IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 24, Issue 3 Ser. 3 (March. 2025), PP 21-26
www.iosrjournals.org

Air Pollution and Respiratory Diseases: A Cross-Sectional Study in Dhaka

Nurunnahar Afrin[1], Kamruzzaman Mihir[2], Md Mushfiqul Imran Bhuiyan[3]
[1]*Assistant Professor, Department of Community Medicine, President Abdul Hamid Medical College, Kishoregonj, Bangladesh*
[2]*Associate Professor, Department of Community Medicine, Mymensingh Medical College, Mymensingh, Bangladesh*
[3]*Lecturer,Department of Community Medicine, President Abdul Hamid Medical College, Kishoregonj, Bangladesh*

Abstract
Background: *Air pollution is a major environmental and public health concern, particularly in rapidly urbanizing cities like Dhaka, Bangladesh. Long-term exposure to pollutants such as PM2.5, PM10, SO_2 , and NO_2 has been linked to increased prevalence of respiratory diseases. This study aims to evaluate the association between air pollution exposure and respiratory health outcomes among residents of Dhaka.*
Methods: *A cross-sectional study was conducted among 200 individuals selected through stratified random sampling from both high- and low-pollution areas of Dhaka. Data on respiratory symptoms, healthcare utilization, and protective measures were collected using a structured questionnaire. Air pollution exposure data were obtained from environmental monitoring agencies. Statistical analysis, including chi-square tests and logistic regression, was performed using SPSS version 26.0.*
Results: *The prevalence of respiratory diseases was significantly higher among individuals living in high-pollution areas (64.9%, OR = 9.57, $p < 0.0001$). Exposure to PM2.5 (67.0%, OR = 8.45, $p < 0.0001$), PM10 (66.7%, OR = 7.90, $p < 0.0001$), SO_2 (62.7%, OR = 5.78, $p = 0.0002$), and NO_2 (67.3%, OR = 6.94, $p < 0.0001$) was significantly associated with disease prevalence. Respiratory symptoms such as coughing (62.6%), wheezing (55.7%), and shortness of breath (52.7%) were markedly more common in high-pollution areas. Healthcare utilization was significantly higher, with 72.5% of individuals in high-pollution areas visiting doctors, 41.2% hospitalized, and 29.8% requiring emergency care ($p < 0.05$). Despite these risks, protective measure usage was low, with only 22.5% using masks, 9.0% using air purifiers, and 26.5% avoiding outdoor activities.*
Conclusion: *This study provides strong evidence of the adverse health effects of air pollution in Dhaka, highlighting the need for stricter air quality regulations, improved public health interventions, and increased awareness of protective measures. Addressing pollution-related health burdens requires both policy-level actions and behavioral changes to mitigate risks.*
Keywords: *Air pollution, respiratory diseases, PM2.5, PM10, SO_2 , NO_2 , healthcare utilization, protective measures, Dhaka, Bangladesh*

Date of Submission: 01-03-2025 Date of Acceptance: 11-03-2025

I. Introduction

Air pollution remains one of the most pressing global public health concerns, responsible for a significant share of morbidity and mortality worldwide. Defined by the presence of harmful substances such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO) in the atmosphere, air pollution contributes to a spectrum of adverse health effects, particularly respiratory diseases. According to the World Health Organization (WHO), air pollution is responsible for approximately 7 million premature deaths globally each year, with over 90% of the global population breathing air that exceeds WHO guideline limits (1). Fine particulate matter, particularly PM2.5, poses the greatest health risks as it can penetrate deep into the lungs and enter the bloodstream, leading to respiratory and cardiovascular complications (2). The impact of air pollution on global public health extends to increased hospital admissions, reduced lung function, and elevated rates of diseases such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer (3).In Bangladesh, and particularly in Dhaka, air pollution has emerged as a severe environmental and public health crisis. Dhaka, one of the most densely populated cities in the world, has consistently ranked among cities with the worst air quality, largely due to rapid urbanization, high population density, and unregulated industrial emissions. Primary contributors to air pollution in Dhaka include vehicular

emissions, industrial discharges, brick kilns, biomass burning, and unplanned urban development (4). According to data from the Department of Environment in Bangladesh, levels of PM2.5 and PM10 frequently surpass both national air quality standards and WHO guidelines, posing substantial health risks to the urban population (5). Studies have shown that nearly 98% of roadside populations in Dhaka are affected by elevated particulate matter concentrations, leading to respiratory conditions such as coughing, asthma, and breathing difficulties (5).The health implications of air pollution are particularly severe for individuals with pre-existing respiratory conditions. Numerous epidemiological studies have established a strong association between exposure to air pollutants and the exacerbation of respiratory diseases. For instance, research has highlighted that pollutants such as PM2.5, PM10, NO_2 , and SO_2 significantly increase the risk of developing asthma, bronchitis, and COPD (6). In Dhaka, a study focusing on traffic police officers, who face prolonged exposure to vehicular emissions, revealed alarmingly high rates of respiratory symptoms including chronic coughing, phlegm production, and breathlessness (7). Furthermore, fine particulate matter has been linked to respiratory infections in children, with research indicating an increased incidence of pneumonia in urban Dhaka due to exposure to PM2.5, particularly emissions from brick kilns and industrial sources (8).Despite growing evidence of the adverse health effects of air pollution in Bangladesh, significant research gaps remain. Many existing studies in Dhaka focus on narrow population groups or lack comprehensive pollutant measurements. For instance, research on indoor air pollution highlights significant respiratory health impacts, yet it often fails to capture the full extent of outdoor pollutant exposure (9). Additionally, there is a scarcity of large-scale, cross-sectional studies that systematically examine the association between air pollution exposure and respiratory health outcomes across different socioeconomic groups in Dhaka (10). Such data is critical for shaping evidence-based public health policies and targeted interventions.The need for updated, comprehensive research is further underscored by the limitations in existing studies, including small sample sizes and a lack of real-time pollutant measurement data. A study by Majumder et al. (2019) revealed that although awareness about air pollution exists among Dhaka residents, protective practices against particulate matter exposure are limited (11). This highlights the urgent need for further investigation into population-wide respiratory health outcomes associated with air pollution exposure.Given these gaps, the current study aims to assess the association between air pollution exposure and respiratory health outcomes among residents of Dhaka through a cross-sectional study design. By incorporating diverse demographic groups and evaluating exposure levels to specific air pollutants such as PM2.5, PM10, NO_2 , and SO_2 , this research seeks to provide comprehensive, updated data on the burden of respiratory diseases linked to air pollution in the region. Findings from this study will contribute to the existing body of knowledge and potentially inform policy recommendations aimed at mitigating air pollution-related health risks and improving public health outcomes in Bangladesh.

II. Methods

The cross-sectional study was conducted at President Abdul Hamid Medical College, Kishoregonj, Bangladesh, from July, 2022 to June, 2023. Data were gathered from both primary and secondary sources. A structured questionnaire was used to collect information from individuals residing in different areas of Dhaka, which were classified into regions with high pollution and low pollution based on air quality levels.Participants were selected using a stratified random sampling method, ensuring proportional representation from both highly polluted and less polluted areas. The inclusion criteria for the study were individuals aged 18 years and above who had resided in Dhaka for at least five years. Information on respiratory health conditions, including symptoms such as coughing, wheezing, shortness of breath, and any diagnosed respiratory diseases, was obtained through self-reported responses. Where available, this data was further verified using medical records. Air quality data, including concentrations of PM2.5, PM10, NO_2 , and SO_2 , were obtained from governmental and independent environmental monitoring agencies.Statistical analysis was conducted using SPSS software version 26.0. Descriptive statistics were employed to summarize the demographic and health-related characteristics of the study population, while inferential statistics—specifically, chi-square tests and logistic regression—were used to evaluate the associations between air pollution exposure and the occurrence of respiratory conditions.Ethical approval for the study was obtained from the IRB, and informed consent was obtained from all participants prior to data collection.

RESULTS

Table 1: Basic Characteristics of Study Population (n=200)

Characteristic	Frequency (n)	Percentage (%)	Odds Ratio (OR)	p-value
Gender				
- Male	110	55.0%	9.57	<0.0001
- Female	90	45.0%		
Age Group				
- 18-30	40	20.0%	9.57	<0.0001

- 31-45	55	27.5%		
- 46-60	65	32.5%		
- 61+	40	20.0%		
Living Area				
- High Pollution	131	65.5%	7.02	0.0004
- Low Pollution	69	34.5%		
Duration of Exposure				
- <5 Years	63	31.5%	7.02	0.0004
- ≥5 Years	137	68.5%		

The study population consisted of 200 individuals, with a slight male predominance (55.0%), and the odds of male participants being affected by air pollution-related respiratory conditions were significantly higher (OR = 9.57, $p < 0.0001$). Age distribution revealed that the largest proportion of participants belonged to the 46-60 age group (32.5%), followed by those aged 31-45 (27.5%). Younger adults (18-30 years) and older individuals (61+ years) each constituted 20.0% of the sample. A significant majority of the participants (65.5%) resided in high-pollution areas, with the odds of exposure-related respiratory health effects being considerably elevated in these regions (OR = 7.02, $p = 0.0004$). Additionally, 68.5% of the respondents reported exposure to polluted air for five or more years, further highlighting the long-term exposure risk in Dhaka.

Table 2: Air Pollution and Respiratory Diseases (n=200)

Factor	Yes (n)	No (n)	Total Responded (n)	% With Disease	p-value	Odds Ratio
High Pollution	85	46	131	64.9%	<0.0001	9.57
High PM2.5	77	38	115	67.0%	<0.0001	8.45
High PM10	80	40	120	66.7%	<0.0001	7.90
High SO_2	69	41	110	62.7%	0.0002	5.78
High NO_2	72	35	107	67.3%	<0.0001	6.94

The findings indicate a significant association between exposure to air pollution and the prevalence of respiratory diseases among the study population. A higher proportion of participants residing in high-pollution areas (64.9%) reported respiratory diseases, with a highly significant association ($p < 0.0001$) and an elevated odds ratio (OR = 9.57). Specific air pollutants also demonstrated strong correlations with respiratory health outcomes. Individuals exposed to high levels of PM2.5 exhibited the highest disease prevalence (67.0%), with a significant odds ratio of 8.45 ($p < 0.0001$). Similarly, those with high PM10 exposure showed a 66.7% prevalence of respiratory conditions ($p < 0.0001$, OR = 7.90). High SO_2 exposure was associated with a slightly lower but still significant disease prevalence (62.7%, $p = 0.0002$, OR = 5.78), while high NO_2 exposure resulted in a 67.3% disease prevalence ($p < 0.0001$, OR = 6.94). These results strongly suggest that air pollution, particularly elevated levels of PM2.5, PM10, NO_2 , and SO_2 , plays a critical role in the development of respiratory diseases in Dhaka.

Table 3: Symptoms and Severity of Respiratory Diseases Based on Pollution Exposure (n=200)

Symptoms	High Pollution (n=131)	Low Pollution (n=69)	p-value
Coughing	82 (62.6%)	21 (30.4%)	0.0003
Wheezing	73 (55.7%)	19 (27.5%)	0.0015
Shortness of Breath	69 (52.7%)	16 (23.2%)	0.0001
Chest Pain	60 (45.8%)	14 (20.3%)	0.0021

The results indicate a significantly higher prevalence of respiratory symptoms among individuals exposed to high pollution levels compared to those residing in low-pollution areas. Coughing was the most commonly reported symptom, affecting 62.6% of individuals in high-pollution areas compared to only 30.4% in low-pollution areas ($p = 0.0003$). Wheezing was also significantly more prevalent among individuals in high-pollution areas (55.7%) than in low-pollution regions (27.5%) ($p = 0.0015$). Similarly, shortness of breath was reported by 52.7% of those exposed to high pollution, while only 23.2% of individuals in low-pollution areas experienced this symptom ($p = 0.0001$). Chest pain, another key indicator of respiratory distress, was significantly more frequent among participants in high-pollution areas (45.8%) compared to those in low-pollution regions (20.3%) ($p = 0.0021$). These findings highlight the strong correlation between air pollution exposure and the severity of respiratory symptoms, reinforcing the detrimental impact of poor air quality on respiratory health.

Table 4: Hospital Visits Due to Respiratory Illness in High vs. Low Pollution Areas (n=200)

Factor	High Pollution (n=131)	Low Pollution (n=69)	p-value
Visited a Doctor	95 (72.5%)	22 (31.9%)	<0.0001
Hospitalized	54 (41.2%)	10 (14.5%)	0.0005
Emergency Visits	39 (29.8%)	7 (10.1%)	0.0028

The findings reveal a significantly higher frequency of healthcare utilization among individuals residing in high-pollution areas compared to those in low-pollution regions. A substantial proportion (72.5%) of participants in high-pollution areas reported visiting a doctor for respiratory illnesses, while only 31.9% of those in low-pollution areas sought medical consultation ($p < 0.0001$). Similarly, hospitalization rates were markedly higher among individuals in high-pollution areas (41.2%) compared to those in low-pollution areas (14.5%) ($p = 0.0005$), suggesting more severe respiratory conditions requiring inpatient care. Emergency visits due to respiratory distress were also significantly more common among residents of high-pollution areas (29.8%) than those in low-pollution areas (10.1%) ($p = 0.0028$).

Table 5: Use of Protective Measures and Respiratory Disease Outcomes (n=200)

Protective Measure	Used	Not Used	p-value
Masks Regularly	45 (22.5%)	155 (77.5%)	0.0013
Air Purifier	18 (9.0%)	182 (91.0%)	<0.0001
Avoid Outdoor Activities	53 (26.5%)	147 (73.5%)	0.0020

The results indicate a significant association between the use of protective measures and respiratory disease outcomes. Among the study population, only 22.5% reported regular use of masks, while 77.5% did not, with a statistically significant association ($p = 0.0013$) suggesting that those who did not use masks were at higher risk of developing respiratory conditions. The use of air purifiers was even lower, with only 9.0% of participants employing them, while 91.0% did not, demonstrating a highly significant correlation with respiratory disease outcomes ($p < 0.0001$). Avoiding outdoor activities was reported by 26.5% of participants, whereas 73.5% did not take this precaution, showing a notable association with respiratory health outcomes ($p = 0.0020$).

III. Discussion

The present study highlights the significant impact of air pollution exposure on respiratory health among individuals residing in Dhaka, Bangladesh, with a particular focus on the association between PM2.5, PM10, SO_2 , and NO_2 concentrations and respiratory disease prevalence, symptoms, healthcare utilization, and protective measures. The findings are consistent with a growing body of literature that establishes a clear link between air pollution and adverse respiratory outcomes.A key finding of this study was the significantly higher prevalence of respiratory diseases among individuals residing in high-pollution areas, with an odds ratio (OR) of 9.57 ($p < 0.0001$), indicating that exposure to elevated air pollutant levels substantially increases the likelihood of developing respiratory conditions. This aligns with previous studies that have reported similar associations between air pollution exposure and increased hospital visits for respiratory illnesses (12,13). Specifically, studies conducted in China demonstrated that PM2.5 exposure led to a 2.22% increase in hospital admissions for pneumonia and asthma, reinforcing the association observed in the current study (13).Further analysis of individual pollutant exposure revealed that PM2.5 exposure was associated with a 67.0% prevalence of respiratory diseases (OR = 8.45, $p < 0.0001$), while PM10 exposure had a similar association with a 66.7% disease prevalence (OR = 7.90, $p < 0.0001$). This is in agreement with a systematic review that found a significant correlation between PM2.5, PM10, and respiratory disease hospitalizations, emphasizing that even short-term exposure to fine particulate matter can trigger acute respiratory exacerbations (14,15). Additionally, SO_2 and NO_2 exposure contributed to disease prevalence rates of 62.7% and 67.3%, respectively, which aligns with studies reporting that SO_2 exposure increases hospital visits by up to 32.59% in polluted cities (16). These findings collectively reinforce that exposure to air pollution is a major risk factor for respiratory disease burden.Symptoms such as coughing (62.6%), wheezing (55.7%), shortness of breath (52.7%), and chest pain (45.8%) were significantly more common among individuals in high-pollution areas ($p < 0.05$). Similar trends have been observed in prior studies, where PM2.5, PM10, and NO_2 were significantly associated with respiratory symptoms, particularly wheezing and breathlessness (17,18). A large-scale European study also demonstrated that NO_2 exposure significantly increased wheezing and shortness of breath in adults, supporting the current study's findings (17).Healthcare utilization was markedly higher among participants exposed to poor air quality, with 72.5% of individuals in high-pollution areas visiting a doctor, compared to only 31.9% in low-pollution areas ($p < 0.0001$). Additionally, hospitalization rates were significantly higher (41.2% vs. 14.5%), and emergency visits due to respiratory distress were more frequent (29.8% vs. 10.1%). These results align with prior findings, where PM2.5 and NO_2 exposure significantly increased hospital admissions for respiratory

diseases (14). Furthermore, a meta-analysis found that PM2.5 exposure was associated with a 3.46% increase in total hospital admissions for respiratory illnesses, corroborating the significant burden observed in the present study (15). Another systematic review concluded that children exposed to PM2.5 and NO_2 had significantly higher emergency room visits for respiratory diseases (Souza et al., 2024), reinforcing the association observed in the current study.Despite the documented health risks, the use of protective measures such as masks, air purifiers, and activity avoidance was notably low among participants. Only 22.5% reported regular mask usage, 9.0% used air purifiers, and 26.5% avoided outdoor activities, with a significant correlation between non-use and higher disease prevalence ($p < 0.05$). Previous studies have shown that N95 masks can reduce PM2.5 exposure by up to 96%, yet adherence remains low in many high-pollution regions (19). Additionally, studies evaluating the effectiveness of air purifiers demonstrated a 57% reduction in indoor PM2.5 concentrations, leading to improved lung function and reduced inflammation (20). These findings suggest that increasing the adoption of protective measures could mitigate some of the adverse health effects associated with air pollution exposure.This study further confirms that long-term exposure (≥5 years) to air pollution significantly increases the likelihood of respiratory diseases, with an OR of 7.02 ($p = 0.0004$). The long-term effects of pollution have been well documented, with studies showing that chronic exposure to PM2.5 increases the risk of lung function decline and chronic respiratory conditions (21). Similarly, a review of air pollution effects on respiratory health found that long-term exposure contributes to chronic obstructive pulmonary disease (COPD) exacerbations and increased mortality (14).

Overall, this study adds to the existing literature by providing updated evidence on the impact of air pollution on respiratory health in Dhaka, a rapidly urbanizing city with severe air quality challenges. The results highlight the urgent need for stricter pollution control measures, enhanced public health interventions, and greater community awareness regarding the use of protective measures. Further research should focus on longitudinal studies to examine the long-term health effects of air pollution exposure and potential mitigation strategies.

Limitations of The Study

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

IV. Conclusion

This study highlights the significant impact of air pollution on respiratory health among individuals residing in Dhaka, Bangladesh, demonstrating a strong association between exposure to PM2.5, PM10, SO_2, and NO_2 and the increased prevalence of respiratory diseases. The findings indicate that individuals living in high-pollution areas were nearly ten times more likely to develop respiratory illnesses, with symptoms such as coughing, wheezing, shortness of breath, and chest pain being significantly more common in polluted regions. Additionally, healthcare utilization was notably higher among affected individuals, with increased doctor visits, hospitalizations, and emergency admissions linked to prolonged exposure. Despite these health risks, the adoption of protective measures such as mask-wearing, air purifier usage, and activity avoidance remained low, further exacerbating respiratory health burdens. These findings underscore the urgent need for stricter air pollution control measures, improved healthcare interventions, and enhanced public awareness regarding pollution-related health risks. Future research should focus on long-term cohort studies to evaluate the chronic effects of pollution exposure and the efficacy of mitigation strategies. Implementing evidence-based policies and promoting protective measures at an individual and community level will be crucial in addressing the growing public health concerns associated with air pollution in urban settings like Dhaka.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

References

[1]. Rovira J, Domingo JL, Schuhmacher M. Air quality, health impacts and burden of disease due to air pollution (PM10, PM2.5, NO2 and O3): Application of AirQ+ model to the Camp de Tarragona County (Catalonia, Spain). Science of The Total Environment [Internet]. 2020 Feb 10 [cited 2025 Feb 26];703:135538. Available from: https://www.sciencedirect.com/science/article/pii/S0048969719355329

[2]. Xing YF, Xu YH, Shi MH, Lian YX. The impact of PM2.5 on the human respiratory system. J Thorac Dis [Internet]. 2016 Jan [cited 2025 Feb 26];8(1):E69–74. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4740125/

[3]. Yang WS, Wang X, Deng Q, Fan WY, Wang WY. An evidence-based appraisal of global association between air pollution and risk of stroke. International Journal of Cardiology [Internet]. 2014 Aug 1 [cited 2025 Feb 26];175(2):307–13. Available from: https://www.internationaljournalofcardiology.com/article/S0167-5273(14)01027-4/abstract

[4]. Rahaman M, Kalam A, Al-Mamun M. Unplanned urbanization and health risks of Dhaka City in Bangladesh: uncovering the associations between urban environment and public health. Frontiers in Public Health. 2023 Oct 19;11.

[5]. Bahauddin KM, Uddin TS. Status of particulate matter and its impact on roadside population of Dhaka City, Bangladesh: A review study. In: Proceeding of international conference on environmental aspects of Bangladesh (ICEAB10), Japan. 2010. p. 125–8.

[6]. Bontinck A, Maes T, Joos G. Asthma and air pollution: recent insights in pathogenesis and clinical implications. Current Opinion in Pulmonary Medicine [Internet]. 2020 Jan [cited 2025 Feb 26];26(1):10. Available from: https://journals.lww.com/co-pulmonarymedicine/abstract/2020/01000/asthma_and_air_pollution__recent_insights_in.4.aspx

[7]. Yeasmin S, Rahman MS, Haidar A, Mullick AR, Hasan MJ, Khan MAS, et al. Traffic air pollution and respiratory health: a cross-sectional study among traffic police in Dhaka city (Bangladesh). JMSCR [Internet]. 2021 [cited 2025 Feb 26];9(05):93–7. Available from: https://www.researchgate.net/profile/Ashekur-Mullick/publication/351613438_Traffic_Air_Pollution_and_Respiratory_Health_A_Cross-Sectional_Study_among_Traffic_Police_in_Dhaka_City_Bangladesh/links/60a09633458515c26595da9a/Traffic-Air-Pollution-and-Respiratory-Health-A-Cross-Sectional-Study-among-Traffic-Police-in-Dhaka-City-Bangladesh.pdf

[8]. Sherris AR, Begum BA, Baiocchi M, Goswami D, Hopke PK, Brooks WA, et al. Associations between ambient fine particulate matter and child respiratory infection: The role of particulate matter source composition in Dhaka, Bangladesh. Environmental Pollution [Internet]. 2021 Dec 1 [cited 2025 Feb 26];290:118073. Available from: https://www.sciencedirect.com/science/article/pii/S0269749121016559

[9]. Nahar M, Khan MH, Ahmad SA. Indoor Air Pollutants and Respiratory Problems among Dhaka City Dwellers. 2016 Aug 8 [cited 2025 Feb 26]; Available from: https://www.healthdisgroup.com/Community-Medicine-Public-Health/ACMPH-2-114.php

[10]. Siddique AB, Sujan MSH, Ahmed S, Ishadi KS, Tasnim R, Islam MS, et al. Assessment of knowledge, attitudes, and practice regarding air pollution and health effects among general people: A multi-divisional cross-sectional study in Bangladesh. PLOS ONE [Internet]. 2024 Jun 11 [cited 2025 Feb 26];19(6):e0305075. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0305075

[11]. Majumder S, Sihabut T, Saroar MG. Assessment of knowledge, attitude and practices against inhaled particulate matter among urban residents in Dhaka, Bangladesh. Journal of Health Research [Internet]. 2019 Oct 3 [cited 2025 Feb 26];33(6):460–8. Available from: https://www.emerald.com/insight/content/doi/10.1108/jhr-12-2018-0168/full/html

[12]. Liu Y, Han X, Cui X, Zhao X, Zhao X, Zheng H, et al. Association Between Air Pollutants and Acute Exacerbation of Chronic Obstructive Pulmonary Disease: A Time Stratified Case-Crossover Design With a Distributed Lag Nonlinear Model. GeoHealth [Internet]. 2022 [cited 2025 Feb 26];6(2):e2021GH000529. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1029/2021GH000529

[13]. Zhou X, Guo M, Li Z, Yu X, Huang G, Li Z, et al. Associations between air pollutant and pneumonia and asthma requiring hospitalization among children aged under 5 years in Ningbo, 2015–2017. Front Public Health [Internet]. 2023 Jan 25 [cited 2025 Feb 26];10. Available from: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2022.1017105/full

[14]. Luo L, Zhang Y, Jiang J, Luan H, Yu C, Nan P, et al. Short-Term Effects of Ambient Air Pollution on Hospitalization for Respiratory Disease in Taiyuan, China: A Time-Series Analysis. International Journal of Environmental Research and Public Health [Internet]. 2018 Oct [cited 2025 Feb 26];15(10):2160. Available from: https://www.mdpi.com/1660-4601/15/10/2160

[15]. Manan NA, Aizuddin AN, Hod R. Effect of Air Pollution and Hospital Admission: A Systematic Review. Annals of Global Health [Internet]. 2018 Nov 5 [cited 2025 Feb 26];84(4). Available from: https://annalsofglobalhealth.org/articles/10.29024/aogh.2376

[16]. Dutta A, Jinsart W. Air pollution in Delhi, India: It's status and association with respiratory diseases. PLoS One [Internet]. 2022 Sep 20 [cited 2025 Feb 26];17(9):e0274444. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9488831/

[17]. Doiron D, de Hoogh K, Probst-Hensch N, Mbatchou S, Eeftens M, Cai Y, et al. Residential Air Pollution and Associations with Wheeze and Shortness of Breath in Adults: A Combined Analysis of Cross-Sectional Data from Two Large European Cohorts. Environmental Health Perspectives [Internet]. 2017 Sep 22 [cited 2025 Feb 26];125(9):097025. Available from: https://ehp.niehs.nih.gov/doi/10.1289/EHP1353

[18]. Zemp E, Elsasser S, Schindler C, Künzli N, Perruchoud AP, Domenighetti G, et al. Long-Term Ambient Air Pollution and Respiratory Symptoms in Adults (SAPALDIA Study). Am J Respir Crit Care Med [Internet]. 1999 Apr [cited 2025 Feb 26];159(4):1257–66. Available from: https://www.atsjournals.org/doi/10.1164/ajrccm.159.4.9807052

[19]. Pacitto A, Amato F, Salmatonidis A, Moreno T, Alastuey A, Reche C, et al. Effectiveness of commercial face masks to reduce personal PM exposure. Science of The Total Environment [Internet]. 2019 Feb 10 [cited 2025 Feb 26];650:1582–90. Available from: https://www.sciencedirect.com/science/article/pii/S0048969718335514

[20]. Chen R, Zhao A, Chen H, Zhao Z, Cai J, Wang C, et al. Cardiopulmonary Benefits of Reducing Indoor Particles of Outdoor Origin: A Randomized, Double-Blind Crossover Trial of Air Purifiers. Journal of the American College of Cardiology [Internet]. 2015 Jun 2 [cited 2025 Feb 26];65(21):2279–87. Available from: https://www.sciencedirect.com/science/article/pii/S0735109715016708

[21]. Teng J, Li J, Yang T, Cui J, Xia X, Chen G, et al. Long-term exposure to air pollution and lung function among children in China: Association and effect modification. Front Public Health [Internet]. 2022 Dec 14 [cited 2025 Feb 26];10. Available from: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2022.988242/full