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Review Article

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Impact of Atmospheric Parameters on Human Respiratory Tract Infections (RTIs)

Buhari Samaila[1], **Zaharaddin Muhammad Kalgo**[2]

[1]Department of Physics with Electronics, Federal University Birnin Kebbi (FUBK), Birnin Kebbi, Kebbi State, PMB 1157 Kalgo, Nigeria
[2]Department of Microbiology, Federal University Birnin Kebbi (FUBK), Birnin Kebbi, Kebbi State, PMB 1157 Kalgo, Nigeria

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Abstract: Respiratory tract infections (RTIs) are a significant public health issue globally, with varying degrees of severity and implications. Environmental factors, particularly atmospheric parameters, can exacerbate these health conditions. Understanding the relationship between atmospheric conditions and RTIs is crucial for effective public health interventions. This systematic literature review analyzes research on the impact of atmospheric parameters on RTIs through a systematic search across multiple electronic databases using different keyword combinations. The retrieved articles were categorized based on atmospheric parameters investigated, such as temperature, humidity, air pollution, and rainfall. The review findings indicate that various atmospheric factors, including wind speed, air pollution (PM10, PM2.5, CO, and O_3), air temperature, atmospheric pressure, and humidity, influence the occurrence and severity of respiratory infections. Low wind speed and high air pollution were identified as risk factors for severe acute respiratory infection (SARI). In children, meteorological factors like air temperature, atmospheric pressure, rainfall, sunlight hours, wind speed, and relative humidity were associated with lower respiratory tract infections. Pollutants like PM2.5, carbon monoxide, sulfur dioxide, and tropospheric ozone directly impact pediatric respiratory infections. Climate variables affect the seasonal activity of pathogens like respiratory syncytial virus (RSV). These findings underscore the importance of considering atmospheric parameters in understanding and preventing RTIs. Addressing these challenges requires a comprehensive approach integrating environmental and public health interventions. This approach can better mitigate the effects of atmosphere-related risks on respiratory health.

Keywords: Air Pollution; Metrological Parameters; Morbidity; Severe Acute Respiratory Infection (SARI); Temperature.

1. Introduction

Atmospheric parameters or conditions refer to the various factors that describe the state of the atmosphere, such as temperature, humidity, wind speed, wind direction, and atmospheric pressure [1]–[3]. The diversity of atmospheric conditions plays a crucial role across different research fields, providing essential data for understanding and optimizing various natural and human-made systems [4], [5].

In wind energy research, the characterization of atmospheric conditions is fundamental for multiple aspects of wind plant design and operation [6], [7]. Stationary conditions, which refer to stable and predictable atmospheric patterns, are important for ensuring the consistent performance of wind turbines. For instance, understanding these stable patterns helps optimize the energy output and improve the reliability of wind energy systems [8], [9]. Conversely, extreme weather events, such as storms and high winds, need to be considered in the structural design to ensure the resilience and safety of wind plants. These extreme conditions can pose significant risks to the integrity of wind turbines, making it essential to incorporate robust engineering solutions to withstand such events [10], [11].

Moreover, wind speed and direction changes significantly influence wind turbines' efficiency and energy yield. Accurate modeling and validation of these parameters are therefore crucial for optimizing the placement and performance of wind energy systems. Researchers focus on these variations to enhance

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Corresponding author: Buhari Samaila (buhari.samaila@fubk.edu.ng)

predictive models to forecast energy production better and identify optimal sites for new wind farms [12].

In studying stellar atmospheres, determining atmospheric parameters such as temperature and metallicity is essential for understanding stellar structure and evolution. These parameters help astronomers decipher the physical characteristics and lifecycle of stars. For example, temperature measurements provide insights into the energy output and spectral classification of stars. At the same time, metallicity – the abundance of elements heavier than hydrogen and helium – offers clues about the star's formation history and age. Researchers use these atmospheric parameters to build models that simulate stellar environments, improving our comprehension of phenomena like star formation, nuclear fusion processes, and the distribution of elements in the universe. By comparing these models with observational data, scientists can refine their theories about stellar evolution and the dynamics of galaxies [13].

Atmospheric parameters significantly impact cardiovascular health, with numerous studies indicating that changes in temperature and humidity can influence the incidence of acute cardiovascular diseases. For instance, research by Nora et al. [14] demonstrated that extreme temperature fluctuations, whether hot or cold, are associated with an increased risk of myocardial infarction and other cardiovascular events. This is likely due to the body's physiological responses to temperature stress, which can exacerbate underlying cardiovascular conditions. Furthermore, humidity levels can affect blood viscosity and arterial stiffness, further impacting cardiovascular health.

In addition to these findings, comparing spectroscopic surveys has become a crucial study area. Researchers like Hegedűs et al. [16] and Change et al. [17] have focused on the accuracy and precision of derived atmospheric parameters and elemental abundances in various spectroscopic surveys. These studies aim to understand the discrepancies between different surveys and improve the reliability of atmospheric data. For example, Hegedűs et al. [16] highlighted the need for standardized methods to reduce variations and enhance data consistency in atmospheric and climate models.

Respiratory tract infections (RTIs) present a significant global health challenge, imposing substantial burdens on healthcare systems due to their high morbidity and mortality rates. RTIs can be acquired in the community or within healthcare settings and affect both immunosuppressed and non-immunosuppressed individuals. These infections are caused by various pathogens, including viruses, bacteria, fungi, and parasites [18]. Acute lower respiratory infections (ALRIs) are particularly concerning as they are a leading cause of mortality in children under five years old worldwide. Niederman and Torres reported that respiratory viral infections (RVIs) contribute significantly to these deaths, emphasizing the urgent need for effective prevention and treatment strategies [19].

The development of advanced diagnostic tools, such as nanopore sequencing, holds promise in improving the identification and management of RTIs. Robert et al. [20] demonstrated the potential of nanopore sequencing to identify a wide range of pathogens rapidly and accurately, enabling timely and targeted treatment. This technology could revolutionize the diagnosis of RTIs, particularly in resource-limited settings where traditional diagnostic methods may be less accessible.

Forecasting models have also been developed to predict the burden of upper respiratory tract infections (URTIs) and guide healthcare resource planning. Lim et al. [21] explored factors influencing URTI transmission, including seasonal variations, population density, and public health interventions. These models are essential for anticipating outbreaks and allocating resources effectively to mitigate the impact of URTIs on public health. Lower respiratory infections (LRIs) contribute significantly to global mortality, morbidity, and economic burden. Safiri et al. [22] identified several major risk factors for LRIs, including child wasting, household air pollution, and lack of access to handwashing facilities. Addressing these risk factors through targeted public health initiatives is crucial for reducing the incidence and severity of LRIs, particularly in low- and middle-income countries.

Additional research has further highlighted the interplay between environmental factors and respiratory health. For instance, a study by Liu et al. [23] examined the effects of air pollution on respiratory infections, finding a strong correlation between high levels of particulate matter and increased rates of RTIs. This underscores the importance of environmental policies to reduce air pollution and improve respiratory health outcomes. Atmospheric parameters are potentially linked to respiratory tract infections (RTIs). Several studies have investigated this relationship and identified various factors that may contribute to the spread and prevalence of RTIs. These factors include temperature, humidity, air pollution, and wind speed [24]–[29].

Temperature and humidity play critical roles in the survival and transmission of respiratory viruses. Research has shown that these parameters affect viral inactivation in the air and viral deposition in the respiratory tract. For instance, certain viruses thrive in low humidity and cooler temperatures, which can lead to higher transmission rates during the winter months. Conversely, high humidity can cause viral particles to settle more quickly from the air, potentially reducing transmission but increasing surface contamination risks.

Air pollution, including particulate matter (PM), nitrogen dioxide (NO_2), and carbon monoxide (CO), has been associated with increased susceptibility to viral infections and impaired immune responses. Particulate matter can carry viruses, enhancing their ability to penetrate the respiratory tract. Pollutants like NO_2 and CO can exacerbate underlying respiratory conditions, making individuals more vulnerable to infections. Studies by Wu et al. [24] and Mao et al. [25] have highlighted the correlation between high levels of air pollution and increased incidence of RTIs, particularly in urban areas with dense populations and heavy traffic.

Wind speed also influences the spread of respiratory infections. Low wind speed can lead to accumulating pollutants and viral particles in the air, increasing the likelihood of inhalation by nearby individuals. Conversely, higher wind speeds can disperse these particles more widely, potentially reducing local concentrations but increasing the geographic spread of pathogens. Further research by Ji-Hyun et al. [26] and Allison [27] has reinforced the understanding that atmospheric parameters significantly impact RTI prevalence. Their studies emphasized the need for integrated public health strategies that consider environmental factors in preventing and controlling respiratory infections.

The main objective of this systematic literature review is to examine the impact of atmospheric parameters on human respiratory tract infections. The review aims to gather evidence on the relationship between sociodemographic and climatic factors, such as temperature, humidity, rainfall, and air pollutants, and the occurrence and spread of respiratory infections. By understanding these relationships, the study aims to provide insights that can help develop strategies for preventing and managing RTIs, ultimately reducing their burden on healthcare systems and improving public health outcomes.

2. Material and Methods

2.1 Enhanced Search Strategy

A comprehensive and systematic search was conducted across multiple electronic databases, including PubMed, Web of Science, ResearchGate, and Google Scholar. Additionally, relevant journal websites were searched. The search strategy included using Boolean operators and combining keywords and Medical Subject Headings (MeSH) terms related to atmospheric parameters and respiratory tract diseases. Keywords included terms such as "temperature," "humidity," "air pollution," "atmospheric conditions," "asthma," and "respiratory infections" [30], [31]. To ensure a thorough search, filters were applied for publication dates from database inception to 2023 and for English language studies. The detailed search strings were tailored for each database to maximize sensitivity and specificity [32].

2.2 Enhanced Inclusion and Exclusion Criteria

For the systematic review of the impact of atmospheric parameters on respiratory tract diseases, the inclusion and exclusion criteria were meticulously defined to ensure the relevance and quality of the selected studies. Studies were included if they investigated the relationship between atmospheric parameters—such as temperature, humidity, and air pollution—and human respiratory diseases. Relevant outcome measures were required to include the incidence or prevalence of respiratory conditions, symptom severity, or hospitalization rates. The review considered a range of study designs, including observational studies (cohort, case-control, cross-sectional), interventional studies, systematic reviews, and meta-analyses [31], [32].

Studies were excluded if they did not focus on the specified atmospheric parameters or respiratory diseases. Additionally, studies that lacked relevant outcome measures or involved animal or in vitro models were omitted. Non-English language studies were excluded due to resource constraints. This careful selection process ensured that only high-quality, directly relevant studies were included, facilitating a focused analysis of the impact of atmospheric parameters on respiratory health [33], [34].

2.3 Enhanced Study Selection Process

The rigorous study selection process involved two independent reviewers (Reviewer A and Reviewer B) who screened the titles and abstracts of all retrieved articles for relevance. Articles deemed potentially eligible underwent a full-text review. Any discrepancies were resolved through discussion or consultation with a third reviewer (Reviewer C) [31], [35].

2.4 Enhanced Data Extraction

Data extraction from the included studies was carried out using a standardized data extraction form, ensuring a consistent and thorough information collection. Extracted data included study design, sample size, demographic characteristics of participants, atmospheric parameters examined, respiratory outcomes measured, and key findings, including effect sizes where applicable. To ensure the accuracy and consistency of the data extraction process, it was piloted on a subset of studies and refined accordingly [32].

2.5 Enhanced Data Synthesis and Analysis

The findings were categorized based on the atmospheric parameters investigated in synthesizing and analyzing the data. Quantitative data, such as effect sizes and odds ratios, were pooled using meta-analysis techniques when appropriate. Random-effect models accounted for heterogeneity between studies [36]. Heterogeneity was assessed using the I^2 statistic, and potential sources of heterogeneity were explored through subgroup analyses and meta-regression. Qualitative data were summarized narratively, highlighting common themes, patterns, and discrepancies across the studies. The quality of evidence and strength of recommendations were assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach [37], [38].

2.6 Ethical Considerations

Ethical approval was not required since this systematic review utilized publicly available data from previously published studies and did not involve direct interaction with human participants. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, ensuring transparency and reproducibility [39]. This comprehensive and methodologically rigorous approach aimed to provide a robust understanding of the impact of atmospheric parameters on human respiratory tract diseases, contributing valuable insights to the field.

3. Result and Discussion

Research has extensively scrutinized the link between atmospheric parameters and respiratory tract infections, focusing on air pollution, meteorological conditions, and climatological variables. Studies highlight that wind speed, particulate matter (PM10, PM2.5), ozone (O_3), carbon monoxide (CO), air pressure, temperature, diurnal temperature range, humidity, and sunlight exposure significantly influence respiratory infection rates and mortality. Particulate matter can penetrate the lungs, exacerbating asthma and chronic bronchitis [40]. Short-term exposure to elevated ozone levels is linked to increased respiratory mortality [41]. Carbon monoxide poses severe risks by impairing oxygen delivery, especially in poorly ventilated and heavily trafficked areas [42]. Moreover, meteorological conditions like wind speed and air pressure affect pollutant dispersion, influencing respiratory health outcomes [1], [43].

Notably, a non-linear lag relationship exists between environmental factors and respiratory infections, with lower wind speeds and higher pollution levels being significant risk factors for severe acute respiratory infections (SARI). Falagas et al. [44] show a positive association between high temperatures and increased RTI cases during the dry season. Urban air pollution from vehicular rates of respiratory infections in the region [45]. Additionally, Chen et al. [46] found that prolonged exposure to high levels of PM2.5 and PM10 significantly increases the risk of chronic respiratory conditions such as asthma and COPD.

Research by Wu et al. [24] demonstrated that diurnal temperature fluctuations worsen respiratory symptoms and increase hospital admissions. Zhang et al. [47] emphasized that elevated ozone concentrations are strongly associated with increased emergency room visits for asthma and other respiratory diseases. Cohen et al. [48] identified air pollution as a leading environmental risk factor for respiratory infections, causing millions of premature deaths annually. This body of research underscores the critical impact of atmospheric parameters on respiratory health, highlighting the need for robust environmental policies and public health strategies to mitigate these effects and improve respiratory outcomes, especially in vulnerable populations and regions.

3.1. Temperature

Extreme temperatures, whether high or low, profoundly impact respiratory diseases [49]–[52]. Studies have shown that high temperatures can increase the risk of respiratory diseases with a lag effect of up to seven days [53]. In contrast, extremely low temperatures may have an even longer lag effect, extending up to 22 days. Older people are particularly vulnerable to these temperature extremes. Additionally, large-scale temperature fluctuations, such as those occurring over 48 hours, are associated with an increased risk of respiratory diseases, and this risk is more pronounced with extreme heat compared to extreme cold.

Both high and low temperatures contribute significantly to increased morbidity from respiratory diseases. Non-optimal temperatures, especially moderate heat, account for a substantial proportion of respiratory-related morbidity. Given these findings, monitoring temperature variations and implementing targeted public health measures are crucial in mitigating the adverse effects of extreme temperatures on respiratory health. Tables 1, 2, and 3 provide a detailed summary of the impact of temperature on respiratory tract infections (RTIs), highlighting the need for continuous surveillance and proactive public health strategies to address these challenges effectively.

Table 1. An Overview of the Effect of Temperature on RTI

Titles	Objective	Methods	Results	Conclusions	Sources
Influencing mechanisms of urban heat island on respiratory diseases.	Investigation on the influence of urban heat island (UHI) on respiratory diseases.	Evaluation of landscape pattern indexes. Analysis of spatial distribution characteristics of influences.	Findings indicated that UHI causes a higher mortality rate for respiratory diseases by increasing the average daily air temperature in summer. Fluctuating influence of UHI on respiratory diseases increased from 1992 to 2018. Mortality risk increased by 101%, and influenced area reached 349 km2.	UHI increases the mortality risk of respiratory diseases. Influence areas are fragmented and concentrated in urban centers.	Huanchun et al., 2020 [49]
Effects of extreme temperature on respiratory diseases in Lanzhou, a temperate climate city of China.	To analyze the effect of extreme temperature on respiratory diseases.	A distributed lag non-linear model (DLNM) was used to evaluate the lag effect, and Epidemiological studies were conducted to assess the correlation between extreme temperature and respiratory diseases.	The relative risk of respiratory diseases was highest at lag 0 days and decreased to 1.0 at lag 5 days. Extremely low temperatures affect respiratory diseases more than extremely high temperatures.	Extreme low temperature affects respiratory diseases more than extreme high temperature. Elderly individuals are at the greatest risk of extreme temperatures.	Fengliu et al., 2021 [51]
Ambient air pollution, temperature, and hospital admissions due to respiratory diseases in a cold, industrial city.	To investigate ambient air pollution, temperature, and hospital admissions due to respiratory diseases in a cold, industrial city.	The time-series decomposition, generalized additive models, and distributed lag non-linear models were used to explore the effects.	Respiratory diseases in Changchun showed an increasing trend with obvious seasonality. Increased air pollutants and extreme temperatures increase the risk of hospitalization for respiratory diseases.	Respiratory diseases in Changchun showed an increasing trend with obvious seasonality. Increased air pollutants and extreme temperatures increase the risk of hospitalization for respiratory diseases.	Huanhuan et al., 2022 [50]
Effect of meteorological factors on respiratory system diseases in Funan, China.	The paper states that high temperature is a risk factor for respiratory system diseases at short time lags but reduces the number of patients at long time lags. Low relative humidity and large-scale 48-hour temperature changes also increase the risk of respiratory system diseases.	Distributed lag non-linear model and generalized additive models were used	The findings indicated that High temperature reduces the number of patients with respiratory system disease. Low relative humidity increases the risk of respiratory system diseases.	High temperature decreases the number of patients with respiratory system disease at long time lags, while Low relative humidity increases the risk of respiratory system diseases.	Zhao, 2019 [52]

Table 2. An Overview of the Effect of Temperature on RTI (Continued)

Titles	Objective	Methods	Results	Conclusions	Sources
Morbidity burden of respiratory diseases attributable to ambient temperature: a case study in a subtropical city in China	To examine the associations between ambient temperature and morbidity of respiratory diseases. It states that high and low temperatures increase the risk of respiratory morbidity, with moderate heat responsible for most of the morbidity burden caused by temperature exposure.	Standard time series quasi-Poisson regression with a distributed lag non-linear model (DLNM) was applied.	The results showed that low and high temperatures increase the risk of respiratory morbidity. Moderate heat contributes to most temperature-related respiratory morbidities.	Both high and low temperatures increase the morbidity risk of respiratory diseases. Moderate heat is mainly responsible for the morbidity burden caused by temperature exposure. However, it does not specifically mention the impact of temperature fluctuations on respiratory tract diseases.	Yiju et al., 2019. [53]
Climate Change and Respiratory Infections	To investigate the relationship between climatic change and respiratory infection	MS Word, Excel, mathematical modeling, and statistical software were used.	The results showed that temperature fluctuations, such as sharp drops, can increase the incidence of childhood pneumonia. It also revealed that extreme weather events, including heat waves, can change the incidence of respiratory infections.	Climate change poses a threat to human health and healthcare systems. Knowledge of the associations between climate and respiratory infections is important for public health policies and disaster preparedness.	Mehdi et al., 2016 [54]
Assessing the Impact of Meteorological Conditions on Outpatient Visits for Childhood Respiratory Diseases in Urumqi, China	To assess the impact of Meteorological Conditions on Outpatient Visits for Childhood Respiratory Diseases	The distributed lag non-linear model was used.	The results showed that children are more susceptible to respiratory illnesses at high and low temperatures. The impact of low temperatures is greater than that of high temperatures.	Children are more susceptible to respiratory illnesses in both hot and cold conditions. Both high and low wind speeds can harm children's respiratory diseases.	Yang et al., 2022 [55]
Impact of temperature on upper respiratory tract infections in Lanzhou based on the distributed lag model	The paper analyzed the impact of temperature on upper respiratory tract infections (URI) in Lanzhou. It found that low temperature significantly affected the morbidity of URI, with the peak occurring between November and February of the next year in Lanzhou.	A distributed-linear model examined the relationship between temperature and URI. Correlation analysis was conducted between meteorological factors and URI cases.	The correlation between meteorological conditions and the morbidity of upper respiratory tract infections (URI) in Lanzhou is noteworthy. The daily morbidity of URI is most affected by low temperatures.	The morbidity of upper respiratory tract infections (URI) in Lanzhou is significantly related to meteorological factors. Low temperature is the main factor triggering the morbidity of URI.	Guangyu et al., 2021 [56]

Table 3. An Overview of the Effect of Temperature on RTI (Continued)

Titles	Objective	Methods	Results	Conclusions	Sources
Lag effect of air temperature on the incidence of respiratory diseases in Lanzhou, China	To investigate the effects of air temperature on the incidence of respiratory diseases in Lanzhou, China	A distributed lag non-linear model coupled with a generalized additive model was used.	Both low and high temperatures increase the risk of hospital visits for respiratory illness. Temperature-related respiratory morbidity affects females and adolescents aged 6-14 years more.	The effects of high temperatures were acute and short-term, while the impact of low temperatures was persistent over longer lag periods. However, the study suggests that caregivers and health practitioners should be aware of the potential threat of cold and hot temperatures.	Guorong et al., 2020 [57]
Assessing the Impact of Meteorological Conditions on Outpatient Visits for Childhood Respiratory Diseases in Urumqi, China	To assess the Impact of Meteorological Conditions on Outpatient Visits for Childhood Respiratory Diseases	A distributed-linear model was constructed to analyze the impact of meteorological factors.	Both high and low temperatures increase the risk of respiratory diseases in children. High and low wind speeds can adversely affect respiratory diseases in children.	Both high and low temperatures increase the risk of respiratory diseases in children. High and low wind speeds can adversely affect respiratory diseases in children.	Zhen et al., 2022 [55]

Table 4. An Overview of the Effect of Humidity on RTIs

Titles	Objective	Methods	Results	Conclusions	Sources
The role of absolute humidity in respiratory mortality in Guangzhou, a hot and wet city of South China.	High and low absolute humidity contribute to respiratory disease mortality, with the greater burden attributed to high absolute humidity.	Daily respiratory disease mortality and meteorological data were collected.	The role of absolute humidity in respiratory mortality in Guangzhou, a hot and wet city of South China.	High and low absolute humidity contribute to respiratory disease mortality, with the greater burden attributed to high absolute humidity.	Shutian et al., 2021 [58]
Interactive Effects between Temperature and Humidity on Outpatient Visits of Respiratory Diseases in Lanzhou, China	The paper states that high temperature affects upper respiratory tract infection, but it does not specifically mention the impact of high or low humidity on respiratory tract disease.	Poisson generalized linear model	Interactive Effects between Temperature and Humidity on Outpatient Visits of Respiratory Diseases in Lanzhou, China	The paper states that high temperature affects upper respiratory tract infection, but it does not specifically mention the impact of high or low humidity on respiratory tract disease.	Hua et al., 2021 [59]
Effects of Low Humidity and High Humidity on the Nasal Area of the People	To investigate the effects of low and high humidity on nasal symptoms. The research aims to expose people to high and low humidity levels.	Mathematical modeling in Designing	Low humidity can cause dryness of the skin, nose, and eyes. High humidity can lead to nasal congestion and runny nose.	The researchers have designed an Arduino-controlled device to alert individuals. The research does not provide information on the impact of humidity on respiratory tract diseases.	Arsenal et al., 2023 [60]

Table 5. An Overview of the Effect of Humidity on RTIs (Continued)

Titles	Objective	Methods	Results	Conclusions	Sources
Hydrating the Respiratory Tract: An Alternative Explanation Why Masks Lower Severity of COVID-19 Disease	The paper discusses the correlation between low humidity of inhaled air and increased disease severity in respiratory tract diseases, including COVID-19. It suggests that increased humidity of inspired air, such as through the use of face coverings, may lower disease severity.	Sensors were used to record temperature, humidity, and CO2 levels. Measurements were made by breathing into a sealed steel box.	Facemasks increase the effective humidity of inhaled air.	Facemasks increase the effective humidity of inhaled air.	Joseph & Courtney, 2020 [61]
The contrasting relationships of relative humidity with influenza A and B in a humid subtropical region	To explore the relationship between relative humidity and influenza A and B in a humid subtropical region.	The time series seasonal decomposition method explored seasonality and the trend of daily influenza cases.	Increased humidity of inspired air may explain the link between mask-wearing and lower disease severity.	Increased humidity of inspired air may explain lower disease severity	Qian et al., 2021 [62]
The Interaction Effects of Temperature and Humidity on Emergency Room Visits for Respiratory Diseases in Beijing, China	The paper states that temperature and humidity jointly affect emergency room visits for respiratory diseases. Below the temperature threshold, the temperature effect is stronger in low humidity levels, while above the temperature threshold, the temperature effect is greater in high humidity levels.	A generalized linear model fitted in conjunction with the distributed lag non-linear model was used to quantify associations of RH with influenza A and B.	High relative humidity (RH) is associated with an increased risk of influenza A.	High relative humidity (RH) is associated with an increased risk of influenza A.	Qin et al., 2014 [63]

Table 6. An Overview of the Dust Storms and Sandstorms

Titles	Objective	Methods	Results	Conclusions	Sources
Desert dust and respiratory diseases: Further insights into the epithelial barrier hypothesis	To analyze the relationship between Desert dust and respiratory diseases.	A generalized additive Poisson regression model was used	Findings show that dust storms increase the risk of respiratory morbidity and mortality. Exposure to dust particles is associated with respiratory diseases and hospitalizations.	Dust storms increase the risk of respiratory diseases and hospitalizations.	Gennaro & Cezmi, 2022 [64]
Infectious Diseases Associated with Desert Dust Outbreaks: A Systematic Review	To systematically search the relationship between Infectious Diseases and Desert Dust Outbreaks from databases	A systematic search of various databases was used. Fifty-one studies were included in the review after screening and selection.	An association between desert dust outbreaks and infectious diseases was found.	Finally, desert dust events transport pathogenic or potentially pathogenic microorganisms. Limited data suggest a positive association between dust events and infectious disease outbreaks.	Eleni et al., 2022 [65]

Table 7. An Overview of the Dust Storms and Sandstorms (Continued)

Titles	Objective	Methods	Results	Conclusions	Sources
Exploring Meteorological Conditions and Human Health Impacts during Two Dust Storm Events in Northern Cape Province, South Africa: Findings and Lessons Learnt.	To explore Meteorological Conditions and Human Health Impacts during Two Dust Storm Events in Northern Cape Province, South Africa	Distributed non-linear lag analysis and wavelet transform analysis were used, and Maximum temperature and two air quality 'proxy measures' were used.	There are no statistically significant changes in hospital admissions during dust storms.	There are no statistically significant changes in hospital admissions during dust storms.	Vusumuzi et al., 2022 [66]
A Critique of Studies on the Combined Effects of Dust Storms and Meteorological Elements on Cardiovascular, Cerebrovascular, and respiratory diseases.	To Study the Combined Effect of Dust Storms and Meteorological Elements on Cardiovascular and Respiratory Diseases	The study reviewed studies from various databases using specific keywords.	Eye irritation was the most common dust-related hospital admission.	Ground-based air quality and local wind data are required for future studies.	Ali et al., 2022 [67]
Health effects of Asian dust events: a review of the literature.	The review aimed to evaluate the health effects of Asian dust (kosa), focusing on its impact on mortality, hospitalizations, and respiratory health.	It analyzed studies published between 1980 and 2009, retrieved from PubMed and JMEDPlus, and identified 19 relevant studies.	Some studies suggested that Asian dust could raise mortality and hospital visits for cardiovascular and respiratory conditions, while others found no significance.	The review called for more precise studies to better understand the health impacts of Asian dust in Japan.	Masahiro et al., 2010 [68]
Effects of Desert Dust and Sandstorms on Human Health: A Scoping Review	To explore the relationship between the Effects of Desert Dust and Sandstorms on Human Health	Systematic search of PubMed/MEDLINE, Web of Science, and Scopus Cross-tabulation of health effects with study design variables was used	The result showed that 204 studies were identified for the scoping review. Most studies reported significant associations between desert dust and adverse health effects.	Desert dust and sandstorms have significant adverse health effects. Existing studies have limitations in exposure measurement and statistical analysis.	Kaung et al., 2023 [69]
Effect of desert dust storms and meteorological factors on respiratory diseases	To investigate the effect of dust storms on respiratory diseases.	Generalized additive Poisson regression model	Findings showed that dust storms increase the risk of asthma mortality and ER visits.	The epithelial barrier hypothesis explains the increase in chronic diseases.	Mustafa et al., 2022 [70]
Dust Storms and Respiratory Emergency Department Visits in the Southwestern United States	To examine the association between Dust Storms and Respiratory Emergency Department Visits	The Data from IMPROVE monitoring sites in California, Arizona, Nevada, and Utah were used, and Patient-level ED visit data was obtained from state agencies.	Associations observed between respiratory ED visits and dust storms The strongest associations found in Arizona for respiratory ED visits	Dust storms are associated with respiratory-related emergency department visits. Dust storms pose a health threat, particularly in Arizona.	Claire et al., 2022 [71]

3.2. Humidity

Both high and low humidity levels significantly impact respiratory tract diseases. Low humidity can alter the rheological properties of mucus, impairing mucociliary clearance and weakening the physical defense barrier against pathogens [72]. For instance, in Guangzhou, China, high and low absolute humidity levels were linked to increased respiratory disease mortality, with the burden from high humidity being more substantial [58]. Similarly, in Lanzhou, China, low temperatures and low relative humidity were associated with increased outpatient visits for respiratory diseases, while high temperatures paired with low humidity impacted different respiratory illnesses [59].

The use of facemasks has been shown to increase the adequate humidity of inhaled air, thus promoting hydration of the respiratory epithelium and potentially reducing disease severity [61]. Moreover, low relative humidity, particularly in indoor environments during winter, can allow respiratory droplets to remain suspended in the air for extended periods, facilitating the spread of droplet-borne diseases [73]. These findings suggest that both ends of the humidity spectrum pose distinct challenges to respiratory health, underlining the need for strategies to manage indoor air quality effectively. Tables 4 and 5 provide a comprehensive overview of the effects of humidity on respiratory tract infections (RTIs), emphasizing the necessity for targeted public health interventions to mitigate these risks.

3.3. Dust Storms and Sandstorms

Dust storms and sandstorms profoundly impact respiratory tract diseases, significantly exacerbating various respiratory conditions. Numerous studies have linked exposure to dust particles from these storms to increased incidences of diseases such as asthma, chronic obstructive pulmonary disease (COPD), lower respiratory tract infections (LRTIs), and pulmonary embolism (PE) [64], [70]. These storms notably elevate the risk of same-day asthma mortality, emergency room visits for asthma and COPD, and hospitalizations due to asthma, LRTIs, and COPD [65], [71]. Inhalation of sand and dust particles triggers a solid pro-inflammatory response in the airways, aggravating respiratory symptoms and prompting acute exacerbations [69]. Fine particles from dust storms can deeply penetrate the lungs, causing inflammation and oxidative stress while exacerbating pre-existing conditions. Moreover, these particles transport diverse microorganisms, including pathogenic and opportunistic agents, which can further compromise health and lead to infectious disease outbreaks.

Dust storms are especially hazardous in regions that experience them frequently, where stronger associations have been observed between dust storms and respiratory-related emergency department visits. Residents in such areas are at higher risk due to persistent exposure to harmful dust particles. The connection between dust storms and heightened respiratory morbidity and mortality highlights the necessity for effective public health interventions. Strategies like public education on protective measures, timely health warnings, and protective gear can help minimize exposure and its adverse health effects. Dust storms and sandstorms pose significant health risks, particularly for individuals with pre-existing respiratory conditions. This calls for heightened awareness and comprehensive strategies to protect vulnerable populations and effectively manage respiratory health impacts. Tables 6 and 7 summarize the effects of dust storms and sandstorms on respiratory tract infections (RTIs), emphasizing the critical need for ongoing research and public health preparedness in affected regions.

3.4. Rainfall

Rainfall significantly influences the prevalence and seasonality of respiratory tract diseases through various mechanisms across different climatic regions. In tropical climates, acute respiratory infections (ARI) often surge during the pre-rainy and rainy seasons due to increased indoor crowding, as highlighted by Murray et al. [74]. The increased humidity and closeness foster the spread of respiratory pathogens. Conversely, in subtropical regions like Malaysia, respiratory syncytial virus (RSV) activity peaks during periods with lower rainfall and fewer rainy days, suggesting that drier conditions may favor its spread [75]. Air pollution, closely linked to rainfall patterns, further impacts respiratory health. Deepak and Mukesh [76] observed that winter months, marked by reduced rainfall, see higher levels of particulate and gaseous pollutants, which correlate with increased respiratory diseases. These pollutants exacerbate conditions like asthma and chronic obstructive pulmonary disease (COPD).

Seasonal climate variations also influence the incidence of respiratory diseases. Juliana et al. [77] found that the highest registered respiratory cases occur in autumn and winter, with significant temperature and humidity fluctuations that can weaken the respiratory system and enhance pathogen transmission. Rainfall and related factors, such as increased indoor crowding during rainy periods and elevated air pollution levels during dry spells, underline the need to understand these patterns for public health strategies. Implementing measures like improving indoor ventilation, reducing crowding, and controlling air pollution could significantly mitigate the impact of respiratory tract diseases linked to seasonal rainfall variations.

3.5. Air Pollution

Air pollution, including sulfur and nitrogen oxides, PM10 and PM2.5 particles, lead, benzene, and carbon monoxide, significantly impacts human respiratory tract diseases. Studies have shown that air pollution is associated with increased mortality and morbidity rates caused by respiratory diseases, including lung malignancies [78]. Both indoor and ambient air pollution contribute to a range of cardiac and respiratory illnesses, including chronic obstructive pulmonary disease (COPD), asthma, respiratory allergies, and lung cancer [79]. Air pollutants, such as particulate matter (PM) and ozone, can penetrate the human airway, triggering airway inflammation and exacerbating symptoms of respiratory diseases [80]. The complex composition of ambient airborne particulate matter, including transition metals and organic compounds, initiates the synthesis of inflammatory mediators and activates transcription factors, leading to chronic respiratory diseases, including cancer [81]. Exposure to particulate matter, especially ultrafine particles (PM0.1), can cause pulmonary inflammation, worsen asthma, and increase the risk of cardiovascular disease and hypertension [82].

Carmen et al. [78] assessed the influence of air pollution on respiratory diseases based on an analysis of principal pollutants and mortality/morbidity data sets. In this respect, four types of data are used: pollution sources inventory, air quality data sets, mortality/morbidity data at the local and national level, and clinical data of patients diagnosed with different forms of lung malignancies. The results showed increased deaths caused by respiratory diseases for the studied period correlated with decreased air quality due to industrial and commercial activities, households, transportation, and energy production.

Saleem et al. [79] state that air pollution is a worldwide health risk. A global study of diseases showed that air pollution is one of the top ten global health risk factors. Approximately 7 million people in the world and 400.000 people experience early death due to air pollution. The most common pollutants include particulate matter, carbon monoxide, ozone, nitrogen oxide, and sulfur dioxide. The two types of air pollution, indoor and ambient, contribute to various cardiac and respiratory illnesses. General ambient air pollution, chiefly due to the incomplete combustion of fossil fuels, may be responsible for increased lung cancer rates. Exposure to excess levels of air pollution is significantly associated with a variety of acute and chronic respiratory illnesses, such as chronic obstructive pulmonary disease, asthma, respiratory allergies, and lung cancer. The effects of air pollution disproportionately impact the extremes of the age distribution, perhaps due to altered immune responses. The presence of one or more contaminants in the atmosphere, such as dust, fumes, gases, gas, 'fog,' odor, or vapor in quantities or with characteristics and of a duration that may be detrimental to humans, animals, or plants. Combustion-source air pollution contributes to the occurrence of lung cancer among the general population. Using modern techniques to control pollution, such as multi-vortex wet air scrubber technology, nanotechnology, and recycle reuse techniques, is very helpful in controlling pollution.

A similar study by Yun-Gi et al. [80] noted that many combustible materials emit large quantities of air pollutants (toxic particles and gases). They also include particulate matter (PM), ozone, and biological contaminants, such as viruses and bacteria, which can penetrate the human airway and reach the bloodstream, triggering airway inflammation, dysfunction, and fibrosis. Pollutants that accumulate in the lungs exacerbate symptoms of respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD). Asthma, a heterogeneous disease with complex pathological mechanisms, is characterized by particular symptoms such as shortness of breath, a tight chest, coughing, and wheezing. Patients with COPD often experience exacerbations and worsening of symptoms, which may result in hospitalization and disease progression. PM varies in composition and can include solid and liquid particles of various sizes. PM concentrations are higher in urban areas. Ozone is one of the most toxic photochemical air pollutants. In general, air pollution decreases the quality of life and life expectancy. It exacerbates acute and chronic respiratory symptoms in patients with chronic airway diseases and increases the morbidity and risk of hospitalization associated with respiratory diseases. However, the mechanisms underlying these effects remain unclear. Therefore, we reviewed the impact of air pollutants on airway diseases such as asthma and COPD, focusing on their underlying mechanisms.

Martha et al. [81] indicated that redox regulation controls various aspects of metabolism. Reactive oxygen and nitrogen species participate in many reactions under physiological conditions. When these species overcome the antioxidant defense system, a distressed status emerges, increasing biomolecular damage and leading to functional alterations. Air pollution is one of the exogenous sources of reactive oxygen and nitrogen species. Ambient airborne particulate matter (PM) is important because of its complex composition, which includes transition metals and organic compounds. Once in contact with the lungs' epithelium, PM components initiate the synthesis of inflammatory mediators, macrophage activation, modulation of gene expression, and the activation of transcription factors, all related to the physiopathology of chronic respiratory diseases, including cancer. Even though the pathophysiological pathways that give rise to the development of distress and biological damage are not fully understood, scientific evidence indicates that redox-dependent signaling pathways are involved.

Gandhimathi et al. [82] have shown that the Earth consists of land, air, and water. Air contains oxygen, nitrogen, carbon dioxide, water vapor, and other gases above permissible limits, affecting human health. Air pollution is one of the most critical public health issues due to the development of urbanization, industrialization, and globalization in large cities. Air pollution levels in developed countries have increased in recent years, while in developing countries, they remain high. Health studies have become more visible in recent years, showing harmful health effects on the lungs and respiratory system. Air pollution is responsible for 7 million deaths annually, affecting humans and other living beings. Governments have developed guidelines for air quality and rules to restrict emissions to control air pollution. These updated Air Quality Guidelines (AQGs) provide exact guidelines for PM10 and PM2.5.

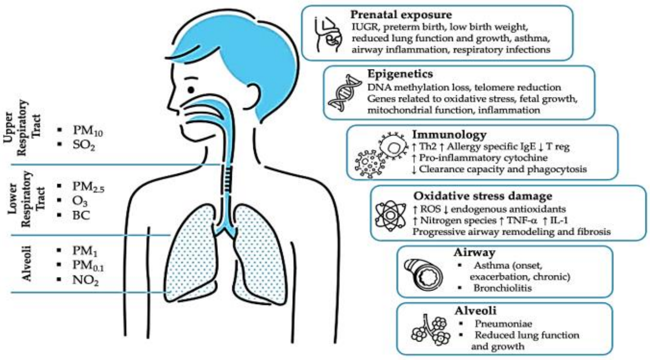

Figure 1. Regional Deposition of Major Air Pollutants and Main Direct and Indirect Mechanisms of Damage to The Respiratory System [15].

The primary objective of this paper is to study ambient air quality and its impact on the lungs. Particulate matter (PM) refers to particles suspended in the air/atmosphere. PM10 and PM2.5 are the ultrafine particles (<1μm) primarily responsible for causing health issues. PM10 and PM2.5 are characterized by their presence in the upper respiratory tract, while some PM2.5 and ultrafine particles are found in deeper regions of the alveoli. Ultrafine particles (PM0.1), present in the air in large numbers, pose a significant health risk. They generally enter the body through the lungs but can translocate to essential organs. Compared to fine particles (PM2.5), ultrafine particles cause more pulmonary inflammation and are retained longer in the lung. Their toxicity increases with smaller size, larger surface area, adsorbed surface material, and the physical characteristics of the particles. Exposure to PM0.1 induces coughing and worsens asthma. Metal fume fever is a systemic disease of lung inflammation most likely caused by PM0.1. This disease manifests with systemic symptoms hours after severe exposure to PM0.1, which could lead to systemic inflammation, endothelial dysfunction, and coagulation changes that predispose individuals to cardiovascular disease and hypertension.

Several studies have investigated the potential synergistic or antagonistic effects of combined atmospheric parameters on respiratory tract disease [83]–[86]. Studies on air pollution have shown that exposure to a single pollutant, such as PM2.5 or NO_2, is associated with a small increase in non-accidental mortality. However, when PM2.5 and NO_2 are adjusted for each other, the health risk is slightly lower than when considering a single pollutant. In the case of cardiovascular heart disease, exposure to PM2.5 or NO_2 adjusted for the other pollutant has been found to have an antagonistic effect on health risk compared to exposure to a single pollutant. On the other hand, both short- and long-term exposure to PM2.5 or NO_2 adjusted for the other pollutant have shown a synergistic effect, resulting in higher mortality from respiratory diseases. The evidence for these associations is moderate to low, with some studies showing statistical significance.

4. Conclusion

Respiratory tract infections (RTIs) are common, and atmospheric parameters significantly influence their prevalence. Studies have shown that meteorological variations and air pollution play crucial roles in the spread of RTIs. A correlation between RTIs and meteorological factors such as temperature, humidity, and wind speed has been observed. Air pollution, including pollutants like nitrogen oxides, sulfur oxides, ozone, carbon monoxide, and particulate matter, also significantly impacts the transmission of RTIs. The Universal Thermal Climate Index (UTCI), which considers air temperature, humidity, and wind speed, has been identified as a valuable predictive parameter for forecasting seasonal increases in RTI cases. These findings enhance our understanding of the relationship between atmospheric parameters and RTIs, underscoring the importance of climate factors in the prevalence of these infections. Addressing atmospheric factors is crucial for preventing and controlling respiratory tract infections.

Research has revealed that environmental factors such as air pollution, atmospheric plastics, and climate change significantly impact respiratory infections. These factors contribute to the spread and dispersion of viruses and bacteria, particularly affecting vulnerable populations such as children. The review found varying degrees of positive or negative associations between temperature, humidity, rainfall, and respiratory infections. However, the impact of these atmospheric parameters alone cannot fully explain the variability in disease occurrence. Additionally, the review highlighted the potential synergistic effects of atmospheric parameters combined with other risk factors, such as air pollutants, on respiratory infections. These findings can inform public health interventions aimed at reducing the morbidity and mortality associated with respiratory tract infections, especially in vulnerable populations such as children.

5. Recommendations for Future Research

Understanding the mechanisms underlying the relationship between atmospheric parameters is crucial for developing effective prevention and treatment strategies. Additionally, metrological parameters pollution modeling can play a significant role in studying and preventing the impact on respiratory infections. It is also important to consider the influence of climate factors, such as temperature, humidity, and precipitation, on the transmission of respiratory viruses. Further research should explore the seasonal variation of these climate variables and their impact on respiratory infections. These measures can contribute to developing effective respiratory infection prevention and control strategies.

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