The Effect of Climatic and Environmental Factors on Mortality Related to Respiratory System Diseases: An Evaluation Study

İklimsel ve Çevresel Etmenlerin Solunum Sistemi Hastalıklarına Bağlı Mortalite Üzerindeki Etkisi: Bir Değerlendirme Çalışması

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Abstract

Aim	Climate change is a global environmental threat that affects public health in a multidimensional manner, and its adverse effects on respiratory health are becoming increasingly evident. Rising temperatures, increasing greenhouse gas emissions, and the growing frequency and severity of extreme weather events may contribute to increased morbidity and mortality related to respiratory system diseases. This study aimed to evaluate the association between selected climatic and environmental parameters and mortality due to respiratory system diseases in Türkiye between 2013 and 2023.
Materials and Methods	This study was a descriptive and ecological investigation based on secondary data. Mortality data related to respiratory system diseases classified according to ICD-10 codes were analyzed. Climatic variables included annual mean temperature, annual maximum temperature, annual total precipitation, and the number of extreme weather events. Environmental indicators consisted of total and per capita greenhouse gas emissions and environmental protection expenditures. Mortality rates were calculated using the mid-year population. Relationships between variables were assessed using Pearson correlation analysis, and the level of statistical significance was set at $p < 0.05$. The coefficient of determination was expressed as R^2.
Results	Statistically significant and positive correlations were identified between total mortality due to respiratory system diseases and total greenhouse gas emissions ($r = 0.81$, $p < 0.01$), per capita greenhouse gas emissions ($r = 0.72$, $p < 0.05$), and annual maximum temperature ($r = 0.73$, $p < 0.05$). Mortality due to pneumonia showed strong positive correlations with total greenhouse gas emissions ($r = 0.87$, $p < 0.01$), per capita greenhouse gas emissions ($r = 0.78$, $p < 0.01$), and annual maximum temperature ($r = 0.77$, $p < 0.01$), and a moderate positive correlation with the number of extreme weather events ($r = 0.61$, $p < 0.05$). No statistically significant association was found between mortality due to chronic obstructive pulmonary disease, bronchiectasis, or asthma and climatic or environmental parameters.
Conclusion	The findings indicate that certain environmental parameters associated with climate change may be correlated with mortality due to respiratory system diseases in Türkiye. Although causality cannot be established, the development of climate-sensitive public health policies and preventive strategies is of great importance.
Keywords	climate change, environment, mortality, respiratory system

Özet

Amaç	İklim değişikliği, halk sağlığını çok boyutlu biçimde etkileyen küresel bir çevresel tehdit olup, solunum sağlığı üzerindeki olumsuz etkileri giderek daha belirgin hale gelmektedir. Artan sıcaklıklar, yükselen sera gazı emisyonları ve aşırı hava olaylarının sıklık ve şiddetindeki artış, solunum sistemi hastalıklarına bağlı morbidite ve mortalitenin artmasına katkıda bulunabilmektedir. Bu çalışmanın amacı, 2013–2023 yılları arasında Türkiye'de seçilmiş iklimsel ve çevresel parametreler ile solunum sistemi hastalıklarına bağlı mortalite arasındaki ilişkiyi değerlendirmektir.
Gereç ve Yöntemler	Bu çalışma, sekonder verilere dayalı, tanımlayıcı ve ekolojik bir araştırmadır. ICD-10 kodlarına göre sınıflandırılmış solunum sistemi hastalıklarına bağlı mortalite verileri analiz edilmiştir. İklimsel değişkenler; yıllık ortalama sıcaklık, yıllık maksimum sıcaklık, yıllık toplam yağış miktarı ve aşırı hava olaylarının sayısını kapsamaktadır. Çevresel göstergeler ise toplam ve kişi başına düşen sera gazı emisyonları ile çevre koruma harcamalarından oluşmaktadır. Mortalite hızları yıl ortası nüfus kullanılarak hesaplanmıştır. Değişkenler arasındaki ilişkiler Pearson korelasyon analizi ile değerlendirilmiş, istatistiksel anlamlılık düzeyi $p < 0,05$ olarak kabul edilmiştir. Açıklayıcılık katsayısı (R^2) ile ifade edilmiştir.
Bulgular	Toplam solunum sistemi hastalıklarına bağlı mortalite ile toplam sera gazı emisyonları ($r = 0,81$, $p < 0,01$), kişi başına sera gazı emisyonları ($r = 0,72$, $p < 0,05$) ve yıllık en yüksek sıcaklık ($r = 0,73$, $p < 0,05$) arasında istatistiksel olarak anlamlı ve pozitif ilişkiler saptanmıştır. Pnömoniye bağlı mortalite ile toplam sera gazı emisyonları ($r = 0,87$, $p < 0,01$), kişi başına sera gazı emisyonları ($r = 0,78$,$p < 0,01$), yıllık en yüksek sıcaklık ($r = 0,77$, $p < 0,01$) arasında güçlü; aşırı hava olaylarının sayısı ile ise orta düzeyde pozitif bir ilişki ($r = 0,61$, $p < 0,05$) bulunmuştur. Kronik obstrüktif akciğer hastalığı, bronşektazi ve astıma bağlı mortalite ile iklimsel veya çevresel parametreler arasında istatistiksel olarak anlamlı bir ilişki saptanmamıştır.
Sonuç	Bulgular, iklim değişikliği ile ilişkili bazı çevresel parametrelerin Türkiye'de solunum sistemi hastalıklarına bağlı mortalite ile korele olabileceğini göstermektedir. Nedensellik kurulamaz olmakla birlikte, iklim duyarlı halk sağlığı politikalarının ve koruyucu stratejilerin geliştirilmesi büyük önem taşımaktadır.
Anahtar Kelimeler	İklim değişikliği, çevre, ölüm, solunum sistemi

INTRODUCTION

Global warming is considered a major environmental threat that directly and indirectly affects public health. Ocean warming, sea level rise, glacier melting, changes in precipitation patterns, and an increase in the frequency and intensity of extreme weather events such as heat waves, droughts, floods, and storms are being observed, This situation has serious implications for the spread of infectious diseases, water and food security, air quality, and morbidity and mortality, particularly among vulnerable groups (children, the elderly, and those with chronic illnesses) (1, 2).

The adverse effects of climate change on human health are particularly evident in respiratory diseases. Increasing air pollution causes flare-ups of chronic respiratory diseases such as asthma and Chronic Obstructive Pulmonary Disease (COPD), while also increasing the incidence of respiratory infections (3). Climate change promotes plant growth, increasing the amount of pollen in the atmosphere, allergen content, production time, and spread area; this situation leads to an increase in the incidence of asthma and allergic rhinitis (1, 4). In addition, the increase in hot and cold air waves and extreme weather events is causing an increase in morbidity and mortality related to respiratory diseases. Floods and other natural disasters are among the important factors that increase the prevalence of respiratory diseases by negatively affecting both environmental conditions and living spaces (5, 6).

This descriptive study covers the period between 2013 and 2023 across Türkiye. The aim of the study is to evaluate the effect of climate and environmental parameters on deaths related to respiratory diseases.

MATERIALS AND METHODS

This study was a descriptive and ecological investigation based on secondary data.

Data Collection

Climate data were examined based on four key parameters: annual average temperatures, annual maximum temperatures, annual number of extreme weather events, and annual total precipitation amounts. These data were obtained from annual climate reports published by the General Directorate of Meteorology of the Ministry of Environment, Urbanization, and Climate Change. Data on greenhouse gas emissions and environmental protection expenditures were obtained from the official website of the Turkish Statistical Institute (TURKSTAT). Data on deaths related to respiratory diseases were provided in response to an official data request made to TURKSTAT.

Data Processing

All deaths related to respiratory system diseases between 2013 and 2023 were examined based on International Classification of Diseases (ICD-10) codes, both in total and at subheading levels. Crude death rates specific to each cause were calculated by dividing the number of deaths by the mid-year population. The total number of deaths from respiratory system diseases, as well as the subcategories (J12-J18) Pneumonia, (J40-J44, J47) COPD, and Bronchiectasis (J45-J46) and asthma, and each disease group was included in a correlation analysis with environmental and climatic parameters (total greenhouse gas emissions, per capita greenhouse gas emissions, annual average temperature, annual maximum temperature, average precipitation, and number of extreme events). The analysis results that were statistically significant were shared in the findings.

Statistical Modeling

Pearson correlation analysis was applied to determine the relationship between climatic and environmental parameters and the number of deaths related to respiratory system diseases, since all variables were found to be normally distributed. In the analyses, a statistical significance level of $p < 0.05$ was accepted. As a result of the analysis, the coefficient of determination (R^2), which indicates the percentage of total variance in the dependent variable that can be explained by the independent variable, was presented.

Software

Microsoft Office Excel and IBM SPSS Statistics for Windows Version 22.0 software were used to analyze the data obtained in the study.

RESULTS

Correlation analyses revealed statistically significant relationships between certain climatic and environmental variables and mortality rates associated with respiratory diseases. In this context, statistically significant relationships were found between total respiratory disease-related deaths and total greenhouse gas emissions, per capita greenhouse gas emissions, and the highest temperature values within the year. Annual precipitation averages, extreme event counts, and annual average temperature analyses were not statistically significant and therefore not included in the findings. The analysis revealed a high-level, positive, and statistically significant relationship between respiratory disease-related deaths and total greenhouse gas emissions ($r = 0.81$, $p < 0.01$). The coefficient of determination (R^2), which

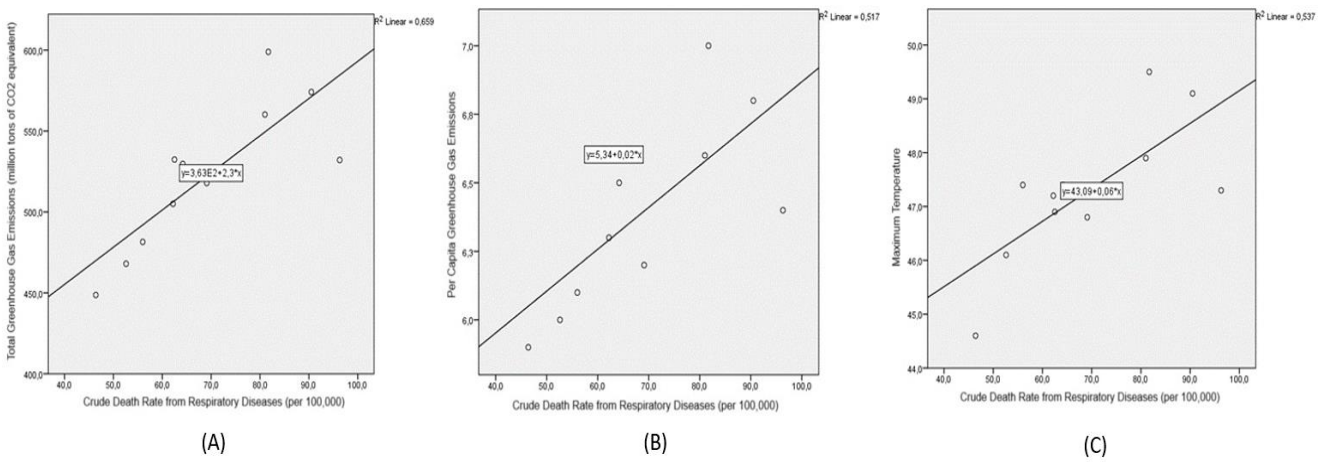

Figure 1. *(A) Linear Relationship Between Crude Death Rate Due to Respiratory Diseases and Total Greenhouse Gas Emissions. (B) Linear Relationship Between Crude Death Rate Due to Respiratory Diseases and Per Capita Greenhouse Gas Emissions. (C) Linear Relationship Between Crude Death Rate Due to Respiratory Diseases and Highest Temperature*

indicates the explanatory power of the relationship between these variables, was found to be 0.66 (Figure 1A).

A high level of positive and statistically significant correlation was found between deaths related to respiratory system diseases and per capita greenhouse gas emissions ($r = 0.72$, $p < 0.05$). The coefficient of determination (R^2) was found to be 0.52 (Figure 1B).

A high-level, positive, and statistically significant relationship was found between deaths related to respiratory system diseases and the highest temperature ($r = 0.73$, $p < 0.05$). The coefficient of determination (R^2) was found to be 0.54 (Figure 1C).

A statistically significant relationship was found between the total number of deaths due to pneumonia and total greenhouse gas emissions, per capita greenhouse gas emissions, the highest temperature values during the year, and the number of extreme events. Since the annual rainfall average and annual average temperature analyses were not found to be statistically significant, they were not included in the findings. A high-level, positive, and statistically significant relationship was identified between pneumonia-related deaths and total greenhouse gas emissions ($r = 0.87$, $p < 0.01$). The coefficient of determination (R^2) was found to be 0.76 (Figure 2A).

A high-level, positive, and statistically significant relationship was found between pneumonia-related deaths and per capita greenhouse gas emissions ($r = 0.78$, $p < 0.01$). The coefficient of determination (R^2) was found to be 0.60 (Figure 2B).

A high-level, positive, and statistically significant relationship was found between deaths related to pneumonitis and the highest temperature ($r = 0.77$, $p < 0.01$). The coefficient of determination (R^2) was found to be 0.59 (Figure 2C).

A moderate, positive, and statistically significant relationship was found between pneumonia-related deaths and the number of extreme events ($r = 0.61$, $p < 0.05$). The coefficient of determination (R^2) was found to be 0.37 (Figure 2D).

No statistically significant relationship was found between deaths related to COPD, bronchiectasis, and asthma and climatic and environmental parameters.

DISCUSSION

This study examined the relationship between various parameters related to climate change and mortality rates associated with respiratory diseases, and found significant correlations between certain variables and mortality rates. In particular, the finding of significant positive relationships between greenhouse gas emissions and average temperature increases and mortality rates supports the impact of climatic factors on respiratory health.

Similar to the findings obtained, another study reported that climatic variables increase morbidity and mortality from respiratory diseases by increasing pollen production, air pollution levels, and infection risks (7, 8). Some studies have demonstrated that air pollution has a significant adverse impact on infectious diseases as well as respiratory diseases, particularly asthma, allergic rhinitis, lung cancer, and chronic obstructive pulmonary disease. In the present study, statistically significant correlations were also identified between increases in greenhouse gas emissions -an indicator closely associated with environmental pollution- and mortality due to respiratory system diseases (9, 10).

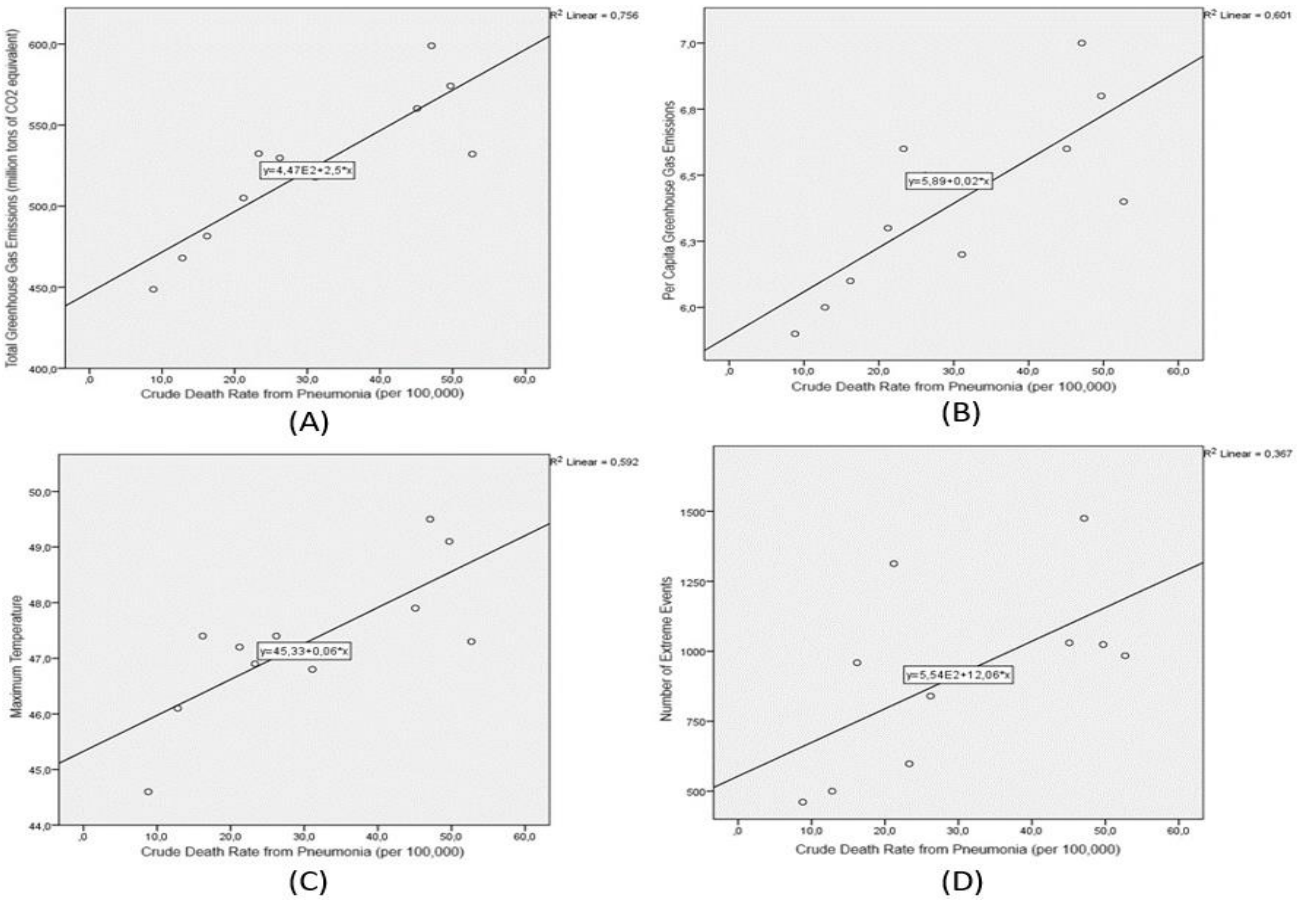

Figure 2. *(A) Linear Relationship Between Crude Death Rate Due to Pneumonia and Total Greenhouse Gas Emissions (B) Linear Relationship Between Crude Death Rate Due to Pneumonia and Per Capita Greenhouse Gas Emissions (C) Linear Relationship Between Crude Death Rate Due to Pneumonia and Highest Temperature (D) Linear Relationship Between Crude Death Rate Due to Pneumonia and Number of Extreme Events*

Although the literature shows that climate change is associated with increased morbidity and mortality from respiratory diseases such as COPD and asthma (1, 11, 12), our study did not find a statistically significant relationship between deaths from these diseases and certain climatic parameters. This situation can be explained by regional differences, uncertainties in the classification of causes of death, or the indirect and long-term effects of climate change.

Some studies have examined the association between respiratory diseases and particulate matter (PM) pollution and have shown that exposure to both outdoor PM2.5 and PM10 is associated with an increase in hospital admissions due to upper respiratory tract infections among children and adolescents(13). Some studies have attempted to explain how extreme weather events influence the transmission of respiratory diseases by altering human behaviors and indoor environmental conditions, suggesting that such extreme events further complicate this relationship and may potentially increase disease transmission (14).

Limitations

Although this study has several strengths, it also has certain limitations. First, the use of secondary data and an ecological study design limits the ability to make causal inferences at the individual level. Correlation analyses provide information on the direction and strength of associations between variables; however, they do not establish causality. Therefore, the observed relationships should not be interpreted as causal.

The evaluation of environmental and climatic data based on annual averages may have obscured short-term fluctuations, seasonal variations, and the effects of acute exposures. Similarly, the use of annual mortality data limited the assessment of potential lag effects between environmental exposures and health outcomes.

In addition, this study relied on aggregate data at the national level, and regional or local differences could not be examined. Given Türkiye's geographical, climatic, socioeconomic, and demographic heterogeneity, environmental exposures and respiratory disease–related mortality may vary across regions. This limitation also entails the risk of ecological fallacy, which is inherent to ecological study designs.

Furthermore, due to the study design, potential individual-level confounding factors -such as smoking status, socioeconomic conditions, access to healthcare services, occupational exposures, comorbidities, and individual-level exposure to air pollution- could not be accounted for. The inability to control for these factors may have resulted in residual confounding in the observed associations.

Finally, data gaps in some environmental variables and the reliance on institutional reporting systems, which may have limitations in data accuracy, represent additional constraints of the study. Despite these limitations, the study provides important insights by covering a long time period and jointly examining multiple environmental indicators, thereby offering a valuable framework to inform future, more detailed analytical and individual-level research.

CONCLUSION

This study reveals the effects of climate change-related parameters on respiratory health. Although correlation studies do not establish a definitive causal relationship, the explanatory power of the significant findings remains noteworthy. Climate change poses a significant threat to human health and healthcare systems in the coming decades. While empirical relationships between climate change and morbidity and mortality are frequently observed in the literature, the causality of these relationships is often not clearly established. This situation makes it difficult to reach a scientific consensus on the effects of climate change on health. In the case of the respiratory system, one of the two systems most affected by climate change, it is of great importance to align public health policies with climatic realities, raise public awareness, and restructure health education programs in order to prevent and reduce the effects of climate-sensitive diseases such as respiratory tract infections. In conclusion, interdisciplinary collaboration, sensitivity to local conditions, and the implementation of science-based strategies are essential to effectively combat the adverse effects of climate change on human health.

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Conflicts of interest

There are no conflicts of interest.

Availability of data and materials

Data sets created and/or analyzed during the current study will be shared upon request by contacting the corresponding author.

Ethical Confirmation

Since open access data was used in the study, no ethical committee approval was required.

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