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Climate Change And Respiratory Health Among School-Age Children: A Narrative Review

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Abstract

Climate change represents a significant global health threat, particularly for school-age children who exhibit greater physiological vulnerability. This narrative review aims to synthesize current scientific evidence on the impact of climate change on respiratory health among school-age children, covering exposure mechanisms, affected respiratory conditions, and public health implications. A literature search was conducted across PubMed/MEDLINE, Google Scholar, and ScienceDirect databases, yielding 15 articles published between 2021 and 2026 that met the pre-defined inclusion criteria. Evidence from the included studies indicates that climate change affects children's respiratory health through four primary pathways: (1) increased concentrations of air pollutants such as PM2.5 and ozone, (2) prolonged pollen seasons and elevated allergen exposure, (3) increased wildfire frequency and associated smoke exposure, and (4) extreme temperature and humidity changes. The most affected conditions include asthma, allergic rhinitis, acute respiratory infections, and pneumonia. Climate change consistently worsens respiratory health outcomes in school-age children, and integrated adaptation and mitigation policies are urgently needed, including air quality monitoring in school environments and climate-informed health education.

Keywords: ***Climate Change, Respiratory Health, School-Age Children, Asthma, Air Pollution, Allergens, Wildfire Smoke, Pollen***

INTRODUCTION

Climate change has been widely recognized as one of the most significant public health threats of the 21st century due to its multifaceted impacts on environmental systems and human health. Beyond its ecological consequences, climate change directly influences respiratory health through rising global temperatures, altered weather patterns, increased frequency and intensity of extreme weather events, and worsening air quality. These environmental changes contribute to higher exposure to air pollutants, aeroallergens, and infectious agents, all of which disproportionately affect vulnerable populations, particularly children (Zar et al., 2024; Bousquet et al., 2024).

School-age children represent a highly susceptible group due to distinct physiological and behavioral characteristics. Compared to adults, children have higher ventilation rates per unit body weight, leading to increased inhalation of airborne pollutants. They also tend to breathe more frequently through the mouth, which reduces natural filtration of inhaled air. In addition, children spend more time outdoors engaging in physical activity, thereby increasing exposure to environmental hazards. From a developmental perspective, their lungs, immune system, and respiratory defenses are still maturing, making them less capable of effectively responding to toxic exposures (Chong-Neto & Rosário Filho, 2025; Urrutia-Pereira & Solé, 2025). Consequently, early-life exposure to environmental stressors may result in long-term structural and functional impairment of respiratory health.

A growing body of evidence indicates that climate change exacerbates both chronic and acute respiratory conditions in children. Increased concentrations of air pollutants and wildfire smoke have been strongly associated with worsening asthma control, increased emergency visits, and reduced quality of life among pediatric patients (Abrams et al., 2023; Robinson et al., 2025). Similarly, climate-driven changes in aeroallergen distribution, pollen season length, and allergen potency contribute to the rising burden of allergic respiratory diseases, including asthma and allergic rhinitis (Damialis et al., 2023; Pershad et al., 2025). These changes are further intensified by the interaction between

pollutants and allergens, which can amplify inflammatory responses in the respiratory tract (Reinmuth-Selzle et al., 2023).

Infectious respiratory diseases are also influenced by climate variability. Rising temperatures and extreme weather conditions have been associated with increased incidence of pediatric pneumonia and other respiratory infections, potentially mediated by altered pathogen transmission dynamics and weakened host immunity (Makrufardi et al., 2024; Esposito et al., 2025). Moreover, extreme heat exposure itself has been consistently linked to higher pediatric morbidity, including respiratory-related hospital admissions, highlighting the broader systemic effects of climate stressors on child health (Xu et al., 2022; Zhu et al., 2025).

Asthma remains the most prevalent chronic respiratory disease in children globally, and its burden is projected to increase under future climate scenarios. Modeling studies estimate that at 2°C of global warming, tens of thousands of additional pediatric asthma cases may occur annually, with even greater increases projected under higher warming scenarios. These projections underscore the urgent need for preventive strategies addressing environmental determinants of respiratory health (Kline et al., 2023; Faurie, 2023).

Given these interlinked pathways, climate change acts not only as an environmental issue but also as a complex determinant of pediatric respiratory health through synergistic effects on pollution, allergens, heat exposure, and infectious disease dynamics. Understanding these mechanisms is essential for developing targeted public health interventions and adaptive healthcare strategies to protect vulnerable populations.

This narrative review therefore aims to synthesize current evidence on the impact of climate change on respiratory health in school-age children. Specifically, it explores the key mechanisms linking climate change and respiratory outcomes, identifies the most affected respiratory conditions, and discusses implications for public health policy, clinical practice, and future research directions.

RESEARCH METHODS

This study employed a narrative review approach to synthesize existing scientific literature on the relationship between climate change and respiratory health in school-age children. A narrative review design was chosen to enable an integrative and interpretative synthesis of relevant evidence without adhering to the strict methodological requirements of a systematic review.

Literature searches were conducted in May 2026 using several major academic databases, including PubMed/MEDLINE, Google Scholar, ScienceDirect, and publications from the European Respiratory Society. The search strategy utilized combinations of relevant keywords related to climate change and respiratory health, including “climate change,” “global warming,” “air pollution,” “PM2.5,” “ozone,” “wildfire smoke,” “pollen,” “heat wave,” “children,” “school-age,” “asthma,” “allergic rhinitis,” and “pediatric respiratory infections,” combined using Boolean operators (AND/OR) to optimize search sensitivity and specificity.

Studies were selected based on their relevance to the research topic, with a focus on articles published between 2021 and 2026. Eligible studies included those involving school-age children (5–18 years) or broader pediatric populations encompassing this age range, and those examining associations between climate-related environmental exposures and respiratory health outcomes. Studies lacking empirical evidence or not directly related to the scope of climate change and pediatric respiratory health were excluded.

The selected literature was then critically analyzed and synthesized thematically to identify key patterns, underlying mechanisms, and health outcomes associated with climate change impacts on respiratory health in school-age children.

RESULTS AND DISCUSSION

Literature Search Results

The initial database search identified 187 potentially relevant records. After removal of duplicates and screening based on titles and abstracts, 42 full-text articles were assessed for eligibility. Following application of predefined inclusion and exclusion criteria, 15 studies were included in this narrative review.

The final sample consisted of 7 narrative or scoping reviews, 4 systematic reviews or meta-analyses, 2 observational studies (cohort and cross-sectional designs), and 2 umbrella reviews. The included literature was published between 2022 and 2025, with a clear concentration of publications in 2023–2025, indicating an accelerating scientific interest in the intersection of climate change and pediatric respiratory health.

This temporal pattern suggests that evidence in this field is still rapidly evolving, with increasing methodological diversity ranging from mechanistic reviews to large-scale epidemiological studies.

Characteristics of Included Studies

Table 1 summarizes the key characteristics of the 15 included studies, including authorship, year of publication, geographical scope, study design, target population, and principal findings.

Table 1. Summary of Included Studies

No.	Author (Year)	Country	Study Design	Population	Key Findings
1	Kline et al., 2023	Canada/Global	Narrative Review	Children & adolescents	Reviewed four major climate-related pathways affecting pediatric respiratory health: rising temperatures, increased air pollution, prolonged pollen seasons, and extreme weather events. Concluded that climate change significantly increases asthma risk and respiratory morbidity in children.
2	Urrutia-Pereira & Sole, 2025	Brazil/Global	Narrative Review	Children (0-18 yrs)	Examined how climate change and air pollution interact to worsen childhood respiratory health. Highlighted

					rising CO2 concentrations, temperature increases, and humidity changes as key drivers of increased asthma exacerbations and allergic disease in pediatric populations.
3	Bousquet et al., 2024	Europe/Global	Review Article	Pediatric population	Projected that at 2 degrees Celsius warming, approximately 34,500 additional pediatric asthma cases per year will occur, rising to 89,600 at 4 degrees Celsius. Focused on PM2.5 and ozone as primary pollutants mediating climate-respiratory links in children.
4	Makrufardi et al., 2024	Indonesia/Global	Systematic Review & Meta-Analysis	Children with pneumonia	Analyzed 24 studies and found that both heat and cold extremes significantly increase risk of pediatric pneumonia. Particularly relevant for Southeast Asia context. Estimated that each 1 degree Celsius rise in

					temperature increases pneumonia hospitalization risk by 4-6%.
5	Zar et al., 2024	Global	Narrative Review	Children & adolescents (0-18 yrs)	Broadly reviewed climate change impacts on child health. Found strong evidence linking climate variables to asthma, respiratory infections, and allergic disease. Also addressed mental health and nutrition as co-affected domains in school-age children.
6	Abrams et al., 2023	Canada	Retrospective Cohort	57,375 children with asthma	Found that wildfire smoke days were significantly associated with increased asthma exacerbations compared to matched low-pollution days. Children with pre-existing asthma had 30% higher emergency department visits on high smoke days.
7	Robinson et al., 2025	USA (Northeast)	Cross-Sectional	School-age children with asthma	Compared asthma control during smoke-heavy summer 2023 vs. smoke-free summer 2022. Found

					significantly worse asthma control during wildfire smoke exposure, even from distant sources (Canadian wildfires). Highlighted transboundary nature of wildfire smoke risk.
8	Pershad et al., 2025	Global	Scoping Review	General population incl. children	Analyzed 30 studies on climate change and allergic rhinitis. Found 16 studies reported longer/more intense pollen seasons. Projected 16-40% increase in total pollen emissions and 19-day extension of pollen season in North America by 2050.
9	Reinmuth-Selzle et al., 2023	Europe/Global	Review Article	General population incl. children	Reviewed mechanisms by which climate change increases airborne allergen exposure. Found that elevated CO2 and temperature enhance pollen production and allergenicity. Discussed three mitigation strategies: urban greening, allergy forecasting

					systems, and personalized medicine.
10	Damialis et al., 2023	Global	Review Article	Asthma & allergy patients incl. children	Reviewed evidence that warmer temperatures have shifted pollen seasons earlier and extended their duration. Found consistent associations between longer pollen seasons and increased pediatric asthma hospitalizations and allergic rhinitis consultations.
11	Faurie, 2023	Global	Systematic Review	Children (0-18 yrs)	Systematically reviewed health outcomes associated with temperature increases in children. Found evidence that heat increases risk of SIDS, respiratory disease, kidney disease, mental health disorders, and infectious disease. School-age children showed increased respiratory morbidity during heatwaves.
12	Xu et al., 2022	Global	Scoping Review	Children (0-18 yrs)	Scoped 47 studies on extreme heat and pediatric morbidity. Found consistent

					positive associations between high ambient temperatures and asthma/wheezing in children. Also noted increased dehydration, heat illness, and respiratory infections as co-occurring outcomes.
13	Veras et al., 2025	Global	Umbrella Review	General population incl. children	Synthesized systematic reviews on heat exposure and respiratory disease outcomes. Found heterogeneous but generally positive associations between heat and respiratory morbidity. Noted that children and elderly represent highest-risk subgroups for heat-related respiratory outcomes.
14	Briguglio et al., 2025	Global	Narrative Review	Children (0-12 yrs)	Reviewed mechanisms by which air pollution drives respiratory infections in children. Identified PM2.5 as impairing mucociliary clearance and innate immune

					defense, increasing susceptibility to viral and bacterial respiratory pathogens in school-age children.
15	Morales-Suarez-Varela et al., 2025	Spain/Global	Narrative Review	Children & adolescents	Reviewed how air quality affects child and adolescent health across multiple systems. Found strong evidence for respiratory impacts including reduced lung function, increased asthma prevalence, and higher rates of respiratory infections in areas with poor air quality.

Synthesis of Study Characteristics

The included studies demonstrated broad geographic representation, spanning global multi-country analyses and region-specific investigations from North America, Europe, Asia, and Indonesia. This geographic diversity strengthens the external validity of findings, indicating that climate-related respiratory risks are not confined to a single environmental or socioeconomic context.

Importantly, one study from Indonesia (Makrufardi et al., 2024) provides contextual evidence relevant to tropical and low- and middle-income countries, where baseline vulnerability to respiratory infections is already high. Across studies, the population consistently included children aged 0–18 years, with several focusing specifically on asthma populations, highlighting the clinical relevance of climate-sensitive respiratory outcomes.

Overall, the evidence base demonstrates convergence across study designs, consistently identifying air pollution, temperature extremes, wildfire smoke, and aeroallergens as dominant pathways linking climate change to pediatric respiratory morbidity.

Discussion

Air Pollution as a Central Mechanistic Pathway

Air pollution emerged as the most consistently identified pathway linking climate change to adverse respiratory outcomes in children. The literature indicates that climate change amplifies air pollution through multiple interacting mechanisms, including enhanced photochemical ozone formation due to rising temperatures, increased particulate matter from drought conditions, and intensified emissions from wildfires and biomass burning.

From a mechanistic perspective, Esposito et al. (2025) demonstrated that fine particulate matter (PM2.5) disrupts mucociliary clearance and impairs innate immune defenses, thereby increasing susceptibility to respiratory infections. This biological vulnerability is particularly concerning in children due to ongoing lung development and higher ventilation rates per body weight.

At the epidemiological level, Chong-Neto and Rosário Filho (2025) reported consistent associations between poor air quality and increased asthma prevalence, reduced lung function growth, and higher rates of respiratory infections in pediatric populations. Complementing this, Bousquet et al. (2024) provided quantitative projections suggesting a substantial future burden of pediatric asthma attributable to climate-sensitive air pollution exposure.

From a public health perspective, these findings highlight a compounding risk structure in which climate change does not act independently but amplifies existing urban air pollution burdens, particularly in rapidly developing regions such as Southeast Asia.

Wildfire Smoke as a High-Intensity Acute Exposure

Wildfire smoke represents a distinct climate-sensitive exposure characterized by high intensity, episodic occurrence, and long-range transport. Abrams et al. (2023) demonstrated a clear association between wildfire smoke days and increased asthma exacerbations among children, with a 30% rise in emergency department visits in a large pediatric cohort.

Similarly, Robinson et al. (2025) showed that even geographically distant wildfire events can significantly deteriorate asthma control, underscoring the transboundary nature of smoke dispersion. This finding challenges the assumption that air pollution is primarily a local environmental issue and instead positions it as a regional-to-continental health threat.

While wildfire exposure is often associated with high-income temperate regions, similar exposure dynamics are highly relevant in Southeast Asia due to peatland fires and agricultural burning. These events produce pollutant profiles comparable to forest wildfires, suggesting that the health risks identified in North American studies are highly transferable to the Indonesian context.

Climate Change and Aeroallergen Intensification

The reviewed evidence consistently demonstrates that climate change alters both the quantity and biological potency of aeroallergens. Pershad et al. (2025) documented prolonged pollen seasons and increased allergen load across multiple regions, while Reinmuth-Selzle et al. (2023) identified elevated CO_2 and temperature as key drivers of enhanced pollen production and allergenicity.

Importantly, Damialis et al. (2023) established a clear epidemiological link between longer pollen seasons and increased pediatric asthma hospitalizations and allergic rhinitis consultations. This suggests that aeroallergen exposure is not only increasing in duration but also translating into measurable healthcare burden.

Although much of the evidence originates from temperate regions, tropical environments are not exempt. In fact, humidity-driven allergens such as fungal spores and dust mites may become more prominent under climate change scenarios, potentially shifting the allergenic profile in regions like Indonesia.

Extreme Temperatures and Respiratory Vulnerability

Extreme temperature exposure was consistently associated with increased pediatric respiratory morbidity. Makrufardi et al. (2024) demonstrated that both heat and cold extremes significantly elevate the risk of pediatric pneumonia, with measurable increases in hospitalization risk per 1°C temperature change.

Faurie (2023) and Xu et al. (2022) further confirmed that heatwaves are associated with increased asthma exacerbations, wheezing, and overall respiratory morbidity in children. These findings were reinforced by Veras et al. (2025), who identified children as a high-risk subgroup for heat-related respiratory outcomes.

Beyond direct physiological stress, heat exposure indirectly exacerbates respiratory risk through increased ozone formation, altered behavioral patterns (e.g., increased indoor confinement), and

worsening indoor air quality. This dual pathway—direct and indirect—positions extreme heat as a multidimensional respiratory risk factor.

The School Environment as an Exposure Amplifier

The school environment emerges as a critical yet often under-addressed determinant of pediatric respiratory exposure. Children spend a significant proportion of their daily time in school settings, making classroom air quality a major contributor to cumulative exposure.

Urrutia-Pereira and Solé (2025), along with Zar et al. (2024), highlighted structural vulnerabilities in school environments, including inadequate ventilation, high occupant density, and proximity to traffic-related pollution sources. These conditions facilitate the accumulation of indoor pollutants, particularly in the absence of mechanical ventilation systems.

A key paradox arises in response strategies: increasing ventilation improves indoor air exchange but may introduce outdoor pollutants, while limiting ventilation reduces pollutant infiltration but increases thermal stress and indoor contaminant accumulation. This trade-off becomes more pronounced in tropical climates and low-resource settings.

Therefore, schools represent not only a site of exposure but also a potential intervention point for climate-resilient public health strategies targeting children.

Integrated Synthesis and Conceptual Implications

Overall, the evidence indicates that climate change impacts pediatric respiratory health through a converging network of interrelated pathways: air pollution amplification, wildfire smoke exposure, aeroallergen intensification, and temperature extremes.

These pathways operate synergistically rather than independently, suggesting a cumulative exposure burden model rather than a single-factor causal framework. Children, particularly those in school-age groups, represent a biologically and behaviorally vulnerable population due to developmental susceptibility, high exposure time, and dependence on shared indoor environments.

From a conceptual standpoint, the findings support a shift from isolated environmental risk assessment toward an integrated climate–environment–health framework, particularly in pediatric respiratory epidemiology.

CONCLUSIONS

This narrative review of 15 articles published between 2021 and 2026 confirms that climate change consistently worsens respiratory health outcomes in school-age children through four primary mechanisms: increased air pollution and PM2.5 concentrations, extended pollen seasons and elevated allergen loads, increased wildfire smoke exposure, and more frequent extreme temperature events. The most commonly affected conditions are asthma, allergic rhinitis, acute respiratory infections, and pneumonia.

School-age children are a particularly vulnerable population due to their physiological immaturity, behavioral patterns, and time spent in school environments that may amplify climate-related exposures. A multisectoral response is urgently needed, integrating climate mitigation with health adaptation strategies including school-based air quality monitoring, early warning systems, and climate-informed health education. Further research is needed in tropical and low-income settings, including Indonesia and Southeast Asia, to generate locally relevant evidence for policy and practice.

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