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Uzbekistan's air pollution and its health effects: A data-driven overview of disease burden and intervention priorities

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ABSTRACT

Introduction: Atmospheric aerosol particles significantly impact ecosystems, global climate, cultural heritage, and public health. Air pollution is a major global health concern, contributing to roughly one quarter of total global mortality, with fine Particulate Matter ($PM_{2.5}$) being particularly harmful. Long-term exposure to elevated $PM_{2.5}$ and gaseous pollutants such as sulfur dioxide, nitrogen dioxide, ozone, and carbon monoxide increases the risk of severe health effects, including chronic respiratory and cardiovascular diseases.

Materials and methods: Air quality trends in Uzbekistan, primarily in Tashkent, were analyzed using Air Quality Index (AQI) data, focusing on wintertime $PM_{2.5}$ levels. Health outcomes were assessed through statistical analysis of Ministry of Health records from 2012 to 2024, with particular attention to respiratory tract infection–related mortality. Comparative analysis was performed between urban and rural populations, and vulnerable groups, including children and senior citizens, were identified.

Results: Analysis revealed that wintertime $PM_{2.5}$ concentrations in Tashkent were approximately six times higher than World Health Organization recommended limits. Statistical evaluation indicated a significant 24.94% increase in respiratory tract infection–related deaths in Tashkent during the study period ($p<0.05$), whereas rural areas showed no significant growth. Urban air pollution, primarily from residential heating and anthropogenic activities, was identified as a major contributor. Children and elderly populations were most affected.

Conclusion: These findings demonstrate the substantial health impacts of urban air pollution in Uzbekistan, particularly in low- and middle-income urban settings. The study emphasizes the urgent need for targeted air quality management strategies to mitigate pollution-related health risks, protect vulnerable populations, and improve public health outcomes.

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Introduction

Atmospheric aerosol particles play a critical role in influencing environments, worldwide climate, public health, and cultural heritage. Among the various environmental hazard, air pollution considered one of the vital threats to human health globally. According to global estimations, environmental pollution contributed to about 13.6 million deaths in 2019, accounting for nearly 24% of total global death [1, 2]. In 2021, air pollution was ranked among the major risk factors for premature death, second only to high blood pressure (Fig. 1). Exposure to polluted air was accountable for approximately one in eight deaths globally. It was also the second leading cause of death among children under five years of age, following malnutrition [3].

The main cause of the air pollution is the combination of natural and anthropogenic activities, including industrial and vehicular discharges, suburbanization, building activities, disforestation, agricultural practices, and residential heating and cooking. Outdoor air pollution contains a complicated mixture of harmful pollutants, with Particulate Matter (PM) frequently used as a proxy indicator due to its robust connotation with adverse health outcomes. Many epidemiological studies have confirmed that long time exposure to high concentration of PM is strongly associated with increased morbidity and death. Key chemical components of PM include Nitrates (NO_3^-), Sulfates (SO_4^{2-}), Ammonium (NH_4^+), mineral dust, black carbon, sea salt, and related water content. In addition to PM, gaseous contaminants such as nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), Ozone (O_3), and Carbon monoxide (CO) contribute meaningfully to the health effect of air pollution. Exposure to these pollutants has been related with a wide range of harmful health effects, including respiratory and cardiovascular ailments, cancers, and premature death. The considerable burden of health problems is related to air pollution underscores the urgent necessity for effective mitigation policies and evidence-based public health interventions. Fig. 2 summarizes the main air pollutants and their related health effects. Fine Particulate Matter ($PM_{2.5}$) has been recognized as the most dangerous pollutant driving air pollution–related disease internationally. In 2021, air pollution was accountable for almost 7.8 million deaths worldwide, of which ambient $PM_{2.5}$ reported for about 4.7 million, whereas domestic air pollution contributed approximately 3.1 million deceases. Cardiovascular diseases alone reported for nearly 19% of deaths attributed to ambient $PM_{2.5}$ exposure. The problem of $PM_{2.5}$-related disease differs considerably across regions, with Southeast Asia, South Asia, East Asia, Central Asia, Oceania, and North Africa suffering mortality rates well above the worldwide average (Fig. 3).

In Central Asia, and mainly in Uzbekistan, fast development, increased energy demand, and dependance on fossil fuels for residential heating have contributed to deteriorating air quality, particularly during winter months. Nevertheless, despite growing concerns, comprehensive analyses connecting air pollution indicators with health outcomes in Uzbekistan remain limited. This study aims to assess tendencies in air quality and related health impacts in Uzbekistan, with a specific focus on Tashkent, and to compare nationwide findings with global patterns. By highlighting Uzbekistan-specific data, this work seeks to highlight critical public health challenges and notify targeted air quality management policies.

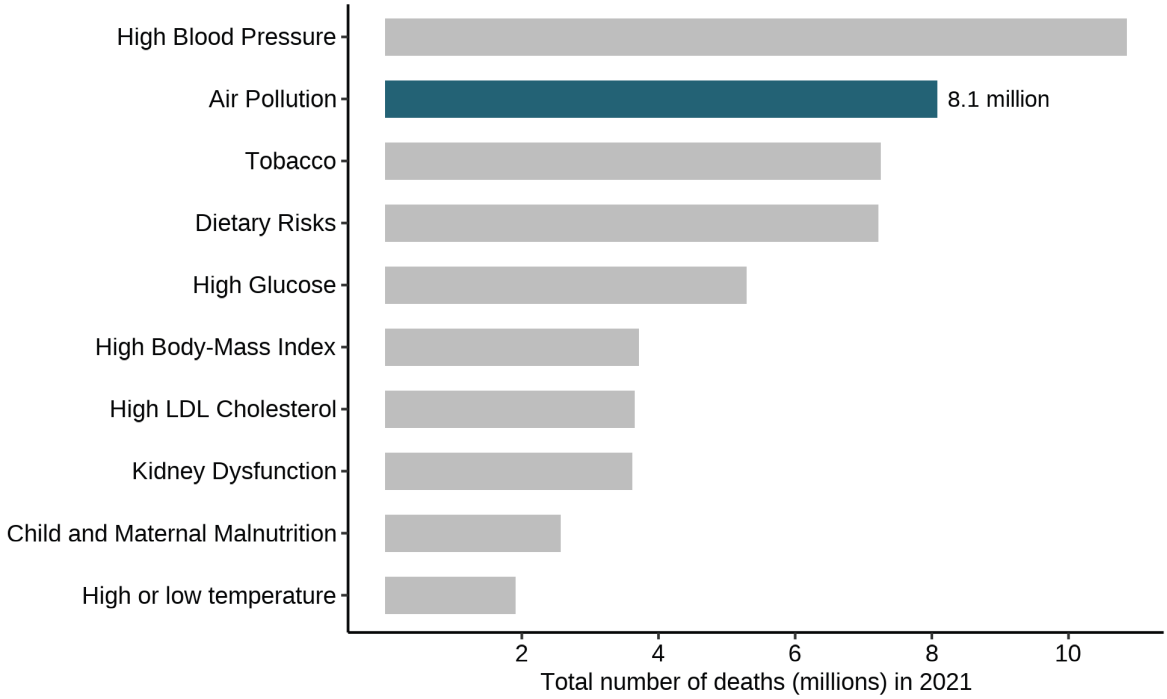

Fig. 1. Worldwide ranking of key risk factors by total number of deaths in 2021 [3]

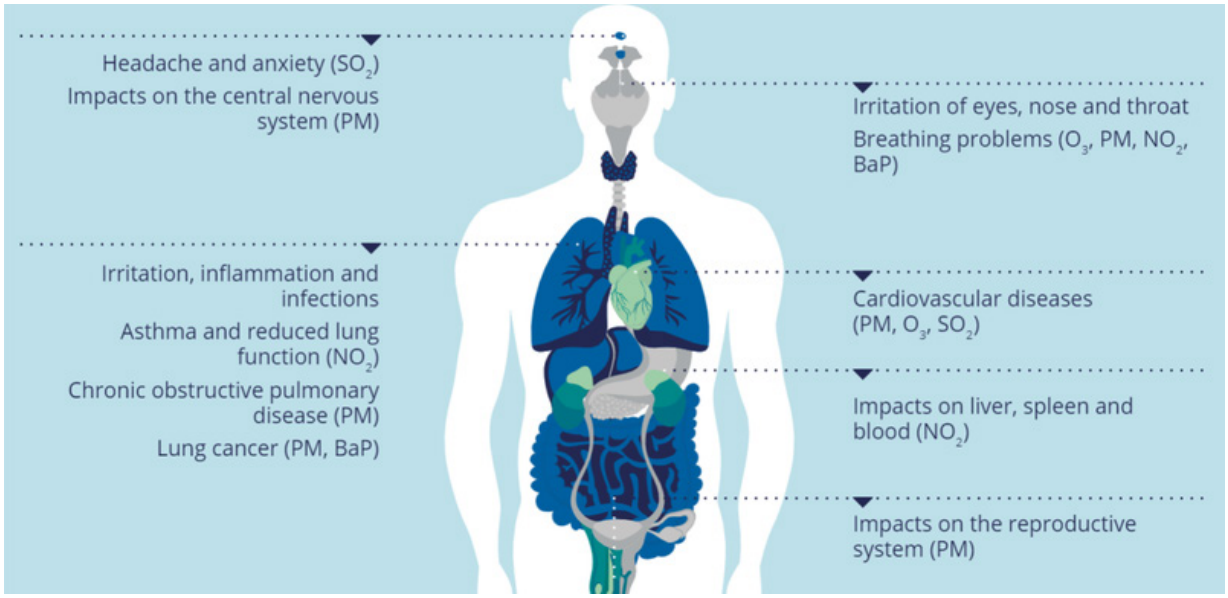

Fig. 2. Most important outdoor air pollutants and their related impacts on public health, including $PM_{2.5}$, PM_{10}, O_3, NO_2, benzo[α]pyrene (BaP), and SO_2 [3]

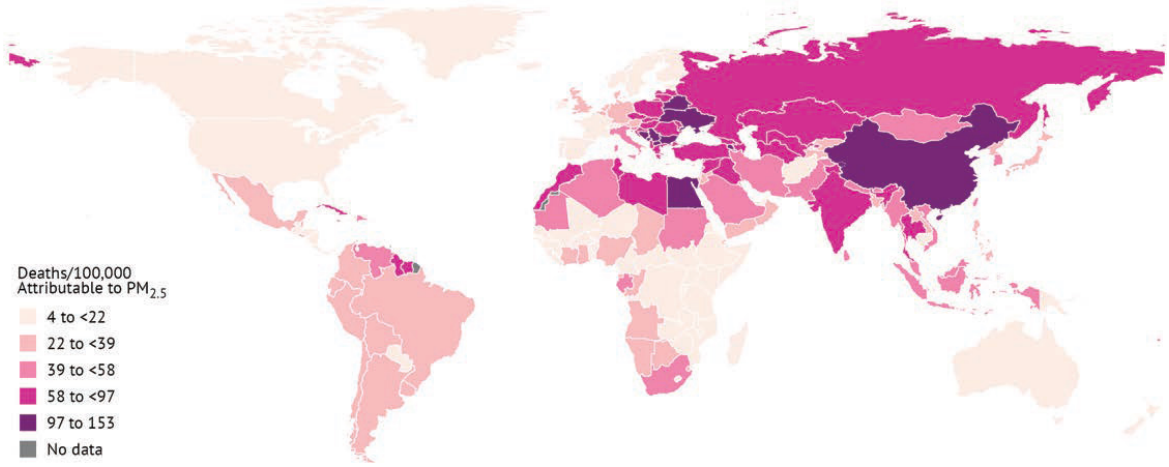

Fig. 3. Worldwide distribution of age-standardized death rates attributable to outdoor air pollution in 2021 [3]

Materials and methods

This research used secondary data attained from legitimately published and widely available sources and were duly quoted in the reference section. $PM_{2.5}$, PM_{10} and Air Quality Index (AQI) data, were collected for the period from 2018 to 2024. AQI standards were founded on standardized indicators including $PM_{2.5}$, PM_{10}, Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), Ozone (O_3), and Carbon monoxide (CO), following globally recognized air quality assessment outlines [4].

Monthly and yearly means of $PM_{2.5}$, PM_{10}, and AQI were considered to evaluate chronological and seasonal distinctions, with specific importance on winter months when contamination levels are maximum. Public health associated data, including death related to respiratory tract contaminations, were attained from authorized statistics published by the Ministry of Health and the national statistical organizations of Uzbekistan for the period 2012–2024.

Statistical investigates were achieved using Microsoft Excel (Microsoft Office 2020). Descriptive statistics, including averages and standard deviations, were used to review air quality indicators. Pearson correlation analysis was applied to inspect the connection between particulate matter concentrations ($PM_{2.5}$ and PM_{10}) and AQI values. Statistical significance was assessed at a threshold of $p<0.05$. Although the analysis focused on correlation-based calculation, the limitations of this method are acknowledged, and underlying associations were not inferred.

Results and discussion

Air quality trends in Uzbekistan

Fig. 4 demonstrates the seasonal variation of $PM_{2.5}$ concentrations, displaying that the uppermost levels consistently occur throughout the winter months. This seasonal peak matches with increased house heating demand, where coal and fuel oil burning account for almost 28% of total $PM_{2.5}$ releases during winter [5]. Apart from the heating season, industrial events and vehicular emissions appear as the leading contributors to the higher ambient particulate matter concentrations [6]. These conclusions

highlight the greater effect of seasonal energy use patterns on air quality in urban Uzbekistan, predominantly in Tashkent.

Correlation analysis exposed a strong positive connection between particulate matter concentrations and complete air quality stages. As shown in Fig. 5 (2023 data), PM_{10} showed a strong linear correlation with AQI values ($r=0.90$, $p<0.05$), while $PM_{2.5}$ also confirmed a significant correlation ($r=0.80$, $p<0.05$). These findings show that particulate matter is a primary factor of AQI unpredictability in Tashkent. Seasonal atmospheric conditions, fast urban growth, and exaggerated construction works are the probable contributor to the experiential variations.

Long-term investigation of $PM_{2.5}$ concentrations from 2018 to 2023 (Fig. 6) exposed distinguished interannual unpredictability. The lowermost $PM_{2.5}$ levels were detected in 2020, which agreed with COVID-19-related lockdown events that significantly decreased transportation and manufacturing activity. Comparable reduction in particulate matter concentration throughout the pandemic-related restrictions have been reported worldwide, supporting the view that anthropogenetic releases play a leading role in municipal air pollution.

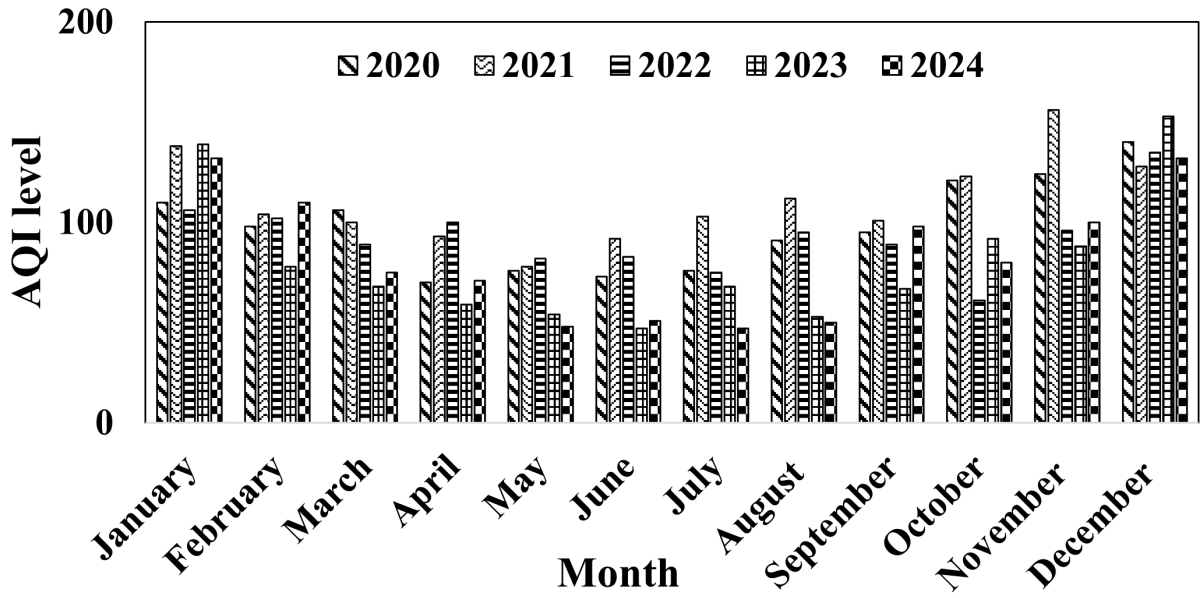

Fig. 4. Monthly average AQI tendencies from 2020 to 2024

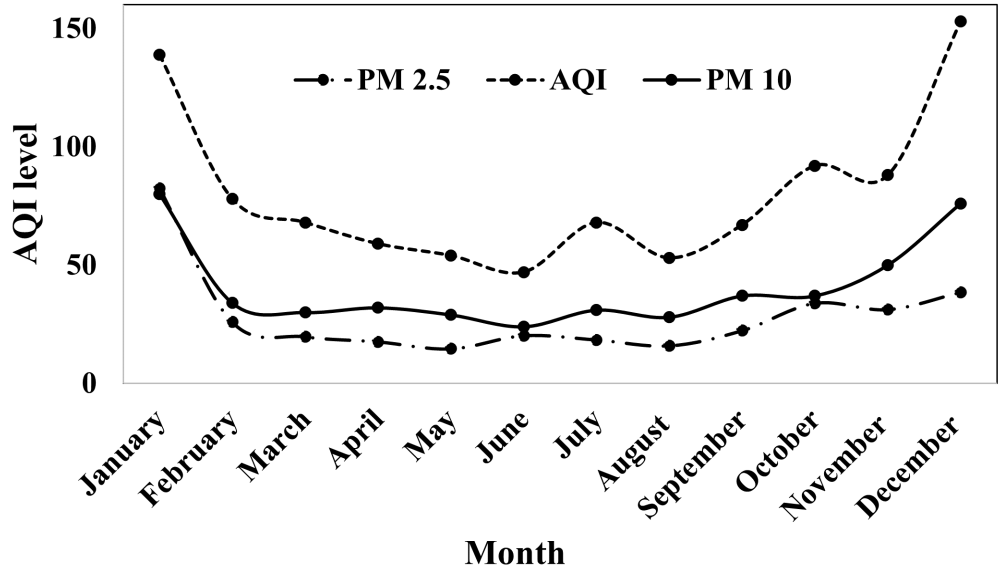

Fig. 5. Average monthly variations in particulate matter concentrations ($PM_{2.5}$ and PM_{10}) and AQI

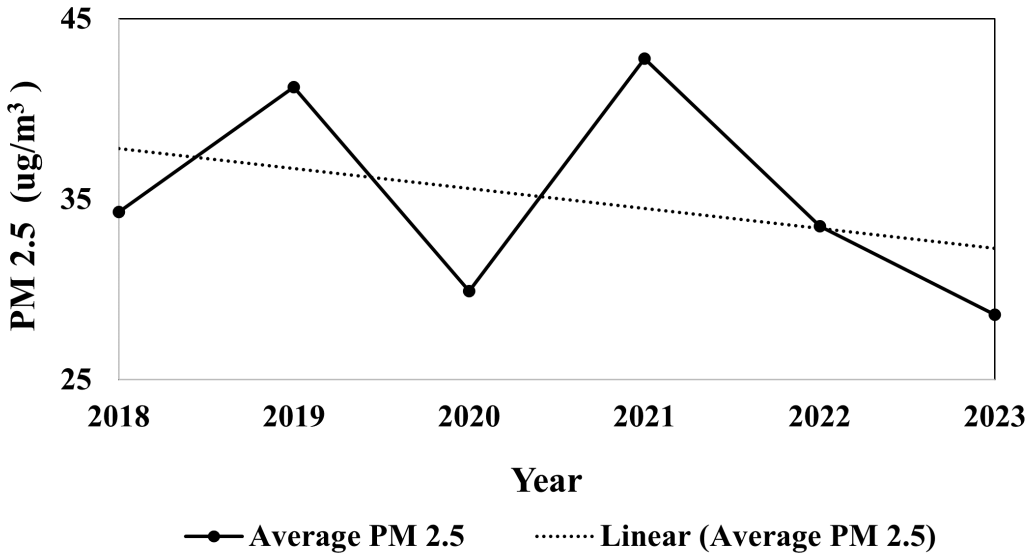

Fig. 6. Tendencies in annual mean fine particulate matter ($PM_{2.5}$) concentrations between 2018 and 2023

Health outcomes associated with air pollution

Respiratory diseases

Respiratory diseases continue among the most prominent health problems related with the long-term exposure in polluted air. Chronic Obstructive Pulmonary Disease (COPD), asthma, and lesser respiratory contaminations are mainly sensitive to higher $PM_{2.5}$ concentrations. Global Burden of Disease (GBD) approximations designate that air pollution contributes to about 43% of COPD-related deaths globally [7]. Consistent with global indication, AQI data indicate that $PM_{2.5}$ concentrations in Tashkent regularly reach hazardous levels throughout winter, increasing the risk of respiratory illness.

In Uzbekistan, COPD remains a principal reason of death, with approximations signifying that 10–15% of COPD-related deaths may

be attributable to air pollution exposure [7, 8]. Asthma occurrence has also increased in urban areas, predominantly among children. Ministry of Health data show that about 2.7% of the urban population was identified with asthma in 2020, with symptom aggravation frequently stated during winter months due to increased coal burning for household heating [9].

Lower respiratory contaminations, including pneumonia, characterize another key health problem. Worldwide, outdoor air pollution is projected to contribute to 10–15% of pneumonia cases in vulnerable people, including children and the senior citizens [10]. In Uzbekistan, more than 5,000 pneumonia cases are diagnosed yearly, with a considerable number happening in urban regions with high level of pollution [8, 9]. Fig. 7 establishes a continued rise in respiratory infection–related death in Tashkent between 2012 and 2023, growing from 46% to 71%, however nationwide tendencies remained reasonably constant. This discrepancy recommends a strong urban-specific pollution significance.

Cardiovascular diseases

Long-term contact to air contaminants such as $PM_{2.5}$, NO_2, and CO is strongly related with cardiovascular illness, including ischemic heart disease and stroke. Epidemiologic studies show that extended residence in extremely polluted areas can increase the danger of myocardial infarction by up to 20% [11]. Worldwide, about 29% of ischemic heart disease deaths have been linked to polluted air exposure [12].

In Uzbekistan, ischemic heart disease remains a chief cause of mortality, with urban centers such as Tashkent showing higher disease occurrence. Health Effects Institute and WHO assessments approximation that 20–25% of cardiovascular demises in major Uzbek cities may be connected to air pollution exposure [13]. Stroke frequency has also increased, with air pollution assessed to contribute to roughly 15% of stroke cases in urban Uzbekistan [8, 9]. These verdicts are reliable with global indication connecting fine particulate matter exposure to vascular inflammation and atherosclerosis.

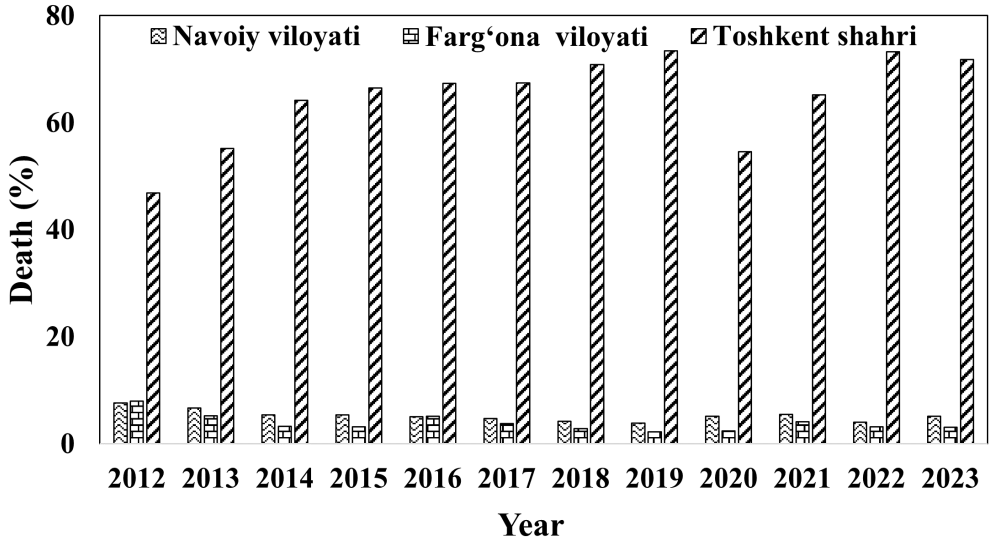

Fig. 7. Tendencies in respiratory infections and related death across various regions of Uzbekistan from 2012 to 2023

Cancer

Air pollution is characterized as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC), with potential indication connecting $PM_{2.5}$ contact to lung cancer. Internationally, around 29% of lung cancer cases are accredited to ambient air pollution [14]. In Uzbekistan, industrial releases and vehicular exhaust characterize main causes of carcinogenic contaminants, mainly in urban regions. Current data show increasing lung cancer related death in metropolitan areas, consistent with the elevated long-term exposure to $PM_{2.5}$ and vehicular-related pollutants.

Premature Mortality

Air pollution continues as one of the chief contributors to premature death globally. Around 7 million premature deaths yearly are accredited to indoor and outdoor air pollution in combination [13]. In Uzbekistan, approximations suggest that 4,500–5,000 premature deaths every year are connected with air pollution, including cardiovascular disease, respiratory illness, cancer, and stroke [15, 16]. Municipal inhabitants bear a uneven share of this problem, reflecting higher exposure levels and population density.

Neurological health effects (Emerging evidence)

Emerging global researches recommend potential connection between air pollution exposure and neurological illness, including cognitive decline and neurodevelopmental disorders. Nevertheless, through epidemiologic evidence from Uzbekistan remains inadequate. Hence, neurological effects are discussed here as an emerging concern rather than a confirmed causes. Advanced studies combining neurological health data from Uzbekistan are required to better measure these risks.

Implications for low- and middle-income countries

Uzbekistan, classified as a low- to middle-income country, faces challenges common to quickly urbanizing areas, including higher energy demand, vehicular emissions, and dependance on solid fuels. Urban to rural differences in air pollution exposure contribute to unsatisfactory health problems, with urban centers suffering higher disease problems. Addressing air pollution in such circumstances needs combined policy methods that unified emission control, cleaner energy changes, and public health interventions.

Conclusion

The outcomes of this study establish a strong association between worsening air quality and adverse health effects in Uzbekistan, mainly in urban areas such as Tashkent. Excessive wintertime $PM_{2.5}$ concentrations, determined mainly by residential heating and anthropogenic emissions, coincide with larger respiratory and cardiovascular death. The distinct increase in respiratory infection–related deaths in Tashkent underscores the imperative need for targeted air quality management tactics. Strengthening emission procedures, indorsing cleaner energy sources, and enhancing public consciousness are indispensable to alleviate the growing health concerns of air pollution in Uzbekistan.

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Competing interests

Authors declare no competing interests.

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Ethical considerations

"Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely ob-served by the authors."

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