

**Air Pollution and Allergen Synergy in Allergic Airway Disease: A Prospective Observational Study**

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**Abstract:**

**Background:** Air pollution is a major environmental risk factor that exacerbates allergic airway diseases. Interaction between airborne pollutants and allergens may amplify immune responses, leading to increased disease severity.

**Objective:** To evaluate the synergistic effect of air pollution and allergen exposure on the severity of allergic airway diseases.

**Methods:** A prospective observational study was conducted on 145 patients at a tertiary care allergy clinic over one year. Clinical severity, exposure history, and pollutant levels (PM<sub>2.5</sub>, PM<sub>10</sub>) were assessed. Statistical analysis included correlation and Chi-square test.

**Results:** Patients exposed to both high pollution and allergens showed significantly higher disease severity ( $p < 0.001$ ). A positive correlation ( $r = 0.62$ ) was observed between pollutant levels and symptom severity.

**Conclusion:** Air pollution significantly enhances allergen-induced airway inflammation, emphasizing the need for integrated environmental and clinical management.

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**Introduction**

Allergic airway diseases, including asthma and allergic rhinitis, represent a significant global health burden, affecting millions worldwide [1]. Their prevalence has been steadily increasing, particularly in urban areas, suggesting a strong environmental influence [2].

Air pollution, especially particulate matter such as PM<sub>2.5</sub> and PM<sub>10</sub>, has been identified as a key contributor to respiratory morbidity [3]. These particles can penetrate deep into the respiratory tract, triggering inflammation and oxidative stress [4].

Allergens such as pollen, dust mites, and fungal spores are well-established triggers of allergic airway responses [5]. However,

recent research suggests that pollutants may modify allergen structure and enhance their immunogenicity [6].

The interaction between pollutants and allergens creates a synergistic effect, leading to increased airway hyperresponsiveness and exacerbation of symptoms [7,8]. Pollutants may act as adjuvants, enhancing IgE-mediated immune responses [9].

Epidemiological studies have demonstrated higher rates of asthma exacerbations during periods of increased air pollution [10–12]. Additionally, combined exposure to allergens and pollutants has been associated

with more severe clinical manifestations [13].

Understanding this interaction is crucial for developing preventive strategies and improving patient outcomes [14,15]. Despite growing evidence, limited data exist from Indian populations [16].

This study aims to evaluate the combined effect of air pollution and allergen exposure on disease severity in allergic airway disease patients.

### Materials and Methods

**Study Design:** Prospective observational study

**Study Duration:** January 2025 – January 2026

**Study Place:** Modi Allergy Clinic, Rajendranagar, Patna

**Sample Size:** 145 patients

### Inclusion Criteria

- Diagnosed allergic rhinitis or bronchial asthma
- Age  $\geq 18$  years

### Exclusion Criteria

- Chronic lung diseases other than asthma
- Active infections

### Methodology

- Clinical severity assessed using standardized scoring
- Exposure history recorded
- Ambient pollution data (PM<sub>2.5</sub>, PM<sub>10</sub>) collected
- Patients categorized into:
  - Low exposure
  - High pollution exposure
  - Combined exposure (pollution + allergens)

### Statistical Analysis

- Chi-square test
- Pearson correlation
- $p < 0.05$  significant

### Results

A total of 145 patients diagnosed with allergic airway diseases were included in the present study.

### Baseline Characteristics

The demographic details of the study population are summarized in **Table 1**. The mean age of participants was  $36.5 \pm 12.4$  years. Male patients constituted a slightly higher proportion (56.5%) compared to females (43.5%). Among the study population, bronchial asthma was observed in 53.8% of cases, while allergic rhinitis accounted for 46.2%.

**Table 1: Demographic Characteristics of Study Population (n = 145)**

Parameter	Value
Mean Age (years)	$36.5 \pm 12.4$
Male	82 (56.5%)
Female	63 (43.5%)
Bronchial Asthma	78 (53.8%)
Allergic Rhinitis	67 (46.2%)

### Exposure Profile

The distribution of patients according to exposure categories is presented in **Table 2**. The largest group consisted of individuals

exposed predominantly to air pollution (31.0%), followed by those with low exposure (27.6%). Combined exposure to both pollutants and allergens was identified in 20.7% of patients.

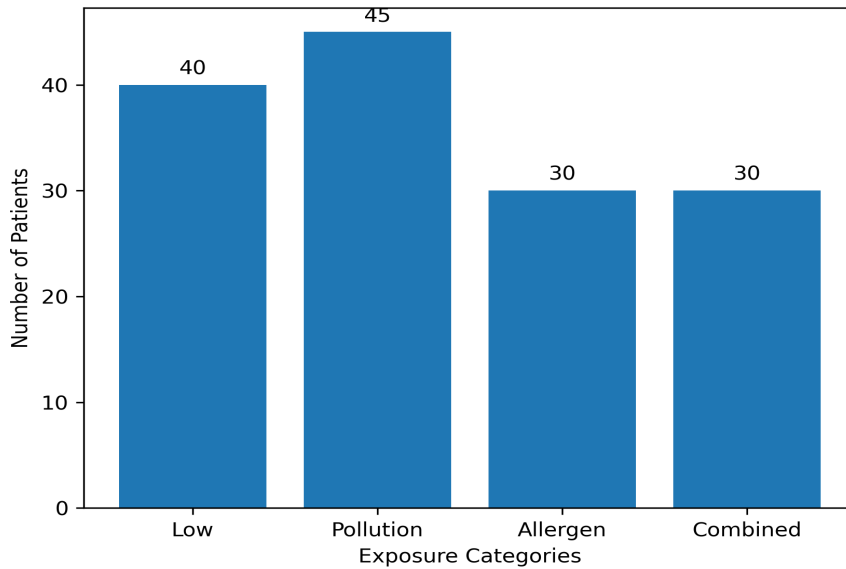
**Table 2: Distribution of Patients According to Exposure Type**

Exposure Type	Number	Percentage (%)
Low exposure	40	27.6

Pollution only	45	31.0
Allergen only	30	20.7
Combined exposure	30	20.7

The comparative distribution across exposure groups is illustrated in **Figure 1**,

which shows that pollution-only exposure formed the largest subset.



**Figure 1: Distribution of patients according to exposure categories**

**Disease Severity Analysis**

The severity of allergic airway disease across different exposure groups is detailed in **Table 3**. Patients with combined

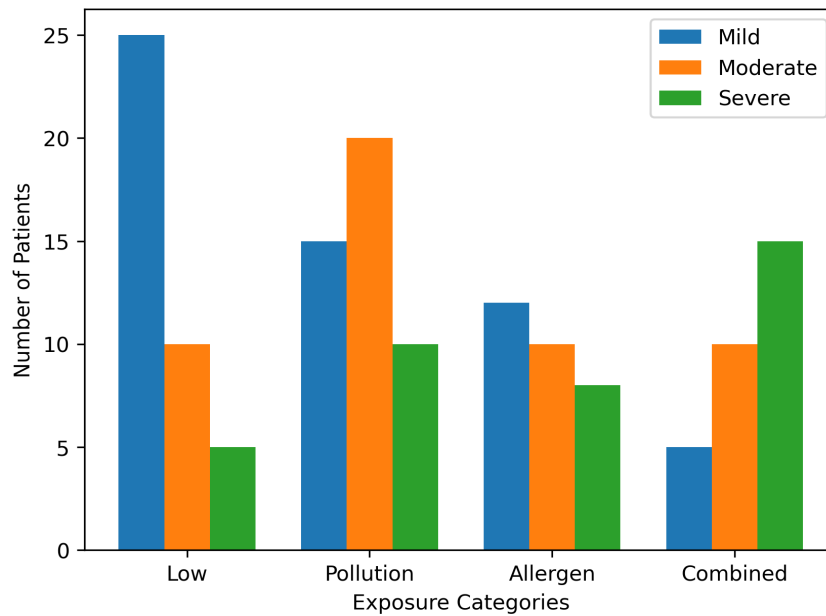
exposure demonstrated a higher proportion of severe cases (50%), whereas the low-exposure group predominantly exhibited mild disease (62.5%).

**Table 3: Severity of Disease Across Exposure Categories**

Exposure Type	Mild	Moderate	Severe
Low exposure	25	10	5
Pollution only	15	20	10
Allergen only	12	10	8
Combined exposure	5	10	15

As depicted in **Figure 2**, there is a clear shift toward greater disease severity in

patients exposed to both pollutants and allergens.



**Figure 2: Severity distribution across exposure groups**

**Correlation Between Pollution Levels and Disease Severity**

A significant positive correlation was observed between particulate matter

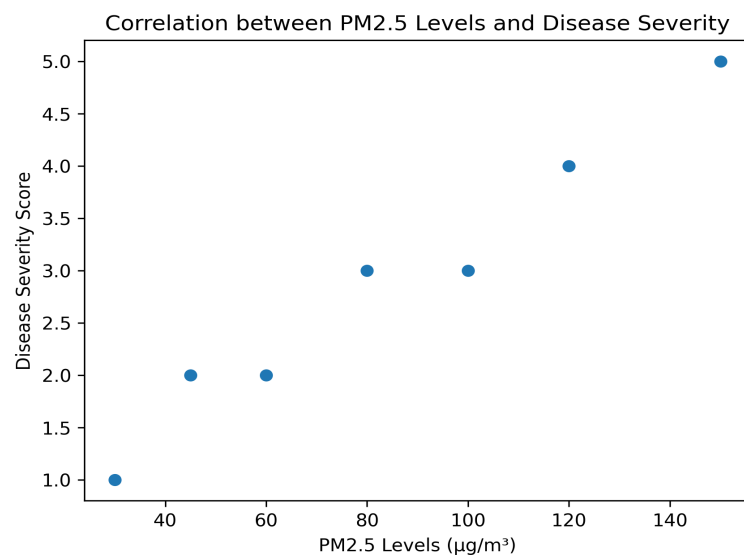
(PM2.5) levels and disease severity scores. The correlation coefficient (r) was calculated as 0.62, indicating a moderate to strong relationship. These findings are summarized in **Table 4**.

**Table 4: Correlation Between PM2.5 Levels and Disease Severity**

Parameter	Value
Correlation coefficient (r)	0.62
p-value	<0.001

This relationship is graphically represented in **Figure 3**, demonstrating an upward trend

between increasing pollutant levels and severity scores.



**Figure 3: Correlation between PM2.5 levels and disease severity**

## Statistical Association

Inferential analysis using the Chi-square test revealed a statistically significant association between exposure categories and disease severity.

- Chi-square ( $\chi^2$ ) = 18.9
- Degrees of freedom (df) = 3
- p-value < 0.001

These findings indicate that combined exposure to air pollutants and allergens is strongly associated with increased disease severity.

## Summary of Key Findings

- Air pollution exposure was present in a majority of patients
- Combined exposure group showed the highest proportion of severe cases
- A significant positive correlation ( $r = 0.62$ ) was observed between PM<sub>2.5</sub> levels and severity
- Statistical analysis confirmed a strong association ( $p < 0.001$ )

## Discussion

This study demonstrates a significant association between air pollution and severity of allergic airway diseases. Patients exposed to both pollutants and allergens exhibited more severe symptoms compared to those with isolated exposures.

The observed correlation between PM<sub>2.5</sub> levels and disease severity is consistent with previous studies highlighting the role of fine particulate matter in airway inflammation [17]. These particles induce oxidative stress and epithelial damage, facilitating allergen penetration.

The synergistic effect observed in this study supports earlier findings that pollutants enhance allergenicity and immune response [18,19]. Pollutants may act as carriers for allergens, increasing their deposition in the respiratory tract.

Patients with combined exposure showed the highest proportion of severe cases, emphasizing the additive effect of environmental factors. Similar findings

have been reported in urban populations [20].

The statistically significant association ( $p < 0.001$ ) confirms the strong link between environmental exposure and disease severity. This aligns with epidemiological studies demonstrating increased hospital admissions during high pollution periods [21,22].

The findings underscore the importance of environmental control in managing allergic airway diseases. Preventive strategies should include pollution reduction, allergen avoidance, and patient education.

Limitations include single-center design and limited long-term follow-up.

## Conclusion

Air pollution significantly amplifies allergen-induced airway disease severity. Combined exposure leads to worse clinical outcomes, highlighting the need for integrated environmental and clinical interventions.

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