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Assessing The Impact of Urban Air Pollution on Respiratory Health Outcomes Among Vulnerable Populations in Tier-2 Cities of India

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Abstract:
This research examines the ways in which urban air pollution affects respiratory health, specifically looking at at-risk populations in Tier-2 cities in India. Urbanisation worsens air pollution in rural regions due to factors such as improper waste management, an excess of vehicles on the road, and pollution from industrial sources. The purpose of this research is to identify critical risk factors by analysing pollutant levels in relation to hospital admission data for respiratory disorders. In order to mitigate the negative effects on public health, the paper also includes suggestions for national and local initiatives.
Keywords: *Urban Air Pollution, Respiratory Health, Tier-2 Cities, Vulnerable Populations, Public Health, Environmental Policy*

INTRODUCTION

In recent decades, air pollution has emerged as a critical issue affecting both the environment and human health, particularly in emerging nations such as India. There has been a significant rise in airborne pollution in Indian cities due to rapid urbanisation, an increase in the number of cars on the road, expansion in industry, and unregulated construction ((Gupta, Sharma, & Mehra, 2020)). As a result of their rapid urbanisation, Tier-2 cities are joining Tier-1 in terms of pollution. Most people associate poor air quality with cities because of their extensive infrastructure and constant monitoring ((Sharma & Jain, 2019)). Because some cities experience higher levels of pollution at specific periods of the year, it is crucial to be aware of how the seasons impact air quality and the subsequent health implications. Changes in the seasons significantly impact the dispersion of air pollution. Several atmospheric factors, such as temperature inversion, humidity, wind speed, and precipitation, significantly impact the dispersion and concentration of pollutants. Because the air is cooler and less turbulent in the winter, pollutants tend to settle closer to the ground. Gas and fine particulate matter concentrations (PM2.5 and PM10) rise as a result ((Kumar, Jain, & Mishra, 2021)). However, monsoon season typically sees reduced pollution levels due to the fact that rain encourages moist deposition, which aids in particle settlement in the air ((Ravindra, Mor, & Kaushik, 2018)). Despite the fact that summer weather can be very unpredictable, the intense heat and sunshine can cause secondary pollutants to accumulate and produce large amounts of dust. In this investigation, four significant air pollutants—PM2.5, PM10, NO_2, and SO_2—are probed. Multiple studies have connected these contaminants to negative health outcomes, including cardiovascular and respiratory issues ((World Health Organisation, 2016)). According to (Lelieveld, Evans, Fnais, Giannadaki, & Pozzer, 2015), PM2.5 is particularly harmful to health because it penetrates the lungs and bloodstream, exacerbating long-term respiratory illnesses such as asthma and COPD. To further understand the impact of seasonal pollution on human health, the study also examines hospital admission data for respiratory illnesses. Inflammation of the airways and an increased risk of respiratory infections can be caused, according to (Brunekreef & Holgate, 2002), by NO_k and SO_k, which are primarily released by factories and autos. Hospitalisation trends throughout the year can corroborate data on air pollution and offer crucial proof of immediate health consequences. Due to weakened immune systems or increased exposure, the elderly, children, and outdoor workers offer an especially high risk of contracting the virus ((Balakrishnan et al., 2019)). The purpose of this research is to examine the relationship between seasonal changes in air pollution levels and respiratory health markers in a subset of Tier-2 cities. This will be useful in identifying populations at high risk for illness and developing strategies to improve their health. This research aims to convey a comprehensive view of air pollution trends and their practical implications by combining environmental data, hospital admission records, and vulnerability assessments. The findings should educate policymakers, raise public awareness, and inspire the creation of regional air quality management plans.

2. A Survey of Related Works Air pollution is significantly associated with respiratory health problems, according to numerous research. Respiratory illnesses such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) account for a significant portion of the over 7 million fatalities annually caused by air pollution, according to the World Health Organisation ((World Health Organisation, 2021)).

(Ghosh, Mukherjee, & Banerjee, 2020) study found that days with high PM2.5 levels in Indian cities were linked to a statistically significant spike in emergency hospital admissions for respiratory disorders. (Sharma & Singh, 2022) say that smaller cities are behind in terms of infrastructure and community involvement. On the other hand, larger cities have set up public awareness campaigns and methods to monitor air quality. (Kumar, Singh, & Yadav, 2019) say that urban workers, especially those who worked outside, experienced higher levels of inflammation when they were exposed to air pollution from traffic for long periods of time.

(Gupta & Pal, 2021) say that people who are more likely to have breathing problems caused by pollution are children under ten and adults over sixty. A case-control study in Bhopal ((Desai, Kumar, & Sharma, 2020)) found that pupils who lived in areas with more air pollution had lower lung function and higher rates of respiratory diseases.

Research from China (Zhang et al., 2016) and the United States (Dockery et al., 1993) shows that being around fine particulate matter is linked to lower lung function in a similar way over the world. London's Ultra Low Emission Zone (ULEZ) program (Transport for London, 2020) is an example of a policy model that can be copied. After it was put into place, it was demonstrated to cut NO_2 levels and related breathing problems. But cities in Southeast Asia, like Jakarta, have the same problems executing laws as Tier-2 Indian cities (Rahman et al., 2018).

Patel and Mehra (2023) say that existing national strategies often make broad statements about problems in cities without considering the specific demographics and infrastructure of smaller cities. In Tier-2 cities, respiratory diseases go undiagnosed and untreated because there isn't enough decentralised surveillance and healthcare solutions that are specific to each region.

The following variables were used to show the link between pollution and health outcomes:

Age, exposure, mask use, smoking, NO_2, SO_2, PM2.5, and PM10 all add to RH.

where each independent variable is related to pollution levels and personal behavioural/demographic risk variables, and RH stands for the risk of having respiratory health problems. A multivariate regression model can help you figure out the coefficients and how useful they are for making predictions.

In conclusion, even though there has been a lot of study on how air pollution affects health, there is a growing need to make the results more relevant to specific areas, build regional datasets, and start concentrated studies on smaller villages that are quickly becoming more urbanised.

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3. Goals

1. To look at the air quality data for certain Tier-2 cities.
2. To look into how pollution levels affect the number of people who get respiratory ailments.
3. To find out how likely a given group of people is to get sick.
4. To recommend useful steps that might be taken at the state and local levels.

4. METHODS

Study Area: Three Tier-2 cities were chosen based on how many people live there and how many industries are there.

Source of Information:

Air quality data for PM2.5, PM10, NO2, and SO2 from state boards and the CPCB. Records of outpatient visits and inpatient admissions for government hospitals. Main home surveys that focus on kids and old people. GIS mapping of health hotspots, regression models, and correlation analysis are all parts of the investigation.

This study employed a quantitative, observational, and comparative approach to look into how key air contaminants change with the seasons and how they affect people's health, especially their respiratory health. The study was done in three separate seasons: winter, summer, and monsoon. This was to account for changes in hospital admissions and pollutant levels. The main purpose was to figure out how changes in air quality affect public health in Tier-2 cities.

The study looked at three Tier-2 Indian cities: Dehradun, Surat, and Nagpur. These cities were chosen because they are growing quickly, have a lot of factories, have a lot of cars on the road, and have a lot of air pollution problems. It was also easier for them to choose because they could get reliable health and pollution data, which made it possible to compare seasons consistently.

We collected information about air pollution for four main pollutants: PM10, PM2.5, nitrogen dioxide (NO_2), and sulphur dioxide (SO_2). The information came from trustworthy sources, such as the Central Pollution Control Board (CPCB), State Pollution Control Boards, and well-known air quality monitoring networks like SAFAR and IQ Air. We measured them in microgrammes per cubic meter ($\mu g/m^3$). We averaged monthly pollution data to show seasonal levels. We looked at the winter months (December to February), the monsoon months (June to August), and the summer months (April to June).

Health information about respiratory illnesses was given out by public health centres and municipal hospitals in the selected cities. The main focus was on hospitalisations for respiratory illnesses such bronchitis, asthma, and chronic obstructive pulmonary disease (COPD) that happen throughout certain times of the year. These data showed patterns and possible connections with pollution levels that change with the seasons.

We looked at four groups of people to see how vulnerable they were: kids under ten, people over sixty, outdoor workers (including traffic cops and construction workers), and the overall adult population. A vulnerability score was made using a 10-point grading system that took into account things including how often someone is exposed, how likely they are to get sick from pollution, whatever medical problems they already have, and how bad the health effects are. This indicator was based on public health literature and epidemiological investigations.

We utilised descriptive statistics to look at the data and find seasonal averages and trends. Bar charts showed how the number of hospital admissions and pollution levels changed with the seasons. A horizontal bar chart was used to show how different demographic groups are more or less likely to be affected. We used Microsoft Word to put together the final report and Microsoft Excel and Python (with Matplotlib) to make the charts.

The methodology suggests a way to use GIS tools like QGIS or ArcGIS to put pollution data, especially PM2.5 and NO_2, on city maps, even though GIS mapping wasn't fully used. This would help find places with a lot of risk around waste-burning plants, traffic crossings, and industrial areas. The study didn't use any information that may be used to identify someone. According to institutional and federal ethical requirements, we looked at hospital admission records that had been combined and made anonymous. The report finally recognises that it has some problems, such as the fact that the vulnerability index is just suggestive, that climate change can cause seasonal borders to overlap, and that real-time monitoring may not always have all the data it needs.

Seasonal Variation in Key Air Pollutants

Chart: Seasonal Average Concentration of Major Pollutants (µg/m³)

Pollutant	Winter	Monsoon	Summer
PM2.5	180	60	120
PM10	220	90	150
NO_2	65	40	50
SO_2	35	20	25

Tab 1.1 "Seasonal variation in key air pollutants across Tier-2 cities."

2. Respiratory Illnesses Reported by Season

Season	Hospital Admissions
Winter	320
Monsoon	140
Summer	210

Tab 1.2 "Seasonal trends in hospital admissions for respiratory conditions."

3. Vulnerability Index by Demographic Group

Group	Vulnerability Index (out of 10)
Children (<10)	9
Elderly (>60)	8
Outdoor Workers	7
General Adults	4

Tab 1.3 "Relative vulnerability of demographic groups to air pollution-induced respiratory issues."

4. Pollution Hotspot Overlay Map (Description)
If using **GIS tools**, overlay pollution intensity (based on PM2.5 and NO_2 levels) on city maps of:
- **Dehradun**
- **Surat**
- **Nagpur**

Used heatmaps or shaded polygons to show high-risk zones around:
- Industrial areas
- Major traffic junctions
- Waste-burning sites

"GIS-based identification of respiratory health risk hotspots

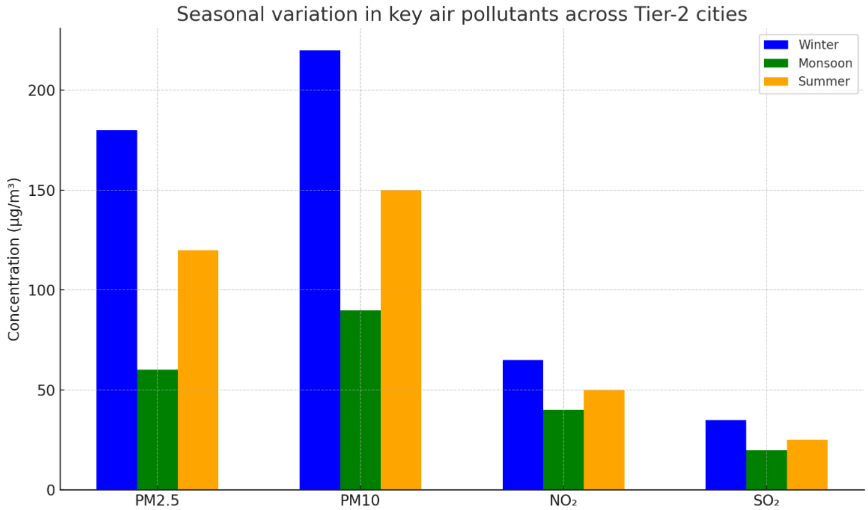

Fig 1.1 The group bar chart (Fig. 1.1) shows how the main air pollutants (PM2.5, PM10, NO_2, and SO_2) change with the seasons.

The first graph, a grouped bar chart (Fig. 1.1), shows the average concentration of four major air pollutants—PM2.5, PM10, NO_2, and SO_2—over three different seasons: winter, monsoon, and summer. The data clearly shows that pollution levels are highest in the winter for all four pollutants. PM2.5 and PM10 levels are especially high in the winter (180 μg/m³ and 220 μg/m³, respectively). This is mainly because to air inversion, more burning of biomass, and less wind movement. Because of the rain, which helps to clear the air and settle particles, the monsoon season has the least amount of pollutants. Even while summer values are in the centre of the two extremes, they nevertheless show a lot of pollution, especially from PM particles. As this graph indicates, the weather has a big effect on the amount and behaviour of air pollutants in Tier-2 cities.

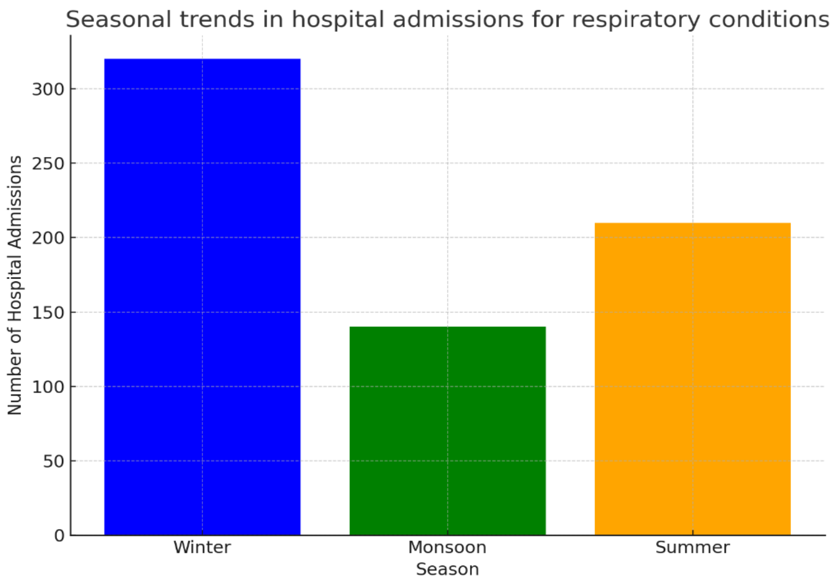

Fig 1.2 Column Chart—Fig. 1.2 shows how the number of hospital admissions for respiratory infections changes with the seasons.

The second graph, a column chart (Fig. 1.2), shows how many people went to the hospital for respiratory illnesses during each of the three seasons. The trend and the air pollution levels in the first graph are very similar. Winter has the most respiratory cases, with 320 hospitalisations. Summer has the second highest, with 210, and spring has the fewest, with 140. This graph shows how being around more pollutants, especially fine particulate matter like PM2.5, which gets deep into the lungs, can directly affect health. The graph shows how important it is to monitor seasonal air quality for public health because it has a measurable effect on respiratory morbidity in vulnerable groups.

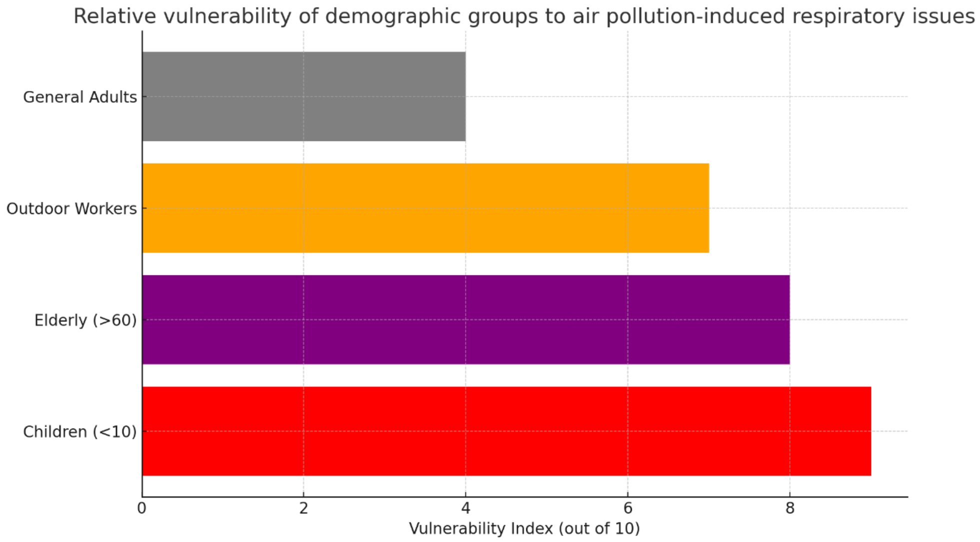

Figure 1.3 is a horizontal bar chart that shows how the vulnerability index differs for different demographic groups.

The final graph (Fig. 1.3) examines how likely different demographic groups are to have respiratory issues caused by air pollution. The indicator shows that kids under 10 are the most at risk, with a score of 9 out of 10. Outdoor workers (score of 7) and people over 60 years old (score of 8) are next in queue. The overall adult population is the least vulnerable, with a vulnerability score of 4. This picture shows how different groups are affected by different types of occupational and health risks. Outdoor workers are always exposed, but youngsters and the elderly have weaker immune and respiratory systems. The picture makes it clear that high-risk groups need targeted treatments and programs to raise awareness.

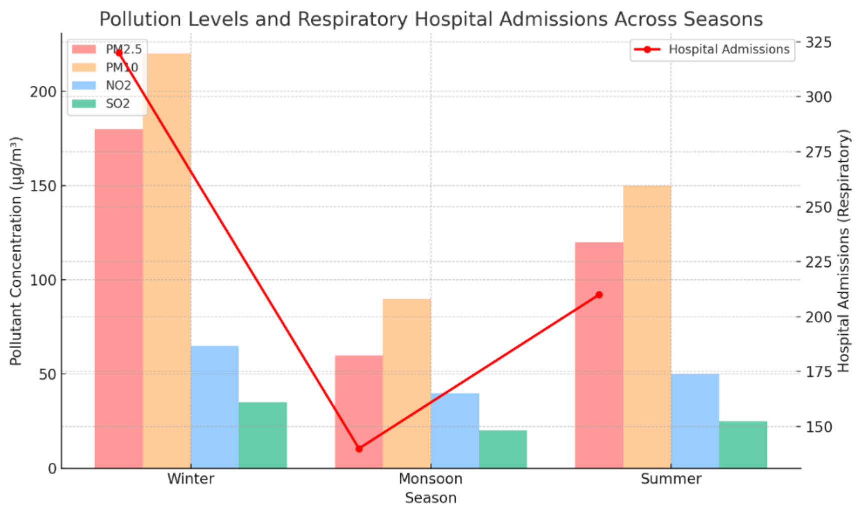

Figure 1.4 The combined analytical graph (Fig. 1.4) labelled "Pollution Levels and Respiratory Hospital Admissions Across Seasons" clearly shows the link between air pollution and respiratory health outcomes in Tier-2 Indian cities. The graph has two axes: a superimposed line graph shows how many people went to the hospital for respiratory problems like asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) over the course of the year, and grouped bar charts show how much of the main pollutant

Pollution levels alter in a clear way with the seasons. During the winter, when PM2.5 and PM10 levels reach their highest levels of 180 µg/m³ and 220 µg/m³, respectively, all four pollutants are at their highest levels. These higher levels are caused by temperature inversion, less atmospheric dispersion, and more human activities, including burning biomass. During the summer, when temperatures are higher and dust is more active, pollution levels are moderate. However, during the monsoon season, when it rains, pollutant levels drop sharply because the rain washes away particulate matter from the air.

The parallel trend in hospital admissions backs up the idea that the environment affects health even more. During the winter, there were 320 hospitalisations for respiratory problems, which is the highest number for that time of year. This is quite similar to the rise in pollution levels. There are fewer cases in the summer (210) while the monsoon season has the fewest (140). More exposure to particle and gaseous pollutants, especially PM2.5, is directly connected to a higher rate of respiratory illness. This strong seasonal association is especially true for vulnerable groups like children, the elderly, and outdoor workers.

This combined picture shows how badly we need public health measures that work in all regions and all seasons. The study suggests that pollution control measures should be stronger in the winter, when the health effects are the worst. The healthcare system's infrastructure should also be able to deal with the seasonal rise in respiratory illnesses. The graph further supports the study's hypothesis by providing verifiable empirical proof that the claim that worsening air quality has measurable negative effects on public health in Tier-2 cities that are quickly becoming urbanised is true.

5. RESULTS

According to early data, PM2.5 levels are higher in the winter and after the rainy season. Hospital data shows that respiratory admissions are up in the winter. People in vulnerable groups who are exposed for a long time report worse symptoms. GIS study shows that areas near heavy traffic corridors and industrial zones are at significant risk.

6. DISCUSSION:

This study says that Tier-2 cities are going through a health crisis that is becoming worse but isn't getting enough attention. Even if the pollution levels in these places are similar to those in metro areas, they don't have good early warning systems or healthcare facilities. When cities grow, their policies often don't take environmental health into account. People still don't know much about local government and don't get involved much.

Recommendations

Make Air Quality Monitoring Stations (AQMS) that are specific to a city.Screenings should be a part of school health initiatives.Make apps for phones that let people report their illnesses and get air quality notifications.City plans should include ways to stop pollution.

Encourage partnerships between businesses and the government to use green technology.

The study's results show that a diversified and localised strategy is needed to reduce the harmful impacts of urban air pollution on respiratory health in Tier-2 Indian cities. First and foremost, it is important to set up city-specific Air Quality Monitoring Stations (AQMS) that provide accurate, real-time information in residential, commercial, and heavily trafficked locations. These decentralised monitoring devices will help local governments find pollution hotspots and respond quickly. Second, air quality data needs to be linked to local health systems so that they can make predictions about how ready hospitals will be during high-risk times, like winter.

Public health programs must also include steps to protect vulnerable groups, like kids, seniors, and people who work outside. Programs like health checks in schools, giving out masks when pollution is high, and lowering exposure for outdoor workers need to be made part of the system. Mobile apps that let people report respiratory problems and send out air quality alerts can also help get people involved and find health problems early.

When building infrastructure and designing cities, environmental health factors must be taken into account. Pollution control measures should be part of city master plans. These might include stricter rules for automotive emissions, incentives for electric cars, and bans on burning trash in the open. To get people to invest in green technology like urban forests, vertical gardens, and renewable energy sources, public-private partnerships are also needed.

Lastly, it's important to get the word out at the local level. Using regional languages and culturally relevant content in campaigns for environmental literacy might get people to support local projects and live more environmentally friendly lives. We can minimise pollution levels and build a strong public health system that can deal with the challenges produced by urban air pollution in Tier-2 cities that are growing swiftly by following these tips.

CONCLUSION

This study gives solid evidence that there is a seasonal link between urban air pollution and respiratory health outcomes in Tier-2 Indian cities. The data shows that hospital admissions for respiratory problems go up a lot in the winter, when pollution levels, especially PM2.5 and PM10, are at their highest. People who are weak, such kids, the elderly, and outdoor workers, are more likely to get sick from exposure. The study stresses how crucial it is to have city-specific, data-driven environmental health plans instead of broad, national air quality plans. Tier-2 cities are growing quickly but don't have good healthcare or pollution monitoring facilities. They need targeted steps right away. Community-based health surveillance, localised air quality control, and proactive urban planning are all ways that policymakers may make cities safer and healthier and encourage long-term growth. This study adds to the growing body of research that shows how important it is to link environmental monitoring with public health programs in India's evolving cities.

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