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Influence of Air Conditioning on the Vertical Deposition and Inhalation Risk of Indoor Microplastics

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A B S T R A C T

Indoor environments are important pathways of microplastic (MP) exposure because people spend long periods indoors and are surrounded by synthetic textiles and plastic-based furnishings. This study examined how air-conditioning (AC)-induced air recirculation affects the vertical deposition and inhalation risk of MPs in a closed, furnished bedroom. Passive samplers were placed at floor level (0.2 m) and breathing height (1.2 m) under stagnant air (SA), low-temperature AC (LTA), and high-temperature AC (HTA) conditions. Results showed that AC transformed the indoor atmosphere from a settling-dominant to a recirculating-suspension state. Under SA, larger MPs (>500 µm) settled mainly to the floor, whereas AC increased MP deposition at breathing height and redistributed particles into the inhalation zone. Smaller fractions (<100 µm) and more diverse polymers, including polypropylene, polystyrene, and polyvinyl acetate, were also detected under AC operation. Overall, AC may improve comfort while unintentionally increasing indoor inhalation exposure to MPs.

A R T I C L E   I N F O

1. INTRODUCTION

Microplastics (MPs), broadly defined as synthetic polymer particles smaller than 5 mm in diameter, have emerged as a growing concern in indoor environments, where human exposure is intensified by prolonged time spent in enclosed spaces (Soltani *et al.,* 2021; Torres-Agullo *et al.,* 2022). MPs were initially investigated in aquatic ecosystems (Wang *et al.,* 2017). However, recent studies have increasingly focused on atmospheric pathways, particularly within buildings where MP concentrations are often higher than those measured outdoors (Din *et al.,* 2024; Jahanzaib *et al.,* 2025). Various indoor sources, including synthetic textiles, plastic furnishings, and personal care products, continuously generate indoor MPs through fragmentation, abrasion, and desorption (Can-Güven, 2021; Dris *et al.,* 2016; Salthammer, 2022; Torres-Agullo *et al.,* 2022).

Previous studies have reported the presence of MPs in settled dust and indoor air across a wide range of environments, including households, offices, classrooms, and hospitals (Catarino *et al.,* 2018; Wright *et al.,* 2020). The main exposure pathways in such environments include inhalation and ingestion of resuspended particles originating from indoor dust or surface deposition (Catarino *et al.,* 2018; Wright *et al.,* 2020). Among these pathways, inhalation is of particular concern because smaller MPs, especially those below 10 µm, may penetrate deeply into the respiratory tract and potentially induce inflammatory or toxicological responses (Roy *et al.,* 2024; Triantafyllaki *et al.,* 2024). These findings highlight the need to better understand the transport, accumulation, and deposition mechanisms of MPs in indoor environments.

In hot and humid regions such as Malaysia, active cooling is commonly required to maintain indoor thermal comfort (Allah *et al.,* 2023). As a result, air-conditioning (AC) systems are widely used in residential and other enclosed environments (Allah *et al.,* 2023). AC units may influence the transport, deposition, and inhalation risk of indoor MPs because they modify airflow patterns, temperature, and relative humidity within indoor spaces (Chen *et al.,* 2022a; Chen *et al.,* 2022b; Zhai *et al.,* 2023; Zhang *et al.,* 2020). Thermal conditions regulated by AC systems may also affect MP behavior by altering particle buoyancy, hygroscopicity, and air circulation (Henry *et al.,* 2023). Higher temperatures may promote particle resuspension, whereas lower temperatures may enhance deposition through changes in airflow movement and particle settling behavior (Henry *et al.,* 2023).

However, limited information is available on how these temperature variations influence MP abundance and exposure risk under real indoor conditions. For instance, a recent study conducted in an air-conditioned office reported that AC operation influenced both MP concentration and particle morphology, with smaller particles becoming more dominant under cooler conditions (Nor Haida *et al.,* 2024).

Recent experimental studies have begun to address this issue. A breathing thermal manikin has been used to simulate human exposure and demonstrate the inhalation of various plastic fibers under typical indoor conditions (Vianello *et al.,* 2019). Other studies have also shown that fiber-shaped MPs dominate indoor air samples, with mechanical airflow potentially contributing to their spatial variability (Liu *et al.,* 2020). Nevertheless, few studies have systematically examined how different modes of mechanical ventilation, particularly variations in AC temperature settings, influence both deposition rates and human inhalation risks. Temperature settings may affect relative humidity and airflow velocity, which in turn can indirectly influence particle behavior and indoor microclimate stability (Vianello *et al.,* 2019; Liu et al., 2020).

In light of these knowledge gaps, this study evaluates the influence of air-conditioning systems operating under low- and high-temperature regimes on the deposition rate and inhalation risk of indoor MPs in a controlled indoor environment. By including a non-ventilated baseline for comparison, this study provides insight into how commonly used ventilation strategies may either mitigate or exacerbate human exposure to indoor microplastics. The findings contribute to the growing body of evidence needed to inform building design, ventilation practices, and indoor air quality management related to emerging indoor contaminants.

2. METHODS
2.1. Sampling Site

Microplastic deposition was assessed in an indoor environment located in Meru, Selangor (3°8.666'N, 101°26.658'E), as shown in **Figure 1**. The monitored room had a floor area of 18.96 m² and was furnished as a typical bedroom, including a bed, vanity table, wardrobe, and a designated study area consisting of a desk and chair. An air-conditioning unit was installed to maintain indoor climate control. During the sampling period, all windows remained closed, and the curtains were kept drawn during daytime hours to minimize the influence of direct sunlight and maintain stable indoor environmental conditions.

Figure 1. Sampling area for indoor microplastic monitoring.

2.2. Passive Sampling of Indoor Microplastics

Passive sampling, as illustrated in **Figure 2** and adapted from reference (Zhang *et al.,* 2020), was employed to quantify the deposition of indoor microplastics under controlled environmental conditions. The investigation spanned eight consecutive weeks, during which MPs were continuously collected in a single indoor setting under two conditions: with and without air-conditioning operation. A custom-built sampling device was used, consisting of a stainless-steel funnel with a collection surface area of 0.03 m² connected to a 1 L amber glass bottle. Sampling was conducted simultaneously at two vertical positions: near floor level (0.2 m) and at 1.2 m above the floor surface. The latter height represents the typical breathing zone and corresponds to the average breathing height of an adult (Sridharan *et al.,* 2021). For each condition, three samplers were deployed as replicates, along with an additional identical set serving as a field blank. Indoor environmental parameters, including temperature, relative humidity, and wind speed, were recorded throughout the sampling period.

After each 24-hour sampling cycle, the amber glass bottles were sealed with aluminum foil, securely packed in cartons, and transported to the laboratory for analysis. During sample pre-treatment, each bottle was rinsed three times with ultrapure water, and the contents were vacuum-filtered using a Büchner funnel onto 47 mm membrane filters. Prior to filtration, the inner surface of the Büchner funnel was thoroughly rinsed with ultrapure water to minimize

contamination. After filtration, the membrane filters containing microplastic particles and organic residues were transferred to covered petri dishes and dried in a desiccator for 24 hours. Each petri dish was covered with aluminum foil perforated with a small hole to allow controlled drying.
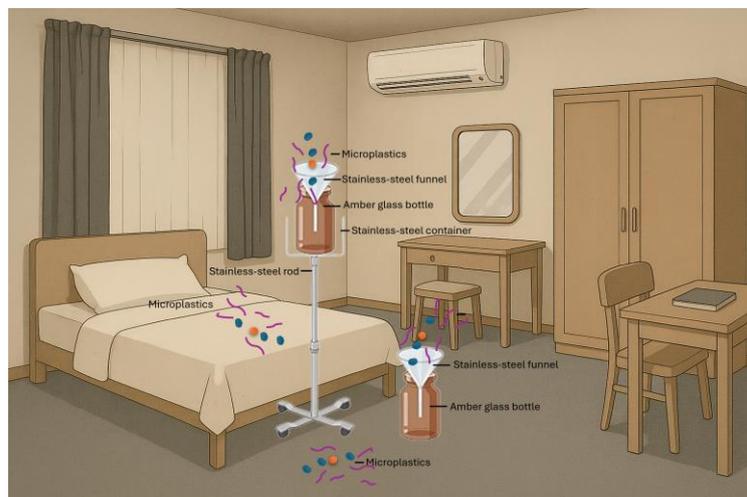

Figure 2. An illustration of the monitored indoor environment of passive sampling method in quantifying MPs at 0 m and 1.2 m height.

2.3. Organic Matter Removal

To isolate microplastics, the initial membrane filter (MCE 1) was placed in a beaker containing 20 mL of 30% hydrogen peroxide (H_2O_2). This oxidative digestion step was conducted to remove organic matter adhering to the microplastic surfaces. Environmental microplastics are often coated with naturally derived organic materials that may interfere with further analysis (Zhou *et al.,* 2022). Hydrogen peroxide treatment is widely applied in microplastic research due to its effectiveness in degrading organic matter without significantly affecting most polymer structures. This step is particularly important for samples with high organic content, as residual organic materials may interfere with spectroscopic analysis by contributing to background noise, particle masking, and surface biofouling (Zhang *et al.,* 2020).

The digestion process was conducted in a fume hood at ambient temperature for 48 hours. After digestion, the treated solution, primarily containing microplastics, was vacuum-filtered through a Büchner funnel onto a new membrane filter labeled as MCE 2. The filter was then dried in a desiccator for 24 hours before further analytical procedures.

2.4. Physical Analysis

Microplastic particles were identified and quantified using a stereomicroscope (Leica EZ4W) with a magnification range of 0.8×–35×. The particles were categorized into three morphological types: fibers, fragments, and pellets. In addition to morphological classification, the color of each particle was recorded based on its predominant surface appearance and grouped into seven categories: black, blue, green, red, purple, yellow, and transparent. Captured microscopic images were used to determine particle size, which was subsequently categorized into four size classes: <50 µm, 51–100 µm, 101–500 µm, and >500 µm.

2.5. Final clarification basin

Microplastic particles consisted of various polymer types that were identified using Raman spectroscopy. Raman spectroscopic analysis was performed using a confocal micro-Raman

spectrometer (WITec GmbH, Ulm, Germany) equipped with a 532 nm excitation laser operating at a power range of 2–10 mW, with 5 mW most commonly applied. The analytical settings followed established procedures commonly used in microplastic characterization studies (Dong *et al.,* 2020; Liu *et al.,* 2019; Xi *et al.,* 2019).

Raman spectra were collected using a 600 lines/mm diffraction grating, providing a spectral resolution of approximately 4 cm⁻¹ across a wavenumber range of 200–3500 cm⁻¹. The integration time for each scan ranged from 1 to 10 seconds, typically set to 5 seconds, and each spectrum was averaged over 1–10 accumulations, commonly four. Two diffraction gratings were used during analysis: a 600 g/mm grating with a spectral resolution of approximately 3 cm⁻¹ and an 1800 g/mm grating providing a higher spectral resolution of approximately 1 cm⁻¹.

2.6. Deposition Rate

The deposition rate of microplastics was estimated based on the number of particles accumulated on the passive sampler over the sampling period. In general, airborne particles remain suspended when the upward vertical air velocity exceeds their gravitational settling velocity. When this condition is not met, particles deposit onto surfaces through gravitational settling. Based on this principle, the deposition rate was calculated using Eq. (1).

In this equation, D represents the deposition rate (MPs/m²/day), n denotes the total number of microplastic particles collected, A is the cross-sectional area of the collection funnel (m²), and t represents the total exposure time (days).

$$D = \frac{n}{(A \times t)} \tag{1}$$

2.7. Quality Control Protocols

To ensure data reliability, rigorous quality assurance and quality control (QA/QC) protocols were implemented throughout the study. To minimize background contamination, all laboratory and field procedures were conducted in a controlled environment where researchers wore 100% cotton laboratory coats and nitrile gloves. All glassware was rinsed three times with ultrapure water and covered with aluminum foil when not in use to prevent airborne contamination.

Procedural blanks (n = 3) were processed alongside the experimental samples using identical collection and analytical procedures. The blanks showed negligible microplastic contamination, with an average of fewer than two particles per blank, indicating that laboratory conditions and sample handling did not significantly influence the results.

3. RESULTS

3.1. Shape

Fibers were the dominant microplastic morphology across all sampling scenarios, accounting for more than 80% of the total detected particles (**Figure 3**). The highest proportion of fibers was observed in floor-level samples under low-temperature air-conditioning (LTA), reaching 90.69%. In contrast, samples collected under stagnant air (SA) conditions showed a slightly lower fiber proportion (88.51%), accompanied by a higher presence of fragments (7.61–8.91%). Pellets were detected in smaller amounts, representing approximately 1.28% of the total particles under stagnant conditions.

At the breathing height (1.2 m), the proportion of fibers decreased slightly to a range of 83.55–89.22%. In contrast, fragments (8.42–14.54%) and pellets (1.91–2.36%) were detected more frequently at this height. These findings suggest that air-conditioning operation reduces the relative dominance of fibers while increasing the occurrence of other microplastic morphologies at both sampling heights.
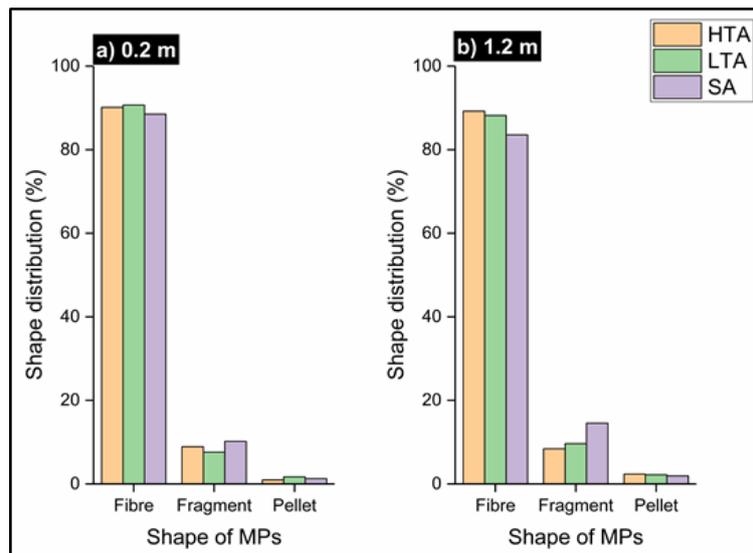
Figure 3. Shape distribution of MPs at two sampling heights: 0.2 m and 1.2 m under different scenario conditions: SA, LTA, and HTA.

3.2. Colour

Transparent MPs were the dominant colour category across all scenarios (**Figure 4**). At floor level, transparent MPs accounted for 74.7–76.3% of the total particles. Their proportion increased further in the breathing zone, reaching 78.90–79.17% under both HTA and LTA conditions.

Coloured MPs, particularly blue and black particles, represented approximately 6–13% of the total detected MPs. Red particles showed the highest variability, reaching 9% under HTA at floor level and 8% at the breathing height (1.2 m). Less common colours such as yellow, green, and purple were detected only under air-conditioning conditions, suggesting their possible mobilization from previously undisturbed or concealed indoor sources.

Overall, the results indicate that ventilation enhances the vertical redistribution of coloured MPs, leading to greater colour diversity within the breathing zone compared with the floor level.
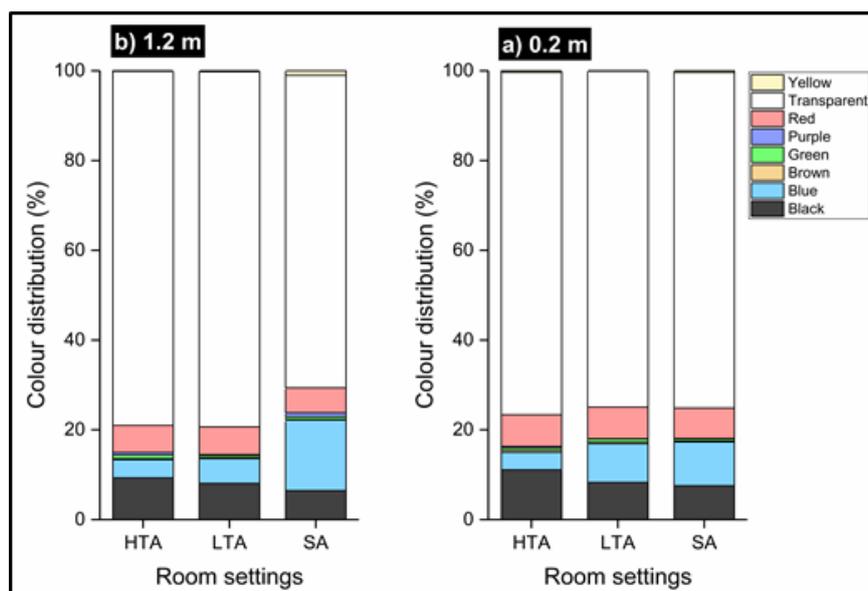

Figure 4. Colour distribution of MPs at two sampling heights: 0.2 m and 1.2 m under different scenario conditions: SA, LTA, and HTA.

3.3. Size

Larger MPs (501–5000 µm) dominated floor-level samples under SA conditions, accounting for 46.46% of the total particles (**Figure 5**). In contrast, the operation of AC shifted the size distribution toward smaller fractions, with particles in the 101–500 µm range accounting for 52.07–58.46%. Particles smaller than 100 µm were also detected under air-conditioning conditions.

At the breathing height (1.2 m), the size distribution was more balanced. Particles within the 101–500 µm range remained the dominant fraction (50.81–61.05%), while both larger particles (501–5000 µm) and smaller fractions (50–100 µm) were also present under ventilated scenarios.

These results suggest that airflow generated by air-conditioning promotes the suspension and vertical redistribution of microplastic particles within the indoor environment, allowing finer particles to remain airborne and reach the breathing zone.
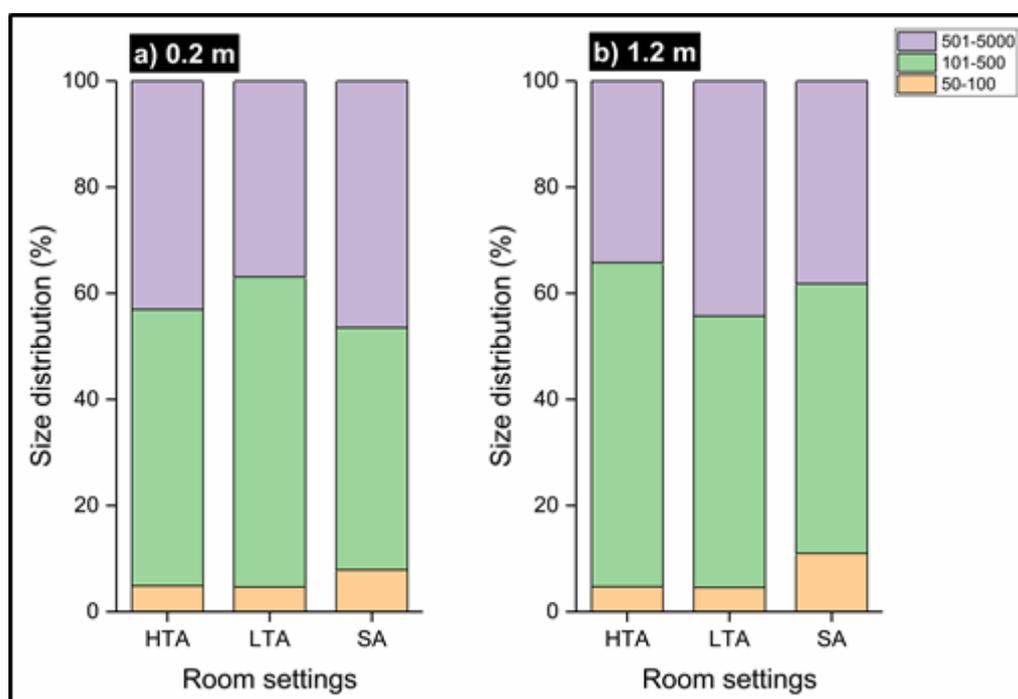

Figure 5. Size distribution of MPs at two sampling heights: 0.2 m and 1.2 m under different scenario conditions: SA, LTA, and HTA.

3.4. Polymer Type

Larger MPs (501–5000 µm) dominated floor-level samples under SA conditions, accounting for 46.46% of the total particles (**Figure 5**). In contrast, the operation of AC shifted the size distribution toward smaller fractions, with particles in the 101–500 µm range accounting for 52.07–58.46%. Particles smaller than 100 µm were also detected under air-conditioning conditions

Polymer analysis revealed that Polyester (PES) was the dominant polymer type under all sampling conditions (**Figure 6**). At floor level, PES accounted for 73.06–78.59% of the detected microplastics, while at breathing height (1.2 m) its proportion ranged from 65.35 to 78.79%.

Under SA conditions, PES constituted more than 65.35% of the total particles, with negligible contributions from Polypropylene (PP) . When air-conditioning (AC) was introduced, the proportion of PES decreased slightly, while PP increased to approximately 1–3%. In addition, other polymers such as Polycarbonate (PC), Polystyrene (PS), and Polyvinyl acetate (PVA) were detected.

Polymer diversity was more pronounced in the breathing zone, particularly under HTA, where the proportion of PES decreased to 78.79%, and other polymers, including PET, PP, PS, and PVA, collectively accounted for more than 21% of the total particles. These findings suggest that although PES fibers remain the primary indoor microplastic source, air-conditioning enhances the presence and vertical redistribution of a broader range of polymer types within the indoor environment.
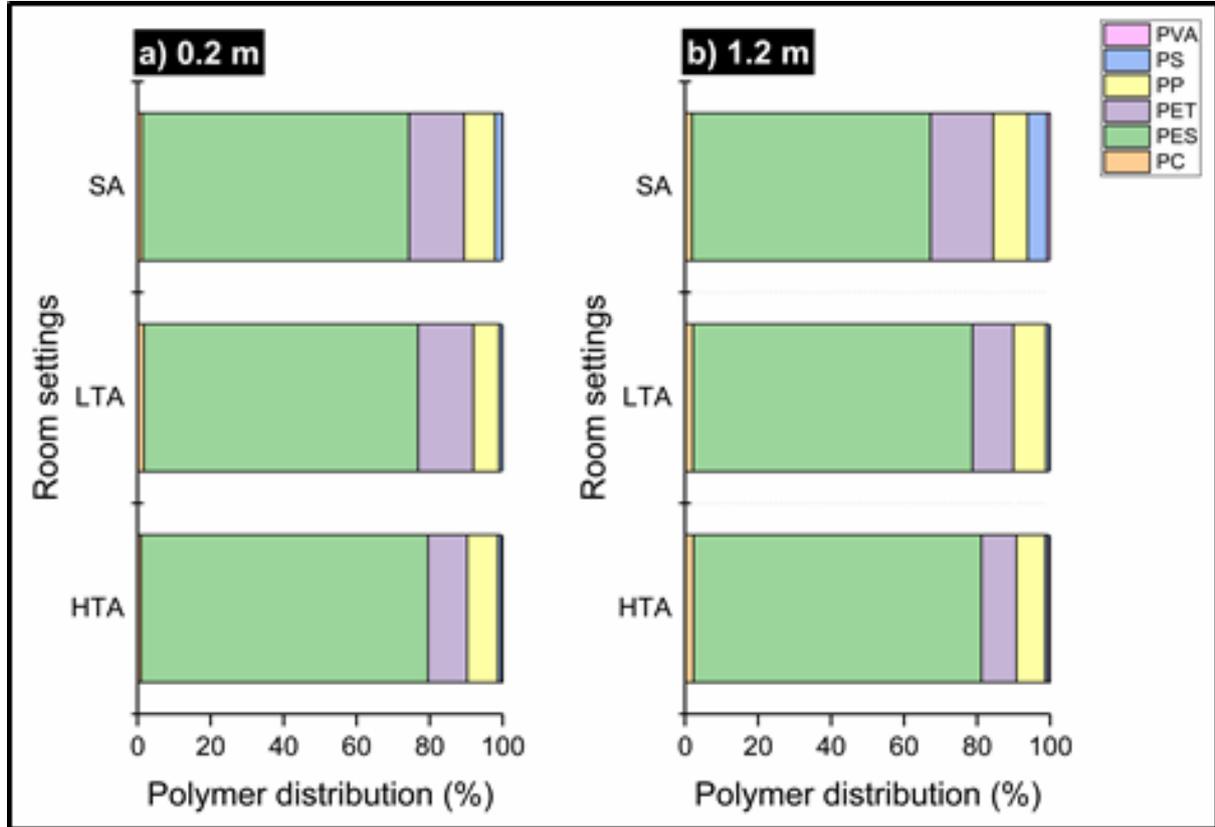

Figure 6. Polymer type distribution of MPs at two sampling heights: 0.2 m and 1.2 m under different scenario: SA, LTA, and HTA.

3.5. Deposition Rate

The deposition rates of indoor MPs under three scenarios (SA, LTA, and HTA) at two sampling heights (0.2 m and 1.2 m) are presented in **Figure 7**.

At 0.2 m, the deposition rate under stagnant air was 3.59×10^3 MPs/m²/day, corresponding to a relatively high indoor temperature of 29.12 °C and relative humidity of 77.23%. When air-conditioning was introduced, deposition rates increased to 5.07×10^3 MPs/m²/day under LTA and 3.83×10^3 MPs/m²/day under HTA. Both air-conditioning scenarios were associated with lower indoor temperatures (approximately 22.5 °C) and reduced relative humidity levels of approximately 52–53%.

At the breathing height (1.2 m), the deposition rate under SA conditions decreased to 2.84×10^3 MPs/m²/day, indicating lower particle deposition compared with the floor level. However, under AC operation, deposition rates increased substantially, reaching 4.73×10^3 MPs/m²/day under LTA and 3.71×10^3 MPs/m²/day under HTA. Indoor wind speed was generally higher under AC conditions (0.08–0.09 m/s) than under stagnant air (0.03–0.04 m/s).

Overall, these results indicate that mechanical ventilation, particularly low-temperature air-conditioning, increases indoor MP deposition and reduces the vertical difference between floor level and breathing height.
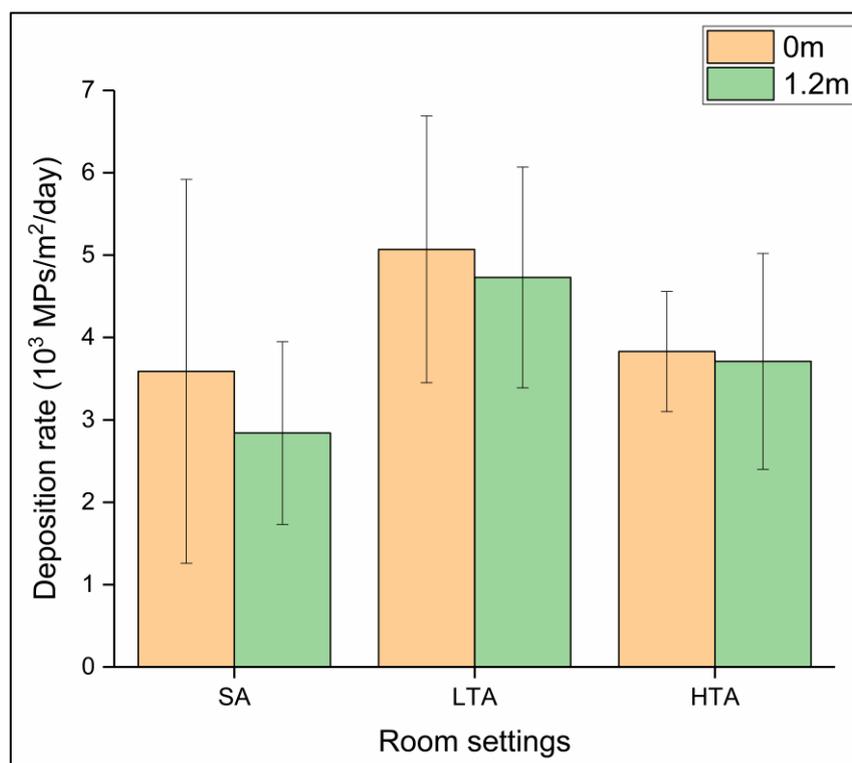
Figure 7. Deposition rates of MPs at two sampling heights: 0.2 m and 1.2 m under different scenario: SA, LTA, and HTA.

4. DISCUSSION

4.1. Shape

Fibers dominated the microplastic morphology across all ventilation scenarios, indicating that textiles and household furnishings are the primary sources of airborne indoor MPs. This pattern is consistent with previous studies showing that polyester and other synthetic fabrics contribute the majority of indoor microplastic fibers in residential environments (Al-Hussayni *et al.,* 2023; Dris *et al.,* 2016). Although fibers remained the dominant category, their relative abundance increased under air-conditioning conditions, while fragments and pellets were present in smaller proportions. This shift suggests that mechanical airflow mobilizes particles from secondary sources such as plastic furniture, packaging materials, and surface coatings. Turbulent air currents generated by air-conditioning systems can enhance abrasion and resuspension processes, influencing the distribution of particle morphologies within indoor environments (Kim *et al.,* 2021).

A comparison between sampling heights showed that the breathing zone contained a more diverse particle profile than the floor level. Under AC conditions, fragments accounted for up to 11.53% at 1.2 m compared with less than 9% at 0.2 m, while pellets—absent in stagnant air—reached nearly 4% at breathing height. This pattern suggests that while fibers dominate due to continuous shedding from textiles, stronger vertical air mixing under ventilation entrains other particle morphologies into the breathing zone.

These findings are important for exposure assessment because particle morphology influences aerodynamic behavior and deposition within the respiratory system. Fibers tend to deposit in the upper airways due to their elongated shape, whereas fragments and pellets may penetrate deeper into the lungs depending on their aerodynamic properties (Saha *et al.,* 2024). Overall, the observed shape distribution demonstrates that air-conditioning modifies both horizontal and vertical MP dynamics. Although fibers remain the predominant type,

enhanced entrainment of fragments and pellets under AC increases the morphological diversity of particles encountered in the breathing zone.

4.2. Colour

Colour distribution provides additional insight into potential sources and transport processes of indoor MPs. Transparent MPs dominated across all scenarios, accounting for more than 70% of particles near the floor and exceeding 75% in the breathing zone under HTA and LTA conditions. This dominance suggests that PES- and PET-based textiles are major contributors because these materials commonly shed transparent or lightly pigmented fibers (Peng *et al.,* 2023).

Blue and black MPs represented the second most common colour categories, accounting for approximately 6%–13% of detected particles. These colours are commonly associated with dyed textiles, carpets, and clothing materials frequently present in bedrooms. Red MPs showed greater variability, reaching 9% under HTA at floor level and 8% at breathing height, suggesting possible mobilization from packaging materials, decorative plastics, or household items during AC operation.

The vertical distribution of colours suggests that transparent MPs may be transported upward more efficiently, possibly due to their smaller size or lower density. In contrast, coloured particles such as red, blue, and black were more pronounced under HTA conditions, indicating that stronger turbulent airflow can mobilize heavier or less abundant particles into higher air layers. The occasional presence of yellow, green, and purple MPs—detected only under ventilated conditions and in very small fractions (<1.5%)—suggests that air-conditioning may mobilize particles from previously undisturbed reservoirs such as furniture surfaces, wall coatings, or plastic components of household appliances.

From an exposure perspective, colour characteristics may also reflect the presence of pigments and additives such as heavy metals, organic dyes, or flame retardants. These additives may introduce additional toxicological risks when inhaled together with MPs (Salthammer, 2022). The broader colour diversity observed in the breathing zone therefore indicates that occupants may be exposed not only to a greater number of particles but also to a more chemically complex aerosol mixture.

4.3. Size

Size distribution patterns highlight the important role of air circulation in shaping indoor MP exposure risk. Under stagnant conditions, larger MPs (500–5000 µm) dominated, particularly at floor level, reflecting gravitational settling as the primary removal mechanism in the absence of airflow. However, air-conditioning substantially altered this pattern by reducing the dominance of coarse particles and increasing the proportion of mid-sized (101–500 µm) and fine particles (<100 µm).

The appearance of particles smaller than 100 µm under ventilated conditions is particularly important because these fractions are more respirable and can remain suspended for longer periods, increasing the likelihood of inhalation exposure (Prata, 2018).

Differences between sampling heights further emphasize the influence of ventilation on particle redistribution. Floor-level samples under SA contained 7.9 particles smaller than 100 µm, whereas breathing-zone samples under LTA and HTA consistently contained approximately 4.65–4.89% of particles in this size range. These findings suggest that AC operation facilitates the suspension and vertical transport of finer MPs, increasing their presence within the breathing zone. Vertical mixing processes generated by ventilation may allow these particles to remain airborne longer than under stagnant conditions (Yuan *et al.,* 2023).

From a health perspective, the presence of smaller MPs in the breathing zone is particularly concerning. Larger MPs are more likely to deposit on surfaces or be removed through mucociliary clearance if inhaled, whereas finer MPs may bypass these defenses and reach the bronchioles or alveoli (Amato-Lourenço *et al.,* 2020). The higher proportion of fine particles observed under LTA compared with HTA may also indicate that stronger cooling airflow produces greater turbulence, promoting the resuspension of smaller particles. Overall, the observed size distribution suggests that AC operation increases the respirable fraction of indoor MPs and therefore may amplify inhalation risks.

4.4. Polymer Type

Polymer analysis indicates that PES was the most abundant polymer under all sampling conditions, reflecting its widespread use in indoor textiles such as polyester fabrics, bedding, and clothing (Ageel *et al.,* 2024; Zheng *et al.,* 2024). Under stagnant air conditions, PES accounted for more than 65% of the detected particles at floor level.

When ventilation was introduced, the relative proportion of PES decreased slightly while other polymers, such as PP, PS, and PVA, appeared in greater proportions. Polymer diversity was particularly evident in the breathing zone under HTA conditions, where PES decreased to 78.79%, and PP, PS, and PVA together accounted for more than 12% of the total particles.

The detection of PS and PVA primarily under ventilated conditions suggests that airflow mobilizes MPs from hidden or secondary indoor sources that are less likely to be resuspended under stagnant conditions. This increase in polymer diversity is important for exposure assessment because different polymers may contain distinct additives, fillers, and degradation by-products.

For example, polystyrene MPs have been associated with inflammatory and cytotoxic responses in inhalation studies, while PVA is widely used in coatings and adhesives that may degrade into smaller fragments (Aloi *et al.,* 2024; Laganà *et al.,* 2024). Therefore, the presence of multiple polymer types in the breathing zone suggests that occupants may be exposed to a chemically complex mixture of microplastic particles.

4.5. Deposition Rate

The results demonstrate that air-conditioning strongly influences indoor MP deposition dynamics. Under stagnant conditions, deposition rates were lower at both sampling heights, with the lowest value observed at breathing height (1.2 m). This pattern reflects an environment dominated by gravitational settling, where particles gradually deposit onto surfaces in the absence of significant air circulation (Ouyang *et al.,* 2022).

In contrast, both AC modes increased deposition rates, particularly under LTA conditions where values exceeded 4.7×10^3 MPs/m²/day at both heights. Because passive samplers capture particles depositing over time, higher deposition under AC scenarios likely reflects repeated cycles of resuspension and redeposition within the indoor environment.

Airflow generated by the AC system, with wind speeds ranging from 0.08–0.09 m/s, likely entrained MPs from indoor surfaces such as bedding, carpets, and desks, promoting redistribution throughout the room. As a result, the difference in deposition between floor level (0.2 m) and breathing height (1.2 m) became relatively small under LTA conditions. Similar observations have been reported in previous studies showing that forced ventilation can homogenize particle distributions within indoor spaces (Choi *et al.,* 2022; Jenner *et al.,* 2021).

Environmental parameters also support this interpretation. Under SA conditions, relative humidity was higher (~77%), which may promote particle agglomeration and gravitational deposition. Under AC operation, humidity decreased to approximately 50%, which may reduce particle aggregation and prolong suspension time (Amato-Lourenço *et al.,* 2022). Air-

conditioning operation also introduces airflow disturbances that facilitate the resuspension and circulation of indoor dust and MPs (Kacprzak *et al.,* 2022).

From an exposure perspective, the increase in deposition rates at breathing height under AC conditions is notable. Deposition at 1.2 m increased substantially under LTA compared with SA, indicating that ventilation can elevate the concentration of particles within the inhalation zone. Similar observations have been reported in studies demonstrating that HVAC systems may increase the presence of MPs in the breathing zone (Vianello *et al.,* 2019; Zhang *et al.,* 2020).

4.6. Implications for Human Exposure and Risk

The comparison between floor level and breathing height highlights distinct pathways of human exposure to indoor microplastics. Floor-level samples showed higher deposition rates but were characterized by a narrower particle profile dominated by fibers, transparent particles, larger size fractions, and PES polymers. These characteristics suggest that MPs near the floor are more likely to accumulate on surfaces and contribute primarily to secondary exposure through resuspension or dermal contact rather than direct inhalation.

In contrast, the breathing zone contained a more complex particle mixture. Air-conditioning increased the proportion of fragments and pellets, broadened the colour spectrum, and introduced smaller particle fractions (<100 μm). Polymer composition was also more diverse, with PES remaining dominant but accompanied by higher proportions of PET, PP, PS, and PVA.

The presence of smaller particles and multiple polymer types indicates a higher probability of respiratory deposition because finer MPs can penetrate deeper into the lungs (Prata, 2018). In addition, pigmented particles may carry dyes and additives that introduce additional toxicological risks when inhaled (Salthammer, 2022).

Overall, these findings suggest a dual exposure scenario in which floor-level MPs contribute primarily to surface contamination and secondary resuspension, while MPs present at breathing height represent the more direct inhalation pathway. Air-conditioning systems appear to enhance vertical mixing and diversify the particle composition in the breathing zone, potentially increasing long-term exposure risks for occupants in mechanically ventilated indoor environments (Vianello *et al.,* 2019).

5. CONCLUSION

This study demonstrates that residential air-conditioning systems significantly influence the distribution and exposure risk of indoor microplastics. Air-conditioning shifts indoor conditions from a settling-dominant environment to a recirculating suspension state, facilitating the vertical transport of smaller and more respirable particles (<100 μm) into the human breathing zone. While larger particles tend to accumulate on floor surfaces under stagnant conditions, AC operation promotes resuspension and redistributes particles throughout the indoor air column. As a result, occupants may be exposed to a more diverse and respirable mixture of microplastics than suggested by surface-level measurements. These findings highlight the importance of improved filtration, optimized ventilation strategies, and further research to better understand and mitigate indoor microplastic exposure.

6. ACKNOWLEDGMENTS

7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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