

Air Pollution and Lung Cancer: A Deep Dive into the Impact in Southern India

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Abstract

Background: Lung cancer incidence is rising in Southern India, with air pollution emerging as a significant risk factor alongside smoking. Rapid urbanization in cities, like Chennai, Bangalore, and Hyderabad, has worsened air quality, particularly due to PM_{2.5} pollution. This study examines the correlation between air pollution and lung cancer incidence in these regions. **Methods:** A retrospective cohort study analyzed data from 1,500 lung cancer patients diagnosed between 2010–2020 across Chennai, Bangalore, and Hyderabad. Data sources included hospital records, cancer registries, and environmental monitoring stations. Statistical analyses (Pearson correlation, logistic regression, Kaplan–Meier survival analysis) were conducted to assess the relationship between PM_{2.5} levels and lung cancer, adjusting for confounders like smoking, age, and gender. **Results: Demographics:** 73.3% of patients were male, 80.7% were smokers, and 42.7% were aged 60+. **Pollution and Incidence:** Chennai had the highest PM_{2.5} levels (75.5 $\mu\text{g}/\text{m}^3$) and lung cancer incidence (33.5%), with strong correlations ($r = 0.92$, $p < 0.001$) between PM_{2.5} and cancer rates across all cities. **Risk Factors:** High PM_{2.5} exposure (OR = 2.5, $p < 0.001$) and smoking (OR = 2.8, $p < 0.001$) significantly increased lung cancer odds. **Survival:** Patients in high-pollution areas had lower median survival (12.5 months vs. 16.2 months) and 5-year survival rates (25% vs. 40%, $p = 0.002$). **Conclusion:** Air pollution, particularly PM_{2.5}, is a major contributor to lung cancer incidence and reduced survival in Southern India. The study underscores the need for stricter air quality regulations, anti-smoking campaigns, and early detection programs to mitigate the lung cancer burden.

Keywords: Air pollution, PM_{2.5}, lung cancer, southern India, smoking, survival analysis

INTRODUCTION

Over the last few decades, lung cancer has emerged as a significant contributor to cancer-related morbidity and mortality across the globe, and its incidence is increasing in certain parts of India, especially in southern states, such as Tamil Nadu, Karnataka, Andhra Pradesh, and Kerala. While smoking continues to be the most important risk factor for lung cancer, other environmental factors, especially urban air pollution, have now become notable risk factors for lung cancer in cities [1]. India's

southern region is home to rapidly growing metropolitan areas, like Chennai, Bangalore, and Hyderabad, which are experiencing worsening air quality, increasingly recognized as a primary cleft risk factor for lung cancer [2].

The damage caused to lung tissue due to air pollution, especially PM_{2.5}, can increase the likelihood of developing respiratory diseases, such as lung cancer. The World Health Organization suggests that exposure to high levels of air pollution can increase the chances of developing lung cancer between 15–20% [3]. Industrialization, vehicular emissions, and urbanization in southern India have adversely affected the air quality over the years,

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with some cities, like Chennai and Bangalore, exceeding the safe limits of pollution during certain periods (Barman et al., 2020).

There is an escalating amount of evidence available that proves the linkage between cancer and air pollution; however, studies analyzing the effects of air pollution on the occurrence of lung cancer in the southern parts of India is scarce. The objective of this study is to analyze the relationship of air pollution with lung cancer incidence in the large southern Indian cities and provide an estimate of the impact of various pollutants, particularly PM_{2.5}, on the incidence of lung cancer in the area. The purpose of this study is to help shape relevant policies and public health initiatives in southern India by clarifying the impact of air pollution on the cancer burden in the region.

METHODOLOGY

Study Design

This study utilized a retrospective cohort design to examine the correlation between air pollution and lung cancer incidence in southern India. Data were collected from existing hospital records, cancer registries, and environmental monitoring stations over a 10-year period (2010–2020) in the cities of Chennai, Bangalore, and Hyderabad. The cohort consisted of 1,500 lung cancer patients who were diagnosed and treated for lung cancer in these cities during the study period. The study design aimed to correlate the levels of air pollution in these cities with the incidence of lung cancer, adjusting for potential confounders, such as smoking, age, and gender.

Study Population

The study population included 1,500 lung cancer patients who were diagnosed with primary lung cancer during the period from 2010 to 2020 in three southern Indian cities: Chennai (500 patients), Bangalore (500 patients), and Hyderabad (500 patients). Patients were selected from hospital records of major cancer treatment centers and hospitals in these cities, which include institutions like the Adyar Cancer Institute (Chennai), NIMHANS (Bangalore), and MNJ Cancer Institute (Hyderabad).

Data Collection Methods

Lung Cancer Data

- *Hospital Records and Cancer Registries:* Data on lung cancer incidence were obtained from hospital records and regional cancer registries for the years 2010–2020. Information collected included the patient's age, gender, smoking status, cancer stage at diagnosis, and treatment details (e.g., surgery, chemotherapy, and radiation therapy).
- *Diagnostic Data:* Clinical data on the diagnostic methods used (e.g., biopsy, CT scans) and the histological type of lung cancer (non-small cell vs. small cell) were also recorded.

Air Pollution Data

- *Environmental Monitoring:* Air quality data, specifically the concentrations of PM_{2.5}, PM₁₀, and other particulate matter, were obtained from local environmental monitoring stations managed by the Central Pollution Control Board (CPCB) and the State Pollution Control Boards in Chennai, Bangalore, and Hyderabad. These stations provide real-time data on air pollution levels across different urban areas. Average annual PM_{2.5} levels (measured in $\mu\text{g}/\text{m}^3$) for each city were used to estimate exposure levels.
- *Seasonal Data:* Data on seasonal fluctuations in air pollution (e.g., higher pollution levels during winter months) were also included to understand how seasonal variations in air quality correlate with lung cancer incidence.

Smoking and Other Risk Factors:

- *Tobacco Use:* Data on smoking status were collected from medical records, including whether the patient had a history of smoking, the duration of smoking, and the average number of cigarettes smoked per day. Patients were categorized as smokers (current or former) or non-smokers based on their medical history and self-reports.

- *Other Risk Factors:* Other potential risk factors for lung cancer, such as occupational exposure to carcinogens, family history of lung cancer, and exposure to indoor air pollutants (e.g., cooking fumes), were also recorded based on patient interviews.

Data Analysis

Data was analyzed using SPSS Statistics (Version 26) and R software for statistical analysis. The following methods were employed:

1. *Descriptive Statistics:* To summarize the demographic characteristics of the study population, including age, gender, smoking status, and clinical characteristics of lung cancer cases.
2. *Chi-Square Test:* To examine the association between categorical variables, such as smoking status and lung cancer incidence, and to test the relationship between lung cancer and air pollution levels across different cities.
3. *Correlation Analysis:* To analyze the relationship between air pollution levels (PM2.5) and lung cancer incidence, the Pearson correlation coefficient was calculated to determine the strength and direction of the relationship. Seasonal variations in PM2.5 levels and lung cancer rates were also analyzed.
4. *Multivariate Logistic Regression:* To identify the independent risk factors for lung cancer, including air pollution, smoking, age, gender, and other socio-demographic factors. This analysis controlled potential confounders, such as smoking status and gender, and provided odds ratios (OR) for the association between air pollution and lung cancer incidence.
5. *Survival Analysis:* To estimate the survival rates of lung cancer patients in relation to their exposure to air pollution, Kaplan–Meier survival curves were generated. The log-rank test was used to compare survival times between patients in high and low pollution areas.

Ethical Considerations

The study was conducted according to the Declaration of Helsinki [4]. This study adhered to ethical guidelines approved by the concerned Institutional Review Board (IRB). Informed consent was obtained from all participants for the use of their medical data in the study. Patient confidentiality was maintained by anonymizing all data, and participants were assured of the voluntary nature of their involvement. All personal and clinical information was securely stored and only accessible to the research team.

RESULTS

This section presents the findings from the study examining the relationship between air pollution and lung cancer incidence in Southern India, with a focus on Chennai, Bangalore, and Hyderabad. A total of 1,500 lung cancer patients were included in the study, and data were analyzed to identify the impact of air pollution, particularly PM2.5, on lung cancer rates across these cities. The results cover demographic characteristics, lung cancer incidence by air pollution exposure, correlation analysis between air pollution and lung cancer rates, and findings from survival analysis.

Demographic Characteristics of the Study Population

Table 1. Demographic characteristics of lung cancer patients.

Variable	Chennai (n = 500)	Bangalore (n = 500)	Hyderabad (n = 500)	Total (n = 1500)
<i>Age Group</i>				
18–29	35 (7%)	20 (4%)	25 (5%)	80 (5.3%)
30–45	100 (20%)	120 (24%)	110 (22%)	330 (22%)
46–60	160 (32%)	140 (28%)	150 (30%)	450 (30%)
60+	205 (41%)	220 (44%)	215 (43%)	640 (42.7%)
<i>Gender</i>				
Male	350 (70%)	380 (76%)	370 (74%)	1,100 (73.3%)

Female	150 (30%)	120 (24%)	130 (26%)	400 (26.7%)
<i>Smoking Status</i>				
Smoker	400 (80%)	420 (84%)	390 (78%)	1,210 (80.7%)
Non-Smoker	100 (20%)	80 (16%)	110 (22%)	290 (19.3%)
<i>Education Level</i>				
Primary or below	300 (60%)	240 (48%)	250 (50%)	790 (52.7%)
Secondary or Higher	200 (40%)	260 (52%)	250 (50%)	710 (47.3%)

The average age of the lung cancer patients was 61.1 years, with the majority being male (73.3%). Smoking was prevalent in 80.7% of cases, and 52.7% of the patients had only primary or below-level education. Chennai had a slightly higher proportion of patients aged 60+ (41%) compared to Bangalore and Hyderabad, where the percentage was 44% and 43%, respectively.

Lung Cancer Incidence by Air Pollution Exposure

Table 2. Lung cancer incidence by air pollution exposure (PM2.5 levels).

City	Average PM2.5 Level ($\mu\text{g}/\text{m}^3$)	Lung Cancer Incidence Rate (%)	High Exposure (PM2.5 > 60 $\mu\text{g}/\text{m}^3$)	Low Exposure (PM2.5 \leq 60 $\mu\text{g}/\text{m}^3$)
Chennai	75.5	33.5%	400 (80%)	100 (20%)
Bangalore	52.3	30.0%	300 (60%)	200 (40%)
Hyderabad	55.0	32.1%	350 (70%)	150 (30%)
Total	61.0	31.8%	1,050 (70%)	450 (30%)

The analysis revealed that lung cancer incidence was higher in cities with elevated levels of PM2.5. Chennai, with the highest average PM2.5 levels (75.5 $\mu\text{g}/\text{m}^3$), had a lung cancer incidence rate of 33.5%, with 80% of patients exposed to high pollution levels (>60 $\mu\text{g}/\text{m}^3$). In comparison, Bangalore (52.3 $\mu\text{g}/\text{m}^3$) and Hyderabad (55.0 $\mu\text{g}/\text{m}^3$) had slightly lower lung cancer incidence rates of 30.0% and 32.1%, respectively, with a significant portion of patients (60% in Bangalore and 70% in Hyderabad) also exposed to high pollution levels.

Correlation Between PM2.5 Levels and Lung Cancer Incidence

Table 3. Correlation Between PM2.5 Levels and Lung Cancer Incidence.

City	PM2.5 Level ($\mu\text{g}/\text{m}^3$)	Lung Cancer Incidence Rate (%)	Pearson Correlation (r)	p-value
Chennai	75.5	33.5%	0.92	<0.001
Bangalore	52.3	30.0%	0.78	0.01
Hyderabad	55.0	32.1%	0.85	<0.001
Total	61.0	31.8%	0.86	<0.001

A strong positive correlation was observed between PM2.5 levels and lung cancer incidence in all three cities, with Pearson correlation coefficients of 0.92 for Chennai, 0.85 for Hyderabad, and 0.78 for Bangalore. The overall correlation for all cities combined was 0.86, with a statistically significant p-value (<0.001), suggesting a strong association between higher PM2.5 exposure and increased lung cancer incidence. These results align with previous studies indicating that prolonged exposure to high levels of air pollution is a major risk factor for lung cancer (Kumar et al., 2017; World Health Organization, 2018).

Logistic Regression: Predictors of Lung Cancer Incidence

Table 4. Logistic regression for lung cancer incidence in relation to air pollution.

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
High PM2.5 Exposure	2.5	1.8–3.5	<0.001

Smoking (Current)	2.8	2.1–3.8	<0.001
Age (60+)	1.6	1.2–2.1	0.002
Gender (Male)	1.9	1.4–2.5	<0.001

Logistic regression analysis confirmed that high PM_{2.5} exposure (OR = 2.5, $p < 0.001$) significantly increased the odds of developing lung cancer. Additionally, smoking (OR = 2.8, $p < 0.001$) and male gender (OR = 1.9, $p < 0.001$) were significant predictors of lung cancer incidence. The odds of lung cancer were higher for individuals aged 60 and above (OR = 1.6, $p = 0.002$), confirming that older age is a risk factor for lung cancer. The regression model highlighted the combined effect of smoking and environmental pollution, with both factors significantly contributing to the increased risk of lung cancer in the studied regions.

Survival Analysis: Impact of Air Pollution on Lung Cancer Survival

Table 5. Kaplan–Meier survival estimates air pollution exposure.

Exposure Level	Median Survival Time (Months)	5-Year Survival Rate (%)	Log-Rank Test (p-value)
High PM _{2.5} Exposure	12.5	25.0%	0.002
Low PM _{2.5} Exposure	16.2	40.0%	0.002
Total	14.0	30.0%	0.002

Survival analysis showed that patients exposed to high PM_{2.5} levels had a significantly lower median survival time (12.5 months) and a 5-year survival rate of 25.0%. In contrast, patients with low PM_{2.5} exposure had a higher median survival time (16.2 months) and a 5-year survival rate of 40.0%. The log-rank test revealed a statistically significant difference in survival times between high and low pollution exposure groups ($p = 0.002$), indicating that prolonged exposure to high air pollution significantly reduces survival rates in lung cancer patients.

DISCUSSION

his research highlights how air pollution, especially PM_{2.5}, plays a major role in increasing the rate of lung cancer in Southern India. The study showed that there is a high-level correlation between the amount of PM_{2.5} and the number of lung cancer patients in metropolitan cities like Chennai, Bangalore, and Hyderabad. These results support other research that has shown a worrying trend of higher lung cancer rates due to increased pollution, which indicates that there is an urgent need for protection from air pollution in big cities in India.

Air Pollution as a Key Risk Factor for Lung Cancer

The link in this research between lung cancer and PM_{2.5} levels was just as damaging as claimed in previous research regarding air pollution and lung health. World Health Organization (WHO) reports suggest that long exposure to particulate matter, especially PM_{2.5}, raise chances of lung cancer by further deteriorating tissues and facilitating change [3]. Through this study, the incidence of lung cancer due to air pollution in southern India was found to be very strong. Pearson correlation coefficients suggest pollution levels in Bangalore were at 0.78 while in Chennai it was 0.92. These results corroborate previous studies that have shown high rates of air pollution in urban regions correlated with higher incidence of lung cancer [3].

This is how in-depth studies can be: imagine in 2020, Barman literally spent time trying to understand why lung cancer rates are high in polluted cities and discovered that excessive PM_{2.5} exposure makes people more likely to get diagnosed, particularly people who have been accustomed to pollution for a long time. Then, a fellow researcher found out Chennai has the most PM_{2.5} pollution at 75.5 $\mu\text{g}/\text{m}^3$, which explains the staggering amount of lung cancer cases in the city. These studies should initiate action towards improving air quality by mitigating industrial and transportation pollution in the southern parts of India.

Smoking as a Co-Factor in Lung Cancer Risk

As observed in this research, lung cancer patients had the highest percentage of smokers, around 80.7 percent. This simply shows that lung cancer is commonly associated with smokers. Smoking remains the top cause of lung cancer worldwide; however, this research supports earlier studies in India that demonstrated how the use of tobacco resulted in lung cancer. But the high correlation noted between PM2.5 and lung cancer cases reveal the possibility that pollution may serve yet another primary or even compound risk factor for lung cancer, especially in individuals who do not smoke. These results are aligned with other research conducted across the world that has demonstrated how some external factors, like pollution, contribute towards lung cancer, whether one is a smoker or a non-smoker.

While smoking has the highest contribution in increasing chances of getting lung cancer, this research illustrates the influence of external factors like pollution. For example, in places, such as Chennai, where there are higher levels of PM2.5, the chances of experiencing lung cancer due to smoking along with pollution is most likely very high. There should be further investigation into the relationship between air pollution and smoking in relation to lung cancer and whether the effects of smoking on the environment energy amplify the rate of cancer.

Lung Cancer Incidence Based on Gender Differences

This research suggests that men have a greater rate of lung cancer (73.3%) which aligns with the global observation that men have a higher incidence of lung cancer due to their increased smoking rates. This is also seen in the studies done by Gupta et al. (2017) [5] where, they reported that men, especially those living in metropolitan India, are at a greater risk because of their higher intake of cigarettes along with greater exposure to tobacco and workplace cancer-causing materials. On the other hand, the growing rate of lung cancer among women in the cities is alarming. Even if the remaining 26.7% of lung cancer patients were women, the increasing trend of lung cancer among women in urban India because of higher smoking habits and pollution needs to be focused on.

In Southern India, cities, such as Hyderabad and Bangalore have also witnessed an increase in the lung cancer-breeding habit of smoking amongst women. Subsequent public health programs need to focus on air pollution, smoking, and other related health concerns for both men and women, especially in cities.

Survival Rates and the Impact of Air Pollution

Patients with exposure to high levels of PM2.5 were found to have significantly lower survival rates as compared to the patients with lower levels of exposure. The five-year survival rate was only 25.0% for high exposure patients as compared to 40.0% for low exposure patients. This also supports previous research which proposed that air pollution exposure not only increases the risk for the incidence of lung cancer but also worsens the survival rates of the patients [6]. The reduced survival rates in high pollution areas can be attributed to several reasons, such as a delayed diagnosis due to lack of awareness, limited access to healthcare facilities, and air pollution fuels the progression of lung cancer.

Patients diagnosed with lung cancer in high pollution areas are known to have more advanced diseases at the time of diagnosis which leads to poor survival rates [1]. The results of this study give enough evidence in support of the need for early detection programs and better access to cancer treatment attending to the patients residing in highly polluted areas. Having awareness and screening programs focusing on the early signs and symptoms of lung cancer is what is needed to greatly improve the survival rate.

Policy Implications and Public Health Recommendations

This research has vital policy implications for public health efforts to decrease lung cancer rates and enhance its management in southern India. Primarily, there is a growing need for tighter air quality standards in cities [6]. Unless remarkable efforts are made to limit pollution, cities, such as Chennai, Bangalore, and Hyderabad are poised to become increasingly polluted, particularly with the expansion of the population. There is a need for the government to take active steps towards tackling vehicular

traffic emissions, industrial waste pollution, and the burning of fossil fuels so that possible air quality improvements can help ease the lung cancer burden.

Moreover, there is a great need for anti-smoking campaigns aimed at men and women alike [7]. Although, smoking is widespread among men, the worrying trend of increasing use of tobacco by women in urban centers calls for urgent action. Also, public health education programs should aim at creating an understanding of the effects of smoking and pollution, particularly the combination of both on lung cancer [8].

Finally, there is an undeniable necessity to improve early detection and screening for at risk populations, particularly in areas with high levels of pollution [9]. They say prevention is better than cure and that is particularly true when it comes to lung cancer. Screening programs should be made available to people living in polluted regions. It is also important to educate other health professionals to detect lung cancer at earlier stages among patients with a prior exposure to pollution [10].

CONCLUSIONS

This research demonstrated the serious effect of air pollution both on the incidence and the survival of lung cancer in the southern part of India. It has also been observed that people exposed to high levels of PM_{2.5} have a greater risk of developing lung cancers. It is vital to undertake efforts to improve people's health by decreasing the pollution levels in cities. Besides cigarette smoking, this type of pollution is another risk factor that needs to be controlled by more stringent legislation and greater public education. It is also in line with other observations that there are capture and control systems, comprehensive programs for control of diseases, especially lung cancer in the southern part of India, which should consider early diagnosis, public education on smoking, and easier access to health services.

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