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Microplastic Inhalation in Urban Areas – Airborne microplastics exposure in Dhaka and its impact on respiratory health in the Long Term

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Introduction

Dhaka, the city of magic, stands with a population of 21.1 million people in the urban area and 10.3 million in the city. Dhaka is one of the most densely populated cities in the world, with 47,400 people per square kilometer.[11] This makes it the sixth most densely populated city in the world and at the same time often ranking among the most air polluted cities globally. Airborne microplastics (AMPs) arise from fragmentation of larger plastics and from primary engineered particles. Urbanization and high plastic use amplify atmospheric loading in cities like Dhaka [1]. Textiles, traffic-related abrasion, industrial emissions and resuspension of contaminated dust are repeatedly identified as dominant indoor and outdoor sources in urban and megacity settings [1], [4].

Plastic waste from degrading things produces microsized plastic (diameter <5 mm) termed as microplastics (MPs). Due to their ubiquitous use in the human world, they pose a serious threat to environments and human health. High consumption, poor waste management and dense industrial clusters increase local AMPs emissions in urban areas [1]. Key sources Textile fibres (wear and processing), vehicle-related abrasion (tyres, roadwear), open burning and uncontrolled waste accumulate and fragment into airborne particles [1], [4]. Particle characteristics AMPs in urban air are often fibrous, length-variable (tens to hundreds of micrometres), polymer-diverse, and their aerodynamic behaviour depends on shape, density and meteorology [1], [4].

The long-term effects of MP absorption on human health is a growing concern. After inhaling or ingesting, MPs accumulate in the respiratory and gastrointestinal tissues, leading to chronic inflammation, oxidative stress, and potential disruption of cellular processes. Sometimes it hinders the normal cell functions and causes serious diseases like cancer. Over prolonged exposure, MPs can act as carriers of toxic additives and environmental pollutants (heavy metals, persistent organic pollutants). Previous evidence also suggests possible interference with endocrine regulation, immune responses, and even carcinogenic pathways.

Research Question

This study seeks to investigate the occurrence, nature, and potential health implications of airborne microplastics (AMPs) in the urban environment of Dhaka. The question is:

To what extent are humans residing in the urban environment of Dhaka being exposed to airborne microplastics, and what are the potential associations between such exposure and respiratory health outcomes?

To address this question, the following specific research questions are posed:

1. Environmental Burden of Microplastics: Concentrations of Airborne MPs in Dhaka environments and their Morphological categories (fibers, fragments, films, spheres), size ranges, colors, and polymer types dominate in these samples.
2. Human Exposure Estimation: Estimated inhalation exposure levels (Average Daily Intake, ADI) of MPs for different demographic groups (infants, children, adolescents, and adults) of Dhaka populations.
3. Respiratory Health Associations: The measurable association between estimated MP inhalation exposure and self-reported respiratory symptoms of chronic cough, wheezing, breathlessness or clinically assessed pulmonary function in residents.
4. Public Health and Policy Implications:The potential chronic AMP inhalation long-term health threat in densely populated urban neighborhoods and how the results may be applied towards the development of targeted public health responses and policy measures that aim to mitigate airborne AMP exposure.

Literature Review

Dhaka-focused studies documented that, AMPs in indoor dust, textile-industrial fallout and urban vegetation, link high particle burdens to the city's dense industrial, traffic and waste contexts [7], [10], [9]. Exposure assessments in Dhaka winter indicate notable inhalation exposure from indoor deposited dust, and textile factory sampling shows high deposition rates of synthetic fibres at source locations [7], [10].

Empirical Dhaka findings Indoor dust assessment found measurable airborne MP proxies in household dust and used that to estimate inhalation exposure during winter [7]. Textile area sampling detected polyester, nylon and regenerated cellulose fibres with high deposition inside factories and nearby outdoor points [10].

Existing literature highlights inflammation, oxidative stress and epithelial injury as primary mechanistic pathways for AMP-induced respiratory effects, many toxicological studies report pro-inflammatory and oxidative responses to plastic particles or fibres in vitro and in vivo [5], [6]. Epidemiological linkage between AMPs per se and population health is still limited, but particle-rich urban air is associated with increased respiratory morbidity in Dhaka and similar megacities [2], [5].

- Mechanisms Oxidative stress and inflammation are commonly reported mechanistic endpoints in toxicology studies of AMPs and associated chemicals [5], [6].
- Epidemiology and particle co-exposures In Dhaka, PM2.5 increases are associated with higher respiratory emergency visits and effect modification by source (combustion related particles more harmful) while these studies target PM, they contextualize respiratory vulnerability where AMPs co-occur with combustion and biomass aerosols [2].
- Vulnerable populations Children and older adults show larger effect sizes for particle-related respiratory outcomes in Dhaka and are expected to be more susceptible to AMP exposure. [2], [10].
- Quantitative exposure proxies Megacity assessments estimated annual inhalation item-loads comparable to dietary microplastic intake, and localized studies in Dhaka reported wintertime indoor dust AMPs concentrations used to estimate inhaled burdens [3], [7].

Methodology

Study area & sampling framework

- Seasons sampled: Winter (January–March 2024) and Summer (April–June 2024).
- Place: Households with Elderly and children , Surfaces and open air round residential areas.
- Sampling frequency: Weekly, included both weekdays and weekends; n = 4 samples per month for each particulate size class (to capture representative dataset).
- Targets / size fractions: PM10, PM2.5, PM1 (aerosol-associated outdoor microplastics).
- Sampling devices & models: PM1 sampler — Envirotech APM 577 M (low-/high-volume as applicable), PM2.5 sampler — Envirotech APM 550 MFC, PM10 sampler — Envirotech APM 460 DXNL.
- Filter types: Quartz and PTFE (polytetrafluoroethylene), 47 mm diameter, pore size 0.5–2 µm — chosen for thermal resistance, low organic background, chemical stability, low contamination risk, and fine-particle capture efficiency.

Sample subsampling & overall contamination prevention

Subsampling: Cut one-quarter of each filter for processing: stated areas used were 100 cm² for PM10 and 15 cm² for PM2.5/PM1 (via clean scissors).

Organic-matter removal (digestion) & particle release

- Initial digestion: Samples digested with 20% hydrogen peroxide (H_2O_2) for 7 days at room temperature to oxidize/remove organics. Fresh H_2O_2 added in stages until visible organic debris was completely broken down.
- Sonication & rinse: After digestion, filters sonicated for 30 minutes (ultrasonication) and rinsed with Milli-Q water to release adhered particles.
- Filtration after digestion: Solution filtered through 0.45 µm nitrocellulose filter papers and rinsed with Milli-Q to remove residual H_2O_2.

- Measurement: Image capture of suspected MPs and dimensional analysis using ImageJ to measure the longest dimension of particles.

Polymer confirmation (FTIR)

- Instrument: Fourier Transform Infrared Spectrometer (Bruker).
- Identification criterion: Spectra compared to polymer reference libraries; ≥ 85% spectral match confidence required to classify a particle as a confirmed MP.

Health-risk assessment (inhalation exposure)

- **Approach:** Estimated inhalation exposure to MPs for both “normal” and “dusty” days following **WHO (2000)** guidance.
- **Population age groups & inhalation rates (IR) used:**
  - Infants (≤ 1 year): **IR = 5.4 m^3/day**
  - Toddlers (1–6 years): **IR = 9.0 m^3/day**
  - Children (6–12 years): **IR = 12.0 m^3/day**
  - Adolescents (12–18 years): **IR = 15.7 m^3/day**
  - Adults (≥ 18 years): **IR = 15.7 m^3/day**

Note: ADI computed per age group using the measured aerosol MP concentrations (C) and the above IR values; exposure scenarios included normal and high (dusty) conditions.

Experimental quality control

- **Glassware / containers:** Cleaned with diluted HCl then Milli-Q water, dried, then covered with aluminium foil
- **Workspace:** All extractions and manipulations performed in a clean airflow area to minimize airborne contamination.
- **Personal protective equipment:** Cotton lab coats and single-use nitrile gloves throughout lab work.
- **Procedural blanks:** Three procedural blanks run through the entire workflow to check airborne contamination; blanks showed no MPs, confirming contamination control.

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