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IMPACT OF AIR QUALITY INDEX (AQI) ON PULMONARY FUNCTION: AN 18 MONTHS CROSS-SECTIONAL STUDY ON INDIAN POPULATION

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ABSTRACT

Introduction: *Ambient air pollution always remains a major threat to public health in India, contributing to a large number of deaths annually, particularly due to respiratory and cardiovascular disorders. Despite growing concerns about air quality and respiratory illness, population-based evidence linking Air Quality Index (AQI) levels with pulmonary function in the Indian context remains sparse. This study aimed to evaluate the impact of ambient air quality on pulmonary function across diverse regions of India over an 18-month period.*

Materials & Methods: *A multi-centric, cross-sectional study was conducted between September 1, 2023, and February 28, 2025. The study recruited 6,000 individuals across urban, semi-urban, and rural locations from 10 Indian states. Daily AQI data was retrieved from the Central Pollution Control Board (CPCB). Spirometry was conducted in accordance with ATS/ERS guidelines. Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), and FEV_1/FVC ratio were analyzed.*

Results: *A significant inverse correlation was observed between AQI levels and all pulmonary parameters ($p < 0.001$). Participants residing in areas with consistently good AQI (< 50) had a mean FEV_1 of 3.1 ± 0.4 L, compared to 2.4 ± 0.6 L in those from severely polluted zones (AQI > 300). Children and the elderly showed the most pronounced lung function impairments in poor AQI zones.*

Conclusion: *This study confirms that poor air quality is strongly associated with impaired lung function across all age groups in the Indian population. Urgent public health interventions, stricter enforcement of the National Clean Air Programme (NCAP), and region-specific pollution control strategies are essential.*

Keywords: *Air Quality Index, Lung Function, India, Spirometry, Pulmonary Health, Cross-Sectional Study*

INTRODUCTION

India is home to 14 of the world's most polluted cities and ambient air pollution always remains a major threat to public health in India, contributing to a large number of deaths annually, particularly due to respiratory and cardiovascular disorders. India's rapid industrialization and urbanization over the past three decades have resulted in a dramatic deterioration in air quality. According to WHO, ambient air pollution is responsible for approximately 4.2 million deaths annually worldwide, and India alone accounts for a substantial proportion. Urban centers such as Delhi, Kanpur, and Varanasi often rank among the top cities globally for hazardous AQI levels. [1]. Despite numerous studies on particulate matter (PM) exposure, large-scale investigations linking ambient Air Quality Index (AQI) directly with spirometry measures among diverse Indian populations remain limited [1, 2]. International data show long-term $PM_{2.5}$ exposure reduces lung function parameters such as FEV_1 and FVC in children and adults [2]. Workplace studies in India, such as petrol pump attendants in Ahmedabad, report restrictive spirometric findings linked to air

pollutant exposure [3]. Although prior studies have addressed the health burden of air pollution, there is limited large-scale, regionally representative data focusing on the direct association between air quality and objective pulmonary function parameters across various Indian demographics [4, 5]. Building on this, our study examined the relationship between ambient AQI and lung function across multiple states and environments in India and thus aims to fill the gap with objectives such as evaluating the association between AQI and pulmonary function (FEV_1, FVC, FEV_1/FVC ratio) with a special focus on stratify findings by age, gender, geographic region, and AQI category to provide evidence for policy-making and urban air quality control.

MATERIALS AND METHODS

Study Design: The design of the present study followed a multi-centric community based cross-sectional study protocol and a comprehensive and convenience sampling strategy was followed [6, 7].

Study Duration: This study was conducted over a duration of 18 months (September 2023 to February 2025)

Study sites and Population: Ten Indian states representing north, south, east, west, and central regions were selected. These included Delhi, Maharashtra, Tamil Nadu, West Bengal, Uttar Pradesh, Rajasthan, Punjab, Karnataka, Assam, and Madhya Pradesh. Participants were enrolled from urban, semi-urban, and rural zones based on the National Census definitions. Residents who belong to an age-group of 10 to 70 years and living in this area for more than two years were included in this study as study participants if they were willing to undergo spirometry and provide voluntary informed consent. Patients with history of chronic pulmonary diseases (e.g., COPD, asthma), Active respiratory infections at the time of testing, and Smokers (>5 pack-years) were excluded from the study.

Sample size calculation: Using an estimated correlation coefficient of 0.3 between AQI and FEV_1, a minimum of 5,000 participants were required to achieve 95% confidence and 80% power. We oversampled to 6,000 to account for dropouts [8].

Collection of the Data:

AQI Data: Retrieved daily from the CPCB online portal, averaged over 7-day and 30-day periods for each participant's locality [9].

Pulmonary Function Tests: Performed using standardized portable spirometers. Calibration was done daily. ATS/ERS 2019 guidelines were followed [4].

Other assessed Variables: Demographic data, socioeconomic status, exposure to biomass fuel, occupational hazards, etc.

Ethical Concerns: Approved by the Institutional Ethics Committees of the Teerthanker Mahaveer University (Ref No: TMU/IEC/2023-24/FACULTY/01A Dated 31-08-2023) on behalf of all the collaborating centers. This decision was taken mutually by all the investigators and also validated by the external research experts and ethical committees of all the collaborating centers as all the investigators of this study were associated to the said university during their work for this particular research project. The informed voluntary consent was obtained from all adult participants and guardians of minors.

Statistical analysis: The obtained data was inserted in a Microsoft Excel sheet and analyzed using an SPSS software version 27. The descriptive data were expressed in percentage and range. The comparison between groups were done by students t-test and ANOVA wherever applicable. Multivariable regression models adjusted for age, sex, BMI, smoking history, biomass exposure, and socioeconomic status. P-values <0.05 considered significant.

RESULTS

Considering the demographics of all the participants (n = 6000), male participants were 52% and female participants were 48% and the age distribution was 10 to 20 years (15%), 21 to 40 years (40%), 41 to 60

years (30%), and more than 60 years (15%). Urban residents formed 55%, semi-urban 25%, and rural 20% of the total study population group.

AQI distribution: Based on CPCB guidelines [9], areas were categorized as Good (0–50): 10%, Satisfactory (51–100): 18%, Moderate (101–200): 32%, Poor (201–300): 25%, and Very Poor to Severe (>300): 15%. Table-1 shows the lung function metrics of the participants.

Sub-group analysis: Out of all the participants, children (10–20 years) showed significant reductions in FEV_1 in areas with AQI > 200. Elderly (>60 years) individuals showed mean FEV_1 dropped to 1.9 L in severe AQI zones and women showed a slightly higher vulnerability to AQI changes, especially among biomass-exposed households.

Regression analysis: Multivariate regression adjusted for confounders (age, sex, BMI, fuel type, occupation) confirmed a negative β coefficient between AQI and FEV_1. Each 10-unit rise in AQI predicted a 0.21 L decrease in FEV_1 (β = –0.021; 95% CI: –0.024 to –0.018; $p < 0.001$), even after adjusting for confounders.

Table-1: Lung function metrics by AQI quality

AQI Category	Mean FEV_1 (L)	Mean FVC (L)	FEV_1/FVC (%)
Good	3.1 ± 0.4	3.8 ± 0.5	81.6 ± 2.3
Satisfactory	2.9 ± 0.5	3.5 ± 0.6	80.3 ± 2.8
Moderate	2.6 ± 0.5	3.2 ± 0.6	78.5 ± 3.0
Poor	2.5 ± 0.6	3.1 ± 0.7	77.3 ± 3.5
Very Poor/Severe	2.4 ± 0.6	3.0 ± 0.7	76.1 ± 3.8
$p < 0.001$ for all pairwise comparisons between adjacent categories. $p<0.05$ was considered as statistically significant.			

DISCUSSION

Principal findings: This study demonstrates a strong inverse association between ambient AQI and lung function in the Indian population, reaffirming the hypothesis that air pollution significantly impairs respiratory health. These findings are in line of the global reports [4, 10, 11].

Comparison with global studies: Our findings are in line with large-scale Chinese studies (e.g., China Pulmonary Health Study, 2021), which reported similar declines in lung function with increased $PM_{2.5}$ levels. In contrast, studies in the United States, where average AQI remains below 100 due to regulatory standards like the Clean Air Act, show relatively preserved lung functions even in industrial cities.

Policy implications: The Indian government's National Clean Air Programme (NCAP), launched in 2019, aims to reduce PM concentrations by 20–30% by 2024 in 122 non-attainment cities. Our findings support urgent scale-up of these efforts, particularly in high-risk zones like Delhi-NCR, where FEV_1 levels in children are nearly 30% lower than those in cleaner cities like Bengaluru [12].

Strength and Limitations of the study: We consider a large sample size, regionally representative sampling, use of standard spirometry as some of the strengths of our study while a cross-sectional nature limits causal inference, indoor pollution and allergen exposure not exhaustively accounted for and reliance on ambient AQI may not fully reflect personal exposure and we do consider these as some of the limitations of our current study.

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Conflicts of Interest: No conflict of interest is declared.

CONCLUSION

This 18-month multi-centric cross-sectional study provides robust evidence that poor ambient air quality is associated with significantly reduced pulmonary function across all age groups in India. The data underscores the need for urgent policy measures, enhanced surveillance, and community engagement to mitigate air pollution's effects on public health.

REFERENCES

1. India State-Level Disease Burden Initiative Air Pollution Collaborators. The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017. Lancet Planet Health. 2019 Jan;3(1):e26-e39. doi: 10.1016/S2542-5196(18)30261-4. Epub 2018 Dec 6. PMID: 30528905; PMCID: PMC6358127.
2. Guo C, Hoek G, Chang LY, Bo Y, Lin C, Huang B, Chan TC, Tam T, Lau AKH, Lao XQ. Long-Term Exposure to Ambient Fine Particulate Matter (PM2.5) and Lung Function in Children, Adolescents, and Young Adults: A Longitudinal Cohort Study. Environ Health Perspect. 2019 Dec;127(12):127008. doi: 10.1289/EHP5220. Epub 2019 Dec 24. PMID: 31873044; PMCID: PMC6957275.
3. Solanki RB, Bhise AR, Dangi BM. A study on spirometry in petrol pump workers of Ahmedabad, India. Lung India. 2015 Jul-Aug;32(4):347-52. doi: 10.4103/0970-2113.159567. PMID: 26180384; PMCID: PMC4502199
4. Arora S, Rasania SK, Bachani D, Gandhi A, Chhabra SK. Air pollution and environmental risk factors for altered lung function among adult women of an urban slum area of Delhi: A prevalence study. Lung India. 2018 May-Jun;35(3):193-198. doi: 10.4103/lungindia.lungindia_263_17. PMID: 29697074; PMCID: PMC5946550.
5. Singh A, Kesavachandran CN, Kamal R, Bihari V, Ansari A, Azeez PA, Saxena PN, Ks AK, Khan AH. Indoor air pollution and its association with poor lung function, microalbuminuria and variations in blood pressure among kitchen workers in India: a cross-sectional study. Environ Health. 2017 Apr 4;16(1):33. doi: 10.1186/s12940-017-0243-3. PMID: 28376835; PMCID: PMC5379539.
6. Patil SM, Khodnapur JP, Das KK, Podder A. The Role of Serum Erythropoietin (EPO) and Vascular Endothelial Growth Factor (VEGF) in Pulse Wave Velocity (PWV) Among Hypertensive Patients: A Cross-Sectional Study. Cureus. 2024 Jun 15;16(6):e62416. doi: 10.7759/cureus.62416. PMID: 39011232; PMCID: PMC11247379.
7. Kumar J, Sharma A, Dasgupta A, Podder A, Naregal G, Iqbal MK, Nazim S, Rehman H. Unraveling the Relationship Between Vitamin D and Oxidative Stress: A Cross-Sectional Study. Cureus. 2024 Aug 26;16(8):e67818. doi: 10.7759/cureus.67818. PMID: 39323715; PMCID: PMC11423786
8. Edginton S, O'Sullivan DE, King W, Lougheed MD. Effect of outdoor particulate air pollution on FEV_1 in healthy adults: a systematic review and meta-analysis. Occup Environ Med. 2019 Aug;76(8):583-591. doi: 10.1136/oemed-2018-105420. Epub 2019 Jun 12. PMID: 31189694.
9. National Air Quality Index. airquality.cpcb.gov.in. https://airquality.cpcb.gov.in/AQI_India/
10. Alyami MM, Balharith FH, Ravi SK, Reddy RS. Urban air pollution and chronic respiratory diseases in adults: insights from a cross-sectional study. Frontiers in Public Health. 2025 Mar 12;13.
11. Chen CH, Wu CD, Lee YL, Lee KY, Lin WY, Yeh JI, Chen HC, Guo YL. Air pollution enhance the progression of restrictive lung function impairment and diffusion capacity reduction: an elderly cohort study. Respir Res. 2022 Jul 14;23(1):186. doi: 10.1186/s12931-022-02107-5. PMID: 35836168; PMCID: PMC9281077

12. National Clean Air Programme (NCAP) to improve air quality in 131 cities by engaging all stakeholders. www.pib.gov.in.
https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1909910