Review

Public Health

Airborne Microplastics
Another Threatening to Our Health

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The omnipresence of microplastics (MPs) in the environment has raised global concern, particularly as these particles become airborne and infiltrate the human respiratory system. This review explores the emerging evidence on airborne microplastics (AMPs), focusing on their sources, atmospheric dynamics, inhalation exposure pathways, and potential health effects. Drawing on studies from environmental science, toxicology, and public health, the review outlines the physicochemical properties of airborne MPs that influence their biological interactions. Particular attention is given to pulmonary inflammation, oxidative stress, endocrine disruption, and the role of particle size in deep lung penetration. Evidence linking MPs with chronic diseases such as asthma, cancer, and cardiovascular conditions is examined. Furthermore, the article discusses detection challenges, the need for standardized measurement protocols, and policy efforts aimed at mitigating human exposure. In conclusion, while scientific understanding is still evolving, airborne microplastics pose a credible threat to human health, warranting urgent interdisciplinary research and regulatory attention.

Keywords: Airborne Microplastics; Respiratory Health; Environmental Toxicology; Oxidative Stress; Public Health; Particle Inhalation

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Introduction

MICROPLASTICS (MPs) are plastic fragments less than 5 mm in diameter that originate from various anthropogenic sources. They are classified into two types: primary and secondary (Saboor et al., 2022). Primary MPs are manufactured at a microscopic scale for commercial purposes, such as in personal care products (e.g., microbeads in exfoliants), industrial abrasives, or biomedical applications. In contrast, secondary MPs result from the environmental degradation of larger plastic debris due to physical, chemical, and biological processes, such as UV radiation, wind erosion, and microbial action (Hettiarachchi & Meegoda, 2023).

Table 1: Major Sources of Airborne Microplastics.

Environment	Source	Description
Outdoor	Tire wear	Abrasion of synthetic rubber during vehicle use
	Textile degradation	Weathering of synthetic fibers outdoors
Indoor	Furniture & carpets	Shedding of synthetic fibers from wear
	HVAC systems	Redistribution of dust-laden particles

The environmental persistence and non-biodegradable nature of MPs have made them a topic of significant concern. These particles act as carriers for hydrophobic organic contaminants (HOCs), heavy metals, and pathogens. The earliest research predominantly focused on aquatic environments, where MPs have been found to affect marine biodiversity and accumulate through the food chain (Guo et al., 2023). However, with advancing detection technologies, attention has shifted toward their presence in the atmosphere, where the implications for human health are increasingly evident.

Rise of Airborne Microplastics as a Public Health Concern

The realization that MPs are not confined to aquatic environments has profound implications for public health. Airborne microplastics (AMPs) are now recognized as a significant source of environmental exposure, particularly in urbanized and industrial regions (Guo et al., 2023). Inhalation represents a direct and continuous route of exposure, bypassing the digestive system and introducing particles directly into respiratory tissues.
The ability of fine and ultrafine plastic particles to penetrate deep into the pulmonary system raises alarms about their potential to cause chronic inflammation, immune dysregulation, and even systemic distribution through the bloodstream (Saha & Saha, 2024). This concern is compounded by findings that indoor air—where people spend the majority of their time—often contains higher concentrations of MPs due to textiles, furniture, and household dust. In this context, AMPs represent not just an environmental pollutant, but a pervasive health hazard affecting both occupational and general populations.

Sources and Types of Airborne Microplastics

Primary Sources

- Synthetic Textiles: The shedding of synthetic fibers during wear and laundering is a well-documented source of AMPs. Research shows that polyester, acrylic, and nylon textiles release microfibers into both water and air. During domestic activities like vacuuming, sitting on furniture, or changing clothes, these fibers become aerosolized and can be readily inhaled (Prendergast‑Miller et al., 2019).
- Tire and Road Wear Particles (TRWPs): TRWPs are produced by the mechanical abrasion of tires against road surfaces. Composed of rubber, synthetic polymers, and various fillers, these particles are a significant component of urban airborne particulate matter. Studies have estimated that a single vehicle can generate several kilograms of TRWPs per year, much of which can become airborne due to vehicular turbulence and weather conditions (Son & Choi, 2022).
- Industrial Processes: Facilities involved in plastic manufacturing, cutting, injection molding, and recycling emit plastic dust and fibers during mechanical handling and thermal processing. In some regions, poor air filtration and lack of emission controls exacerbate this problem (Dissanayake et al., 2022). Occupational exposure in such settings is particularly high, and cases of respiratory issues among workers have been reported (Nalugya et al., 2022) (**Table 1**).

Secondary Sources

- Environmental Degradation: Littered plastic materials subjected to environmental stressors undergo fragmentation, releasing MPs into the surrounding air (Gaspéri et al., 2017). UV radiation from sunlight accelerates the degradation of plastic surfaces, especially in arid climates. Wind action can then lift these fragments into the lower atmosphere (Napieraj et al., 2023).
- Waste Management Sites: Landfills and incinerators represent critical sources of AMPs (De Souza Machado et al., 2019). In landfills, waste sorting, dumping, and compacting release MPs, especially on windy days. Incineration, when inefficient or poorly managed, can produce incomplete combustion products that include volatile MPs (Kumar & Garg, 2021) (**Table 1**).

Composition and Morphology

- The polymer composition of AMPs varies widely and includes polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC) (Covernton et al., 2021). Their morphology includes:
- Fibers: Long and thin, often from textiles and ropes.
- Fragments: Irregularly shaped pieces from degraded plastics.
- Films: Thin plastic layers from bags and packaging.
- Beads or Spheres: Found in cosmetics and industrial abrasives.

These forms influence their aerodynamic properties, deposition sites in the respiratory tract, and interactions with biological tissues. Fibers, due to their shape, are particularly difficult to expel from the lungs and may induce chronic irritation.

Atmospheric Transport and Deposition

Long-Range Transport

Table 2: Mechanisms of Health-related Impacts of Airborne Microplastics.

Mechanism	Health Outcome	Supporting Evidence
Oxidative stress	DNA damage, apoptosis	In vitro studies on human lung cells
Chronic inflammation	Asthma, bronchitis	Murine exposure models
Endocrine disruption	Hormonal imbalances	Plastic additive toxicity studies
Translocation	Cardiovascular issues	Detection in blood and tissues

Airborne MPs are capable of transboundary and intercontinental transport. Their residence time in the atmosphere depends on size, density, and meteorological conditions. Light particles with aerodynamic shapes can travel hundreds to thousands of kilometers (Is et al., 2017). A study found MPs in remote areas of the French Pyrenees, with the nearest urban source over 100 kilometers away, confirming long-range atmospheric dispersal (Shaddick et al., 2020). Similarly, MPs have been discovered in Arctic snow samples, raising concerns about global dissemination (Carriera et al., 2024).

Indoor vs Outdoor Concentrations

Indoor environments often exhibit significantly higher concentrations of MPs compared to outdoor settings. Factors contributing to this include limited air exchange, continuous fiber shedding from textiles, and re-suspension from surfaces due to human movement. A breathing thermal manikin was employed in a residential setting and found that the human exposure to MPs indoors was up to ten times greater than outdoors (Facciolà et al., 2021). High-density urban apartments, especially those with poor ventilation, pose elevated risks.

Seasonal and Geographic Variability

Seasonal changes influence the concentration and distribution of airborne MPs. During dry and windy seasons, resuspension and atmospheric transport increase, while precipitation can reduce airborne concentrations through wet deposition (Sheraz et al., 2023). Geographic factors also matter: urban areas, coastal cities, and regions near plastic manufacturing hubs exhibit higher AMP levels. In contrast, rural and high-altitude regions typically show lower, though not negligible, concentrations.

Human Exposure Pathways

Inhalation

Inhalation is the most significant exposure route for airborne MPs. Particles smaller than 10 µm (PM10) can penetrate the upper respiratory tract, while those smaller than 2.5 µm (PM2.5) can reach alveolar regions (Sripada et al., 2022). Nanoplastics (<1 µm) may cross cellular membranes and enter the circulatory system. Once deposited in lung tissues, these particles may persist, potentially leading to fibrosis and granuloma formation.

Ingestion

Airborne MPs can settle on food, utensils, and cooking surfaces, leading to unintentional ingestion. Additionally, MPs trapped in nasal or tracheal mucus can be swallowed during mucociliary clearance (López et al., 2023). While ingestion routes have been more extensively studied in marine food chains, the contribution of airborne MPs to dietary intake is becoming increasingly evident.

Dermal Contact

Dermal exposure is generally considered minimal due to the skin's barrier properties. However, scenarios such as handling contaminated dust or exposure in industrial settings may present some risk, especially for individuals with skin abrasions or dermatological conditions (Goodman et al., 2023). While evidence for systemic absorption through the skin is limited, the possibility remains for small particles or additives to penetrate compromised barriers.

Toxicological Effects on Human Health

Respiratory Inflammation and Oxidative Stress

AMPs act as foreign bodies that can stimulate immune responses. Upon deposition, macrophages attempt to engulf the particles, often resulting in frustrated phagocytosis, where the size or persistence of the particle prevents complete clearance. This process leads to the release of pro-inflammatory cytokines like IL-6, IL-8, and TNF-α (Anderson et al., 2008). The presence of MPs has also been shown to increase levels of reactive oxygen species (ROS), leading to oxidative stress, mitochondrial damage, and apoptosis in lung epithelial cells (Peng et al., 2020) (**Table 2**).

Cytotoxicity and Genotoxicity

Experimental studies have demonstrated that MPs can be cytotoxic to both human and animal cell lines. Polystyrene particles have been shown to reduce cell viability and disrupt membrane integrity (Ageel et al., 2021). Genotoxic effects include DNA strand breaks, micronucleus formation, and chromosomal abnormalities. These effects are amplified when MPs are loaded with adsorbed pollutants such as polycyclic aromatic hydrocarbons (PAHs) or heavy metals (Ferrante et al., 2022) (**Table 2**).

Endocrine Disruption

Many MPs contain or adsorb endocrine-disrupting chemicals (EDCs), including phthalates, BPA, and alkylphenols. These chemicals interfere with hormone receptors, potentially leading to reproductive disorders, thyroid dysfunction, and developmental abnormalities (Alnuqaydan, 2024). Animal studies have shown altered hormone levels and reproductive performance after exposure to MPs containing EDCs (Lv et al., 2016) (**Table 2**).

Pulmonary Diseases

Emerging epidemiological evidence suggests a link between chronic AMP exposure and respiratory conditions such as asth-

Table 3: Common Detection Techniques for Airborne Microplastics

Technique	Particle Size	Strengths	Limitations
Micro-FTIR	>10 µm	Polymer identification, non-destructive	Limited to larger MPs
Raman Spectroscopy	~1 µm	High resolution, pigment analysis	Fluorescence interference
SEM-EDS	>1 µm	Surface morphology, elemental data	No direct polymer ID
Py-GC/MS	Bulk samples	Polymer quantification	Destructive, no shape data

ma, bronchitis, COPD, and idiopathic pulmonary fibrosis. Occupational studies among workers in synthetic fiber industries have reported elevated incidences of respiratory symptoms and reduced lung function (Kurt et al., 2016). While direct causality is challenging to establish, the biological plausibility and consistency of findings warrant precautionary action (**Table 2**).

Potential for Carcinogenicity

Although long-term epidemiological studies are lacking, MPs' ability to induce chronic inflammation, oxidative stress, and genotoxicity raises concern about carcinogenic potential. The inhalation of plastic-associated carcinogens, such as vinyl chloride monomers and heavy metals, further contributes to the risk. Animal models have demonstrated tumor formation following long-term exposure to certain plastic particles (Goswami et al., 2024) (**Table 2**).

Detection and Measurement Techniques

Sampling Methods

Quantifying airborne microplastics requires robust sampling techniques, often adapted from conventional air particulate collection systems. High-volume air samplers, cascade impactors, and deposition collectors are commonly used (Knobloch et al., 2021). Sampling is performed on quartz or glass fiber filters, which allow for subsequent microscopic or spectroscopic analysis. Indoor and outdoor sampling must account for varying particle concentrations, humidity, and airflows. Challenges include minimizing contamination during sampling and standardizing durations across environments (Cheng, 2018) (**Table 3**).

Analytical Techniques

Analytical identification of AMPs involves a combination of microscopic and spectroscopic tools:

- Fourier-Transform Infrared Spectroscopy (FTIR): Widely used for identifying polymer types. Micro-FTIR enables analysis of individual particles as small as 10 µm.
- Raman Spectroscopy: Allows higher spatial resolution and identification of pigments and additives, though it is sensitive to fluorescence interference.
- Scanning Electron Microscopy (SEM) with Energy-Dispersive X-ray Spectroscopy (EDS): Provides morphological detail and elemental composition.
- Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS): Useful for quantifying total polymer content.

Regulatory Framework and Policy Responses

Current Policies and Guidelines

As of 2025, there are no specific international guidelines governing airborne microplastics. Regulatory efforts have largely focused on plastic pollution in aquatic systems. The European Chemicals Agency (ECHA) proposed restrictions on intentionally added microplastics in products, while the U.S. Environmental Protection Agency (EPA) is conducting risk assessments under the Toxic Substances Control Act (TSCA).

National Initiatives

Countries such as France and the Netherlands have launched initiatives to monitor and reduce microplastic emissions, including those from synthetic textiles. In Asia, South Korea and Japan have implemented measures to regulate industrial plastic emissions. China has announced a roadmap to reduce single-use plastics, which may indirectly curb AMP production.

Occupational Health Standards

Although not specific to AMPs, existing occupational standards for dust and fibers may offer partial protection. Agencies such as OSHA and NIOSH have set exposure limits for particulate matter in industrial settings. However, these do not differentiate between organic and synthetic particles, nor do they address the unique toxicity profile of MPs.

Toward a Precautionary Approach

Given the mounting evidence of harm and scientific uncertainty, a precautionary approach is warranted. This includes incentivizing the development of biodegradable textiles, improving indoor air filtration, and enforcing better waste management practices. Public education campaigns and interdisciplinary research funding will also be a key to addressing this complex issue.

Conclusion

Airborne microplastics represent a growing and insidious threat to human health. Their pervasive presence in both indoor and outdoor environments, combined with their potential to induce respiratory, immunological, and systemic toxicity, necessitates urgent attention from policymakers, scientists, and the public. While detection technologies and toxicological models have made significant progress, critical gaps remain in regulatory oversight and exposure mitigation.

Future research should prioritize long-term epidemiological studies, refine detection protocols, and explore biodegradable alternatives. Without prompt and coordinated action, the health burden of airborne microplastics may become an enduring legacy of the plastic age. ■

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References

Ageel, H. K., Harrad, S., & Abdallah, M. A. (2021). Occurrence, human exposure, and risk of microplastics in the indoor environment. Environmental Science Processes & Impacts, 24(1), 17–31. https://doi.org/10.1039/d1em00301a

Alnuqaydan, A. M. (2024). The dark side of beauty: an in-depth analysis of the health hazards and toxicological impact of synthetic cosmetics and personal care products. Frontiers in Public Health, 12. https://doi.org/10.3389/fpubh.2024.1439027

Anderson, J. M., Rodriguez, A., & Chang, D. T. (2008). Foreign body reaction to biomaterials. Seminars in Immunology, 20(2), 86–100. https://doi.org/10.1016/j.smim.2007.11.004

Carriera, F., Di Fiore, C., & Avino, P. (2024). Occurrence of microplastics in the atmosphere: An overview on sources, analytical challenges, and human health effects. Atmosphere, 15(7), 863. https://doi.org/10.3390/atmos15070863

Cheng, M. (2018). Selective collection of airborne particulate matter. Aerosol and Air Quality Research, 18(6), 1361–1365. https://doi.org/10.4209/aaqr.2018.02.0076

Covernton, G. A., Davies, H. L., Cox, K. D., El-Sabaawi, R., Juanes, F., Dudas, S. E., & Dower, J. F. (2021). A Bayesian analysis of the factors determining microplastics ingestion in fishes. Journal of Hazardous Materials, 413, 125405. https://doi.org/10.1016/j.jhazmat.2021.125405

De Souza Machado, A. A., Lau, C. W., Kloas, W., Bergmann, J., Bachelier, J. B., Faltin, E., Becker, R., Görlich, A. S., & Rillig, M. C. (2019). Microplastics can change soil properties and affect plant performance. Environmental Science & Technology, 53(10), 6044–6052. https://doi.org/10.1021/acs.est.9b01339

Dissanayake, P. D., Kim, S., Sarkar, B., Oleszczuk, P., Sang, M. K., Haque, M. N., Ahn, J. H., Bank, M. S., & Ok, Y. S. (2022). Effects of microplastics on the terrestrial environment: A critical review. Environmental Research, 209, 112734. https://doi.org/10.1016/j.envres.2022.112734

Facciolà, A., Visalli, G., Ciarello, M. P., & Di Pietro, A. (2021). Newly emerging airborne pollutants: Current knowledge of health impact of micro and nanoplastics. International Journal of Environmental Research and Public Health, 18(6), 2997. https://doi.org/10.3390/ijerph18062997

Ferrante, M. C., Monnolo, A., Del Piano, F., Raso, G. M., & Meli, R. (2022). The pressing issue of micro- and nanoplastic contamination: profiling the reproductive alterations mediated by oxidative stress. Antioxidants, 11(2), 193. https://doi.org/10.3390/antiox11020193

Gasperi, J., Wright, S. L., Dris, R., Collard, F., Mandin, C., Guerrouache, M., Langlois, V., Kelly, F. J., & Tassin, B. (2017). Microplastics in air: Are we breathing it in? Current Opinion in Environmental Science & Health, 1, 1–5. https://doi.org/10.1016/j.coesh.2017.10.002

Goodman, R. S., Mittal, L., & Parker, E. R. (2023). Public health risks, dermatological manifestations, and environmental Justice associated with vinyl chloride exposure: Narrative review. JMIR Dermatology, 6, e48998. https://doi.org/10.2196/48998

Goswami, S., Adhikary, S., Bhattacharya, S., Agarwal, R., Ganguly, A., Nanda, S., & Rajak, P. (2024). The alarming link between environmental microplastics and health hazards with special emphasis on cancer. Life Sciences, 355, 122937. https://doi.org/10.1016/j.lfs.2024.122937

Guo, S., Wang, Q., Li, Z., Chen, Y., Li, H., Zhang, J., Wang, X., Liu, J., Cao, B., Zou, G., Zhang, B., & Zhao, M. (2023). Ecological risk of microplastic toxicity to earthworms in soil: A bibliometric analysis. Frontiers in Environmental Science, 11. https://doi.org/10.3389/fenvs.2023.1126847

Hettiarachchi, H., & Meegoda, J. N. (2023). Microplastic Pollution Prevention: The need for robust policy interventions to close the loopholes in current waste management practices. International Journal of Environmental Research and Public Health, 20(14), 6434. https://doi.org/10.3390/ijerph20146434

Is, B., M, K., Am, E., & Rh, E. R. (2017). Assessment and measurement of atmospheric pollution (Particulate matter) around Zawiya City-Libya. Journal of Environmental & Analytical Toxicology, 07(04). https://doi.org/10.4172/2161-0525.1000473

Knobloch, E., Ruffell, H., Aves, A., Pantos, O., Gaw, S., & Revell, L. E. (2021). Comparison of deposition sampling methods to collect airborne microplastics in Christchurch, New Zealand. Water Air & Soil Pollution, 232(4). https://doi.org/10.1007/s11270-021-05080-9

Kumar, V., & Garg, N. (2021). National and regional waste stream in the United States: conformance and disparity. Environmental Research Infrastructure and Sustainability, 1(3), 031002. https://doi.org/10.1088/2634-4505/ac36bd

Kurt, O. K., Zhang, J., & Pinkerton, K. E. (2016). Pulmonary health effects of air pollution. Current Opinion in Pulmonary Medicine, 22(2), 138–143. https://doi.org/10.1097/mcp.0000000000000248

López, A. P. A., Trilleras, J., Arana, V. A., Garcia-Alzate, L. S., & Grande-Tovar, C. D. (2023). Atmospheric microplastics: exposure, toxicity, and detrimental health effects. RSC Advances, 13(11), 7468–7489. https://doi.org/10.1039/d2ra07098g

Lv, X., Xiao, S., Zhang, G., Jiang, P., & Tang, F. (2016). Occurrence and removal of phenolic endocrine disrupting chemicals in the water treatment processes. Scientific Reports, 6(1). https://doi.org/10.1038/srep22860

Nalugya, A., Kiguli, J., Wafula, S. T., Nuwematsiko, R., Mugambe, R. K., Oputan, P., Tigaiza, A., Isunju, J. B., & Ssekamatte, T. (2022). Knowledge, attitude and practices related to the use of personal protective equipment among welders in small-scale metal workshops in Nansana Municipality, Wakiso District, Uganda. Health Psychology and Behavioral Medicine, 10(1), 731–747. https://doi.org/10.1080/21642850.2022.2106987

Napieraj, N., Janicka, M., & Reda, M. (2023). Interactions of polyamines and phytohormones in plant response to abiotic stress. Plants, 12(5), 1159. https://doi.org/10.3390/plants12051159

Peng, J., Chen, C., Zhou, M., Xie, X., Zhou, Y., & Luo, C. (2020). A Machine-learning Approach to Forecast Aggravation Risk in Patients with Acute Exacerbation of Chronic Obstructive Pulmonary Disease with Clinical Indicators. Scientific Reports, 10(1). https://doi.org/10.1038/s41598-020-60042-1

Prendergast-Miller, M. T., Katsiamides, A., Abbass, M., Sturzenbaum, S. R., Thorpe, K. L., & Hodson, M. E. (2019). Polyester-derived microfibre impacts on the soil-dwelling earthworm Lumbricus terrestris. Environmental Pollution, 251, 453–459. https://doi.org/10.1016/j.envpol.2019.05.037

Saboor, F. H., Hadian-Ghazvini, S., & Torkashvand, M. (2022). Microplastics in Aquatic environments: Recent advances in separation techniques. Periodica Polytechnica Chemical Engineering, 66(2), 167–181. https://doi.org/10.3311/ppch.18930

Saha, S. C., & Saha, G. (2024). Effect of microplastics deposition on human lung airways: A review with computational benefits and challenges. Heliyon, 10(2), e24355. https://doi.org/10.1016/j.heliyon.2024.e24355

Shaddick, G., Thomas, M. L., Mudu, P., Ruggeri, G., & Gumy, S. (2020). Half the world's population are exposed to increasing air pollution. Npj Climate and Atmospheric Science, 3(1). https://doi.org/10.1038/s41612-020-0124-2

Sheraz, M., Kim, J., & Kim, J. (2023). Nano/microplastics in indoor air: A critical review of synthesis routes for toxicity testing and preventative measure strategies. Process Safety and Environmental Protection, 180, 274–304. https://doi.org/10.1016/j.psep.2023.10.002

Son, C. E., & Choi, S. (2022). Preparation and characterization of model Tire–Road wear particles. Polymers, 14(8), 1512. https://doi.org/10.3390/polym14081512

Sripada, K., Wierzbicka, A., Abass, K., Grimalt, J. O., Erbe, A., Röllin, H. B., Weihe, P., Díaz, G. J., Singh, R. R., Visnes, T., Rautio, A., Odland, J. Ø., & Wagner, M. (2022). A Children's health perspective on nano- and microplastics. Environmental Health Perspectives, 130(1). https://doi.org/10.1289/ehp9086