Thorac Res Pract. 2026;27(2):77-82 **DOI:** 10.4274/ThoracResPract.2025.2025-7-3

Original Article

Air Pollution, COVID-19–related Air-quality Changes, and Premature Mortality in Türkiye (2019–2023)

Didem Han Yekdeş[1], Ali Cem Yekdeş[2]

[1]Edirne Provincial Health Directorate, Public Health Center, Edirne, Türkiye
[2]Department of Public Health, Trakya University Faculty of Medicine, Edirne, Türkiye

Cite this article as: Han Yekdeş D, Yekdeş AC. Air pollution, COVID-19–related air-quality changes, and premature mortality in Türkiye (2019–2023). *Thorac Res Pract.* 2026;27(2):77-82

ABSTRACT

OBJECTIVE: Long-term exposure to fine particulate matter ($PM_{2.5}$) contributes to about 8 million premature deaths worldwide annually. In Türkiye, few studies have examined long-term health impacts, particularly during and after the coronavirus disease-2019 (COVID-19) pandemic. This study aimed to estimate premature mortality and the respiratory disease burden attributable to $PM_{2.5}$ from 1 January 2019 to 31 December 2023.

MATERIAL AND METHODS: Premature deaths attributable to $PM_{2.5}$ were estimated using the World Health Organization's (WHO) AirQ+ software. Inputs included annual provincial $PM_{2.5}$ concentrations (measured directly or at stations without $PM_{2.5}$ measurements, converted from PM_{10} using the WHO-recommended factor of 0.67 for Türkiye), mortality data for individuals aged ≥25 years, and demographic data from Turkish Statistical Institute. The Estimates focused on chronic obstructive pulmonary disease (COPD) and lung cancer. Population attributable fractions were calculated. Temporal comparisons were made across pre-pandemic (2019), pandemic (2020–2021), and post-pandemic (2022–2023) periods to capture potential effects of COVID-19–related reductions in industrial production and traffic. Differences were assessed using one-way ANOVA.

RESULTS: An annual average of 85,344 premature deaths (95% confidence interval: 79,129–91,559) was attributable to $PM_{2.5}$. COPD and lung cancer accounted for a significant share of $PM_{2.5}$-related deaths, with about one in seven linked to COPD. Although temporary improvements in air quality occurred during the COVID-19 pandemic, no statistically significant difference was observed in COPD-attributable mortality across the three study periods ($P = 0.687$).

CONCLUSION: Air pollution remains a major public health challenge in Türkiye. Sustained, region-specific strategies are needed to reduce the burden of $PM_{2.5}$-related mortality. Inadequate monitoring coverage continues to limit precision in exposure and risk assessment.

KEYWORDS: $PM_{2.5}$, COVID-19, lung cancer, premature mortality, Türkiye, air pollution

Received: 01.07.2025	***Revision Requested:*** 24.09.2025	***Last Revision Received:*** 25.11.2025
Accepted: 30.11.2025	***Epub:*** 20.01.2026	***Publication Date:*** 12.03.2026

INTRODUCTION

Air pollution, defined as the contamination of the atmosphere by physical, chemical, or biological agents, can occur naturally or from anthropogenic sources, such as the burning of fossil fuels.[1] According to the World Health Organization's (WHO) Global Air Quality Guidelines, the principal ambient air pollutants of concern are fine particulate matter ($PM_{2.5}$), coarse particulate matter (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO).[2]

Each year, outdoor and household air pollution contribute to 6.7 million premature deaths worldwide by causing a range of health problems.[3] Its effects often overlooked by healthcare professionals and individuals, include both acute issues such as asthma attacks and infections,[4,5] and chronic conditions like ischemic stroke,[6,7] ischemic heart diseases,[8] chronic obstructive pulmonary disease (COPD),[9] and lung cancer, driven by chronic inflammatory processes.[10] Moreover, climate change, fueled by air pollution, alters the geographical distribution of infectious diseases and intensifies natural disasters. Tackling this global threat demands public awareness and a multidisciplinary approach involving scientific experts and national and international organizations that propose sustainable solutions.[11]

Corresponding author: Didem Han Yekdeş, MD, e-mail: dhanyekdes@gmail.com

Long-term exposure to air pollution substantially increases mortality risk. A meta-analysis conducted in 2020 reported that each 10 μg/m^3 increase in $PM_{2.5}$ concentration was associated with a 1.08-fold increase in mortality [95% confidence interval (CI): 1.06–1.09].[12] The AirQ+ software, developed by the WHO, incorporates cohort-based risk estimates to quantify the health impacts of air pollution.[13] Although national-level assessments of long-term (annual) $PM_{2.5}$ exposure in Türkiye have been published,[14] these analyses were restricted to single-year estimates.

The coronavirus disease-2019 (COVID-19) pandemic created exceptional conditions: nationwide restrictions reduced industrial production and traffic, resulting in temporary improvements in air quality in many countries, while widespread mask use may also have influenced individual-level exposure patterns.[15,16] To address these gaps, the present study aimed to compare the pre-pandemic (2019), pandemic (2020–2021), and post-pandemic (2022–2023) periods to capture these exceptional circumstances and estimate the burden of premature mortality attributable to long-term exposure to ambient $PM_{2.5}$ in Türkiye. Specifically, this study seeks to answer the following questions:

1. What is the estimated burden of premature mortality attributable to long-term exposure to ambient $PM_{2.5}$ (per AirQ+) in Türkiye?

2. How are premature deaths due to long-term exposure to ambient $PM_{2.5}$ (per AirQ+) distributed across regions and provinces in Türkiye?

3. What are the temporal trends in the estimated proportion of premature mortality from COPD attributable to long-term exposure to ambient $PM_{2.5}$ (per AirQ+) before and after the COVID-19 pandemic?

Main Points

- Long-term exposure to particulate matter ($PM_{2.5}$) air pollution is a major contributor to premature deaths and chronic respiratory diseases globally.
- World Health Organization's AirQ+ software is widely used to estimate health impacts of air pollution using exposure and incidence data.
- Most studies in Türkiye have focused on short-term effects; national long-term analyses remain limited.
- This study presents the first multi-year (2019–2023) national estimate of premature mortality 40 from $PM_{2.5}$-related air pollution in Türkiye using AirQ+.
- It reveals notable regional disparities in chronic obstructive pulmonary disease (COPD) and lung cancer mortality, with the greatest burden in Southeastern provinces. Although air quality briefly improved during coronavirus disease-2019, no significant reduction in $PM_{2.5}$-related COPD deaths was observed, highlighting the need for ongoing interventions.

MATERIAL AND METHODS

Design

This ecological study covered the 2019–2023 five-year period at the national scale. To capture potential effects of COVID-19 restrictions, three temporal strata were defined: pre-pandemic (01-Jan-2019–31-Dec-2019), pandemic (01-Jan-2020–31-Dec-2021), and post-pandemic (01-Jan-2022–31-Dec-2023).

Data Collection Tools

Air quality data were based on PM (PM_{10} and $PM_{2.5}$), which were used as pollutant parameters. These data were obtained retrospectively from the official website of the Ministry of Environment, Urbanization and Climate Change.[17] For PM_{10} and $PM_{2.5}$ data to be included, a minimum annual measurement availability of at least 60% was considered acceptable.[18] Since $PM_{2.5}$ measurements were not available at some national ground-based air quality monitoring stations, PM_{10} data were converted to $PM_{2.5}$. Household air pollution was not included in this assessment.

Country-specific conversion factors were calculated as the mean ratio of PM_{10} to $PM_{2.5}$ concentrations among stations reporting both pollutants in the same year. If country-specific conversion factors were not available, regional conversion factors obtained by averaging the available country-specific factors were used. As the conversion factor $PM_{2.5}/PM_{10}$ may vary according to location, the converted PM_{10} (or $PM_{2.5}$) values for individual settlements may deviate from the actual values (generally between 0.4 and 0.8) and should be considered approximate only.[19] The conversion factor of 0.67 recommended by the WHO for converting PM_{10} to $PM_{2.5}$ in Türkiye was applied.

Population data for Türkiye, from 2019 to 2023, were obtained from the Turkish Statistical Institute (TURKSTAT) database.[20] In AirQ+ calculations, the population at risk was defined as the total population excluding individuals younger than 25 years of age.

The data on COPD mortality rates were taken from the COPDTURKEY-1 study, which provides community-based data for 2020.[21] For the lung cancer mortality rate, data from the Globocan (GCO) statistics for Türkiye[22] were used in the calculations. The mortality rate for COPD was 420 per 100,000 population, while that for lung cancer was 35.1 per 100,000 population (GCO).

Ethical Considerations

Ethical approval and institutional permissions were not obtained because the data were collected from online open-access databases for this research. Informed consent was not obtained because disease-specific mortality data were used in the study.

AirQ+ Methodology

The AirQ+ program, developed by the WHO European Region, estimates the health impacts of air pollution by evaluating both

short-term (e.g., hospital admissions, workday losses) and long-term effects (e.g., all-cause and cause-specific mortality) of pollutants such as $PM_{2.5}$, PM_{10}, NO_2, O_3, and black carbon. All calculations, which use an integrated risk function rather than relative risks, are based on meta-analyses of studies published since 2013. Required inputs include the cause-specific mortality rate and the exposed adult population. In this study, $PM_{2.5}$-related premature mortality rates were calculated specifically using the burden of disease (BoD) module for long-term mortality. Due to limited $PM_{2.5}$ data, PM_{10} measurements from 2019–2023 were converted using WHO-recommended factors, and disease burden was estimated following the AirQ+ methodology. For this study, long-term (annual) exposure to ambient $PM_{2.5}$ was used to estimate attributable premature mortality. Inputs included annual provincial $PM_{2.5}$ concentrations, baseline cause-specific mortality rates, and the exposed population (aged 25 and above). Outputs were calculated at the provincial level.

Estimation of Premature Mortality (Non-accidental Deaths) Attributable to $PM_{2.5}$

Mortality estimates were calculated using the BoD module of the WHO AirQ+ software. For input data, cause-specific mortality rates were derived from official TURKSTAT datasets stratified by province and selected causes of death. In this process, the total number of deaths was adjusted by excluding deaths due to accidents and injuries to obtain non-accidental deaths [non-communicable deaths + acute lower respiratory infection (ALRI)]. One required input for the premature mortality calculation is the mortality rate for non-communicable diseases and ALRIs. For each province and year, the total number of deaths was adjusted by excluding external causes (ICD-10 codes V01–Y98). Using the adjusted death counts and the at-risk population obtained from AirQ+, the mortality rate per 100,000 population was calculated. The cut-off value for annual mean $PM_{2.5}$ concentration was set at 2.4 $\mu g/m_3$, consistent with the Global Exposure Mortality Model.[23] This approach enabled estimation of premature mortality attributable to long-term exposure to ambient $PM_{2.5}$ at the provincial level in Türkiye for individuals aged 25 years and older.

Province-specific population attributable fractions (PAFs) were calculated using the AirQ+ BoD module based on annual mean $PM_{2.5}$ concentrations and cause-specific mortality rates. All calculations were performed for individuals aged 25 years and above.

Statistical Analysis

All analyses were conducted using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ± standard deviation. For Türkiye, the estimated proportion of COPD mortality attributable to long-term exposure to $PM_{2.5}$ was derived from the provincial average proportions. These estimated proportions were then compared across the pre-pandemic (2019), pandemic (2020–2021), and post-pandemic (2022–2023) periods using one-way ANOVA. Assumptions of normality and homogeneity were tested with Shapiro–Wilk and Levene tests. Results were reported with 95% CIs, and $P < 0.05$ was considered statistically significant.

RESULTS

Descriptive data on PM_{10} levels in Türkiye from 2019 to 2023 are summarized in Supplementary Table 1. Over the past five years, the provinces with the highest PM_{10} pollution levels were Muş (96.70 $\mu g/m^3$), Batman (82.83 $\mu g/m^3$), Iğdır (79.29 $\mu g/m^3$), Şırnak (74.64 $\mu g/m^3$), and Malatya (72.72 $\mu g/m^3$). Among these, Muş showed a decreasing trend in pollution, Malatya exhibited an increasing trend, while the other provinces displayed a fluctuating pattern. The four provinces with the cleanest air quality during this period, based on the lowest 5-year PM_{10} averages, were Bitlis (22 $\mu g/m^3$), Artvin (24 $\mu g/m^3$), Bilecik (27 $\mu g/m^3$), and Rize (28 $\mu g/m^3$).

Total non-accidental deaths at the provincial level are presented in Supplementary Table 2. In 2023, The highest annual number of deaths occurred in İstanbul (67,985), followed by İzmir (29,715) and Ankara (28,572). The lowest numbers were observed in Bayburt (468), Ardahan (676), and Hakkari (651).

Provincial-level premature deaths attributable to long-term $PM_{2.5}$ exposure are summarized in Supplementary Table 3. From 2019 to 2023, the annual national mean number of premature deaths was 85,344 (95% CI: 79,129–91,559). At the provincial scale, attributable mortality rates ranged from 100 to 300 per 100,000 population. The highest rates were observed in Sinop (295.81), Çorum (289.56), and Kastamonu (284.28), while the lowest rates were observed in Bitlis (100.29) and Çanakkale (100.58), with Rize (177.57) having the next lowest rate (Supplementary Table 3).

Between 2019 and 2023, the PAF values attributable to $PM_{2.5}$ for COPD and lung cancer mortality in Türkiye showed significant regional differences. For COPD, the highest PAF values were observed in Muş (34.4%), Batman (30.9%), and Şırnak (29.4%), while the lowest values were recorded in Bitlis (9.5%), Artvin (10.1%), and Kırşehir (11.7%) (Figure 1). Similarly, for lung cancer, the highest PAF values were found in Muş (29.1%), Iğdır (26.8%), and Şırnak (26.5%), whereas the lowest values were observed in Bitlis (10.3%), Artvin (10.9%), and Bilecik (12.1%). These findings highlight the significant public health impact of air pollution. Particularly in the Eastern and Southeastern Anatolia regions (Figure 1).

Figure 2 shows PAF percentages for deaths from COPD and lung cancer attributable to $PM_{2.5}$ across Türkiye from 2019 to 2023. The highest PAF values for COPD in 2023 were observed in Balıkesir (20.42%) and Aydın (21.86%). For lung cancer, Balıkesir (20.18%) and Aydın (21.30%) also stand out with high PAF values. Meanwhile, cities such as Kırklareli and Çanakkale exhibit lower percentages, suggesting differing levels of pollution exposure or the presence of other risk factors. The persistence of high PAF values in certain regions over multiple years underscores the ongoing health challenges posed by air pollution.

Supplementary Table 4. presents detailed on COPD-specific and lung-cancer-specific burdens associated with long-term $PM_{2.5}$ exposure in 2019 and 2023. For COPD in 2023, the highest PAFs were observed in Balıkesir (20.42%), Aydın (21.86%), Denizli (19.05%), and Manisa (23.92%). For lung cancer, the corresponding highest PAFs were in Balıkesir (20.18%), Aydın

(21.30%), and İzmir (18.21%). The lowest COPD PAFs were found in Bitlis (10.29%), Rize (17.57%), and Bilecik (10.16%), while the lowest lung cancer PAFs were found in Bitlis (10.30%), Artvin (10.90%), and Bilecik (12.10%).

The percentage of COPD mortality attributable to long-term exposure to $PM_{2.5}$ in Türkiye showed minimal variation across the pre-, during-, and post-COVID-19 periods, with means of 18.89% (95% CI: 17.49–20.29), 19.34% (95% CI: 18.14–20.54), and 18.58% (95% CI: 17.45–19.70), respectively. These differences were not statistically significant (P = 0.687; Supplementary Table 5).

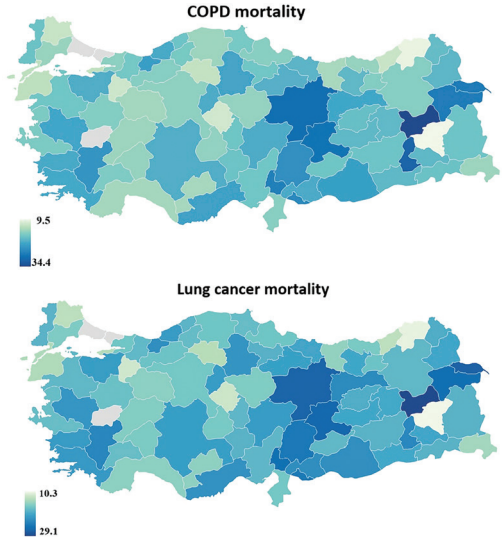

Figure 1. Chronic obstructive pulmonary disease (COPD) and lung cancer mortality attributable to $PM_{2.5}$ in Türkiye (2019–2023)

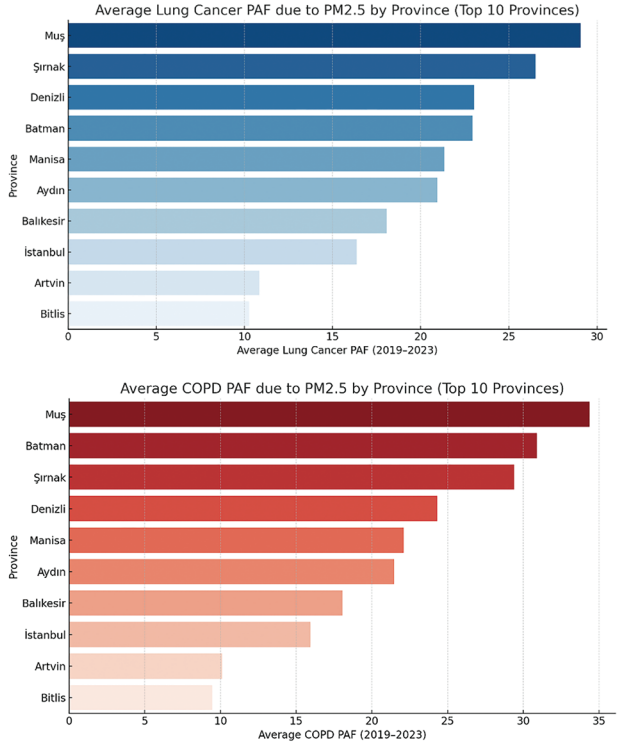

Figure 2. Population of attributable fraction (PAF) of chronic obstructive pulmonary disease (COPD) and lung cancer deaths due to $PM_{2.5}$ in Türkiye (2019–2023)

DISCUSSION

This study aimed to examine long-term trends in premature mortality attributable to air pollution exposure in Türkiye and the burden of respiratory diseases associated with it. Between 2019 and 2023, the provinces with the highest PM_{10} levels were Muş, Batman, Iğdır, Şırnak, and Malatya. The Black Report by the Clean Air Platform (2020–2022) also identified these provinces as among the most polluted areas in the country 24. High pollution levels in Batman may be linked to industrial activities, such as the Petkim Petroleum Refinery, while in Iğdır, geographical conditions and heating-related emissions may be prominent contributors. In Muş, southwestern winds have been identified as a significant factor. Although PM_{10} concentrations in Muş declined from 136 μg/m³ in 2019 to 73 μg/m³ in 2023, they still exceed the acceptable limits.[24] Although Hakkari and Bitlis are listed among the cities with the best air quality, the insufficient number of national ground-based air quality monitoring stations in these cities may not fully reflect the actual situation.[25]

The AirQ+ program, which plays a crucial role in assessing the health effects of air pollution, was widely used in studies conducted between 2002 and 2022. A meta-analysis on this subject found that the majority of these studies were conducted in Iran, followed by India. Additionally, one of the main challenges in this field is the quality and validity of air quality data. The lack of justification for essential data in AirQ+ studies, such as demographic data, relative risks, and incidence rates, has also been noted as a significant issue.[26] In this study, the demographic and mortality data used for premature mortality calculations were obtained from official statistics covering the relevant years, cities, and regions. The mortality rate data for respiratory diseases were obtained from the latest statistical reports published by GCO and national sources.[21,22] These factors eliminate some of the methodological limitations commonly associated with AirQ+ studies. The findings of this research indicate that, between 2019 and 2023, the total annual number of premature deaths attributed to $PM_{2.5}$ pollution in Türkiye was 85,344. The total number of deaths reported in Türkiye for 2022 was approximately 500,000.[27] A global study investigating trends in premature deaths attributed to air pollution found that these deaths increased from approximately 6.87 million in 2000 to approximately 8.89 million in 2015.[28] This figure corresponds to approximately 12% of the 68 million deaths reported worldwide.[29] Our study findings are consistent with the literature; premature mortality rates due to air pollution vary by city and average between 100 and 200 per 100,000 people. A Global Burden of Disease study analyzing premature deaths due to air pollution between 1990 and 2019 reported a similar global average of.[30] These findings not only underscore the reliability and relevance of using official and locally validated data sources in AirQ+ modeling but also reinforce the critical need for country-specific analyses when assessing the health burden of air pollution. The consistency of Türkiye's estimates with global trends highlights the universal impact of $PM_{2.5}$ exposure, while the city-level variability in mortality rates further emphasizes the importance of regionally tailored mitigation strategies. Future research should aim to integrate more granular exposure data and expand temporal coverage to better capture both short- and long-term health effects, thereby

informing more effective public health interventions and policy planning.

COPD and lung cancer are well-known health conditions that are caused by air pollution. This study examines the burden of COPD and lung cancer attributable to air pollution. During the study period, the long-term percentages of COPD and lung cancer attributable to air pollution were particularly high in the southeastern regions of Türkiye, where air pollution levels were also notably elevated. In this study, approximately 70,000 annual deaths were attributed to air pollution, of which approximately 10,000 were linked to COPD. One in every seven air pollution-related deaths was attributable to COPD. According to the WHO, 14% of air pollution-related deaths are associated with COPD, which aligns with our study findings.[3] These findings are consistent with a 2024 study that reported a statistically significant association between ambient air pollution levels and hospital admissions for respiratory diseases.[31] Taken together, these results reinforce the evidence that air pollution poses a substantial public health threat, not only in terms of increased morbidity but also in terms of premature mortality, as observed in our analysis across the pre, during-, and post-COVID-19 periods in Türkiye. Although studies have reported improvements in air quality due to nationwide measures taken during the COVID-19 pandemic, this study did not observe a significant change in the proportion of deaths attributable to air pollution during the COVID-19 pandemic. This finding aligns with literature suggesting that changes in air pollution levels, or improvements in air quality, do not necessarily lead to a significant change in the trend of attributable premature deaths.[28] The absence of a significant COVID-period difference may reflect the lag between exposure and mortality, demographic shifts, limited statistical power, and possible exposure misclassification resulting from conversion of PM_{10} to $PM_{2.5}$.

These results provide further evidence that respiratory diseases such as COPD serve as critical indicators of the long-term health impacts of air pollution. The alignment with WHO estimates and recent empirical studies reinforces the validity of our findings and underscores the persistent nature of air pollution-related health risks, even during periods of temporary environmental improvements. This highlights the importance of sustained, structural interventions rather than relying solely on short-term reductions in pollutant levels.

Study Limitations

The study has some limitations. To ensure data adequacy, a minimum threshold of 60% valid annual measurements was used. However, the Black Report recommends at least 75% for reliability. Due to limited monitoring stations in certain provinces, regional disparities emerged. To address data gaps, the threshold was lowered, allowing broader geographic inclusion and more comprehensive pollutant distribution analysis. This adjustment improved study validity and highlighted infrastructure limitations, offering insights for future research. Additionally, the fixed $PM_{10} \rightarrow PM_{2.5}$ conversion factor (0.67) recommended by the WHO for Türkiye may introduce bias in high-dust regions; this was noted among the study's limitations. Moreover, the inability to use temporal trend analyses, such as Joinpoint, is another limitation, primarily because the five-year evaluation period is too short to detect meaningful changes in trends.

CONCLUSION

This study presents a comprehensive, national-level, multi-year assessment of premature mortality attributable to $PM_{2.5}$ exposure in Türkiye. According to our findings, an average of 85,344 premature deaths per year—approximately 17.0% of all deaths in the country—are attributed to air pollution. The highest provincial premature-death rates were recorded in Sinop (295.8 per 100,000) and Çorum (289.6 per 100,000), while the lowest were observed in Bitlis (100.3 per 100,000) and Çanakkale (100.6 per 100,000). Although temporary improvements in air quality were observed during the COVID-19 pandemic, no statistically significant change was detected in COPD deaths attributable to $PM_{2.5}$. However, the limited number of $PM_{2.5}$ measurements and insufficient distribution of national ground-based air-quality monitoring stations in certain regions of Türkiye may preclude full characterization of the health risks associated with long-term exposure to ambient $PM_{2.5}$ (per AirQ+). The findings suggest that the Western Black Sea and Aegean regions should be prioritized for targeted interventions. Populations with high baseline mortality and populations in areas with dense urban or industrial activity represent key risk groups. Policy measures should focus on tightening national $PM_{2.5}$ standards, ensuring continuous $PM_{2.5}$ monitoring across all provinces, and expanding clean-heating and industrial emission control programs, particularly in high-burden areas. These region-specific interventions would contribute more effectively to reducing long-term air pollution–related health impacts in Türkiye.

Ethics

Ethics Committee Approval: Ethical approval was not obtained because the data were collected from online open-access databases for this research.

Informed Consent: Because anonymous online datasets were used, informed consent was not required.

Footnotes

Authorship Contributions

Concept: D.H.Y., Data Collection or Processing: D.H.Y., A.C.Y., Analysis or Interpretation: D.H.Y., A.C.Y., Literature Search: D.H.Y., Writing: D.H.Y., A.C.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

Supplementary Tables Link: https://d2v96fxpocvxx.cloudfront.net/68ab204c-182b-49da-b227-bc7efe058632/content-images/53c2452f-61c2-43c0-8b2e-85783125c71b.pdf

REFERENCES

1. Saxena P, Naik V. Air pollution: sources, impacts and controls. CAB International; 2019. [Crossref]
2. Organization WHO. WHO global air quality guidelines: particulate matter (PM2. 5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization; 2021. Accessed June 4, 2025. [Crossref]
3. WHO. Ambient (outdoor) air pollution. Accessed January 02, 2025. [Crossref]
4. Zhai G, Zhang L. Impact of fine particulate matter 2.5 on hospitalization for upper respiratory tract infections in Lanzhou urban industrial area, China. *Ann Agric Environ Med.* 2023;30(3):462-467. [Crossref]
5. Orellano P, Quaranta N, Reynoso J, Balbi B, Vasquez J. Effect of outdoor air pollution on asthma exacerbations in children and adults: systematic review and multilevel meta-analysis. *PLoS One.* 2017;12(3):e0174050. [Crossref]
6. Wellenius GA, Burger MR, Coull BA, et al. Ambient air pollution and the risk of acute ischemic stroke. *Arch Intern Med.* 2012;172(3):229-234. [Crossref]
7. Li M, Liao S, Wang C, et al. Global stroke burden attributable to household air pollution: insights from GBD 2021 and projections to 2040. *PLoS One.* 2025;20(7):e0327976. [Crossref]
8. Maimaitiniyazi M, Haibier A, Maimaitiniyazi M, et al. Correction: outdoor air pollution and hospitalizations for ischemic heart disease: a systematic review and meta-analysis. *Front Public Health.* 2025;13:1712503. [Crossref]
9. Wu Y, Zhang S, Zhuo B, et al. Global burden of chronic obstructive pulmonary disease attributable to ambient particulate matter pollution and household air pollution from solid fuels from 1990 to 2019. *Environ Sci Pollut Res Int.* 2022;29(22):32788-32799. [Crossref]
10. Loomis D, Grosse Y, Lauby-Secretan B, et al. The carcinogenicity of outdoor air pollution. *Lancet Oncol.* 2013;14(13):1262-1263. [Crossref]
11. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and health impacts of air pollution: a review. *Front Public Health.* 2020;8:14. [Crossref]
12. Chen J, Hoek G. Long-term exposure to PM and all-cause and cause-specific mortality: a systematic review and meta-analysis. *Environ Int.* 2020;143:105974. [Crossref]
13. WHO. AirQ+: software tool for health risk assessment of air pollution. 2025. Accessed June 4, 2025. [Crossref]
14. Pala K, Aykac N, Yasin Y. Premature deaths attributable to long-term exposure to $PM_{2.5}$ in Turkey. *Environ Sci Pollut Res Int.* 2021;28(37):51940-51947. [Crossref]
15. Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med.* 2000;19(3):335-351. [Crossref]
16. Chen K, Wang M, Huang C, Kinney PL, Anastas PT. Air pollution reduction and mortality benefit during the COVID-19 outbreak in China. *Lancet Planet Health.* 2020;4(6):e210-e212. [Crossref]
17. T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı. Ulusal Hava Kalitesi İzleme Ağı (SİM) – Hava Kalitesi . Accessed May 5, 2025. [Crossref]
18. Yekdeş DH, Yekdeş AC, Çelikkalp Ü, Serin PS, Çağlayan M, Ekuklu G. Chronic obstructive pulmonary disease and lung cancer mortality attributed to air pollution in Türkiye in 2019. *Aerosol and Air Quality Research.* 2023;23(10):230144. [Crossref]
19. World Health Organization (WHO). Air quality database: Update 2016. Geneva: WHO; 2016. Accessed June 4, 2025. [Crossref]
20. TURKSTAT. Population and Demography. 2025. [Crossref]
21. Özdemir T, Yilmaz Demirci N, Kiliç H, Koç O, Kaya A, Öztürk C. An epidemiologic study of physician-diagnosed chronic obstructive pulmonary disease in the Turkish population: COPDTURKEY-1. *Turk J Med Sci.* 2020;50(1):132-140. [Crossref]
22. IARC. Cancer Today, Age-Standardized Rate (World) per 100 000, Mortality, Both sexes, in 2022. Accessed May 5, 2025. [Crossref]
23. Burnett R, Chen H, Szyszkowicz M, et al. Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter. *Proc Natl Acad Sci U S A.* 2018;115(38):9592-9597. [Crossref]
24. DarkReport. Dark Report report reveals the health impacts of air pollution in Turkey. Accessed November 15, 2023. [Crossref]
25. Hava kirliliğinin en yüksek olduğu kentler de en az olduğu kentler de Doğu Anadolu'da: Bitlis ve Hakkari neden vaha? Accessed November 22, 2024. [Crossref]
26. Amini H, Yousefian F, Faridi S, et al. Two decades of air pollution health risk assessment: Insights from the use of WHO's AirQ and AirQ+ tools. *Public Health Reviews.* 2024;45:1606969.
27. TURKSTAT. Mortality and cause of death statistics, 2022. Accessed May 5, 2025. [Crossref]
28. Chowdhury S, Pozzer A, Dey S, Klingmueller K, Lelieveld J. Changing risk factors that contribute to premature mortality from ambient air pollution between 2000 and 2015. *Environmental Research Letters.* 2020;15(7):074010. [Crossref]
29. WHO. The top 10 causes of death. Accessed May 5, 2025. [Crossref]
30. Dhimal M, Chirico F, Bista B, et al. Impact of air pollution on global burden of disease in 2019. *Processes.* 2021;9(10):1719. [Crossref]
31. Grzywa-Celińska A, Krusiński A, Dos Santos Szewczyk K, Kurys-Denis E, Milanowski J. Relationship between concentration of air pollutants and frequency of hospitalisations due to respiratory diseases. *Ann Agric Environ Med.* 2024;31(1):13-23. [Crossref]