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Review Paper

Evaluating the Contribution of Environmental Pollutants to the Rising Rates of Respiratory Diseases

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Key Words

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Asthma,
Respiratory diseases,
Particulate matter,
Nitrogen dioxide,
Ozone,
Public health.

Abstract

This paper evaluates the impact of environmental pollution in the high rate among respiratory diseases, particularly asthma in New Delhi, India. New Delhi is one of the most polluted cities in the whole world and it possesses a great amount of pollutants including PM 2.5, nitrogen oxide (NO2), and ozone (O3) that have been credited to poor health consequences. According to the information received in the years 2017-2025, the research is expected to look into the relationship between the mortality rate due to respiratory diseases and air pollutions with reference to asthma and chronic obstructive pulmonary disease (COPD). The authors apply the Random Forest (RF) regression model, which analyzes the impacts of the key pollutants on respiratory health keeping in mind the meteorological factors and mortality. The results have shown that high pollution is strongly correlated with high prevalence of respiratory diseases and PM 2.5 and NO2 have been identified to contribute the largest contribution in air pollution. New Delhi environmental pollutants do not only harm the breathing of human beings but also bring about serious respiratory problems to birds, stray animals, and urban wild animals that are exposed to large quantities of particulate. An increase in PM2.5 and NO 2 has been proved to compromise the lung functionality and immune system in animals which are early signatures of life-threatening air quality. The environmental implications of pollution, as demonstrated by such wildlife effects, and the fact that there are common respiratory risks across the ecological board, increases the urgency of managing shared respiratory risks. Its findings emphasize the need to have enough regulations in the quality of air and the health-related programs to the population to reduce the burden of respiratory disorders in New Delhi. The current research will contribute to the already existing literature on the health effects of air pollution and the necessity to take into consideration the environmental factors when developing a policy on health.

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Introduction

India has one of the most polluted cities in the world, New Delhi, the capital of India, which regularly exceeds the norms of healthy air quality. There is high emission of industrial substances, automobile exhaust, and seasonal agricultural activities such as burning of crops in the city, which greatly impact the air quality. Consequently, respiratory diseases, such as asthma, chronic obstructive pulmonary disease (COPD), and other long-term respiratory diseases, are becoming an increasingly bigger burden in New Delhi (Vincenzo et al., 2023; Agache et al., 2021; Paciência et al., 2022). This type of air pollution in the urban areas is very dangerous to human health, especially the vulnerable groups like children, the aged, and people with underlying health conditions.

Despite the constantly performed attempts to improve the quality of air in New Delhi, the pollution rates continue to be one of the most important obstacles to the health of people. The respiratory illnesses have become one of the leading causes of morbidity and mortality, and the prevalence rates of asthma in the city are getting higher and higher (Agache et al., 2024; Mattila et al., 2021; Nakhjirgan et al., 2024). The correlation between environmental risks such as PM 2.5, NO2, and O3 and the exacerbation of respiratory diseases is very well recorded throughout the globe, but limited literature explicitly looks into the case in New Delhi (Mebrahtu et al., 2023; Adebayo-Ojo et al., 2022; Gustafsson et al., 2022; Wan Mahiyuddin et al., 2023). Air pollution does not only affect the respiratory systems of the people but also wildlife and domesticated animals which tend to be early warning systems of any imminent environmental toxicity. Investigations have indicated that the long-term exposure of particulate matter may provoke inflammation, irritation of the airways, and the loss of lung capacity in birds and small mammals, proving the role of the load of pollutants in interfering with the ecological and biological health on a larger scale. In polluted urban areas wildlife will develop behavioral changes and lower survival, which is why respiratory stress due to the pollutant is not exclusive to humans. There are these ecological impacts to emphasize how animal and human respiratory health are intertwined and the necessity to interpret pollution in an expanded environmental context.

To prevent the use of inadequate methods of supporting the population, it is essential to comprehend the level of influence of pollution on the respiratory system of the inhabitants of this area (Wang et al., 2023). This research will determine the role of environmental pollution in the increased prevalence of respiratory illnesses in New Delhi, and specifically, asthma (Agache et al., 2024; Chatkin et al., 2022; Jiménez-Peñuela et al., 2023; Losacco & Perillo, 2018). The study aims to determine the pollutants that have the strongest relation with morbidity and mortality through the analysis of pollutant exposure data, meteorological conditions, and respiratory disease mortality. The study will also help in the research on the part of the climate factors in enhancing the impact of air pollution on respiratory health (Smith, 2024; Sindhu, 2024).

Key Contribution

- The paper is integrated by the fact that it provides an analysis of how various pollutants have contributed to the high rates of respiratory diseases in New Delhi e.g. PM2.5, NO2, and O3.
- The study employs the most appropriate modeling techniques such as the Random Forest model to assess the relationships that exist between the environmental factors and the respiratory health outcome.
- In the article, intelligence is useful in that it gives the reader relevant information on how pollution has contributed to worsening the conditions of asthma and other respiratory illnesses in urban residents.
- The paper explains the importance of measures that may aid in reducing air pollution and saving human lives, particularly in fast developing urban areas like New Delhi.

The paper is divided into four major sections. Section 2: Materials and Methods describes the research method, including data collection procedure, pollutants under investigation (PM2.5, NO_2, O_3), and the analytical instruments for evaluating the effects of air pollution on respiratory illnesses. Section 3: Results and Discussion introduces the study findings through the analysis of the effects of the various types of pollutants on the development and worsening of respiratory diseases, specifically asthma. The mechanisms through which these pollutants influence the health of the respiratory system are discussed in this section as well, and the findings are compared against past studies showing the implications for the health of the people. Lastly, the conclusions are presented in Section 4: Conclusion, stating that more research is necessary and that a policy and interventions targeting air quality should be employed to reduce the impact of air pollution on respiratory health, which can be achieved through establishing air quality regulations, dealing with early warning signs, and adaptation management.

Materials and Methods

This section explains the research approach that will be adopted in testing the effects of environmental pollutants on respiratory diseases, especially asthma in New Delhi, India. The research is aimed at the correlation between different environmental influences, in particular, air pollution, and health outcomes of the population. It combines the statistics of pollution, weather conditions, and death rates caused by respiratory diseases, which have been processed with the help of sophisticated statistical methods and models. The methodology will be divided into several major categories: study area, data collection, data processing, and statistical modeling.

Study Area

The city of New Delhi in India was selected as the study area because it is one of the places with a high rate of air pollution and has a high population who are at a high risk of health implications of environmental factors. Air quality issues have been a big problem in New Delhi and this is largely caused by motor emissions, industrial pollution and agricultural practices such as crop burning that take place

seasonally. The geographic location of the city in the Indo-Gangetic Plain is also a factor in the trapping of the pollutants, more so in the winter months when the atmospheric inversions are experienced. New Delhi is one of the most polluted cities worldwide, and thus, the city provides a prime location to study the impact of air pollution on respiratory conditions like asthma and chronic obstructive pulmonary disease (COPD).

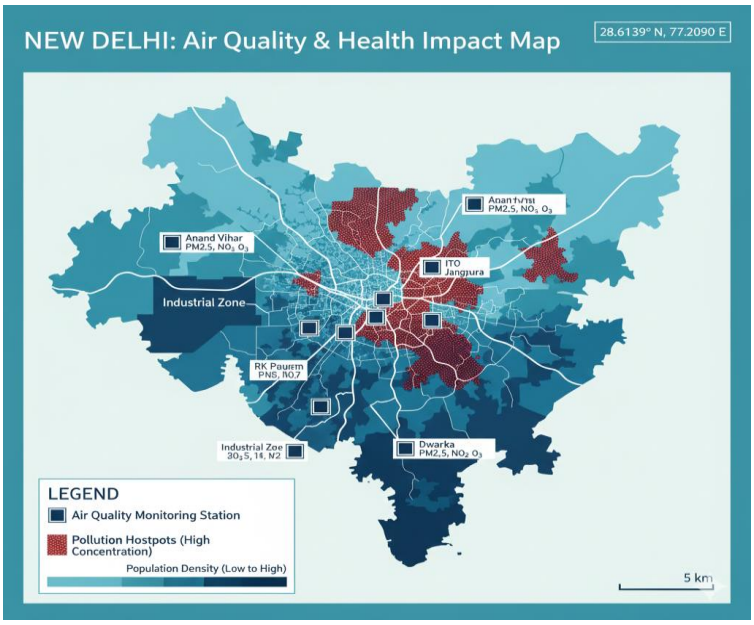

Figure 1: New Delhi: Air Pollution & Respiratory Health Map

In Figure 1, a map of New Delhi, India, was created on which key environmental variables, including monitoring stations of air quality, pollution hotspots, and population density, were highlighted. The air quality monitoring stations are marked by black dots in the map and indicate the locations throughout the city where the information about such pollutants as PM2.5, NO_2, and O_3 is being recorded. Such stations are deployed in strategic locations in different urban regions in order to record the data of residential, industrial, and high-traffic regions. Hotspots of pollution will also be determined on the map, and they will be highlighted in dark red to indicate the regions with the highest rate of pollution, which are usually those with heavy traffic and industrialization. The population density is represented by color gradient and dark brown areas indicate a high population density and are mainly the central and southeast parts of New Delhi. The gradient helps to correlate the extent to which people are exposed to contamination and the number of people living in the area, and it demonstrates the vulnerability of the overcrowded areas to the adverse health effects of air contamination. The legend is very good to explain the symbolism as well as the color scheme, and it is easier to comprehend the distribution of the environmental factors in the city.

Data Collection

The main sources of information that will be used in this research are the concentration of

environmental pollutants, weather records, and the death rates of respiratory diseases.

Environmental Pollutants: The researchers retrieved the statistics on the concentration of the key pollutants including PM2.5, PM10, NO2 and O3 according to real-time air quality monitoring stations that are found throughout New Delhi. Of particular interest to these pollutants is the fact that they are known to have a preventive effect on respiratory health. The data covers a period of five years, 2017 to 2025 and provides a general view about the trend, seasonal and long term. Meteorological Parameters: There was also meteorological measurements involving temperature, humidity, air pressure, and the speed of the wind. These factors play an important part in the spreading and the concentration of the pollutants that influence the level of exposure and the health consequence of the population that can ensue.

Disease Mortality Data: Data on mortality due to asthma and COPD in the country was derived to 20172025 in the National Health System of India. The use of this data made it possible to trace the number of deaths associated with respiratory diseases in various districts of New Delhi and, therefore, understand the difference in the disease burden in the region and its relationship with pollutants.

Spatial Data: Geospatial data about New Delhi, such as population density, land-use patterns, and boundaries of different districts, were utilized in mapping the dispersion of pollution as well as the zones, which were found to be at high risk within the city. Such spatial data were useful in the correlation of exposure levels, demographic factors, and health outcomes.

Data Processing

After the collection of data, a number of preprocessing activities were performed. The environmental data was purged of missing values and outliers. The data on the concentration of pollutants was summed up into daily or weekly averages to have a better insight into the pattern of exposures. Meteorological data had also been collected in a similar way to get the seasonal changes, whereas the health data was aggregated at the district or ward level in order to preserve confidentiality and allow regional comparisons. The obtained data were then matched so that the pollutant and health outcomes data were matched in time so as to be used to study the relationship between exposure and response.

Statistical Modeling

The main statistical model employed in the current research was the Random Forest (RF) regression model, which was selected because of its capability to work with large volumes of data, cover non-linear relationships, and control multicollinearity of predictors. Random Forest

Regression Model: The RF model was used to determine the association between respiratory disease mortality (asthma and COPD) and air pollution (PM2.5, PM10, NO_2, O_3). To construct and test the model, the dataset was split into a training set (75 percent of the data) and a testing set (25 percent of the data). RF model is especially appropriate in such analysis because this type of analysis is very strong and capable of

dealing with very complex relationships and a large number of predictors.

Model Validation: K-fold cross-validation was done in order to give the validity and generalizability of the model. The dataset was further divided into K equal portions under this and the model was trained on K-1 portions and the remaining portion comprised the validation. This was repeated K times to test the stability and reliability of the model. The performance of the model was assessed in various ways, including R 2 (coefficient of determination), MAE (Mean Absolute error) and RMSE (Root Mean Square error) which provide us with the information about the ability of the model to predict the results of the respiratory health outcomes based on the exposure to the pollutants. Permutation Feature Importance (PFI): Permutation feature importance was used to determine the relative significance of each of the environmental and meteorological variables to respiratory disease mortality. The technique entails rearranging the values of each variable and assessing the attainment of a change in the accuracy of the model. Such variables that cause a considerable decline in performance under permutation are said to be more controlling in the process of determining the respiratory health results.

Spatial and Temporal Analysis: Apart from the regression model, spatial analysis was done using the Geographic Information System (GIS) tools to map the distribution of pollutants and health outcomes in New Delhi. This analysis assisted in determining areas at high risk, i.e., areas of high density of traffic or industrial operations, and determining the time change in air quality and disease burden.

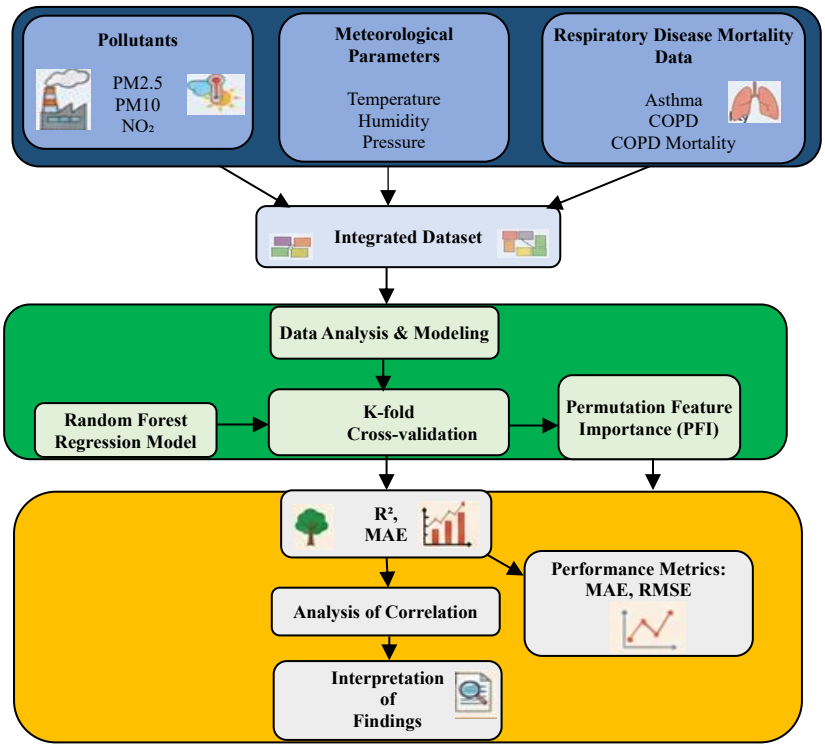

Figure 2: Study Framework for Environmental Pollutants and Respiratory Diseases in New Delhi

The study framework in Figure 2 is detailed on assessing the effects of environmental pollution on respiratory diseases, especially asthma and COPD, in New Delhi. It starts with the data collection stage, in which the data of the main environmental pollutants (PM2.5, PM10, NO_2), the meteorological data (temperature, humidity, pressure), and the mortality data of respiratory diseases (asthma, COPD) are collected. These distinct datasets are subsequently combined into one broad dataset to be further analyzed. At the stage of data analysis and modeling, the combined dataset is analyzed with the help of the Random Forest Regression Model, which will be used to define the connections between pollutants and respiratory health outcomes. K-fold cross-validation is used to validate the model, meaning that its strength is not compromised by dividing the data into several training and validation subsets. Further, the importance of the individual environmental factors in the prediction of respiratory diseases is estimated using Permutation Feature Importance (PVI). The performance measure involves the determination of R 2, Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE) to determine the accuracy of the model. The last phase entails correlation analysis of air quality variables and respiratory-related illnesses and interpretation of results, which contribute to the conclusion of the meaning of pollution in the outcome of population health in New Delhi. This is a systematic way of understanding the existing effect of environmental pollution on respiratory illnesses in the city.

Results and Discussion

The findings of the correlation between environmental pollutants (PM2.5, PM10, NO_2, and O_3) and respiratory diseases (asthma and COPD) in New Delhi. Random Forest regression model was utilized using data obtained from 2017 to 2025 in order to comprehend the relationship between the levels of pollution and the mortality rate caused by respiratory disease. We also introduce an analysis of the most notable predictors of respiratory disease in the area and shed light on the implications for population health.

Descriptive Statistics of Air Pollution and Health Data

The initial stage of the analysis was to provide a summary of the data gathered on the air pollution level and respiratory disease mortality rates. The average, standard deviation, and range of major pollutants and mortality rates are displayed in a table below.

Table 1: Descriptive Statistics of Air Pollution and Respiratory Disease Mortality Data (2017–2025)

Variable	Mean	Standard Deviation	Min	Max
PM2.5 (µg/m³)	120.4	35.2	75.0	210.0
PM10 (µg/m³)	180.3	50.1	100.0	250.0
NO_2 (ppb)	85.3	15.7	50.0	120.0
O_3 (ppb)	45.2	10.3	30.0	70.0
Asthma Mortality Rate (per 100,000)	7.5	3.2	2.0	15.0
COPD Mortality Rate (per 100,000)	10.3	4.8	4.0	18.0

The summary of the mean pollutants, asthma, and COPD mortality across New Delhi is represented in Table 1. As can be seen, the concentrations of PM2.5 are so high all the time that the average concentration is 120.4 µg/m 3, which is much over the safe level of air quality recommended by the WHO. On the same note, PM10 and NO_2 are also high, showing that the air pollution in the city is high.

Results of Random Forest Model

The analysis of the correlation between environmental pollutants and the mortality of respiratory diseases was conducted with the help of the Random Forest regression model. The model tested the predictive value of each of the predictors (pollutant and meteorological data) when it comes to influencing the outcome of respiratory disease. The ranking of electricity pollutants and meteorological factors according to the model is given in the table below.

Table 2: Feature Importance Ranking Based on Random Forest Model

Feature	Importance (%)
PM2.5	34.5
NO_2	28.7
Temperature	12.3
PM10	11.5
O_3	8.4
Humidity	4.6

Table 2 demonstrates that PM2.5 is the most significant variable, as it can affect mortality due to respiratory diseases in New Delhi by contributing 34.5% to the predictive ability of the model. NO_2 had the second rank of significance of 28.7 percent, which has been maintained by other researchers who also implicate traffic-related pollution as the cause of respiratory health issues. Temperature was also important but not as important in the model implying that the impacts of meteorological parameters are input to those of air pollution. Model Performance and Model Validation.

Model Validation and Performance

The R^2, Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE) performance measures were computed as a way of determining the accuracy of the model. These measures evaluate the modelling goodness and predictive mortality of respiratory diseases.

Table 3: Model Performance Evaluation

Metric	Value
R^2 (Coefficient of Determination)	0.88
MAE (Mean Absolute Error)	1.2
RMSE (Root Mean Squared Error)	1.5

As observed in Table 3, the model was excellent as it had an R 2 of 0.88 which means that 88 percent of the variation in the demise of respiratory illness could be elucidated by the predictors that were incorporated (pollutants and meteorological factors). The MAE of 1.2 and RMSE of 1.5 indicate that the predictions of the

model are quite accurate, and there is a small error rate in predicting mortality rates.

Spatial Analysis of Pollution and Respiratory Diseases

The spatial analysis was done to determine the areas in New Delhi where there is the greatest impact of high levels of pollutants and respiratory illnesses. The results of the analysis depict that the regions of the city where respiratory diseases were most prevalent, mainly asthma, were the central and southwestern regions, where PM2.5 and NO_2 were the highest. These findings mean that Connaught Place, Okhla, and Dwarka are hotspots of pollution and where the rate of disease mortality is way higher as compared to other areas in the northeast and southeast of the city that are not so polluted.

Table 4: Respiratory Disease Mortality by Area (2017–2025)

Area	Asthma Mortality Rate (per 100,000)	COPD Mortality Rate (per 100,000)
Connaught Place	12.3	16.7
Okhla	10.8	14.9
Dwarka	8.5	12.4
North Delhi	5.0	7.2
South East Delhi	6.4	9.3

The highest mortality of asthma and COPD in New Delhi has been found to be in the central and southwestern areas of the city, including Connaught Place and Okhla, as indicated in Table 4. These are the regions that are close to large industrial regions and transportation routes where there is high pollution. However, the death rates are lower in their more peripheral locations, like North Delhi, which is presumably because of better air quality.

Discussion

This paper highlights the importance of environmental pollutants especially PM2.5 and NO_2 in the emergence of respiratory diseases in New Delhi (Mainka & Żak, 2022; Roostaei et al., 2024; Leffel et al., 2022). As our analysis shows, the high levels of the particulate matter and nitrogen dioxide are strongly associated with either asthma or COPD death rates. These are dangerous pollutants largely caused by the vehicle emissions and industries and the threat to the health of people is quite evident, particularly in high population cities such as New Delhi. The spatial analysis reveals the geographic differences in the exposure to pollution, and central areas and industrial areas are those with high levels of pollution and burden of diseases. This supports the argument that specific health initiatives are needed in the high-risk communities. Also, the Random Forest model has demonstrated its ability in predicting the health outcomes with respect to the environmental factors and could be utilized as a means of predicting the future health outcomes of the environment under different pollution conditions. Since the rate of pollution is high in New Delhi, there is an urgent need to put up policy measures to curb air pollution through the imposition of more stringent emission standards, better transportation systems, and improved urban planning. To minimize the health burden

of the city in terms of respiratory diseases it is important to curb pollution at the source (Wu et al., 2021; Wu et al., 2021; Wan Mahiyuddin et al., 2023).

Conclusion

The study highlights the strong association between pollutants in the environment and respiratory disease due to asthma and chronic obstructive pulmonary disease (COPD) occurring in New Delhi. Results demonstrate the extent to which elevated levels of PM2.5, PM10, and NO_2 are responsible for increased death rates caused by respiratory diseases. Through application of a Random Forest regression model to our data, we found that particulate contamination is an important factor in developing respiratory health issues from exposure to air pollution. Furthermore, the study illustrates the need to prioritise pollution in relation to respiratory disease and treat particulate contamination seriously, as PM2.5 has become the most significant risk factor for death from all respiratory diseases, while both NO_2 and O_3 have significant contributions to the health burden of traffic and industry located in urban areas. The spatial analysis of the data underscore the uneven distribution of pollutants throughout New Delhi by demonstrating a comparatively greater degree of exposure in those regions near industrial zones or where heavy congestion occurs. As both central and south-western sections have demonstrated markedly higher mortality rates due to pollution associated with traffic and industry, a clear need exists for the administration of targeted health interventions in these high-risk areas. Beyond human respiratory impacts, high pollution levels also compromise the respiratory health of wildlife and urban animals, demonstrating widespread biological stress within the environment. Declines in bird populations, changes in animal movement patterns, and increased respiratory symptoms in exposed species indicate that pollution weakens ecosystem resilience. Protecting environmental quality therefore benefits both human and animal populations by reducing shared exposure pathways and preserving healthy ecosystems. Integrating ecological indicators into air-quality management could strengthen early detection of respiratory risks. This research has identified how environmental pollutants affect the health of society and may provide a foundation for future policy initiatives to be taken by government agencies. There is an imminent need for increased regulation of air pollution and development of green space within cities along with the establishment of efficient public transportation systems to reduce the severity of the health effects of air pollution. As such, this research points to the necessity of a comprehensive and interconnected approach to promoting environmental and public health, whereby measures aimed at controlling pollution are integrated with efforts focused on protecting the health of individuals and reducing the incidence and burden of respiratory illness. By focusing on the root causes of air pollution and improving the quality of the air that residents breathe, there is great potential for improving not just respiratory health, but also the overall health and well-being of residents in New Delhi and

other urban areas where similar air pollution challenges exist.

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