DOI: 10.21120/LE/19/2/2

Acta Geographica Debrecina
Landscape & Environment series 19 (2) 2025. 16-32

EXPLORING AIR QUALITY AND HEALTH EFFECTS DURING DIWALI: A COMPREHENSIVE STUDY IN LUCKNOW CITY

SULEMAN

Department of Geography, Khwaja Moinuddin Chishti Language University, Lucknow, Uttar Pradesh, India
*Email: ksuleman198@gmail.com

Received 19 April 2024, accepted in revised form 10 September 2024

Abstract
Diwali, a major cultural festival in India, significantly impacts air quality, particularly in urban areas like Lucknow. The extensive use of firecrackers during the festival contributes to increased air pollution.
The study aims to examine how Diwali affects air pollution levels, particularly PM_{10} and $PM_{2.5}$, and to identify indoor pollution sources and their health implications. The objective is to provide data-driven recommendations for mitigating environmental impacts and improving community health during the festival.
An exploratory survey design was employed, combining primary and secondary data collection. Secondary data was collected from the Environmental Report, 2023 from the CSIR-Indian Institute of Toxicology Research website. Primary data were collected using structured questionnaires from 523 parents and 179 doctors in Lucknow, selected through quota and purposive sampling. Statistical analyses, including frequency, Chi-square, and exploratory factor analysis, were performed using SPSS version 25.
The survey revealed a significant increase in PM_{10} and $PM_{2.5}$ levels during Diwali, particularly at night, due to firecracker use. There were also minor increases in SO_2 and NO_2, indicating additional combustion. Significant associations were found between locality types and indoor pollution sources, such as burning mosquito repellents and candles. Children aged 0-4 in flats/apartments were identified as highly vulnerable. Seasonal variations and festivals exacerbated pollution effects, with health impacts ranging from respiratory issues to neurological effects.
The findings highlight the need for effective measures to reduce air pollution during Diwali. Recommendations include limiting firecracker use, enhancing indoor air quality, and increasing public awareness to mitigate health risks associated with air pollution.

Keywords: Air pollution, Diwali, Health effect, Children, Locality

1. Introduction

Air pollution has emerged as a pressing issue in megacities globally, with substantial negative effects on human health. The problem is exacerbated during festive seasons, especially in regions where celebrations involve the burning of firecrackers. Diwali, widely known as the "Festival of Lights" in India, is a prime example of this phenomenon. During Diwali, extensive firecracker usage leads to a significant increase in ambient air pollutant concentrations, notably particulate matter (PM) (Singh et al., 2008). This rise

in pollution is associated with various health complications, including respiratory problems such as asthma and bronchitis, as well as cardiovascular diseases (Guttikunda et al., 2014).

The effects of air pollution, however, extend beyond outdoor environments. Research has highlighted that poorly ventilated indoor spaces can trap pollutants, leading to substantial indoor air exposure (Mittal et al., 2020). This is particularly concerning in Lucknow City, where air quality often deteriorates to "very poor" levels during the winter season, as reported by the Central Pollution Control Board (CPCB) (Lawrence et al., 2020). The combination of high outdoor pollution and inadequate indoor air quality creates a significant health risk for residents.

Understanding the specific trends of air pollution during Diwali in Lucknow, along with the factors influencing indoor pollution and its health impacts, is crucial for developing effective mitigation strategies. This study aims to conduct a comprehensive assessment of air pollution trends in Lucknow City during the Diwali festival. By rigorously analyzing outdoor pollutant concentrations, examining factors that contribute to indoor air exposure, and evaluating the potential health effects on the city's residents, this research seeks to provide valuable insights.

The findings of this study are expected to inform policymakers and the general public, offering guidance on how to mitigate the adverse effects of air pollution and ensure a healthier, more sustainable celebration of Diwali. Through these efforts, the research aims to contribute to improved public health outcomes and environmental sustainability during one of India's most significant cultural events.

Rationale & Significance of the study

This study is motivated by the pressing need to comprehensively understand the impacts of air pollution during the Diwali festival in Lucknow, India. By analyzing outdoor pollution trends, investigating indoor sources across different locality types, and identifying health effects on children, the research aims to fill critical knowledge gaps. The significance lies in informing evidence-based interventions and policies to mitigate air pollution's adverse health effects, particularly among vulnerable groups. Understanding the dynamics of pollution during festive periods is crucial for promoting public health and environmental sustainability in urban settings, ultimately

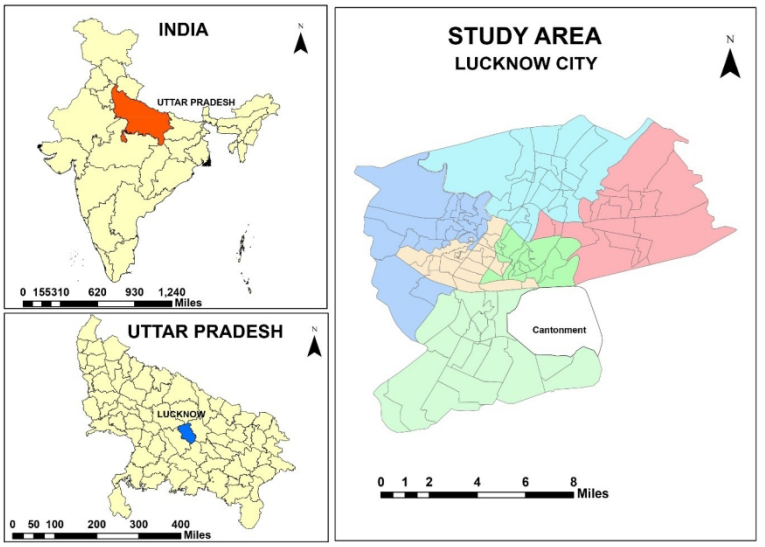

Fig. 1. Lucknow city map

contributing to informed decision-making for cleaner and healthier communities.

Area of the study

The study focuses on Lucknow, a vibrant metropolitan city in northern India and the capital of Uttar Pradesh. Known for its rich history and cultural heritage, Lucknow is a major economic and political center. Rapid population growth and urbanization have led to significant environmental challenges, including heightened air pollution during festivals like Diwali. The city's mix of urban, suburban, and rural areas makes it an ideal location to study how air pollution affects different communities. Insights from this research aim to benefit both Lucknow and other cities facing similar environmental issues in India and globally.

Objectives

1. To assess the impact of Diwali celebrations on air pollution levels (PM_{10}, $PM_{2.5}$, SO_2, and NO_2) in Lucknow, with a focus on the temporal variation, particularly during the night.
2. To examine the relationship between the types of locality (residential areas, mixed residential and commercial areas, and industrial-residential areas) of respondents (parents) and the primary sources of indoor air pollution in their households.
3. To explore doctors' perspectives on the demographic characteristics of children who are particularly vulnerable to health problems related to air pollution.
4. To identify the most significant health effects of air pollution on children, as perceived by doctors..

Table 1. Questionnaires for Doctors & Parents

Questionnaire	Section	Description
For Doctors	Exclusion Criteria	Category of Doctor (Select one): 1. General Physician 2. Pediatrician 3. Pulmonologist
	Section I: Demographic Profile of Children More Prone to Health Issues Related to Air Pollution	Collects information on age, socioeconomic status, and living conditions of children vulnerable to air pollution.
	Section II: Health Effects of Air Pollution	Focuses on observed health effects in children due to air pollution, including types, severity, and frequency of issues.
For Parents	Section I: Demographic Profile	Collects demograohic information of parents
	Section II: Air Pollution Inside House	Gathers information on indoor air quality and pollution sources in the home, including the use of firecrackers and other pollutants, and related health issues experienced by children.

2. Research Methodology

The present study employs an exploratory survey design and uses a quantitative approach. The study utilizes both primary and secondary data. Primary data was gathered through self-developed structured questionnaires while secondary data was collected from the Environmental Report, 2023 from the CSIR-Indian Institute of Toxicology Research website. The secondary data focused on $PM_{2.5}$, PM_{10}, SO_2, and NO_2 due to their significant impact on health and their relevance to firecracker emissions, which are central to our investigation. Most importantly our selection of these pollutants was also majorly based on the availability of the data for these pollutants only.

The structured questionnaires were made separately for parents and doctors, The questions were in dichotomous form, muktople choice form and on 5 point likert based from SA (5) to SD (1). The questionnaires for both respondents have following sections-

Before getting into a final shape the questionnaires underwent a pre-testing. A group of experts were approached to ensure that the tool is valid and for that purpose it was refined by removing few items and some items were merged that were same in sense. Further, anm initial study on 36 doctirs and 58 oarents was cinducted and the reliability of data ws assessed through Cronbach alpha value, The items that have values leass than 0.07 were removed an dhence the quetsionnaires gets into its final sghaoe for main survey. Primary data was collected from a sample of 523 parents & 179 doctors in Lucknow, Uttar Pradesh. These parents include those parents having at least one child between 0-14 years old. Doctors include those who are either general physicians paediatricians or pulmonologists. Further, quota and purposive sampling technique was used to select participants, meaning researchers specifically targeted individuals meeting the criteria.

The data collection included spreading questionnaires for two months (January-February 2024) to nearly 1500 parents and 500 doctors, leading to 523 & 179 remaining usable questionnaires in the case of parents and doctors respectively. While, secondary data was collected for the year 2023 from the website mentioned before Further, to fulfil the objectives, statistical tests like frequency analysis, Chi-square analysis & exploratory factor analysis were used with the help of the Statistical Package for Social Sciences (SPSS) version 25.

3. Results & Discussion

Demographic Profile of Respondents

There are two kinds of respondents in this study namely – doctors and parents. The demographic profile of the 523 parents reveals that a significant portion falls within the age range of 31-40 years, constituting 60.2% of the total, followed by those above 50 years and 41-50 years, each comprising 9.9%. In terms of gender distribution, females represent the majority at 67.3%, while males account for 32.7%. The profile of the doctors reveals that there are a total of 179 respondents (doctors), out of which 49.7% are General physicians, 43.6% are paediatricians and only 6.7% are pulmonologists.

Table 2.- Air pollution survey results for the festival days of Diwali 2023

Locations	Pre-Diwali 2023 (November 11th 2023)		On-Diwali 2023 (November 12th 2023)		Post-Diwali 2023 (November 13th 2023)	
	Day (6:00 am to 6:00 pm)	Night (6:00 pm to 6:00 am)	Day (6:00 am to 6:00 pm)	Night (6:00 pm to 6:00 am)	Day (6:00 am to 6:00 pm)	Night (6:00 pm to 6:00 am)
Pollutant : PM_{10} ($\mu g/m^3$)						
Aliganj	146	190	169	408	189	294
Vikas Nagar	155	182	186	382	174	326
Aminabad	171	230	261	572	292	337
Chowk	190	217	206	495	266	318
Average	166	205	206	464	230	319
Pollutant : $PM_{2.5}$ ($\mu g/m^3$)						
Aliganj	50	82	74	230	84	202
Vikas Nagar	102	85	136	258	100	199
Aminabad	172	168	152	446	115	250
Chowk	120	148	141	409	124	261
Average	111	121	126	336	106	228
Pollutant: SO_2 ($\mu g/m^3$)						
Aliganj	16	18	23	28	12	25
Vikas Nagar	17	23	21	31	18	24
Aminabad	21	20	24	35	23	29
Chowk	15	22	23	33	19	26
Average	17.3	20.8	22.8	31.8	18.0	26
Pollutant: NO_2 ($\mu g/m^3$)						
Aliganj	23	27	32	40	28	36
Vikas Nagar	25	33	31	43	30	36
Aminabad	22	32	37	53	28	40
Chowk	23	31	28	51	25	43
Average	23.3	30.8	32.0	46.8	27.8	39

Source- Assessment of Ambient Air Quality during Pre-Deepawali, Deepawali and Post-Deepawali Festival – (2023). CSIR-INDIAN INSTITUTE OF TOXICOLOGY RESEARCH. Chromeextension://efaidnbmnnnibpcajpcglclefindmkaj/http://iitrindia.org/Admin/EnviromentalReport/2f34591f-

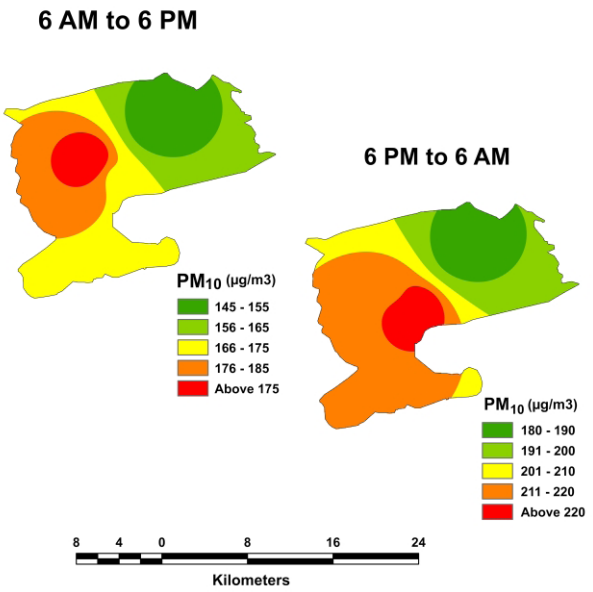

Fig. 2. Map of Lucknow city's Air Pollutant (PM_{10} Levels) Pre-Diwali 2023

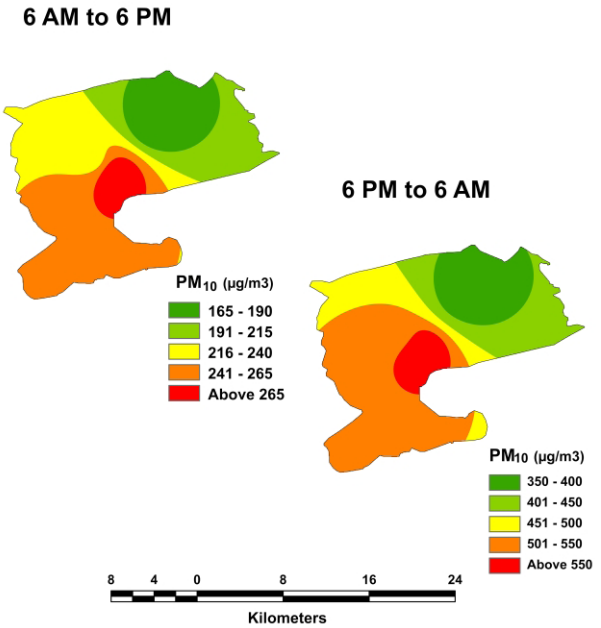

Fig. 3. Map of Lucknow city's Air Pollutant (PM_{10} Levels) On Diwali 2023

PM_{10} Levels

Pre-Diwali: The PM_{10} levels ranged between 146 µg/m^3 and 190 µg/m^3 during the day and night, which are moderate levels but within harmful limits for sensitive groups. Chowk recorded the highest value at night (217 µg/m^3), indicating more congestion in that area.

On-Diwali: There was a significant surge in PM_{10} levels during Diwali, especially at night, when firecracker activity was at its peak. Aminabad recorded the highest PM_{10} value at

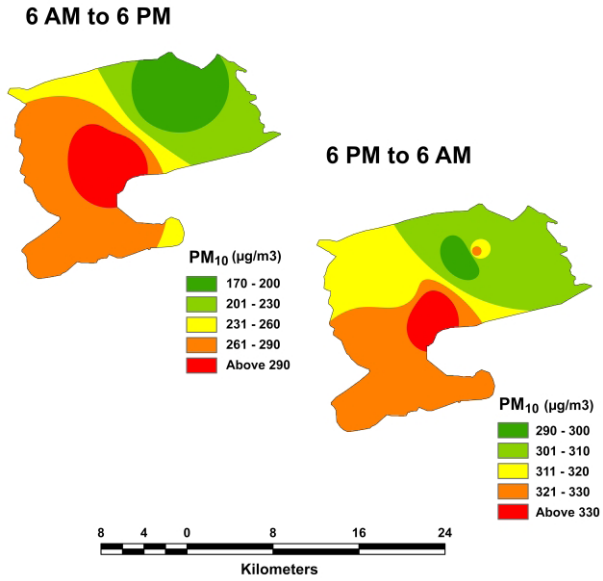

Fig. 4. Map of Lucknow city's Air Pollutant (PM_{10} Levels) Post Diwali 2023

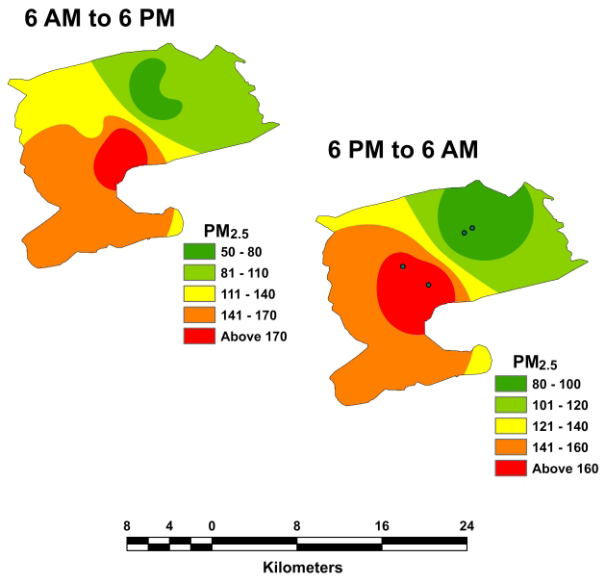

Fig. 5. Map of Lucknow city's Air Pollutant ($PM_{2.5}$ Levels) Pre Diwali 2023

night (572 µg/m^3), more than doubling the Pre-Diwali readings, indicating high levels of particulate matter in densely populated and crowded areas. The average levels increased from 205 µg/m^3 (Pre-Diwali night) to 464 µg/m^3 on Diwali night, demonstrating a sharp spike.

Post-Diwali: Although the PM_{10} levels decreased after Diwali, they remained elevated compared to Pre-Diwali levels, with values ranging from 174 µg/m^3 to 326 µg/m^3 during the day and night. The persistent elevation in PM_{10} post-Diwali suggests residual pollution effects.

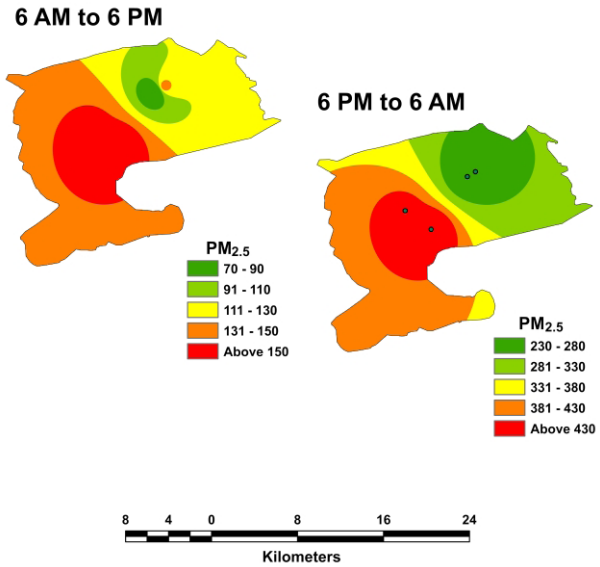

Fig. 6. Map of Lucknow city's Air Pollutant ($PM_{2.5}$ Levels) On Diwali 2023

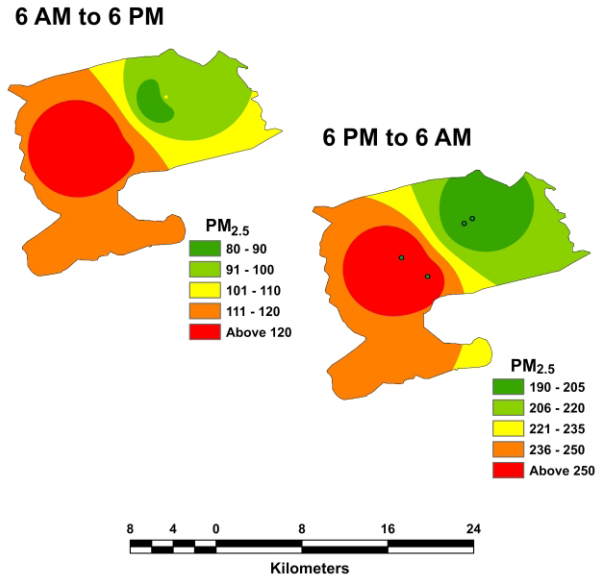

Fig. 7. Map of Lucknow city's Air Pollutant ($PM_{2.5}$ Levels) Post Diwali 2023

$PM_{2.5}$ Levels

Pre-Diwali: $PM_{2.5}$ levels were relatively lower than PM10, with an average of 111 µg/m^3 during the day and 121 µg/m^3 at night. Aminabad recorded the highest levels both during the day (172 µg/m^3) and at night (168 µg/m^3), indicating more indoor or localized sources of fine particles.

On-Diwali: A dramatic increase was observed on Diwali night, with $PM_{2.5}$ levels reaching 446 µg/m^3 in Aminabad and an overall average of 336 µg/m^3, a rise of almost three times the Pre-Diwali levels. This spike can be attributed to firecracker emissions, which release fine particles and have a more immediate impact on air quality.

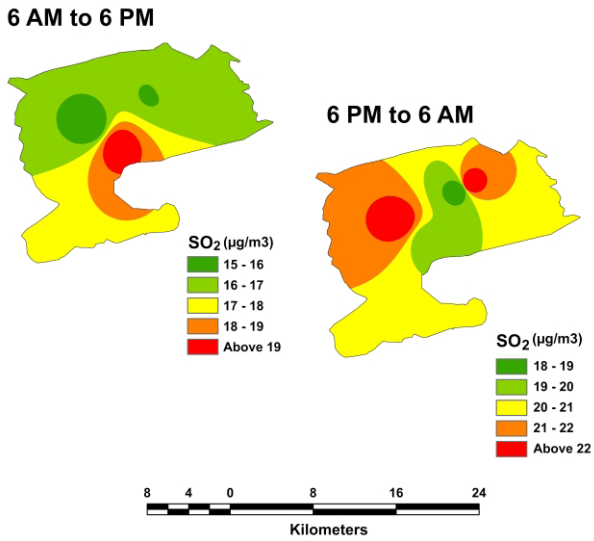

Fig. 8. Map of Lucknow city's Air Pollutant (SO_2 Levels) Pre Diwali 2023

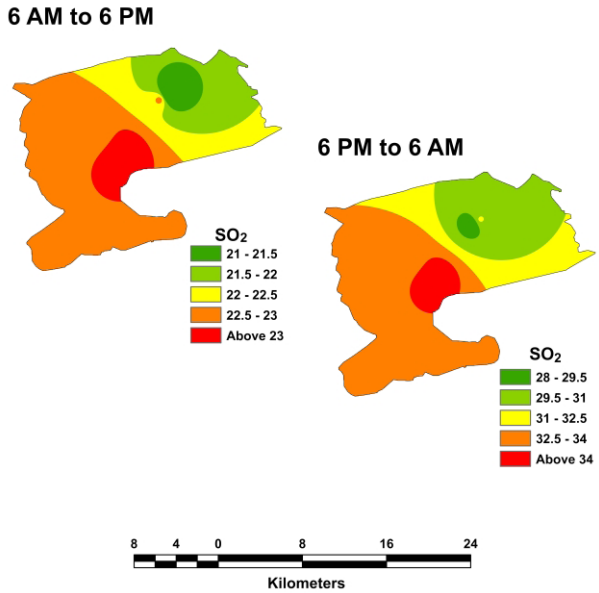

Fig. 9. Map of Lucknow city's Air Pollutant (SO_2 Levels) On Diwali 2023

Post-Diwali: While $PM_{2.5}$ levels dropped after Diwali, they still remained high, particularly at night in areas like Chowk (261 µg/m^3). This shows that fine particles linger longer in the air post-Diwali, posing prolonged health risks.

SO_2 Levels

Pre-Diwali: SO_2 concentrations were relatively low across locations, with an average of 17.3 µg/m^3 during the day and 20.8 µg/m^3 at night, which is within permissible limits for human health.

On-Diwali: There was a moderate increase in SO_2 levels on Diwali, with the highest

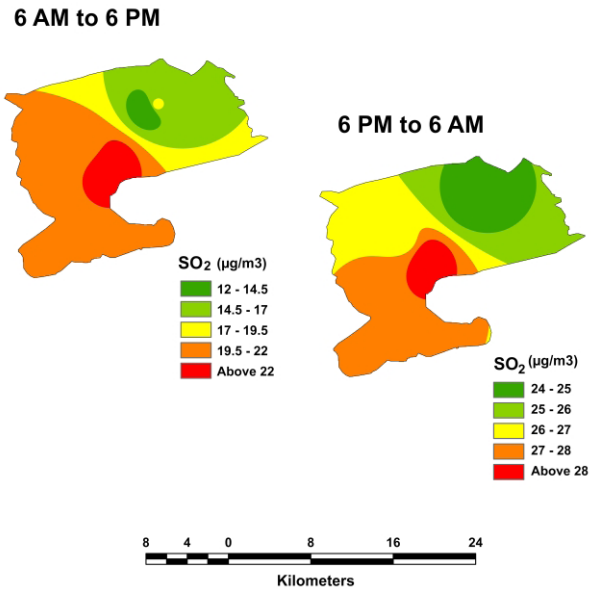

Fig. 10. Map of Lucknow city's Air Pollutant (SO_2 Levels) Post Diwali 2023

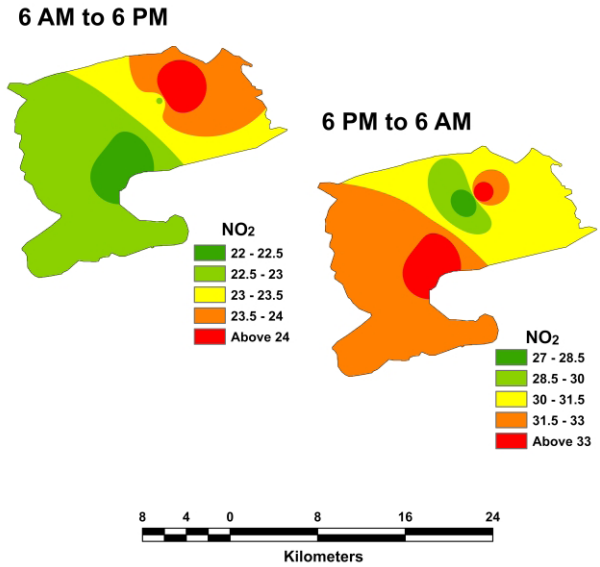

Fig. 11. Map of Lucknow city's Air Pollutant (NO_2 Levels) Pre Diwali 2023

recorded value being 35 µg/m^3 in Aminabad. The overall average increased from 20.8 µg/m^3 to 31.8 µg/m^3 at night. This increase is likely due to the combustion of firecrackers, which release sulfur compounds.

Post-Diwali: SO_2 levels decreased slightly post-Diwali but still remained higher than Pre-Diwali levels. The average ranged between 18 µg/m^3 and 26 µg/m^3, indicating a slower decline in sulfur dioxide levels compared to particulate matter pollutants.

NO_2 Levels

Pre-Diwali: Nitrogen dioxide levels were moderate before Diwali, with an average of 23.3 µg/m^3 during the day and 30.8 µg/m^3

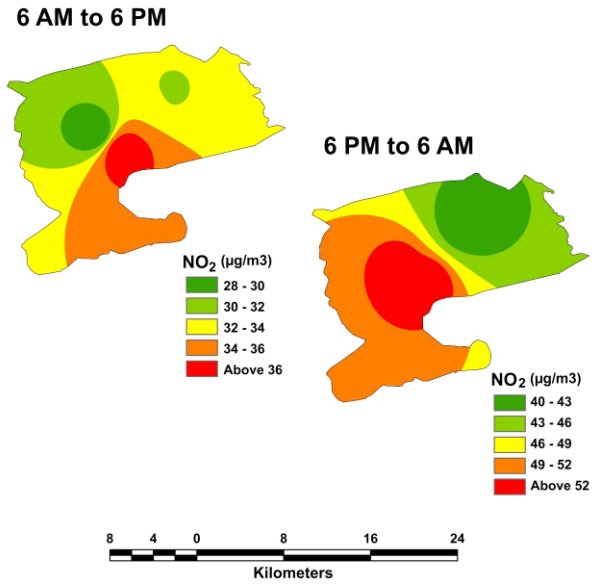

Fig. 12. Map of Lucknow city's Air Pollutant (NO_2 Levels) On Diwali 2023

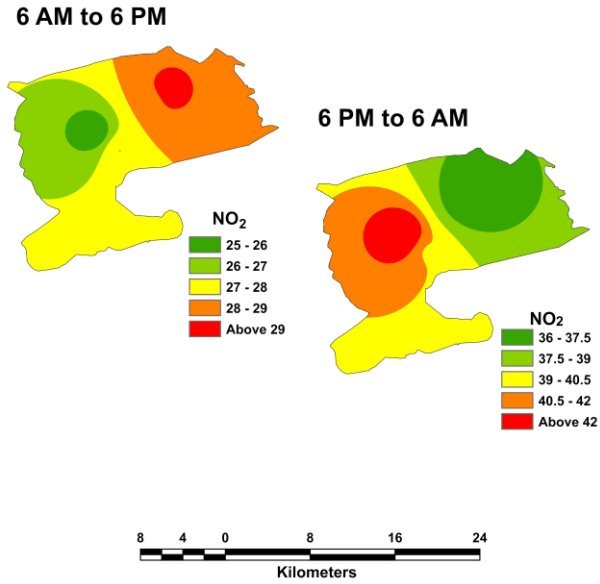

Fig. 13. Map of Lucknow city's Air Pollutant (NO_2 Levels) Post Diwali 2023

at night. The highest NO_2 concentration was recorded in Vikas Nagar at night (33 µg/m^3), suggesting moderate vehicular emissions or localized sources.

Post-Diwali: Post-Diwali levels showed a decline but remained higher than Pre-Diwali, with values ranging from 27.8 µg/m^3 to 39 µg/m^3. The lingering nitrogen dioxide suggests residual pollution effects from vehicular traffic and Diwali festivities.

The data indicates that Diwali has a significant short-term impact on air quality, particularly with regard to particulate matter (PM_{10} and $PM_{2.5}$) and nitrogen dioxide (NO_2). $PM_{2.5}$ and PM_{10} saw the sharpest increase, with nighttime values rising dramatically on

Table 3. Association between the type of locality of respondents (parents) and the most pressing causes of Air Pollution inside the House

Null Hypotheses (H_0)	Asymptotic Significance (2-sided)	Result (Retain/ Reject)
H_0 1: There is no sig. difference between the type of locality and Member/s of the family smoke/s in the house in the presence of children	.106	Retain
H_0 2: There is no sig. difference between the type of locality and Burn Mosquito repellent sticks/coils/ or use liquid.	.011	Reject
H_0 3: There is no sig. difference between the type of locality and the Burning of candles.	.021	Reject
H_0 4: There is no sig. difference between the type of locality and Household Cleaning Products.	.174	Retain
H_0 5: There is no sig. difference between the type of locality and Insecticides.	.000	Reject
H_0 6: There is no sig. difference between the type of locality and Faulty combustion devices, such as gas stoves, fireplaces, and malfunctioning heating systems, can release carbon monoxide, a toxic gas	.047	Reject
H_0 7: There is no sig. difference between the type of locality and Pet Dander (Pets, such as cats and dogs, shed dander (skin flakes) and hair, which can become airborne allergens and contribute to indoor air pollution).	.070	Retain
H_0 8: There is no sig. difference between the type of locality and Volatile Organic Compounds (VOCs): VOCs are emitted by various sources like paints, varnishes, adhesives, carpets, and furniture, and can contribute to indoor air pollution.	.043	Reject
H_0 9: There is no sig. difference between the type of locality and Improperly stored or managed household garbage	.154	Retain
H_0 10: There is no sig. difference between the type of locality and Improper ventilation in the house.	.000	Reject

Diwali compared to Pre-Diwali, highlighting the substantial contribution of firecracker emissions to air pollution. While the SO_2 and NO_2 levels showed moderate increases, the most concerning aspect is the persistence of elevated particulate matter levels even after the festivities. This is indicative of the residual effects of air pollution on ambient air quality, particularly in densely populated and congested areas like Aminabad and Chowk.

The results suggest that air pollution control measures should be reinforced during the festive season, especially in high-density areas, to mitigate the health risks associated with short-term pollution spikes.

3.3 Chi-Square Analysis: Difference between the type of locality (residential areas, commercial cum residential areas & industrial cum residential areas) of respondents (parents) and the most pressing causes of Air Pollution inside the House

3.4 Doctors' Perspective on Demographic Profile of Children More prone to health issues related to Air Pollution during Diwali.

- Out of a total of 179 respondents (doctors), 57.0% said that children living in Flat/Apartment are more affected by Air pollution while 17.3% said Terraced House, 10.6% said Semi-detached houses, 7.3% said Detached houses, 5.0% said Bungalow and only 2.8% said children living in another type of houses are more affected by air pollution.
- Out of a total of 179 respondents (doctors), 57.0% said that children in the age group of 0-4 years are particularly vulnerable to the health effects of air pollution. While 58.7% and 11.7% of the doctors considered 5-9 years and 10-14 years respectively as the vulnerable age group of children facing health effects due to air pollution.
- Out of a total of 179 respondents (doctors), all the doctors said that children with pre-existing respiratory conditions have a higher risk of developing complications due to air pollution exposure.
- Out of a total of 179 respondents (doctors), 6.7% consider Low income or poverty, 27.9% consider Lack of access to healthcare, 16.8% consider Living in densely populated urban areas, 39.1% consider Exposure to indoor air pollution and 9.5% consider all of these as the socioeconomic factors that can influence a child's susceptibility to air pollution-related diseases.
- Out of a total of 179 respondents (doctors), 7.3% consider the Family history of respiratory diseases, 16.2% consider Genetic predisposition to inflammation, 28.5% consider Specific gene mutations related to lung function and 48.0% consider all of these as the genetic factors that may contribute to a child's susceptibility to the health effects of air pollution.
- Out of a total of 179 respondents (doctors), 16.8% said that Boys are more susceptible than girls, 3.9% said that Girls are more susceptible than boys and 79.3% said that there is no significant gender difference when asked- are there any gender differences in the susceptibility of children to air pollution-related diseases?
- Out of a total of 179 respondents (doctors), 8.4% consider a Sedentary lifestyle, 26.8% consider Exposure to second-hand smoke, 24.6% said Poor nutrition, 13.4% said Lack of physical activity and 26.8% consider all these lifestyle factors that can influence a child's susceptibility to air pollution-related diseases.
- Out of a total of 179 respondents (doctors), 43.% consider Asthma, 29.1% consider Allergies, 16.8% consider Chronic obstructive pulmonary disease (COPD) and 11.2% consider Heart conditions as certain underlying medical conditions that children have that lead to a higher risk of developing complications due to air pollution exposure.
- Out of a total of 179 respondents (doctors), 10.1% consider Proximity to industrial areas, 21.2% consider Living in areas with high traffic congestion, 6.7% consider Exposure to pollutants from agricultural activities, 8.4% consider Proximity to power plants or factories and 53.6% consider all these geographical factors that can impact a child's susceptibility to air pollution-related diseases.
- Out of a total of 179 respondents (doctors), 14.5% consider Winter months, 25.7% consider Spring allergy season, 44.1% consider Summer heatwaves and 15.6% consider High pollution days as the specific periods or seasons when children are more vulnerable to the health effects of air pollution
- Out of a total of 179 respondents

(doctors), 38.0% consider Spending time outdoors in polluted areas, 27.9% consider Engaging in physical activities in polluted environments, 21.8% consider Not using protective masks when necessary and 12.3% consider Eating a diet high in antioxidants and anti-inflammatory foods as the behavioural factors that can affect a child's susceptibility to air pollution-related diseases.

- Out of a total of 179 respondents (doctors), 33.5% consider Holi, 49.7% consider Diwali, 6.7% consider Dusshera, 3.9% consider Eid and 6.1% consider Janmashtami as the specific festivals when there is more air pollution
- Out of a total of 179 respondents (doctors), 38.0% consider Holi, 52.0% consider Diwali, 5.0% consider Dusshera, 1.7% consider Eid and 3.4% consider Janmashtami as the specific festivals when there is an increased frequency of children suffering from air pollution.
- Out of a total of 179 respondents (doctors), 8.4% consider Winter months, 42.5% consider Spring allergy season, 31.3% consider Summer heatwaves and 17.9% consider High pollution days as the specific season and period which are commonly associated with an increased risk of asthma exacerbations in children
- Out of a total of 179 respondents (doctors), 89.4% consider Winter months, 4.5% consider Spring allergy season, 3.9% consider Summer heatwaves and 2.2% consider High pollution days as the specific season and time period that are commonly associated with an increased risk of flu or colds in children.
- Out of a total of 179 respondents (doctors), 50.8% consider Winter months, 26.3% consider Spring allergy season, 2.8% consider Summer heatwaves and 20.1% consider High pollution days as the specific season and time period which are typically associated with the highest number of

Table 4. Identifying the most pressing Health Effects of Air Pollution on Children from the perspective of doctors

Component	% of Variance	Variables Covered
1	13.624	Rhinitis Bronchitis Asthma Irritation in the eyes, nose, and throat Negatively affects Neurodevelopment
2	10.749	Stress and anxiety Depression Skin allergies / Eczema
3	7.958	Heart disease Frequent colds
4	7.415	Pneumonia Immature immune system
5	6.778	Sinusitis Memory problems
6	6.474	Other lung/chest problems
7	6.003	Lung Cancer Poor lung function

respiratory infections in children

- Out of a total of 179 respondents (doctors), all doctors 100.0% said yes that allergies are more common in children during the spring or fall season.
- Out of a total of 179 respondents (doctors), all doctors 100.0% said yes that certain skin conditions tend to worsen during the winter season.
- Out of a total of 179 respondents (doctors), all the doctors 100.0% said yes that heat-related illnesses are more prevalent among children during the summer months.
- That out of a total of 179 respondents (doctors), all doctors 100.0% said yes there are specific vaccinations recommended for children during certain seasons.
- Out of a total of 179 respondents (doctors), all the doctors 100.0% said yes that certain seasonal allergies tend to affect children more than others.

3.5 Factor Analysis: Identifying the most pressing Health Effects of Air Pollution on Children in Diwali from the perspective of doctors.

The data is adequate as the KMO measure of Sampling Adequacy is 0.547 and also there is enough correlation between the variables (0.000) to proceed with the analysis.

Interpretation- Based on the initial eigenvalues less than 1 or equal to 1, output has identified 7 linear components explaining 13.624%, 10.749%, 7.958%, 7.415%, 6.778%, 6.474% & 6.003% of the variance respectively by each component. As evident, component 1 explains the highest percentage of variance among all 7 components, therefore it is the most important component. Further, the table also lists the important variables within each component.

4. Conclusion and Recommendations

The findings from the air pollution survey conducted during Diwali 2023 in Lucknow City reveal a notable increase in air pollutant concentrations, particularly PM_{10} and $PM_{2.5}$, across all four surveyed locations compared to pre-Diwali levels. This escalation, particularly evident during nighttime, suggests a significant influence from the burning of firecrackers. Additionally, slight rises in SO_2 and NO_2 levels during Diwali hint at potential contributions from additional fuel combustion. Overall, these results highlight the substantial impact of Diwali celebrations on air quality in Lucknow City.

Regarding the association between respondents' locality types and the primary causes of indoor air pollution, several hypotheses were tested. While some associations were retained, indicating no significant correlation, others were rejected, signifying notable connections. Notably, factors such as burning mosquito repellent sticks/coils or using liquid, burning candles, exposure to indoor air pollution, genetic predispositions, and geographical factors were found to be significantly associated with respondents' locality types.

Furthermore, insights gathered from doctors shed light on the demographic profile of children vulnerable to health issues related to air pollution. The majority of doctors identified children living in flats/apartments, particularly those aged 0-4 years, as most susceptible to the health effects of air pollution. Socioeconomic factors such as exposure to indoor air pollution and genetic factors like specific gene mutations related to lung function were also deemed influential by surveyed doctors. Additionally, behavioural factors such as a sedentary lifestyle and exposure to secondhand smoke were recognized as contributing to children's susceptibility to air pollution-related diseases.

Moreover, doctors unanimously acknowledged certain seasonal variations and festivals as exacerbating factors for air pollution-related health issues in children. Diwali was singled out as a festival associated with heightened air pollution levels, aligning with the survey data's observations.

Additionally, specific seasons such as winter months and spring allergy seasons were identified as periods of increased susceptibility to respiratory infections and allergies in children.

Lastly, doctors highlighted various health effects of air pollution on children, ranging from respiratory ailments like asthma and bronchitis to neurological impacts such as stress and anxiety. Other notable health effects included heart disease, skin allergies, and compromised immune function. These findings emphasize the multifaceted nature of health risks posed by air pollution on children and emphasize the importance of concerted efforts to mitigate its adverse effects.

5. Recommendations

Based on the results & conclusion, the following recommendations can be provided-

- Implement strict regulations on firecracker usage during festivals like Diwali to mitigate air pollution spikes.
- Enhance public awareness campaigns on indoor air pollution sources and promote alternatives to reduce exposure.
- Prioritize respiratory health screenings for children, especially those in high-risk demographics identified by doctors.
- Develop interventions targeting socioeconomic disparities to address indoor air pollution and genetic susceptibility factors.
- Encourage lifestyle modifications such as reducing sedentary behaviour and avoiding secondhand smoke exposure to mitigate air pollution-related health risks.
- Invest in research to better understand the interplay between seasonal variations, festivals, and air pollution to inform targeted preventive measures.

6. References

Abdullahi, M. A., Hassan, M. N., Majeed, F. A., Alias, I. W., & Abu Hassan, M. A. (2012). Factors affecting indoor air quality in single-family terrace houses in Kuala Lumpur, Malaysia. Indoor air, 22(4), 359-368.

Areal, N., Liu, C., Li, B., Chen, X., & Deng, H. (2023). The interaction effect of air pollution and temperature on respiratory mortality and hospital admissions in Chinese cities. Environmental research, 222, 105542.

Bojjagani, V. S., Singh, N., Rani, M., & Jangid, A. (2023). Characterization, source apportionment and dissemination analysis of PM2.5 mass and metals in a residential area of Lucknow, India. Environmental Science and Pollution Research, 1-14.

Bonyadi, M., Hosseini, M., Forouzanfar, M. H., Yunesian, M., & Naieni, A. S. (2021). The association between ambient air pollution (O3, NO2, SO2) and hospital admissions for asthma in Shiraz, Iran: A time-series analysis. Environmental pollution (Barking, Essex, England), 286, 117456.

Chen, H., Goldberg, M. S., & Bates, D. V. (2008). Fine particulate air pollution and daily mortality. Respiratory research, 9(1), 73.

Dai, L. (2021). The association of indoor air pollution sources with prevalent respiratory morbidity in rural China. Environmental science & pollution research, 27(11), 14262-14271.

Duan, X., Chen, D., Wu, F., Liu, S., Fu, H., & Zhu, Y. (2016). Indoor air quality and the impacts of ventilation on PM2.5 concentrations in domestic environments in northern China. Building and Environment, 102, 146-154.

Guttikunda, S. K., Goel, A., Mohan, D., & Khanna, S. (2014). Assessment of the impact of festival-related emissions on air quality and public health in Delhi. Atmospheric environment, 88, 151-161.

Jain, S., Sharma, S., Singh, D., Mandal, T. K., Sinha, V., & Gautam, S. (2013). Characterization of particulate matter during Diwali festival over Kanpur, India. Environmental monitoring and assessment, 185(10), 7735-7744.

Jung, H. R., & Kim, Y. C. (2017). Effects of source control and ventilation strategies on indoor air quality in elementary school classrooms. Building and Environment, 125, 443-452.

Kang, Y. X., Liu, S., Qian, Z. M., Ji, P. F., & He, Q. H. (2023). The burden of lower respiratory infections and its risk factors in China. International journal of environmental research and public health, 20(3), 2327.

Kumar, A., & Dwivedi, A. K. (2021). Assessment of air quality and human health risks due to particulate matter exposure in Lucknow City, India. Environmental Pollution, 286, 117430.

Kumar, P., Singh, A. K., & Srivastava, M. K. (2023). Assessment of deteriorating air quality due to firecracker bursting during Diwali in Lucknow (India). Environmental Monitoring and Assessment, 195(2), 842.

Lawrence, S. J., Nawle, R., Karmakar, S., & Deshpande, A. (2020). Assessment of PM10 and PM2.5 pollution sources in Lucknow City, India. Urban Climate, 34, 100688.

Lim, S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair, H.,.. & Murray, C. J. L. (2012). A comparative risk assessment of burden of disease and injury attributable to environmental risk factors in 2004 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet, 380(9859), 2224-2260.

Mittal, S., Goyal, P., Sharma, S., & Mittal, A. (2020). Assessment of indoor air quality and their inter-association in hospitals of northern India—a cross-sectional study. Environmental science and pollution research, 27(12), 5513-5524.

Prasad, D., & Sanyal, S. (2016). Indoor air quality and respiratory health implications in rural and urban areas of Lucknow, India. Environmental monitoring and assessment, 188(8), 488.

Ravindra, K., Prasad, B., & Sokhi, R. S. (2003). Effects of Diwali festival emissions on respiratory health in Kanpur, India. Environmental science & technology, 37(4), 781-786.

Simeonova, V., Loleva, N., & Ilieva, E. (2021). Long-term trends of air pollution and potential health benefits of emission reduction measures in a highly industrialized area in Bulgaria. Environmental science and pollution research international, 28(31), 52248-52262.

Singh, D. P., Prasad, B., & Aher, M. C. (2008). Ambient air quality during the Diwali festival in Delhi, India. Journal of hazardous materials, 152(3), 490-498.

Slezak-Deszcznik, J., Wilczyńska-Cichoń, M., & Włochowicz, A. (2020). The impact of human activity on PM2.5 concentration in indoor air. International journal of environmental research and public health, 17(17), 6328.

Srivastava, A., & Shukla, A. K. (2021). Assessment of vehicular emissions and mitigation strategies for sustainable urban environment in residential areas of Lucknow, India. Environmental Science and Pollution Research, 28(23), 18206-18219.

Srivastava, A., Gupta, S., Jain, S., & Mandal, T. K. (2018). Source apportionment of PM10 and PM2.5 during pre-Diwali, Diwali and post-Diwali periods in an urban environment of Agra, India. Environmental Science and Pollution Research, 25(11), 10922-10933.

Tripathi, N., Sharma, L., & Gupta, P. K. (2021). Machine learning models for prediction of hospital visits due to respiratory morbidity associated with variations in air pollutant concentrations in Lucknow, India. Environmental Science and Pollution Research, 28(18), 12225-12237.