

THE IMPACT OF AIR POLLUTION ON OUR HEALTH

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Air pollution remains one of the most pressing environmental and public health challenges of our time, affecting billions of people worldwide and contributing significantly to premature mortality and disease burden. It involves a complex mixture of harmful gases and particulate matter that, when inhaled, trigger oxidative stress, chronic inflammation, and direct cellular damage across multiple organ systems. According to the State of Global Air 2025 report, air pollution contributed to 7.9 million deaths globally in 2023 and 232 million healthy years of life lost. Of these deaths, 6.8 million (86%) were attributed to noncommunicable diseases (NCDs) such as ischemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), lung cancer, diabetes, and dementia. This positions air pollution as the second leading risk factor for death worldwide, after high blood pressure, with particularly severe impacts in low- and middle-income countries. In 2023 alone, dementia linked to air pollution accounted for over 626,000 deaths and nearly 12 million healthy years of life lost. Ambient PM2.5 alone was responsible for 4.9 million deaths.

This paper offers a comprehensive overview of the major air pollutants and their primary sources, the

detailed biological mechanisms driving health harm, and the broad spectrum of effects on respiratory, cardiovascular, neurological, reproductive, metabolic, and other systems. It addresses vulnerable populations, regional challenges in Uzbekistan and Central Asia (including Samarkand), and the absence of any truly safe exposure threshold. The study is based on a literature review and presents key results from global and regional data. Finally, it highlights evidence-based strategies for reduction and the critical role of healthcare professionals in integrating environmental considerations into patient care. Reducing air pollution represents one of the most cost-effective investments in public health.

Introduction

In the field of medicine and public health, the impact of air pollution on human health has become increasingly recognized as a major modifiable risk factor that affects populations across all age groups and regions. Although many individuals associate poor air quality primarily with temporary symptoms such as coughing, eye irritation, or shortness of breath, extensive scientific evidence demonstrates that its effects are far more profound and systemic. Air pollutants can penetrate deep into the lungs and enter the bloodstream, causing widespread inflammation, oxidative stress, and cellular damage that contribute to the development and exacerbation of numerous chronic diseases over both short and long terms.

The primary pollutants of concern include fine particulate matter (PM_{2.5} — particles with a diameter of less than 2.5 micrometers), nitrogen dioxide (NO₂) mainly from vehicle exhaust, ground-level ozone (O₃) formed through chemical reactions in sunlight, sulfur dioxide (SO₂) from industrial processes, and carbon monoxide (CO). Among these, PM_{2.5} is particularly hazardous because its small size allows it to reach the deepest parts of the lungs (alveoli) and even cross into the bloodstream, where it can affect distant organs including the heart, brain, and blood vessels. Household air pollution from the burning of biomass fuels for cooking and heating adds another significant layer of exposure in many communities, especially in rural or lower-income settings.

The mechanisms through which air pollution harms the body are now well understood. Inhaled pollutants generate excessive reactive oxygen species (free radicals), which overwhelm the body's natural antioxidant defenses and lead to oxidative damage to cell membranes, proteins, and DNA. This process is accompanied by persistent low-grade systemic inflammation and immune system dysregulation. Over time, these changes promote atherosclerosis in blood vessels, fibrosis in lung tissue, neuronal injury in the brain, and metabolic disturbances that increase the risk of diabetes and other conditions. Importantly, there is often no completely safe threshold for exposure — harm occurs along a continuous dose-response curve, meaning even relatively lower levels of pollution can contribute to population-level disease burden when exposure is chronic.

In clinical practice, physicians increasingly encounter patients whose respiratory complaints, cardiovascular events, or developmental issues may be influenced or worsened by environmental exposures. Recognizing air pollution as a key determinant of health allows for better diagnostic reasoning, more effective patient counseling, and stronger advocacy for preventive measures at both individual and societal levels. This paper examines the issue through a structured literature review.

Methods

This study is based on a comprehensive review of scientific literature, global health reports, and regional data sources. Primary sources include the State of Global Air 2025 report (produced by the Health Effects Institute in collaboration with the Institute for Health Metrics and Evaluation), World Health Organization fact sheets and guidelines on ambient air quality, standard medical textbooks such as Robbins and Cotran Pathologic Basis of Disease and Bates' Guide to Physical Examination, and recent peer-reviewed articles on air pollution mechanisms and health outcomes published between 2020 and 2025.

Data on exposure levels and health impacts were drawn from epidemiological studies, toxicological research, and burden-of-disease analyses. For the regional context, information on air quality in Uzbekistan was obtained from UzHydromet monitoring data, IQAir reports, and local scientific assessments covering 2024–2025. Key pollutants analyzed include PM_{2.5}, PM₁₀, NO₂, SO₂, and O₃. Health outcomes were categorized by organ system (respiratory, cardiovascular, neurological, metabolic, reproductive, and others), with emphasis on vulnerable populations such as children, elderly individuals, pregnant women, and those with pre-existing conditions.

Comparative analysis was performed to highlight differences between global patterns and the situation in Central Asia. No primary data collection was conducted; instead, the study

synthesizes existing evidence to provide an updated overview suitable for medical education and clinical awareness. Limitations include reliance on modeled estimates for some burden-of-disease figures and variability in local monitoring coverage.

Results

The review confirms that air pollution is a leading environmental risk factor, with 7.9 million deaths and 232 million healthy years of life lost in 2023. Ambient PM_{2.5} accounted for 4.9 million of these deaths. Approximately 86% of pollution-related deaths stem from noncommunicable diseases, and 95% of attributable deaths in adults over 60 years are NCD-related. Globally, 36% of the world's population lives in areas where PM_{2.5} levels exceed the least stringent WHO interim target of 35 $\mu\text{g}/\text{m}^3$.

Respiratory effects are prominent: acute exposure exacerbates asthma, bronchitis, and infections, while chronic exposure drives COPD, emphysema, and lung cancer. In children, repeated exposure impairs lung development, leading to permanently reduced lung function. Cardiovascular impacts are substantial, with nearly half of deaths linked to ischemic heart disease and stroke. PM_{2.5} promotes endothelial damage, atherosclerosis, hypertension, and clotting, increasing risks of heart attacks and strokes even with short-term spikes.

Neurological consequences include accelerated cognitive decline, higher dementia risk (over 626,000 deaths in 2023), Alzheimer's and Parkinson's progression, and potential links to ALS. Prenatal and early-life exposure correlates with lower birth weight, premature birth, developmental delays, and reduced IQ. Metabolic effects involve impaired insulin sensitivity and elevated type 2 diabetes risk. Additional associations exist with certain cancers, reproductive issues, and mental health symptoms through chronic inflammation.

In Uzbekistan, including Samarkand, air quality data from 2024–2025 show frequent exceedances of WHO guidelines. PM_{2.5} levels in Tashkent often reach 40–70 $\mu\text{g}/\text{m}^3$ during stagnant conditions, while Samarkand and Bukhara record 35–55 $\mu\text{g}/\text{m}^3$, influenced by vehicle emissions, industrial sources, construction dust, and Aral Sea-related dust events. On certain days in late 2025, Tashkent ranked among the world's most polluted cities. Uzbekistan's national standards (35–50 $\mu\text{g}/\text{m}^3$) remain less stringent than WHO recommendations (annual mean 5 $\mu\text{g}/\text{m}^3$). Chronic exposure elevates local risks for respiratory infections, hypertension, heart disease, and stroke. Nearly the entire population (over 99%) has historically been exposed to levels above some WHO interim targets.

Vulnerable groups bear a heavier burden: children face impaired development, elderly individuals experience accelerated frailty, and pregnant women risk adverse fetal outcomes.

Socioeconomic factors amplify exposure in lower-income communities near pollution sources.

Discussion

The results align with global evidence that air pollution acts through shared pathways of oxidative stress and inflammation to affect multiple organ systems. The absence of a safe threshold underscores the need for continuous reduction efforts. In Uzbekistan, the combination of urban growth, traffic, industry, and climate-driven dust events creates a challenging environment, though initiatives like the “Clean Air” project and improved monitoring offer pathways forward. Healthcare professionals should routinely consider environmental history in patient assessments, particularly for respiratory and cardiovascular complaints.

Interventions such as cleaner transport, renewable energy, green urban planning, and stricter emission controls have proven effective elsewhere, yielding rapid declines in hospital admissions and gains in life expectancy. Integrating environmental health into medical training will better equip future clinicians to address this modifiable risk factor.

Conclusion

Air pollution is a major, largely preventable driver of ill health whose effects reach nearly every organ system through shared mechanisms of oxidative stress, inflammation, and cellular damage. With 7.9 million deaths and 232 million healthy years of life lost in 2023 alone — the vast majority from NCDs — its global toll is enormous. In regions like Samarkand and Uzbekistan, addressing air quality is essential for protecting respiratory and cardiovascular health, supporting healthy child development, and reducing the burden on healthcare systems. Coordinated actions at individual, community, national, and international levels can yield substantial benefits. Clean air is a fundamental human right and a cornerstone of healthy societies; investing in it offers one of the highest-return opportunities for advancing public health and sustainable development.

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