]. Studies on the consequences of COVID-19 lockdowns have been conducted all over the world [11,17–19], but none of them have attempted to examine the prevalence of microplastics in street dust in Dhaka, Bangladesh, during partial and complete lockdown, as well as post-lockdown. In light of the foregoing discussion, the current study was carried out with the following objectives of assessing the distribution of microplastics in street dust during partial and complete lockdown, as well as after lockdown, in Dhaka city and to determine possible sources and human health risk of microplastics in street dust during partial and complete lockdown, as well as after lockdown, in Dhaka city.

2. Materials and Methods

2.1. Sampling Site

The study focused on collecting dust samples from various streets within the bustling Dhaka metropolitan area, the capital and largest city of the country. With an extensive urban sprawl covering over 1500 km^2, Dhaka is home to a massive population of approximately 20 million people. The population of the city is increasing at a rate of 7% per year, which has caused an increase in the quantity of automobiles, industries, and severe air pollution [20,21]. Two-stroke auto-rickshaws, aged trucks, and mini-buses are major contributors to air pollution, and heavy and light industries, such as textile, glass, ceramic, battery, pharmaceutical, metallurgical, and leather processing, also contribute to the problem [22,23]. The ecosystem of Dhaka city is severely harmed because of human activity, which greatly contributes to the development of large amounts of garbage, effluents, and air pollutants. [22]. According to the Dhaka Urban Transport Network Development report, Dhaka city is predominantly comprised of various land-usage categories. Residential areas constitute the largest portion, accounting for 44.35% of the city's land. Commercial areas cover 4.29%, while industrial areas occupy 2.01% of the city. Public facilities areas encompass 7.97%, followed by urban green areas at 1.20%. Roads and railways make up 10.46% of the city, and restricted areas represent 8.42% of the overall land usage in Dhaka. (source: https://openjicareport.jica.go.jp/pdf/11996782_03.pdf, accessed on 5 May 2023). Figure 1 illustrates the specific sampling locations within the region.

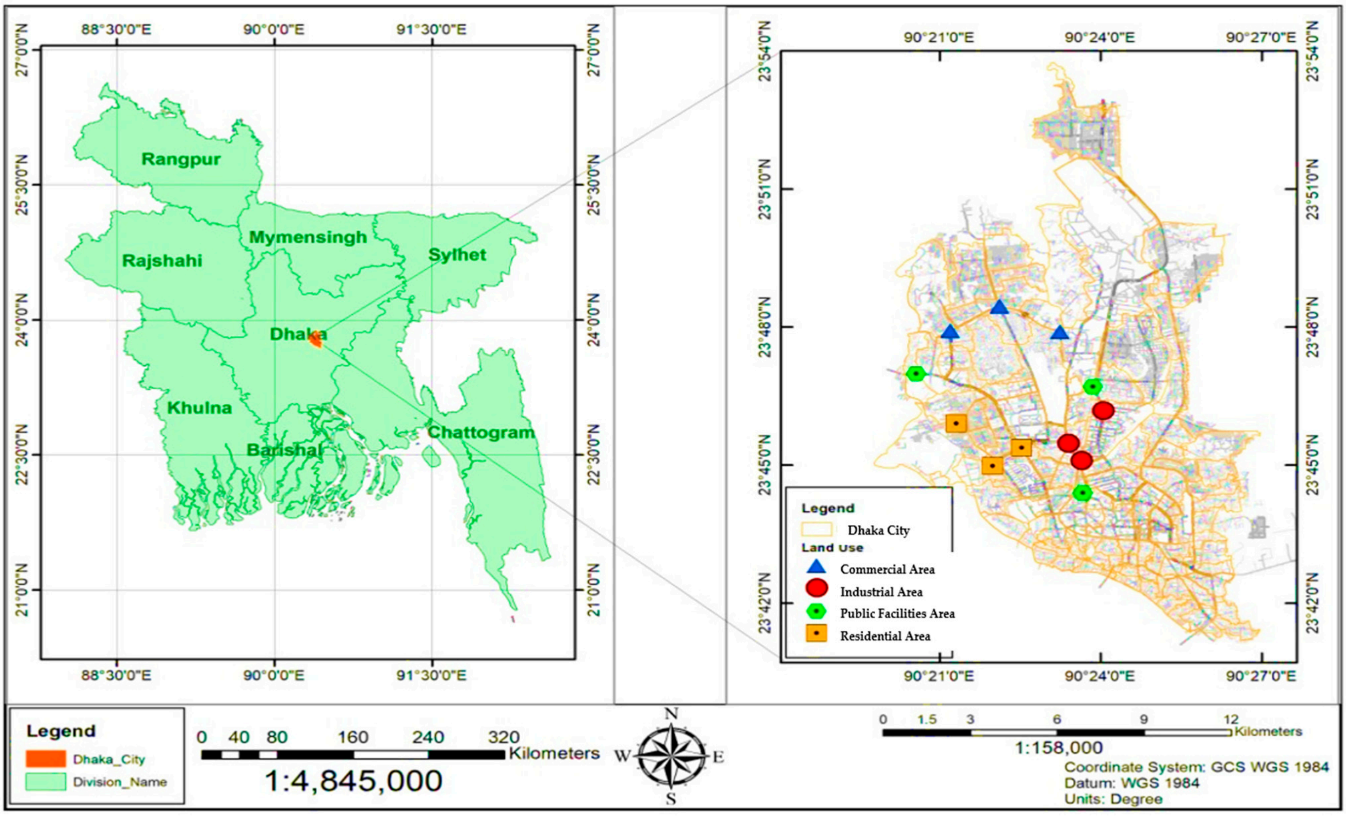


Figure 1. A map of Bangladesh showing the research site's location (the red-marked region on the map is the metropolitan area of Dhaka City), along with four sites for sampling various land-use categories [9]. Blue = commercial area; red = industrial area; green = public facility area; and yellow = residential area.

2.2. Sample Collection and Processing

Based on their importance, which included elements like population density, transportation volume, and surrounds, sample locations were chosen. A pre-cleaned metal dustpan and wooden brushes were utilized under partial, complete, and post-lockdown circumstances to gather street dust samples. In this study, a meticulous approach was used to collect soil samples. A wooden brush was skillfully employed to sweep the soil surface into a dustpan, ensuring a clean and uncontaminated collection process. Subsequently, the collected sample was transferred to a sterile Ziploc bag for transportation to Japan, where the study was conducted. Prior studies confirmed the reliability of using Ziploc bags for sample preservation without any risk of contamination [24,25]. Sampling for partial, complete, and after lockdowns circumstances took place between 5 and 11 April 2021, 14 to 28 April 2021, and 21 to 22 December 2021, respectively, when the average temperature was 33 °C for April and 26 °C for December, with no precipitation or rainfall (https://weather-and-climate.com/Dhaka-April-averages; https://weather-and-climate.com/Dhaka-december-averages, assessed 17 July 2023). The study covered sites selected based on land usage, including an industrial area (IA), commercial area (CA), public facilities area (PFA), and residential area (RA). A 1 m^2 area that includes impermeable surfaces, including roadways, pavements, and gutters, had around 500 g of street dust randomly swept off it [26]. A composite representative sample was created by thoroughly combining four sub-dust samples [27]. A total of 144 street dust samples were taken from 12 different locations around the metropolitan area of Dhaka during partial, complete, and after lockdown periods. Extraneous trash, including cigarette buds, stones, scrap plastic, and deconstructed construction detritus, was collected and removed from the sample location before sampling. A vibrating sieve shaker (AS 200-digit Retsch AS200) was used to sort the samples into various particle sizes, after they had been placed in sealed glass bottles with the proper labelling.

2.3. Sample Pretreatment Procedure for Microplastics Analysis in Street Dust

The dust samples that were sieved using a vibratory sieve shaker were then dried for 24 h in a drying oven at 70 °C. After drying, 1 g aliquots of the samples with a particle size between 150 and 250 µm were taken, and each sample was replicated three times. To oxidize the organic matter present in the samples, hydrogen peroxide (H_2O_2, 35%) was used. After oxidation, the samples were sieved through a mesh filter with a pore size of 100 µm. The sieved samples were then mixed with a NaCl solution (density: 1.2 g/cm^3) and allowed to stand for 2 h to undergo density separation. The supernatant obtained after the separation was decanted into a cleaned beaker, and this process was repeated thrice. The samples that were separated based on their density were then filtered using a track-etched polycarbonate filter (47 mm Diameter, 5 µm Pore Size) and left to dry in a desiccator for 24 h [28]. A fluorescence microscope (MX6300, Meiji Techno Co., Tokyo, Japan) was used to visually inspect the residues on the filter sheets. Pixera IN studio software Ver.3.5.2 was used to further analyze the fluorescence microscope's picture for form and size (Figure 2).

All detected and counted particles were divided into other particles and microplastics, and those that were thought to be polymers were examined using an ATR-FTIR (attenuated total reflectance with Fourier-transform infrared spectroscopy) system (JASCO FTIR-6100) for functional groups to categorize the MPs as polymers [29]. To avoid airborne contamination, particle extraction and all testing were conducted in a laminar flow chamber. For the duration of the investigation, a lab coat made entirely of cotton was worn. All materials used to treat the samples were cleaned in filtered ultrapure water (Direct Q-3UV, Merck-KGaA, Darmstadt, Germany) before use. Throughout the trial, 70% ethanol was used to clean all laboratory workbenches and surfaces. Samples that were not being processed (extraction and characterization) were covered with aluminum foil. As contamination controls, water used for particle extraction (procedural blank) and water left open in the lab during extraction (air blank) were both used. These controls and the samples were examined.

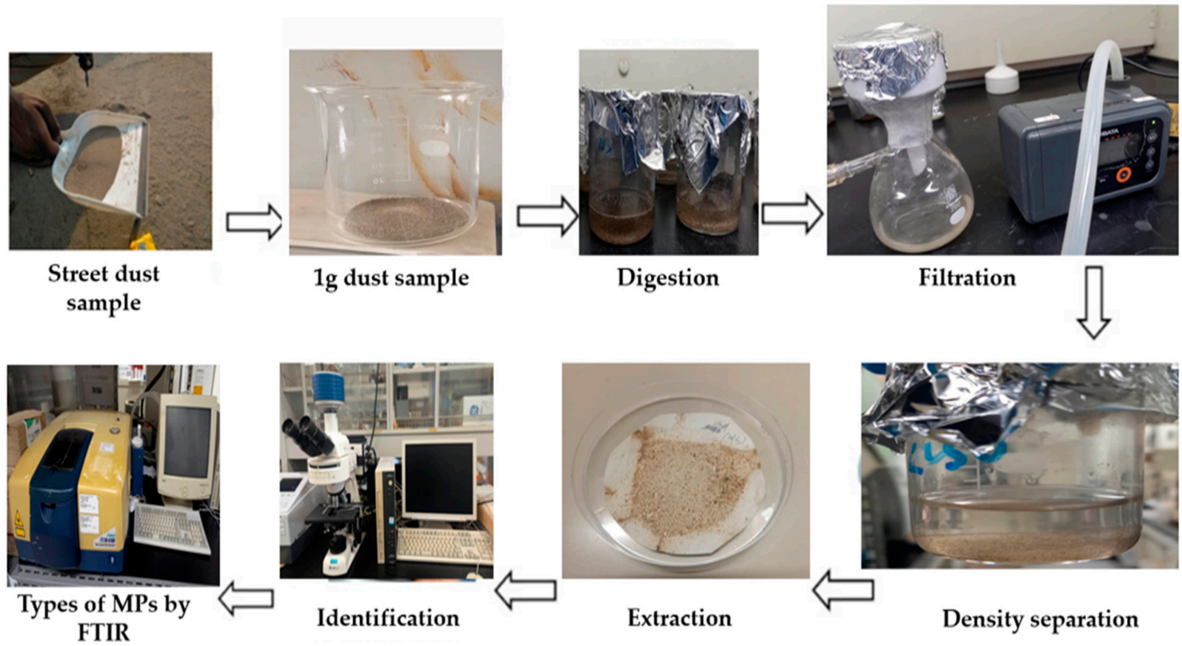


Figure 2. Sample pretreatment procedure of MPs in street dust.

2.4. Health Risk Assessment

2.4.1. Non-Carcinogenic Risk Estimation

According to the preceding description, the MP polymeric risk indices for street dust samples were determined [12,29,30]. The equations for computing the polymer risks indices (pRi) for the samples and the index (pRarea) for the study area are provided by Formulae (1) and (2).

According to Lithner et al. [31], the hazard values provided based on the toxicity levels of the detected MP polymers in the samples were used to calculate the chemical toxicity coefficient or risk scores (*Sj*). The hazard scores for the polymers found in the street dust samples were Polypropylene (PP) = 1, polyethylene (PE) = 11, polyethylene terephthalate (PET) = 4, polystyrene (PS) = 30, high-density polyethylene (HDPE) = 11, nylon = 47, polyamide (PA) = 50, polyoxymethylene (POM) = 871, polyvinyl alcohol (PVA) = 1, poly acrylamide (PAA) = 230, and low-density polyethylene (LDPE) = 211; polychloroprene (PCP), polydimethylsiloxane (PDMS), fiber, and cellulose were not accessible and were taken out of the computations. The number of each unique MP polymer identified in sample 1 is represented by *pRi*, whilst the nth root of the polymer risks indices products is represented by *pRarea*. *Pi* and *Pt* represent the individual and total plastic polymers, respectively.

$$pR_i = \sum (P_i / P_t \times S_j) \tag{1}$$

$$pR_{area} = (pR_1 \times pR_2 \times pR_3 \times \ldots\ldots\ldots\ldots \times pR_n)^{1/n} \tag{2}$$

2.4.2. Carcinogenic Risk Estimation

The *LADD* is the lifetime average daily dosage (items/g/day) as specified below [32–34]:

$$LADD_{ingestion} = C \times \frac{EF}{AT} \times \left(\frac{IngR_{child} \times ED_{child}}{BW_{child}} + \frac{IngR_{adult} \times ED_{adult}}{BW_{adult}} \right) \times 10^{-6} \tag{3}$$

$$LADD_{inhalation} = C \times \frac{EF}{AT \times PEF} \times \left(\frac{InhR_{child} \times ED_{child}}{BW_{child}} + \frac{InhR_{adult} \times ED_{adult}}{BW_{adult}} \right) \tag{4}$$

By combining the carcinogenic risk (*CR)* associated with ingestion ($CR_{ingestion}$) and inhalation ($CR_{inhalation}$), the cumulative carcinogenic risk (*CCR*) associated with exposure to harmful components in street dust was calculated. In this study, the potential carcinogenic risks of PE, PET, PP, PA, PAA, HDPE, and LDPE polymers were investigated. Based on established slope factors, it is thought that ingestion and inhalation absorption are the main exposure routes to these hazardous components.

$$CR_{ingestion} = LADD_{ingestion} \times CSF_{ingestion} \tag{5}$$

$$CR_{inhalation} = LADD_{inhalation} \times CSF_{inhalation} \tag{6}$$

$$CCR = \sum CR = CR_{ingestion} + CR_{inhalation} \tag{7}$$

where $CSF_{ingestion}$ and $CSF_{inhalation}$ are the cancer slope factors (items/g/day) associated with hazardous polymers ingested and inhaled, respectively. The *CSFs* were PE = PET= HDPE = LDPE= 1.02, PA = 4.5, and PP = 0.24 [35] (Table 1).

Table 1. The factors used to determine the MPs' daily average intake and health risk assessment for street dust.

Factor	Definition	Unit	Value of Children	Value of Adult	Reference
C	Number of MP polymer	items/g	C	C	This study
ED	Exposure duration	y	6	30	[36]
EF	Exposure frequency	d/y	180	180	[36]
BW	Average body weight	g	16,200	61,800	[37]
$AT_{non\text{-}cancer}$	Average time	d	ED × 365	ED × 365	[36]
AT_{cancer}	Average time	d	LT × 365	LT × 365	[36]
LT	Average lifetime	y	76	76	[37]
IngR	Ingestion rate	g/d	0.2	0.1	[38]
InhR	Inhalation rate	m^3/d	7.6	20	[39]
PEF	Particle emission factor	m^3/g	1.36×10^6	1.36×10^6	[38]

2.5. Statistical Analysis

Microsoft Excel 2016 was used to conduct descriptive statistics. Software packages Origin Lab Pro 8 and SPSS version 23 were used to analyze the data. The frequency test and q-q graphs were used to examine the data for the normality and uniformity of variations. Given that the data met the requirements for ANOVA, parametric tests were selected. To identify significant variations ($p < 0.05$) within the data, one-way ANOVA was conducted. To explore potential pollution sources, principal component analysis (PCA) was employed, utilizing varimax rotation and retaining major components with eigenvalues greater than one, following the Kaiser criteria.

3. Results and Discussion

3.1. Distribution of Particles and MPs in Samples

The distribution of particles in street dust samples and the quantity of microplastics are presented in Figure 3, while some photographs of the different MP shapes identified are presented in Figure 4. In all samples during the different lockdown conditions, the dust contained a smaller proportion of MPs, i.e., 47.3%, 42.8%, and 42.1% during without, partial, and complete lockdown periods, respectively (Figure 3a–c), compared to other particles such as glass. In general, the highest number of other particles/g of street dust was found in public facilities areas (19.33 particles/g), followed by industrial, commercial, and residential areas. However, the maximum number of MP particles/g of street dust sample was recorded from industrial areas (17.33 MP particles/g) and the minimum number was recorded from residential area (13.99 MP particles/g) during the without lockdown period

(Figure 3d). In Chennai metropolitan city, India, lower concentrations (2.2 MP particles/g) were reported by Arunkumar et al. [40]. However, higher concentrations were reported in the street dust of Bushehr city, Iran [41]; Da Nang, Vietnam; and Kusatsu, Japan [42].

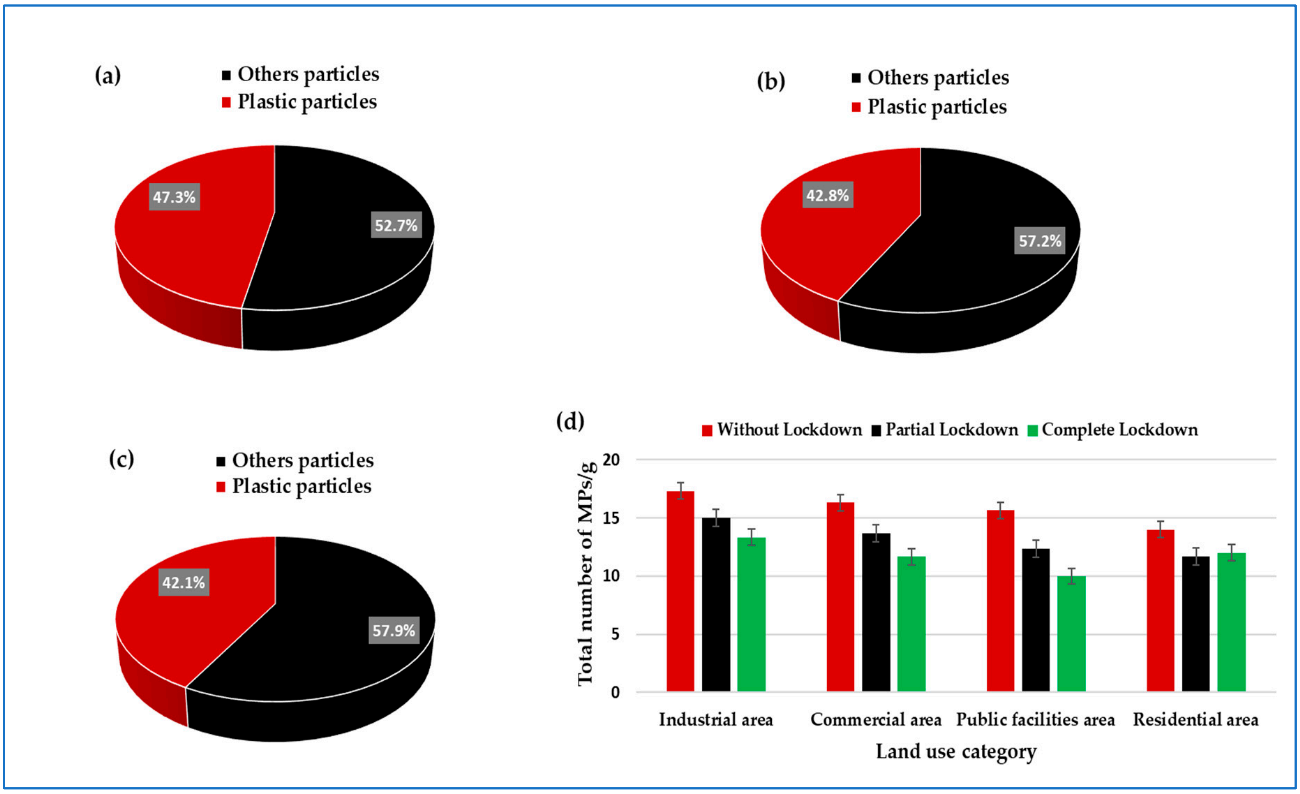
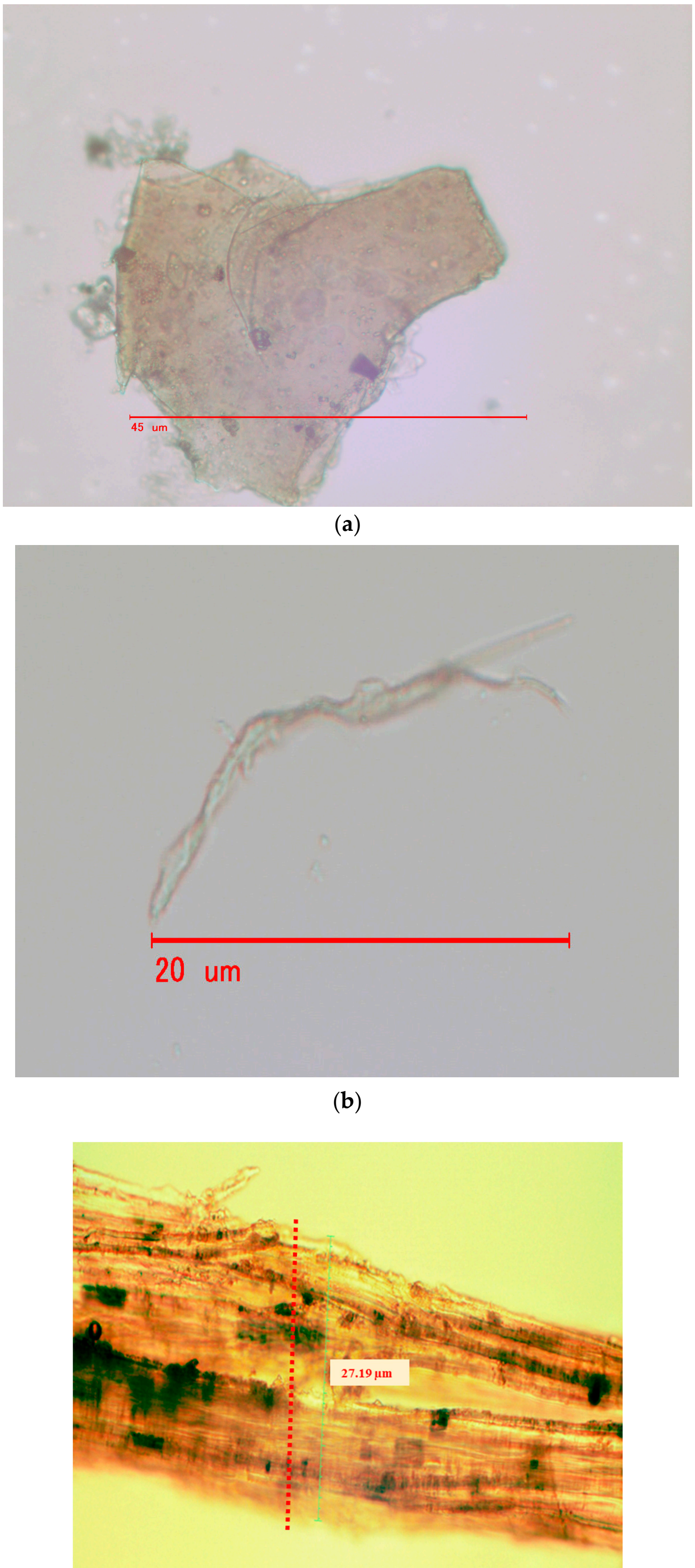


Figure 3. Distribution of other and plastic particles in street dust from different land-use categories during the different lockdown conditions: (**a**) without lockdown, (**b**) partial lockdown, and (**c**) complete lockdown; (**d**) microplastics.

The trend in MPs in one gram of dust was as follows: without lockdown > partial lockdown > complete lockdown (Figure 3d). With complete lockdown measures in place, there was a significant reduction in human activity and vehicular traffic on the streets. This reduction in traffic means that there was less wear and tear on the tires of vehicles, which is a significant source of microplastics in the environment [28]. As a result, there may be a decrease in the amount of microplastics that are released into the air and ultimately deposited onto street surfaces. Furthermore, the reduction in human activity, such as outdoor recreation, also contributed to the reduced quantity of MPs in the dust during complete lockdown.

The shapes of the MPs in the dust samples are presented in Figure 4. Regarding the fragment, the visuals depict a surface that is quite uneven or with sharp edges and crevices, which suggests that it has been separated from a larger piece of plastic material. Concerning the line, the picture displayed a form that resembled a strand or a lengthy and narrow impression or stroke, which is greater in length than in width. On the other hand, the film appeared like a slim sheet [29]. Multiple studies have reported the presence of these shapes in street dust in many world cities [28,41,42].



(a)

(b)

(c)

Figure 4. Shape of MPs in the street dust: (**a**) fragment (**b**) line/fiber (**c**) Film.

3.2. FTIR Analysis for Type Identification of MPs in Street Dust

The FTIR technique is a versatile method of vibrational spectroscopy that can be employed to examine a wide range of polymers. An infrared spectrum serves as a distinctive characteristic of a substance, with absorption peaks corresponding to the frequencies of atomic vibrations within the material. As each polymer consists of a distinct blend of atoms, no two compounds have identical infrared spectra [43]. Using the FTIR technique, plastic samples with unique visual appearances were examined, and the resulting spectra are displayed in Figure 5. The spectra were matched and interpreted using Openspecy software with standard spectrums (for the peak assignment, see Table S1). The similarities in the main peaks and a minimum match of 90% with standard spectrums were taken as a confirmation of the plastic type. The FTIR spectra of MPs from the street dust indicate that the MPs were degraded [44] and included as high-density polyethylene (HDPE), nylon 6, polyacrylamide (PAA), polydimethylsiloxane (PDMS), polypropylene (PP), fiber, cellulose, polyethylene terephthalate (PET), polyvinyl alcohol (PVA), low-density polyethylene (LDPE), polyethylene (PE), and polychloroprene (PCP), during without and partial lockdown conditions (Figure 5a,b). Meanwhile, during complete lockdown, the MPs identified included 10 types, namely cellulose, fiber, PP, PDMS, PCP, PVA, PE, HDPE, LDPE, and polyoxymethylene (POM) (Figure 5c). The reduction in the number of MP types during complete lockdown is attributed to the complete turnoff of human activities within the study area.

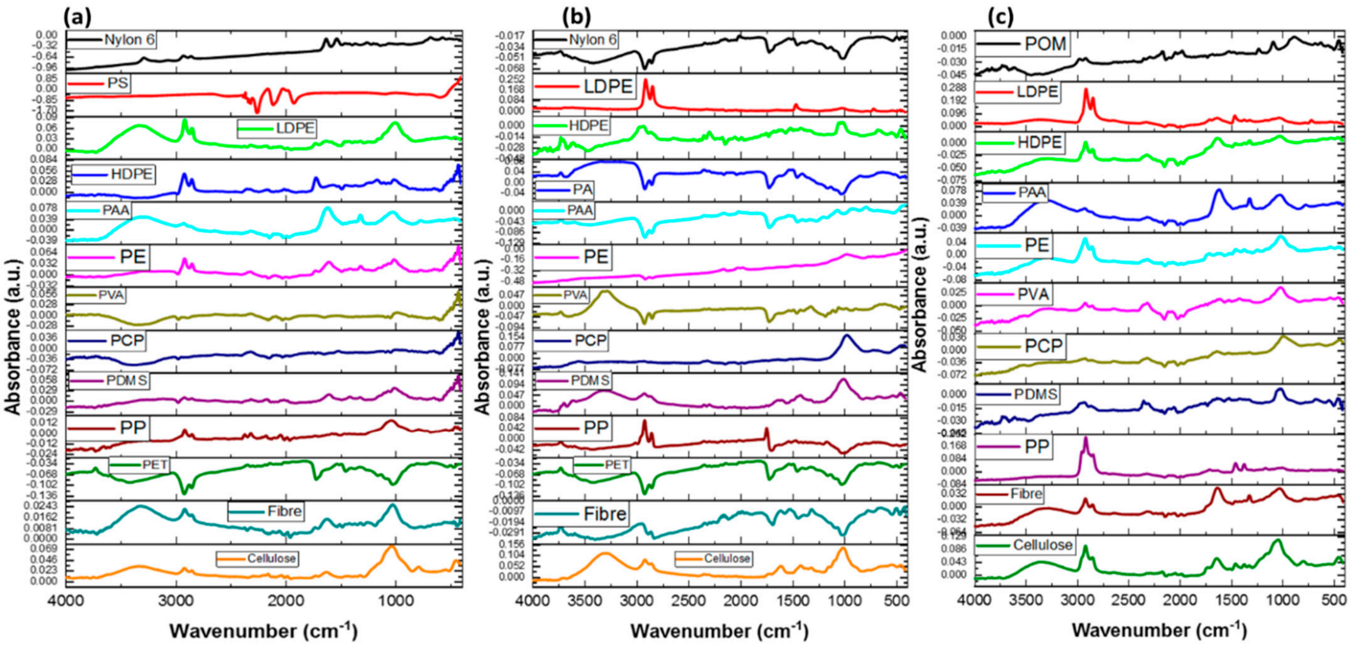


Figure 5. FTIR-ATR spectra of different MP types in dust samples during (**a**) without lockdown, (**b**) partial lockdown, and (**c**) complete lockdown conditions.

In Figure 6, the quantity of MP types in the street dust from different land-use categories during the different lockdown conditions is presented. PET was only identified in public facilities areas (1.33 particles/g) during the without lockdown condition, while it was only present in dust from industrial area (2.33 particles/g) during partial lockdown and was not detected during complete lockdown. Furthermore, during the different lockdown conditions, POM (1 MP/g) and PAA (1 MP/g) were only detected during the complete lockdown at public facilities areas and residential areas, respectively. POM MPs have been found in various environmental samples, such as water, sediment, and fish, collected from the remote Dafeng River in China, according to a study by Liu et al. [45]. These MPs could have originated from sources on land or in the ocean, as stated by Sfriso et al. [46]. The unique properties of this polymer, including excellent mechanical strength, durability, stability, chemical resistance, and insulation, make it a popular material in various industries, such as electronics, automotive, and consumer goods. It is also utilized in medical applications, such as surgical implants, drug-delivery systems, and medical devices, as described in studies by Król-Morkisz et al. [47] and Tang et al. [48].

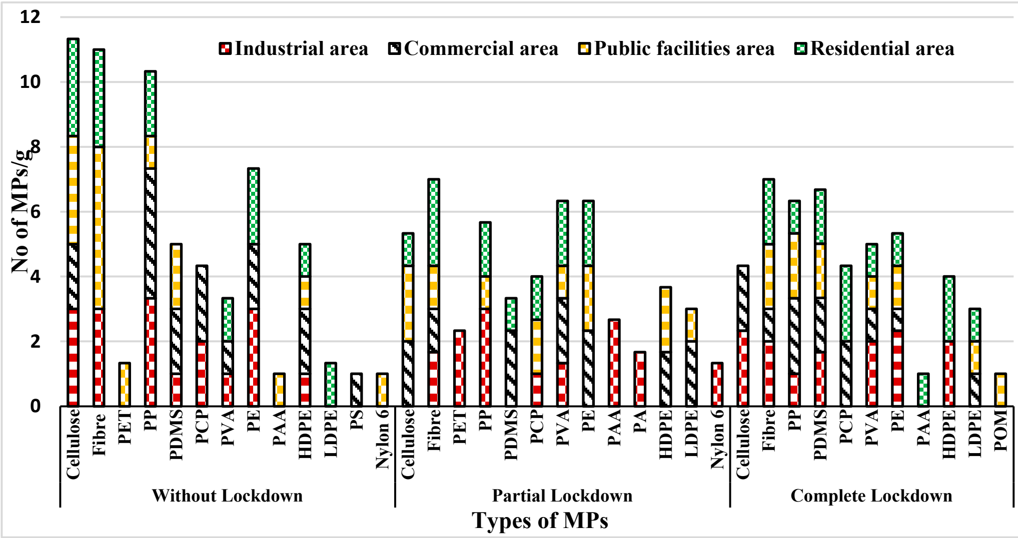


Figure 6. Quantity (mean) of MP types in the street dust from different land-use categories during the different lockdown conditions.

The distribution of the different polymers is presented in Figure S1. During the without lockdown condition, PP was the most abundant in industrial areas (19%) and commercial areas (25%), while fiber (32%) and cellulose (21%) were the most abundant MPs in public facilities and residential areas (Figure S1). This result for industrial areas agrees with [49], who found that polypropylene (PP) was the dominant polymer detected in road dust in an industrial area in Myanmar. During partial lockdown, PP was still the most abundant in the industrial area (20%), while PDMS (17%) was the most abundant in commercial areas. Furthermore, cellulose and fiber were still the most abundant in public facilities and residential areas. However, during complete lockdown, there were some changes in MP type distributions, cellulose (17%), PP (20%), PP/fiber (20%), and PCP (20%) showed the most abundance in industrial, commercial, public facilities, and residential areas, respectively. Geobags made of polyester, which are widely used in Bangladesh, should release microfibers into the air and street dust and could explain the why there are more fibers in the area. However, changes in MP type distributions during lockdown may be due to changes in human behavior, such as reduced traffic and industrial activity, which can affect the types and quantities of MPs that are generated and released into the environment [44]. The fact that different MP types are more prevalent in different areas suggests that different sources of MPs may be responsible for pollution in different areas of the city. The results in this study are similar to that in research conducted in Bushehr city, Iran, where fibers were abundant, constituting 75% of the MPs in street dust samples [50]. Other types of MPs were coming to the street dust from the discharge of plastic items [29].

3.3. Source Appraisal by Principal Component Analysis (PCA) for MPs in Street Dust

To determine the source(s) of microplastics (MPs) found in the dust samples, principal component analysis (PCA) was carried out. PCA is a technique that reduces the dimensions of a data set by using a small number of independent variables, referred to as "principal components", which explain most of the variance in the data [29]. Using an orthogonal transformation approach, the first principal component, which captures the most variation in the original data, is obtained. By limiting subsequent components to be orthogonal to all preceding components, often through eigenvalue decomposition as part of a matrix operation, subsequent components are found. Eigenvectors with the highest eigenvalue (>1) make up the bulk of the data set.

PCA biplot analysis conducted during different lockdown conditions revealed interesting insights into the sources of microplastics (MPs) in dust samples (Figure 7). The extraction of two principal components (PCs) allowed for the visualization of the dispersion of MPs in space and provided a clearer understanding of the different groupings of MPs [51]. During the period without lockdown, the results showed that multiple sources were responsible for the presence of MPs in the dust samples (Figure 7a). This finding is not surprising as MPs can originate from various sources, including plastic waste, synthetic textiles, and personal care products. However, the presence of closely grouped MP types, such as PAA/PET/nylon, fiber/cellulose, PE/PVA, and PCP/PP/HDPE, suggests that these specific groups of MPs may have similar sources. For instance, the PAA/PET/nylon group of MPs could be attributed to the degradation of plastic packaging materials or discarded synthetic textiles made from these materials [44]. The fiber/cellulose group of MPs could be attributed to the wear and tear of natural textile fibers, such as cotton and wool [44], while the PE/PVA group may be related to the degradation of plastic bags and packaging materials. The PCP/PP/HDPE group could be related to the degradation of various plastic products, including bottles, containers, and other single-use plastic items [44].

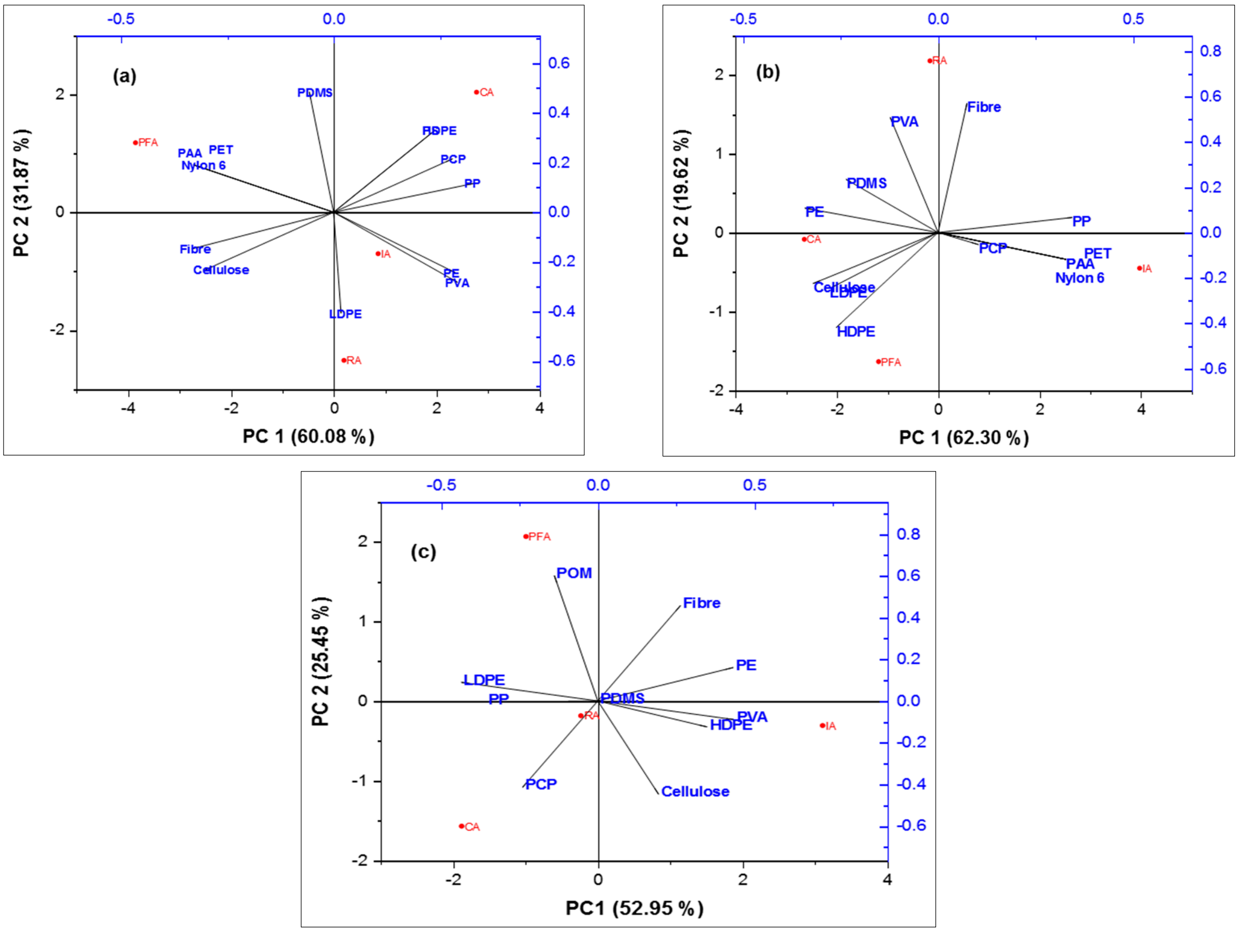


Figure 7. PCA biplot for MPs in dust samples during (**a**) without lockdown, (**b**) partial lockdown, and (**c**) complete lockdown conditions.

The results of the partial lockdown period in PCA biplot analysis (Figure 7b) showed that the cellulose/LDPE/HDPE, PCP/PET/PP/PAA/nylon, and PE/PDMS/PVA/fiber groups of microplastics (MPs) were closely grouped, indicating that they may have similar sources. The cellulose/LDPE/HDPE group of MPs may have originated from the degradation of plastic packaging materials, such as bags and bottles, or from other sources of cellulose fibers, such as paper and cardboard. The PCP/PET/PP/PAA/nylon group of MPs could be attributed to the degradation of plastic products, such as bottles, containers, protective equipment, and other single-use plastic items, as well as discarded synthetic textiles made from these materials. The PE/PDMS/PVA/fiber group may have arisen from a variety of sources, including synthetic textiles, personal care products, and plastic packaging materials.

However, during complete lockdown, the PCA biplot showed multiple sources of MPs (Figure 7c). The similar grouping of these MP types suggests that they may share similar sources of origin, which could include plastic waste and other products made of synthetic materials. These sources may include plastic packaging materials, single-use plastic items, and discarded synthetic textiles. Additionally, the presence of cellulose fibers in the groupings may suggest that natural materials may also be contributing to the release of MPs into the environment. In general, the identification of similar sources of MPs in these groupings highlights the importance of implementing measures to mitigate the release of MPs from these sources. This could include reducing the use of single-use plastic items, promoting the use of natural and biodegradable materials, improving waste-management practices, and implementing stricter regulations on the use and disposal of plastic products in Bangladesh.

3.4. Health Risk Assessment of MPs in Street Dust

Based on their composition, MPs may offer non-carcinogenic health risks, which were computed, and the findings are shown in Table 2. The *pRi* are divided into low (less than 150), medium (150–300), considerable (300–600), high (600–1200), and very high (more than 1200) categories [52]. Following the classification, the MPs in dust pose low non-carcinogenic risk to inhabitants of the study area and across lockdown periods, and there were no significant differences for some MP types. However, among all MP types, the highest risks were recorded for POM (87.10), followed by PAA (14.69 to 40.94). Exposure to POM and PAA can pose non-carcinogenic health risks, such as skin and eye irritation, respiratory irritation, gastrointestinal effects, neurological effects, allergic reactions, and reproductive and developmental effects [53]. The degree and duration of exposure, as well as the concentration and form of PAMs, can influence the level of risk.

Table 2. Non-carcinogenic risks of MPs in different land use of street dust during without (WL), partial (PL), and complete lockdown (CL) periods.

MPs	Industrial Area			Commercial Area			Public Facilities Area			Residential Area		
	WL	PL	CL	WL	PL	CL	WL	PL	CL	WL	PL	CL
Polymer risk indices (*pRi*)												
PE	1.91	-	1.92	1.35	1.88	0.63	-	1.78	1.46	1.83	1.89	0.92
PP	0.19	0.20	0.08	0.25	-	0.20	0.06	0.0	0.20	0.14	0.14	0.08
PVA	0.06	0.09	0.15	0.06	0.15	0.09	-	0.08	0.10	0.09	0.17	-
HDPE	0.63	-	1.65	1.35	1.35	-	0.70	1.78	-	0.79	-	1.83
LDPE	-	-	-	-	1.61	0.94	-	0.89	1.10	1.05	-	0.92
PS	-	-	-	1.84	-	-	-	-	-	-	-	-
PET	-	0.62	-	-	-	-	0.34	-	-	-	-	-
PAA	-	40.94	-	-	-	-	14.69	-	-	-	-	19.17
Nylon 6	-	4.17	-	-	-	-	3.00	-	-	-		-
PA	-	5.57	-	-	-	-	-	-	-	-	-	-
PDMS	-	-	-	-	-	0.14	-	-		-	0.086	-
POM	-	-	-	-	-	-	-	-	87.10	-	-	-
Total polymer risk indices (*pRt*)												
pRt	0.34	1.48	0.44	0.55	1.48	0.27	0.92	0.45	1.23	0.52	0.25	1.19

A person's lifetime probability of getting cancer is determined by their carcinogenic risks (*CRs*). To calculate the lifelong risk of the affected groups because of exposure to MPs from dust, the ingestion and inhalation cancer slope factor was used. Table 3 lists the carcinogenic dangers to MPs from inhaling and ingesting grit. The outcomes were compared to the permissible cancer risk limit set by the US Environmental Protection Agency, which is 1×10^{-6} to 1×10^{-4} [54].

Table 3. Carcinogenic risk (*CR*) and cumulative carcinogenic risk (*CCR*) of children and adults due to ingestion and inhalation of MPs in different land use of street dust during without, partial, and complete lockdown periods.

MPs	Industrial Area			Commercial Area			Public Facilities Area			Residential Area		
	WL	**PL**	**CL**	**WL**	**PL**	**CL**	**WL**	**PL**	**CL**	**WL**	**PL**	**CL**
Cancer risk (CR) via ingestion pathway												
PE	8.11×10^{-13}	-	1.89×10^{-12}	1.62×10^{-12}	1.89×10^{-12}	5.43×10^{-13}		1.62×10^{-12}	1.08×10^{-12}	1.89×10^{-12}	1.62×10^{-12}	8.11×10^{-13}
PP	6.35×10^{-13}	5.72×10^{-13}	1.91×10^{-13}	7.63×10^{-13}	-	4.45×10^{-13}	1.91×10^{-13}	1.91×10^{-13}	3.82×10^{-13}	3.82×10^{-13}	2.54×10^{-13}	4.45×10^{-13}
PET	-	1.89×10^{-12}	-	-	-	-	1.08×10^{-12}	-	-	-	-	-
PA	-	5.97×10^{-12}	-	-	-	-	-	-	-	-	-	-
PAA	-	9.55×10^{-12}	-	-	-	-	7.16×10^{-12}	-	-	-	-	3.58×10^{-12}
HDPE	1.62×10^{-12}	-	1.62×10^{-12}	1.62×10^{-12}	1.89×10^{-12}	-	8.11×10^{-13}	1.35×10^{-12}	-	1.08×10^{-12}	-	1.35×10^{-12}
LDPE	-	-	-	-	1.62×10^{-12}	1.62×10^{-12}		8.11×10^{-13}	8.11×10^{-13}	8.11×10^{-13}	-	8.11×10^{-13}
Cancer risk (*CR*) via inhalation pathway												
PE	6.08×10^{-11}	-	1.42×10^{-10}	1.22×10^{-10}	1.42×10^{-10}	4.07×10^{-11}	-	1.22×10^{-10}	8.09×10^{-11}	1.42×10^{-10}	1.22×10^{-10}	6.08×10^{-11}
PP	4.76×10^{-11}	4.29×10^{-11}	1.43×10^{-11}	5.72×10^{-11}	-	3.33×10^{-11}	1.43×10^{-11}	1.43×10^{-11}	2.86×10^{-11}	2.86×10^{-11}	1.90×10^{-11}	3.33×10^{-11}
PET	-	1.42×10^{-10}	-	-	-	-	8.09×10^{-11}	-	-	-	-	-
PA	-	4.48×10^{-10}	-	-	-	-	-	-	-	-	-	-
PAA	-	7.16×10^{-10}	-	-	-	-	5.36×10^{-10}	-	-	-	-	2.68×10^{-10}
HDPE	1.22×10^{-10}	-	1.22×10^{-10}	1.22×10^{-10}	1.42×10^{-10}	-	6.08×10^{-11}	1.02×10^{-10}	-	8.09×10^{-11}	-	1.02×10^{-10}
LDPE	-	-	-	-	1.22×10^{-10}	1.22×10^{-10}	-	6.08×10^{-11}	6.08×10^{-11}	6.08×10^{-11}	-	6.08×10^{-11}
Cumulative cancer risk (*CCR*) via ingestion and inhalation pathway												
PE	6.16×10^{-11}	-	1.44×10^{-10}	1.23×10^{-10}	1.44×10^{-10}	4.13×10^{-11}		1.23×10^{-10}	8.19×10^{-11}	1.44×10^{-10}	1.23×10^{-10}	6.16×10^{-11}
PP	4.83×10^{-11}	4.35×10^{-11}	1.45×10^{-11}	5.80×10^{-11}	-	3.38×10^{-11}	1.45×10^{-11}	1.45×10^{-11}	2.90×10^{-11}	2.90×10^{-11}	1.93×10^{-11}	3.38×10^{-11}
PET	-	1.44×10^{-10}	-	-	-	-	8.19×10^{-11}	-	-	-	-	-
PA	-	4.54×10^{-10}	-	-	-	-	-	-	-	-	-	-
PAA	-	7.26×10^{-10}	-	-	-	-	5.44×10^{-10}	-	-	-	-	2.72×10^{-10}
HDPE	1.23×10^{-10}	-	1.23×10^{-10}	1.23×10^{-10}	1.44×10^{-10}	-	6.16×10^{-11}	1.03×10^{-10}	-	8.19×10^{-11}	-	1.03×10^{-10}
LDPE	-	-	-	-	1.23×10^{-10}	1.23×10^{-10}	-	6.16×10^{-11}	6.16×10^{-11}	6.16×10^{-11}	-	6.16×10^{-11}

By comparing with USEPA limits, the MPs in the dust do not pose carcinogenic risks to inhabitants. However, during lockdown periods, PP in dust from all land-use areas showed the highest carcinogenic risks via ingestion. PE showed the highest carcinogenic risks via ingestion of dust only during complete lockdown at commercial and residential areas. HDPE during the without lockdown period at industrial areas and residential areas showed the highest carcinogenic risk via the ingestion pathway. Furthermore, LDPE showed the highest carcinogenic risks via ingestion in all computed samples, except for commercial areas during partial lockdown and residential areas during the without lockdown period. The results generally suggest that certain types of polymers, specifically PP, PE, HDPE, and LDPE, may pose carcinogenic risks to human health via ingestion of dust over a prolonged period of time. The level of risk varies based on the type of polymer and the specific circumstances, such as the level of lockdown and the land-use area. Polypropylene (PP), polyethylene (PE), high-density polyethylene (HDPE), and low-density polyethylene (LDPE) are all considered to be relatively safe and non-carcinogenic when used in their intended applications. However, specific carcinogenic risks of these polymers are yet to be established.

The inhalation exposure pathway showed values for MPs outside the recommended range, but they will not pose carcinogenic risks due to their low *CR* values (Table 3). The cumulative cancer risks followed similar trends as the ingestion pathway. Furthermore, looking critically at the results, the cancer risks decreased from the without lockdown to complete lockdown period, which could be due to reduced human activities. Generally, it is important to note that these results are based on computed samples and may not necessarily reflect real-world exposure levels. However, the findings do suggest that there may be a need for further research and potentially regulatory action to address the potential health risks associated with these polymers.

4. Conclusions

The current study investigated the abundance of microplastics (MPs) in street dust samples from different areas in Dhaka city, Bangladesh to determine their potential origins and health risks. The findings revealed higher concentrations of MPs in industrial regions, followed by commercial, public, and residential areas. Human activities significantly influence the generation and distribution of MPs, as evidenced by changes during lockdown periods. Identifying similar sources of MPs highlights the need for measures to mitigate their release, such as reducing single-use plastics, promoting biodegradable materials, and improving waste management. The risk assessment showed low non-carcinogenic risks for inhabitants, while certain polymers (PP, PE, HDPE, and LDPE) may pose carcinogenic risks when ingested via dust. Further research and potential regulatory action are needed to address these health risks. Although reduced human activities during lockdowns can decrease cancer risks, the study's reliance on computed samples may not fully reflect real-world exposure levels. Finally, understanding and addressing potential health risks from polymer exposure remains crucial.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/environments10070130/s1, Table S1: FTIR spectra peak assignment for the MP type identification; Figure S1: Distribution of MP types in dust from different land-use categories.

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References

1. Ali, M.; Devnath, B. Air Pollution in Bangladesh: Bangladesh Air World's Worst in 2019. Available online: https://www.tbsnews.net/environment/bangladesh-air-worlds-worst-2019-47959 (accessed on 4 January 2022).
2. Islam, M.S.; Chowdhury, T.A. Effect of COVID-19 Pandemic-Induced Lockdown (General Holiday) on Air Quality of Dhaka City. *Environ. Monit. Assess.* **2021**, *193*, 343. [CrossRef] [PubMed]
3. Hasnat, G.N.T.; Kabir, M.A.; Hossain, M.A. Major Environmental Issues and Problems of South Asia, Particularly Bangladesh. In *Handbook of Environmental Materials Management*; Springer: Cham, Switzerland, 2018; pp. 1–40.
4. Haque, H.; Huda, N.; Zaman Tanu, F.; Sultana, N.; Shahid Hossain, M.A.; Hasinur Rahman, M. Ambient Air Quality Scenario in and Around Dhaka City of Bangladesh. *Barisal Univ. J. Part* **2017**, *1*, 203–218.
5. Mercier, F.; Glorennec, P.; Thomas, O.; Bot, B.L. Organic contamination of settled house dust, a review for exposure assessment purposes. *Environ. Sci. Technol.* **2011**, *45*, 6716–6727. [CrossRef] [PubMed]
6. Fortoul, T.; Rodriguez-Lara, V.; Gonzalez-Villalva, A. *Health Effects of Metals in Particulate Matter*; InTech: London, UK, 2015.
7. Leslie, H.A.; van Velzen, M.J.M.; Brandsma, S.H.; Vethaak, A.D.; Garcia-Vallejo, J.J.; Lamoree, M.H. Discovery and Quantification of Plastic Particle Pollution in Human Blood. *Environ. Int.* **2022**, *163*, 107199. [CrossRef]
8. Enyoh, C.E.; Duru, C.E.; Ovuoraye, P.E.; Wang, Q. Evaluation of Nanoplastics Toxicity to the Human Placenta in Systems. *J. Hazard. Mater.* **2023**, *446*, 130600. [CrossRef] [PubMed]
9. Frias, J.P.G.L.; Nash, R. Microplastics: Finding a Consensus on the Definition. *Mar. Pollut. Bull.* **2019**, *138*, 145–147. [CrossRef] [PubMed]
10. Sohrabi, C.; Alsafi, Z.; O'Neill, N.; Khan, M.; Kerwan, A.; Al-Jabir, A.; Iosifidis, C.; Agha, R. World Health Organization Declares Global Emergency: A Review of the 2019 Novel Coronavirus (COVID-19). *Int. J. Surg.* **2020**, *76*, 71–76. [CrossRef]
11. Rabin, M.H.; Wang, Q.; Kabir, M.H.; Wang, W. Pollution Characteristics and Risk Assessment of Potentially Toxic Elements of Fine Street Dust during COVID-19 Lockdown in Bangladesh. *Environ. Sci. Pollut. Res.* **2022**, *30*, 4323–4345. [CrossRef]
12. Enyoh, C.E.; Ohiagu, F.O.; Verla, A.W.; Wang, Q.; Shafea, L.; Verla, E.N.; Isiuku, B.O.; Chowdhury, T.; Ibe, F.C.; Chowdhury, M.A.H. "Plasti-Remediation": Advances in the Potential Use of Environmental Plastics for Pollutant Removal. *Environ. Technol. Innov.* **2021**, *23*, 101791. [CrossRef]
13. Yunus, A.P.; Masago, Y.; Hijioka, Y. COVID-19 and Surface Water Quality: Improved Lake Water Quality during the Lockdown. *Sci. Total Environ.* **2020**, *731*, 139012. [CrossRef]
14. Aravinthasamy, P.; Karunanidhi, D.; Shankar, K.; Subramani, T.; Setia, R.; Bhattacharya, P.; Das, S. COVID-19 Lockdown Impacts on Heavy Metals and Microbes in Shallow Groundwater and Expected Health Risks in an Industrial City of South India. *Environ. Nanotechnol. Monit. Manag.* **2021**, *16*, 100472. [CrossRef] [PubMed]
15. Karunanidhi, D.; Aravinthasamy, P.; Subramani, T.; Setia, R. Effects of COVID-19 Pandemic Lockdown on Microbial and Metals Contaminations in a Part of Thirumanimuthar River, South India: A Comparative Health Hazard Perspective. *J. Hazard. Mater.* **2021**, *416*, 125909. [CrossRef] [PubMed]
16. Khan, R.; Saxena, A.; Shukla, S. Assessment of the Impact of COVID-19 Lockdown on the Heavy Metal Pollution in the River Gomti, Lucknow City, Uttar Pradesh, India. *Environ. Qual. Manag.* **2021**, *31*, 41–49. [CrossRef]
17. Arora, S.; Bhaukhandi, K.D.; Mishra, P.K. Coronavirus Lockdown Helped the Environment to Bounce Back. *Sci. Total Environ.* **2020**, *742*, 140573. [CrossRef]
18. Kumar, M.; Mazumder, P.; Mohapatra, S.; Kumar Thakur, A.; Dhangar, K.; Taki, K.; Mukherjee, S.; Kumar Patel, A.; Bhattacharya, P.; Mohapatra, P.; et al. A Chronicle of SARS-CoV-2: Seasonality, Environmental Fate, Transport, Inactivation, and Antiviral Drug Resistance. *J. Hazard. Mater.* **2021**, *405*, 124043. [CrossRef]
19. Rabin, M.H.; Wang, Q.; Wang, W.; Enyoh, C.E. Pollution Characteristics, Source Apportionment, and Health Risk of Polycyclic Aromatic Hydrocarbons (PAHs) of Fine Street Dust during and after COVID-19 Lockdown in Bangladesh. *Process* **2022**, *10*, 2575. [CrossRef]
20. Saha, N.; Bodrud-Doza, M.; Islam, A.R.M.T.; Begum, B.A.; Rahman, M.S. Hydrogeochemical Evolution of Shallow and Deeper Aquifers in Central Bangladesh: Arsenic Mobilization Process and Health Risk Implications from the Potable Use of Groundwater. *Environ. Earth Sci.* **2020**, *79*, 477. [CrossRef]
21. Department of Environment. *Air Pollution Reduction Strategy for Bangladesh Final Report*; Department of Environment, Government of Bangladesh: Dhaka, Bangladesh, 2012.
22. Bhuiyan, M.S.I. Public Transport and Environmental Pollution: A Case Study of Dhaka City World Vision. *World Vis. Res. J.* **2018**, *12*, 96–108.
23. Rahman, M.; Khan, M.D.H.; Jolly, Y.N.; Kabir, J.; Akter, S.; Salam, A. Assessing Risk to Human Health for Heavy Metal Contamination through Street Dust in the Southeast Asian Megacity: Dhaka, Bangladesh. *Sci. Total Environ.* **2019**, *660*, 1610–1622. [CrossRef]
24. Enyoh, C.E.; Verla, A.W.; Qingyue, W.; Ohiagu, F.O.; Chowdhury, A.H.; Enyoh, E.C.; Chowdhury, T.; Verla, E.N.; Chinwendu, U.P. An Overview of Emerging Pollutants in Air: Method of Analysis and Potential Public Health Concern from Human Environmental Exposure. *Trends Environ. Anal. Chem.* **2020**, *28*, e00107. [CrossRef]
25. Pandey, D.; Banerjee, T.; Badola, N.; Chauhan, J.S. Evidences of Microplastics in Aerosols and Street Dust: A Case Study of Varanasi City, India. *Environ. Sci. Pollut. Res.* **2022**, *29*, 82006–82013. [CrossRef] [PubMed]

26. Delibašić, Š.; Đokić-Kahvedžić, N.; Karić, M.; Keskin, I.; Velispahić, A.; Huremović, J.; Herceg, K.; Selimović, A.; Silajdžić, S.; Žero, S.; et al. Health Risk Assessment of Heavy Metal Contamination in Street Dust of Federation of Bosnia and Herzegovina. *Hum. Ecol. Risk Assess.* **2020**, *27*, 1296–1308. [CrossRef]
27. Jiang, X.; Lu, W.; Zhao, H.; Yang, Q.C.; Yang, Z.P. Potential Ecological Risk Assessment and Prediction of Soil Heavy-Metal Pollution around Coal Gangue Dump. *Nat. Hazards Earth Syst. Sci.* **2014**, *14*, 1599–1610. [CrossRef]
28. Wang, Q.; Enyoh, C.E.; Chowdhury, T.; Chowdhury, A.H. Analytical techniques, occurrence and health effects of micro and nano plastics deposited in street dust. *Int. J. Environ. Anal. Chem.* **2022**, *102*, 6435–6453. [CrossRef]
29. Enyoh, C.E.; Wang, Q.; Rabin, M.H.; Bakare, R.O.; Dadiel, J.L.; Shangrong, W.; Lu, S.; Ilechukwu, I. Preliminary characterization and probabilistic risk assessment of microplastics and potentially toxic elements (PTEs) in garri (*Cassava flake*), a common staple food consumed in West Africa. *Environ. Anal. Health Toxicol.* **2023**, *38*, e2023005. [CrossRef] [PubMed]
30. Rakib, M.R.J.; Al Nahian, S.; Alfonso, M.B.; Khandaker, M.U.; Enyoh, C.E.; Hamid, F.S.; Alsubaie, A.; Almalki, A.S.A.; Bradley, D.A.; Mohafez, H.; et al. Microplastics Pollution in Salt Pans from the Maheshkhali Channel, Bangladesh. *Sci. Rep.* **2021**, *11*, 23187. [CrossRef] [PubMed]
31. Lithner, D.; Larsson, A.; Dave, G. Environmental and Health Hazard Ranking and Assessment of Plastic Polymers Based on Chemical Composition. *Sci. Total Environ.* **2011**, *409*, 3309–3324. [CrossRef]
32. Ferreira-Baptista, L.; De Miguel, E. Geochemistry and Risk Assessment of Street Dust in Luanda, Angola: A Tropical Urban Environment. *Atmos. Environ.* **2005**, *39*, 4501–4512. [CrossRef]
33. US EPA. *Soil Screening Guidance: Technical Background Document*; Office of Emergency and Remedial Response U.S. Environmental Protection Agency: Washington, DC, USA, 1996.
34. US EPA. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*; US Environmental Protection Agency: Washington, DC, USA, 2002; pp. 1–187.
35. Enyoh, C.E.; Verla, A.W.; Rakib, M.R.J. Application of Index Models for Assessing Freshwater Microplastics Pollution. *World News Nat. Sci.* **2021**, *38*, 37–48.
36. Zheng, N.; Liu, J.; Wang, Q.; Liang, Z. Heavy Metals Exposure of Children from Stairway and Sidewalk Dust in the Smelting District, Northeast of China. *Atmos. Environ.* **2010**, *44*, 3239–3245. [CrossRef]
37. China Statistics Bureau. *China Statistical Yearbook*; National Bureau of Statistics of China: Beijing, China, 2012; p. 62791819.
38. US EPA. *Methods for Collection, Storage and Maripulation of Sediment for Chemical and Toxicological Analyses: Technical Manual*; US Environmental Protection Agency: Washington, DC, USA, 2001.
39. Van den Berg, R. *Human Exposure to Soil Contamination: A Qualitative and Quantitative Analysis towards Proposals for Human Toxicology C-Standard Values*; Report No.7252010; National Institute of Public Health and Environmental Protection: Bilthoven, The Netherlands, 1995.
40. Patchaiyappan, A.; Dowarah, K.; Zaki Ahmed, S.; Prabakaran, M.; Jayakumar, S.; Thirunavukkarasu, C.; Devipriya, S.P. Prevalence and Characteristics of Microplastics Present in the Street Dust Collected from Chennai Metropolitan City, India. *Chemosphere* **2021**, *269*, 128757. [CrossRef] [PubMed]
41. Abbasi, S.; Keshavarzi, B.; Moore, F.; Delshab, H.; Soltani, N.; Sorooshian, A. Investigation of Microrubbers, Microplastics and Heavy Metals in Street Dust: A Study in Bushehr City, Iran. *Environ. Earth Sci.* **2017**, *76*, 798. [CrossRef]
42. Yukioka, S.; Tanaka, S.; Nabetani, Y.; Suzuki, Y.; Ushijima, T.; Fujii, S.; Takada, H.; Van Tran, Q.; Singh, S. Occurrence and Characteristics of Microplastics in Surface Road Dust in Kusatsu (Japan), Da Nang (Vietnam), and Kathmandu (Nepal). *Environ. Pollut.* **2020**, *256*, 113447. [CrossRef]
43. Veerasingam, S.; Ranjani, M.; Venkatachalapathy, R.; Bagaev, A.; Mukhanov, V.; Litvinyuk, D.; Mugilarasan, M.; Gurumoorthi, K.; Guganathan, L.; Aboobacker, V.M.; et al. Contributions of Fourier transform infrared spectroscopy in microplastic pollution research: A review. *Crit. Rev. Environ. Sci. Technol.* **2021**, *51*, 2681–2743. [CrossRef]
44. Enyoh, C.E.; Wang, Q.; Eze, V.C.; Rabin, M.H.; Rakib, M.R.J.; Verla, A.W.; Ibe, F.C.; Duru, C.E.; Verla, E.N. Assessment of Potentially Toxic Metals Adsorbed on Small Macroplastics in Urban Roadside Soils in Southeastern Nigeria. *J. Hazard. Mater. Adv.* **2022**, *7*, 100122. [CrossRef]
45. Liu, S.; Chen, H.; Wang, J.; Su, L.; Wang, X.; Zhu, J.; Lan, W. The Distribution of Microplastics in Water, Sediment, and Fish of the Dafeng River, a Remote River in China. *Ecotoxicol. Environ. Saf.* **2021**, *228*, 113009. [CrossRef] [PubMed]
46. Sfriso, A.A.; Tomio, Y.; Rosso, B.; Gambaro, A.; Sfriso, A.; Corami, F.; Rastelli, E.; Corinaldesi, C.; Mistri, M.; Munari, C. Microplastic Accumulation in Benthic Invertebrates in Terra Nova Bay (Ross Sea, Antarctica). *Environ. Int.* **2020**, *137*, 105587. [CrossRef]
47. Król-Morkisz, K.; Karaś, E.; Majka, T.M.; Pielichowski, K.; Pielichowska, K. Thermal Stabilization of Polyoxymethylene by PEG-Functionalized Hydroxyapatite: Examining the Effects of Reduced Formaldehyde Release and Enhanced Bioactivity. *Adv. Polym. Technol.* **2019**, *2019*, 9728637. [CrossRef]
48. Tang, C.C.; Chen, Y.T.; Zhang, Y.M.; Chen, H.I.; Brimblecombe, P.; Lee, C.L. Cracking and Photo-Oxidation of Polyoxymethylene Degraded in Terrestrial and Simulated Marine Environments. *Front. Mar. Sci.* **2022**, *9*, 607. [CrossRef]
49. Mon, E.E.; Tun, T.Z.; Agusa, T.; Yeh, H.M.; Huang, C.H.; Nakata, H. Monitoring of Microplastics in Road Dust Samples from Myanmar and Taiwan. *Environ. Monit. Contam. Res.* **2022**, *2*, 112–119. [CrossRef]
50. Keshavarzi, B.; Abbasi, H.S.; Moore, F.; Delshab, H.; Soltani, N. Polycyclic Aromatic Hydrocarbons in Street Dust of Bushehr City, Iran: Status, Source, and Human Health Risk Assessment. *Polycycl. Aromat. Compd.* **2017**, *40*, 61–75. [CrossRef]

51. Yao, X.; Luo, X.S.; Fan, J.; Zhang, T.; Li, H.; Wei, Y. Ecological and Human Health Risks of Atmospheric Microplastics (MPs): A Review. *Environ. Sci. Atmos.* **2022**, *2*, 921–942. [CrossRef]
52. Christian, E.E.; Wang, Q.; Andrew, W.V.; Tanzin, C.; Christian, E.E.; Wang, Q.; Andrew, W.V.; Tanzin, C. Index Models for Ecological and Health Risks Assessment of Environmental Micro-and Nano-Sized Plastics. *AIMS Environ. Sci.* **2022**, *9*, 51–65. [CrossRef]
53. Anderson, F.A. Amended final report on the safety assessment of polyacrylamide and acrylamide residues in cosmetics. *Int. J. Toxicol.* **2005**, *24*, 21–50. [CrossRef]
54. USEPA. *Guidelines for Carcinogen Risk Assessment*; US Environmental Protection Agency: Washington, DC, USA, 2005.