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Research article

Human inhalation exposure assessment of the airborne microplastics from indoor deposited dusts during winter in Dhaka, Bangladesh

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A R T I C L E I N F O

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A B S T R A C T

Microplastic (MP) contamination has become a concern due to its ubiquitous presence. Recent studies have found MPs to be present in multiple human organs. This study was carried out to evaluate the presence and characterize MPs in indoor dust deposition. Deposited dust was collected from fifteen households in Dhaka city. The samples underwent quantification of MPs using stereomicroscopy. Fourier Transform Infrared (FTIR) spectroscopy was performed to understand the polymer composition. MPs of the size group ranging from 50 to 250 μm were the most dominant. The deposition rates varied from 7.52×10^3 MPs/m^2/day to 66.29×10^3 MPs/m^2/day, with the mean deposition rate being 34×10^3 MPs/m^2/day. Notably, the number of occupants and the height of the sampling location above the ground level were found to influence the deposition rates. Various polymers, including polyester (PET), polyethylene (PE), Nylon, and polypropylene (PP), were identified. The estimated mean inhalation exposure was 2986 ± 1035 MPs/kg-BW/day. This work highlights the need for additional research to explore indoor microplastic deposition and its potential effect on human health in the densely inhabited and severely polluted megapolis of Dhaka, Bangladesh.

1. Introduction

Plastic is a widely utilized material known for its versatility, attributed to its lightweight nature, strong mechanical properties, and high durability while being cheaper than other alternative materials [1–3]. As of 2021, about 390 million tons of plastic products are produced globally of which only 21.3 % is recycled and the rest ends up in landfills and ultimately in the environment [4,5]. Microplastics (MPs) are small plastic fragments within a size range of 0.001 mm–5 mm [6,7]. MPs are also produced industrially as beads or pellets used in cleaning and hygiene products [8–10]. MPs are pervasive, bio-accumulative, and often found ingested by seabirds, fishes, muscles, and even zooplanktons [8,11–14], and thus pose a serious concern. Also, they cause adverse effects such as intestinal blockage, inflammation, oxidative stress, and reduced growth [15–17]. MPs have also been found in several regions of the

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human body, including the lungs and blood[18–20]. Yet little is known regarding the health impact of MPs. Nevertheless, the MPs carry with them various additives such as plasticizers, dyes, and antioxidants in them [21]. Moreover, MPs surface contains pores or cracks which give a better adhesive character [22]. Due to this property, polychlorinated biphenyls (PCBs), polybrominated dibenzofurans (PBDFs), heavy metals, and even bacteria can be carried by MPs and then enter human bodies [23,24].

Humans are primarily exposed to MPs mostly through ingestion and inhalation [3,15,25]. Until recently, studies had mainly focused on the pathways of exposure via food intake: analysis of MPs in aquatic systems or different kinds of seafood [4,26,27]. Studies have also been done to investigate the exposure to MPs from liquid food containers or personal care products [28,29]. However, several investigations in recent years have indicated that MPs are prevalent in indoor as well as outdoor environments [7,30–33]. It should also be mentioned that people spend about 80 % of their time indoors and thus indoor air quality largely affects human health [34,35]. MPs originate from various sources such as packaging materials, and textiles, and then enter the atmosphere through re-suspension [33]. Airborne MPs are potentially responsible for the contamination in remote areas [36,37].

Dhaka, Bangladesh has one of the densest populations with 22 million people living in it. (Bangladesh Bureau of Statistics). In Bangladesh, MPs have been observed in a wide range of samples, including freshwater fish, beach sediment, rivers, and landfills [38–41]. So far as we know, there are no detailed studies related to airborne microplastics in Dhaka, Bangladesh. MPs are prevalent in indoor environments, generated largely from textile products containing Polyethylene terephthalate (PET), Polyamide (PA), and Nylon, etc. [33,42–44]. Additionally, non-textile sources like packaging, cosmetics, and detergents also introduce MPs into the atmosphere which are composed of Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), and others [42,43,45]. Furthermore, common indoor engineering materials like Polyvinyl chloride (PVC) and Polyurethane (PUR) also contribute to the presence of MPs in the dust [42]. Indoor air can also be contaminated with MPs from the outdoor sources [46]. This study aimed to assess the levels of airborne microplastics (MPs) in indoor environments, their abundance, and potential human exposure in the highly polluted winter season in Dhaka, Bangladesh. In addition, the study aimed to identify potential sources by examining the characteristics and polymer composition of the microplastics detected.

Table 1
A table of locations and relevant information of the households sampled.

Sample No.	Location	Area type	Coordinates	Number of occupants	Floor level	House cleaning method	Window condition
S1	Dhaka Cantonment	Residential	23° 50 ′ 5″, 90° 23 ′ 18″	5	1st	Sweeping and mopping	Open
S2	Mohammadpur	High-traffic	23° 46 ′ 41″, 90° 21 ′ 25″	5	4th	Sweeping and mopping	Open
S3	Farmgate	High-traffic	23° 45 ′ 50″, 90° 23 ′ 35″	3	5th	Sweeping and mopping	Open
S4	Basabo	Residential	23° 44 ′ 10″, 90° 26 ′ 17″	5	1st	Sweeping and mopping	Open
S5	Siddhirganj, Narayanganj	Industrial	23° 41 ′ 52″, 90° 29 ′ 42″	5	4th	Sweeping	Closed
S6[a,b]	Curzon Hall	Official	23° 43 ′ 38″, 90° 24 ′ 11″	N/A	Ground	Sweeping	Closed
S7	Mohakhali	High-traffic	23° 46 ′ 33″, 90° 23 ′ 48″	2	3rd	Sweeping	Open
S8	West Kazipara	High-traffic	23° 47 ′ 53″, 90° 22 ′ 18″	5	3rd	Sweeping	Closed
S9	Tongi	Industrial	23° 55 ′ 41″, 90° 23 ′ 10″	4	1st	Sweeping, mopping	Open
S10	Khilkhet	Residential	23° 50 ′ 4″, 90° 25 ′ 40″	4	1st	Sweeping	Open
S11[a,c]	Fazlul Huq Muslim Hall	Official	23° 43 ′ 33″, 90° 24 ′ 13″	3	Ground	N/A[d]	Closed
S12	Shantinogor	High-traffic	23° 44 ′ 37″, 90° 24 ′ 34″	4	6th	Vacuum cleaning	Closed
S13	Mirpur-13	High-traffic	23° 48 ′ 40″, 90° 22 ′ 39″	4	2nd	Sweeping and mopping	Open
S14	Arambagh	High-traffic	23° 43 ′ 51″, 90° 25 ′ 12″	12	2nd	Sweeping	Open
S15	Mugda	Residential	23° 43 ′ 30″, 90° 26 ′ 52″	1	3rd	N/A[d]	Closed

[a] Sampling location is inside the University of Dhaka.
[b] Sampling was carried out inside a library with varying population.
[c] Sampling was carried out inside a dormitory room.
[d] The locations were not cleaned during the sampling period.

2. Materials and methods

2.1. Study sites

Bangladesh is a country in South Asia, situated north of the Bay of Bengal. Dhaka (23° 48′ 37.1916″ N and 90° 24′ 45.0756″ E), situated on the bank of the Buriganga River, is the capital of Bangladesh [47]. The past few years have witnessed Bangladesh experiencing fast economic growth, albeit accompanied by surging population numbers, rapid urbanization, traffic congestion, excessive pollution, and related challenges [48,49]. Such factors leave the population highly susceptible to pollution.

To better understand the environmental conditions, fifteen households were selected from different parts of Dhaka city, mainly the southwest part, which is more populated (Fig. S1). The locations were chosen to represent different types of environments, including residential, high-traffic, official, and industrial areas (Table 1). The household floors are mostly tiled or concrete except for S12 (sampling location 12) which has carpeted floors. Most households are apartment buildings, with the exception of S6 and S11, which are an office, and a dormitory room, respectively. These locations were chosen to provide a contrast among the households.

2.2. Sampling and extraction

For sampling and extraction, we have followed the methods from several recent research works, e.g., Dris et al. [31], Jenner et al. [50], Soltani et al. [7] and Zhang et al. [33].

The airborne dust sampling was conducted by using passive sampling technique in a glass Petri dish of 100 mm diameter. These dishes were positioned face-up approximately 1.2 m above the floor inside the living room to capture airborne particles [31,51]. This height was chosen to simulate the average breathing zone of a standing adult. The sampling height ensures the collecting of lighter MP particles are collected that would otherwise remain suspended in air. The lid was kept away in aluminum foil over the sampling period. Additionally, information about the household such as the number of occupants, and floor level was collected and the corresponding questionnaire is included in the supplementary file. Sampling was conducted for seven days at each sampling site from December 2021 to January 2022. This period was chosen because air pollution levels are usually at their highest level during the winter season in Bangladesh [49,52]. The lid was put back on and the dishes were covered again using aluminum foil after the sample collection was completed.

The samples were extracted by filtration. Deposition on the Petri dishes were collected by washing the dishes with DI water. The washings were filtered using quartz fiber filter of pore size 0.4 μm and diameter of 75 mm (Pall Life Sciences, 2500 QAT-UP). The dishes were washed multiple times ensuring the complete transfer of deposited MPs. This protocol was followed as it has been utilized in several studies reporting a particle recovery rates ranging from 70 % to 90 % [7,53,54]. The filter papers were then dried in an electric oven (50 °C) and kept in clean Petri dishes for microscopic analysis. To ensure minimal contamination, the extraction procedure was conducted in a clean laboratory environment. The working area and all apparatus were thoroughly cleaned before use. We minimized airflow within the room to reduce potential contamination from airborne microplastics. Blank samples were included throughout the process to monitor the background contamination. The samples obtained through deposition in indoor environments had a smaller quantity and contained minimal interfering matter compared to other sample matrices such as seafood, and street dust samples. Natural fibers and other particles were distinguished utilizing the criteria outlined by Prata et al. [54].

2.3. Visual observation with stereomicroscope

Most studies present, have deployed microscopy for carrying out MPs quantification [33,50,55,56]. Thus, this study also utilized microscopy for quantifying MPs. The stereomicroscope (NZ. 1902P, Euromex, The Netherlands), equipped with a 10-megapixel camera (CMEX-10PRO, Euromex, The Netherlands), was used to observe the particles on the filter papers. A stereomicroscope provides improved visibility and satisfactory resolution up to 50 μm, enabling differentiation between transparent and colored particles [33,54]. The particles were subjected to analysis at 15× magnification. Each filter paper (75 mm) was observed in 20 distinct regions (8.35 × 6.40 mm^2) chosen randomly, as opposed to adopting a quarter-section approach. This resulted in a more uniform estimation. These regions added up to cover approximately 25 % of the filter papers and were utilized for estimating the overall content. Additional efforts were undertaken to distinguish natural from synthetic fibers, minimizing the potential overestimation of microplastics. This differentiation relied on factors such as color, uniformity, and the presence of cellular components [54]. They were observed while considering the different shapes and colors of the particles, in accordance with the criteria detailed by Hartmann et al. [57]. The image analysis software, ImageJ, from the National Institutes of Health (NIH) with the Laboratory for Optical and Computational Instrumentation (LOCI) was used for the measurements of the length of the fibers [54]. The deposition rates of MPs for each location, D_r (× 10^3 MP/m^2/day) were calculated using the following formula [7]:

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

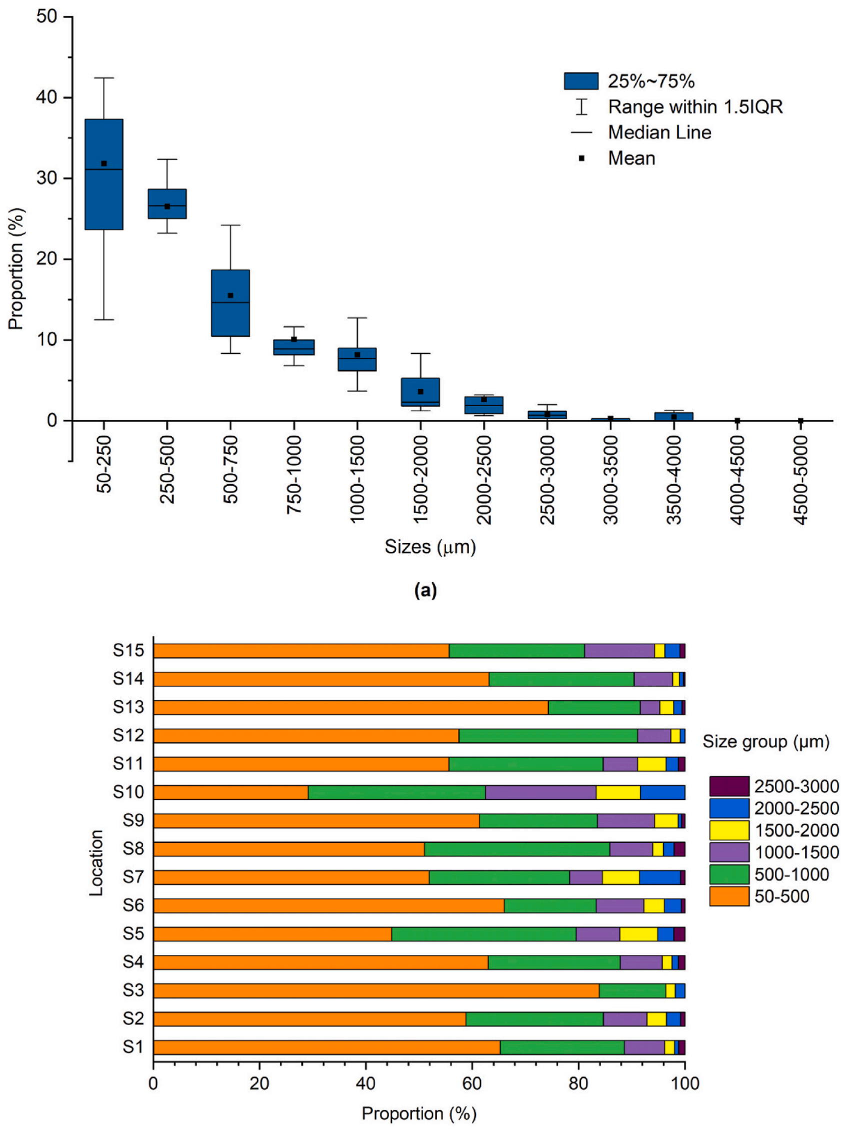
Here, “n" represents the quantity of MP particles within the observed area (A_o) of the filter paper, “d" signifies the sampling duration in days, and “A_f” and “A_p” denote the dimensions of the filter paper and Petri dish areas in mm^2, respectively. Thus, the Deposition rate is expressed as the number of microplastic particles falling out over an area of 1 square meter at a height of 1.2 m.

2.4. Quality assurance

Carefully minimizing cross-contamination, plastic materials were replaced with glass equipment that was thoroughly washed with DI water before each analysis [7,53,54]. Glassware remained covered using aluminum foil when not in use. Work surfaces were cleaned using an ethanol solution [7], and efforts were made to reduce airflow by closing ventilators, windows, and air-conditioning [58]. During the analysis, a cotton laboratory apron was consistently worn [50]. For handling samples, petri dishes were enveloped in aluminum foil. The Petri dishes were rinsed multiple times to collect all the adhering particles. Quartz fiber filters were stored likewise and exposed only during analysis. Natural or semi-synthetic fibers and other particles were distinguished visually utilizing the criteria outlined by Prata et al. [54]. Natural/semi-synthetic fibers tend to appear irregular and twisted, while synthetic plastics appear smoother under a microscope and can be differentiated [42,59]. The procedural blanks exhibited minimal MP content, with counts of 9, 14, and 17 MPs, respectively and were taken in consideration during calculation.

2.5. Human exposure

The inhalation exposure E_i (MPs/kg-BW/day) was calculated by adjusting the method applied by Soltani et al. [7] which is as follows:



(a)

(b)

Fig. 1. A plot showing the distribution of particles according to their sizes (a) mean and (b) individual locations.

$$E_i = \frac{D_r \times B_r}{1.2 \times W} \times P_i \quad (2)$$

D_r is the previously calculated rate of deposition; B_r is the inhalation rate (m^3/day) and W is the respective body weight (kg). P_i is the proportion of inhalable fibers (50–250 μm) according to Soltani et al. [7].

Corresponding body weights and inhalation rates were acquired from the US EPA Exposure Factors Handbook, 2011 [60] as adopted by Soltani et al. [7]. The vertical distance between the ceiling and Petri dish containing suspended MPs is taken to be 1.2 m in accordance with the recommended minimum ceiling height of 2.4 m specified in Bangladesh [61]. Therefore, the term D_r can be described as the concentration of particle suspended in an air volume of 1.2 m^3 above the Petri dish.

2.6. Polymer characterization using FTIR

Thirty-five MPs were chosen as representatives from different samples based on their appearance to identify polymer composition. The particles were transferred with the help of a tweezer and FTIR spectra were collected using an Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectrophotometer (IR Prestige-21, Shimadzu). The IR range was 4000–600 cm^{-1} and the spectra were in absorbance vs wavenumber. The obtained spectra were compared with a spectral database [62] using the Spectra-Gryph software. Additionally, the spectra were manually compared, considering the visual characteristics of the MPs to identify the polymer material.

3. Results and discussion

3.1. Visual characteristics

The observed particles were mostly of fiber shape (>90 %). The rest of the particles were filaments and fragments, which comprised only a minority of the sample. This observation is in agreement with the findings from other research [7,31,50]. Fibers are more likely to become airborne due to their higher aerodynamic drag [63].

The MPs were categorized into distinct groups according to their lengths (Fig-1). Particles measuring under 250 μm constituted the majority (32 %). The proportion of MPs decreased exponentially with increased size. This is likely attributable to the fact that smaller particles, being lighter, have a higher tendency to become airborne. Consequently, larger particles were relatively less common. Smaller particles raise more concern due to their increased susceptibility to inhalation.

The colors of the MPs were also observed using the stereomicroscope (Fig-2). MPs of color red, black, blue, green, yellow, white, and transparent fibers were present. Additionally, the observation revealed semi-bleached fibers, indicating environmental weathering (Fig. S2).

3.2. Deposition rates

The deposition rates of microplastics were estimated in the range of 7.52×10^3–66.29×10^3 MP/m^2/day (Fig-3). The mean value of the rate of deposition was 34×10^3 MP/m^2/day. Although there is no standard guideline value for MPs yet, the obtained deposition rate is notably higher than similar studies conducted in other countries [7,31,33]. Zhai et al. [64] reported a concentration of 14×10^3 particles/m^3 in a dormitory of Xiamen University, China. Zhang et al. [33] reported a deposition rate of 13×10^3 fibers/m^2/day in Shanghai, China while an average deposition rate of 3.10×10^3 fibres/m^2/day was measured by Soltani et al. [7] in Australia. The table below summarizes findings on microplastic concentration from various studies are summarized in Table 2.

It is worth noting that Dhaka is among the most densely inhabited megacities in the world with a significant consumption of plastic products resulting in a high plastic contamination [66]. The higher population density in Bangladesh has significantly reduced the

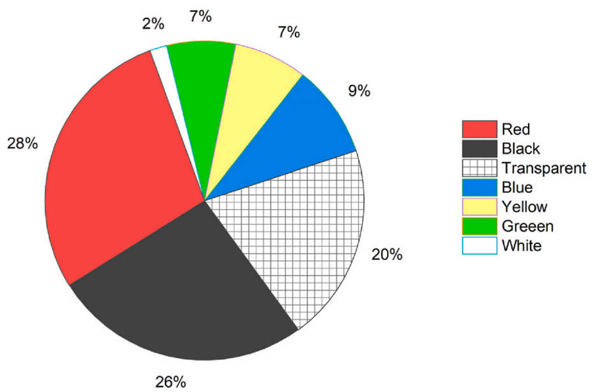


Fig. 2. A plot showing the distribution of particles according to their color.

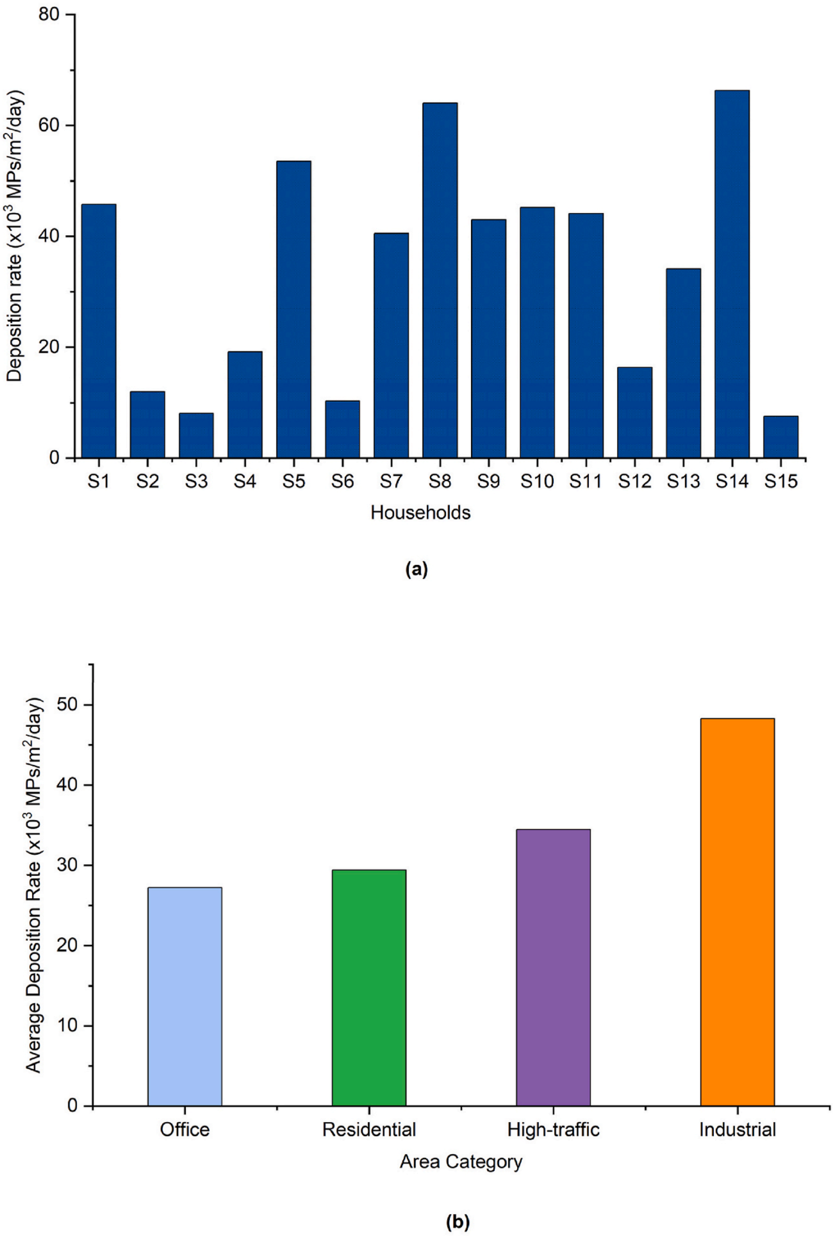


Fig. 3. Deposition rate of microplastics in different (a) households and (b) types of areas.

Table 2
Deposition rate of microplastic concentrations in different locations of the world.

Location	Deposition Rate	Indoor Type	Sampling method	Reference
Dhaka, Bangladesh	34×10^3 MP/m^2/day	Residential	Passive	This study
Paris, France	6.36×10^3 MP/m^2/day	Residential	Passive	[31]
Sydney, Australia	3.10×10^3 MP/m^2/day	Residential	Passive	[7]
Shanghai, China	29×10^3 MP/m^2/day	Dormitory	Passive	[33]
Xiamen University, China	14×10^3 MP/m^3	Dormitory	Passive	[65]
Humber, UK	6.2×10^3 MP/m^2/day	Residential	Passive	[50]

living space per capita, resulting in smaller average house sizes compared to other study locations mentioned in Table 2. High deposition rate could be due to relatively smaller living space [33]. In addition, houses in Dhaka lack integrated home heating systems. Consequently, residents wear winter clothing indoors for warmth, potentially contributing to higher concentrations of MPs [50,64]. The differences in lifestyle among people in different countries may also significantly impact the deposition rates. Lack of use of vacuum cleaner for room cleaning could be another potential source of high deposition rate in Dhaka. Frequent use of vacuum cleaner resulted in significantly lower MPs deposition compared to less frequent use [7]. Lack of proper ventilation could be another potential source in Dhaka. MPs can be remobilized into residences as a result of the ultraviolet degradation of outdoor plastics and tire wear [67].

The sampling locations S1, S4, S10, and S15 are situated in less busy residential areas while S6 and S11 were collected from a library and dormitory respectively from the University of Dhaka. The remaining sampling locations were situated in relatively busy commercial areas (Fig-3a). The households (Table 1) located near industrial areas had higher mean deposition rates. Typically, residential zones exhibit comparatively lower levels of pollution in contrast to industrial regions (Fig-3b). Nonetheless, there was no notable variation in deposition rates observed for the other locations due to the strong influence of different indoor factors. The indoor deposition rates are affected largely by different human activities [33,68]. This could elucidate the considerable variations in deposition rates across distinct sites, including the notably high deposition rate at S14, where 12 occupants were present. Thus, an attempt was made to correlate the deposition rates with different parameters.

Fig-4(a) reveals a positive association between deposition rate and the number of occupants. Deviation from the trend can be noticed as the deposition rates are affected by a combination of other factors. It can be seen that the deposition rate is increased as the number of residents in a household increase. Conversely, another study in 32 Australian homes reported that the number of occupants did not impact the deposition rate [7].

In Bangladesh, sweeping and mopping are prevalent cleaning practices. While sweeping is effective for larger particles, it can lead to the mixing and resuspension of smaller ones, as depicted in Fig-4(b). Homes employing solely sweeping exhibit higher deposition rates compared to those that incorporate mopping. Mopping, by contrast, permanently removes particles by adhering them to the wet

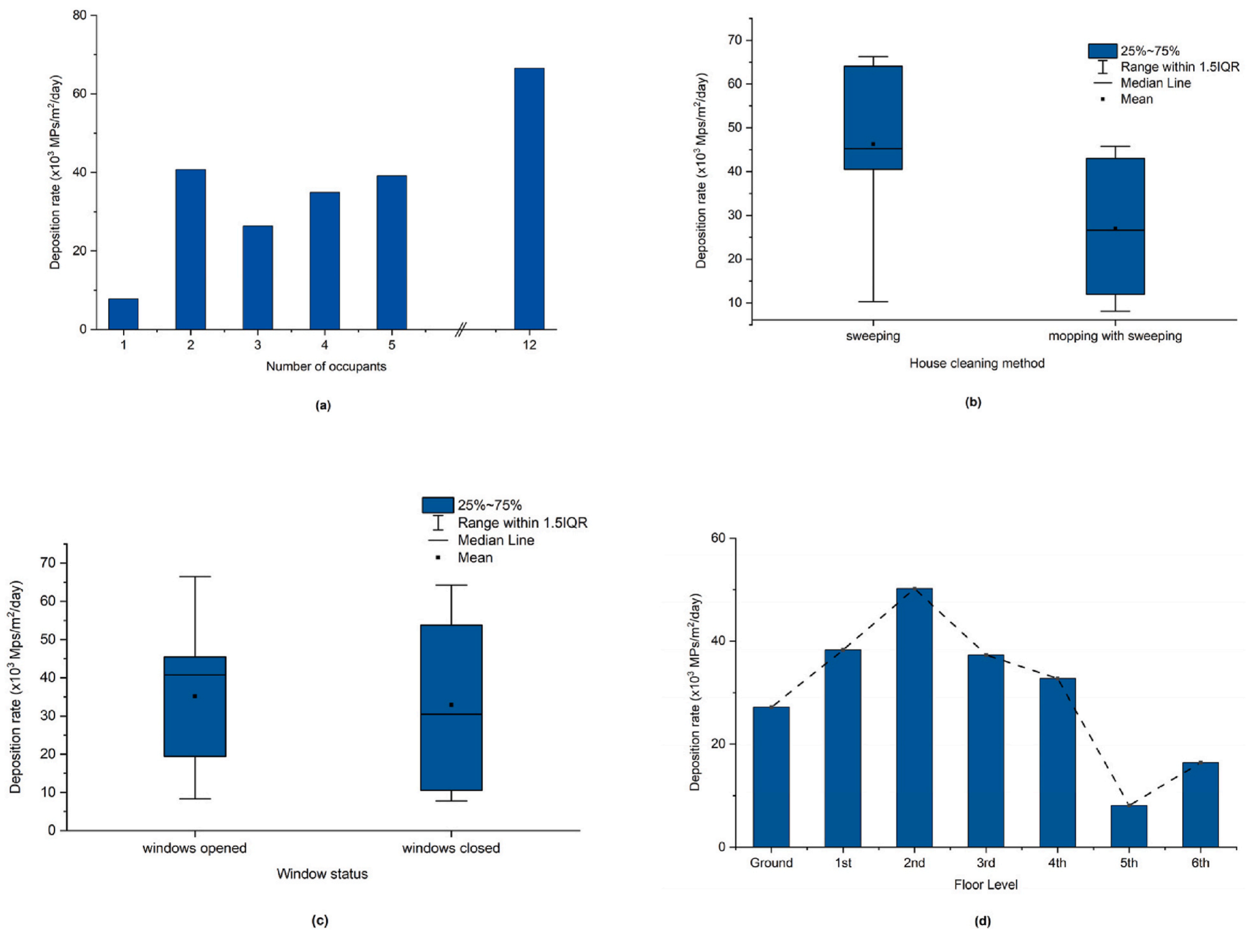


Fig. 4. Variation of Deposition rate with different factors (a) variation with number of occupants (b) variation with cleaning method (c) variation with ventilation (d) variation with the height from ground.

surface.

Deposition rates were similar whether windows were open or closed, as shown in Fig-4(c) implying little difference between indoor and outdoor MP concentration. While various studies have reported indoor concentration surpassing outdoor MP concentration [31, 69], it's important to acknowledge the absence of conclusive data concerning outdoor airborne MP concentration in Dhaka.

Fig-4(d) shows the relation between deposition rates and floor level. The highest mean deposition rate of 50.21×10^3 MP/m^2/day was observed at floor level-2 while the lowest value was obtained at floor level-5 with a mean deposition rate of 8.07×10^3 MP/m^2/day. The plot reveals a gradual deposition rate increase up to the 2nd level, followed by a subsequent decline. The observed decrease at floor level 5 is likely attributable to the lower population in that location (S3; number of occupants-3). In contrast, the higher deposition rate on the 6th floor (S12; the number of occupants-4) suggests a potential contribution from the carpeted floor.

3.3. Inhalation exposure

Fig-5 depicts the calculated MP inhalation rates for males and females across different ages. The inhalation exposure varied from 1453 MPs/kg-BW/day to 4279 MPs/kg-BW/day. Notably, children exhibit higher exposure rates due to their elevated breathing rates and lower body weight. Conversely, women have lower exposure compared to men. It is important to note that since the deposition samples were collected at a height of 1.2 m, ingestion exposure was not assessed as it might lead to an underestimate.

MPs, although considered large particles, can enter the lungs and lead to inflammation and the generation of reactive oxygen species [18,70,71]. Controlled exposure to nylon fibers has been shown to impair lung cell growth and development [72]. They also act as carriers for organic pollutants, and heavy metals, and contain endocrine-disrupting compounds such as bisphenol A, phthalates, and flame retardants [73–75].

These findings emphasize the potential health risks associated with the inhalation of MPs and the need for extensive research to comprehensively understand their health effects.

3.4. Results from Fourier transform infrared spectrophotometer analysis

From the study of the collected FTIR spectra, seven different kinds of MPs could be identified. The present polymers included polyvinyl alcohol (PVA), polyethylene terephthalate or polyester (PET), polyamide or nylon (PA), polyvinyl acetate (PVAc), alkyd, polypropylene (PP) and polyethylene (PE) (Figs. S3 and S4). Cellulose, a natural polymer, was also identified which occurred once among the thirty-five samples. The polymers are often mixed with different additives and they are also subjected to contamination and degradation which may alter their physical properties [71]. Consequently, the spectra of the samples may shift and vary significantly from the uncontaminated polymer [24,76]. Thus, it was not possible to identify all thirty-five samples.

The common sources of indoor MPs are textiles and plastic packaging [33]. The composition of indoor MPs is also influenced by outdoor sources [31]. The airborne movement of MPs in the atmosphere is primarily governed by mechanisms of transport, dispersion, and deposition [37]. The complete movement of MP particles is facilitated by their size, shape, and length [77]. Recent research has focused on the presence of MPs in indoor dust. Infiltration, tracking, and penetration are the sources of MP in indoor environments [78]. Indoor MP are also produced as a result of the release of microbeads from personal care products, furniture, textiles, and garments, as well as from plastic items and toys [79,80]. Polymers like PVA, PP, PET, Nylon, PA were reported in the different indoor environments around the world [31,32,81,82]. PVA is mostly used in textile fibers and paper as a sizing material to increase their strength [83]. A variety of fabric products are made from PET which releases MPs while washing and is a primary contributor to MP pollution [84]. Nylon and PP are also common materials for products like carpets, clothes, ropes, and food packaging [85]. Alkyd resin is a component of paints and varnishes [76]. PE is most commonly used to produce plastic bags. Despite being prohibited since 2002, PE bags are still in use [86]. PE is also used to produce microbeads in cleaning products [83].

This study acknowledges the limitations of visual observation with a stereomicroscope in distinguishing microplastics from other

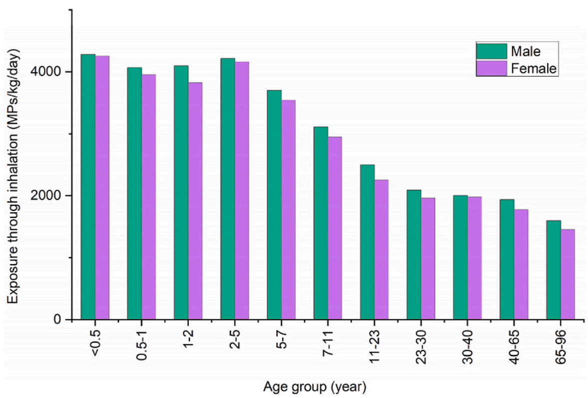


Fig. 5. Daily exposure to indoor airborne microplastics through inhalation for different ages.

particles. While we recognize the value of advanced techniques such as microscopic FT-IR spectrophotometry, Raman microscopy, and Py-GC-MS, resource constraints prevented us from employing these in our study. Future research efforts should aim to incorporate these sophisticated methods to enhance the accuracy and reliability of microplastic analysis.

4. Conclusion

This study presents significant insights into the prevalence and characterization of airborne microplastics (MPs) within the indoor environment of Dhaka, Bangladesh. The abundant presence of MPs was evident not only in densely populated official areas but also in less populated residential zones. Notably, a higher prevalence of smaller-dimensional (50–250 μm) fibers was observed. The investigation into indoor variables revealed correlations between airborne MP concentrations, population density, building height, and cleaning practices. Bangladeshi households exhibited markedly elevated MP levels. Despite the detection of various polymer types, such as polyester, PE, and PP, the sources are unclear. Nonetheless, the study highlights the alarming extent of MP contamination. A need exists for standardized analytical techniques to detect airborne MPs accurately. This research underscores the potential for MPs to enter the human body via indoor pathways, thereby posing health risks beyond direct toxic effects. Consequently, comprehensive exploration of terrestrial MP pollution within Bangladesh is imperative to comprehend and effectively address this pressing contamination issue.

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Data availability statement

Data will be shared upon request.

CRediT authorship contribution statement

Md. Zubayer Islam: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Shahid Uz Zaman:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Nafis Ibtida Sami:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Shatabdi Roy:** Writing – review & editing, Writing – original draft, Supervision. **Farah Jeba:** Writing – review & editing, Supervision. **Md. Safiqul Islam:** Writing – review & editing, Supervision. **Abdus Salam:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Abdus Salam reports financial support was provided by University Grants Commission (UGC)- University of Dhaka. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e36449.

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