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COMPREHENSIVE ASSESSMENT OF AIR POLLUTION TRENDS DURING DIWALI FESTIVAL AND HEALTH IMPACTS: A STUDY IN LUCKNOW CITY

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Introduction

Air pollution represents a pressing issue in megacities worldwide, exerting significant adverse effects on human health. During festive seasons, this concern often intensifies, particularly in regions where celebrations involve the burning of firecrackers. Diwali, known as the "Festival of Lights," serves as a prominent example in India. Studies like Singh et al. (2008) have meticulously documented a substantial surge in ambient air pollutant concentrations, especially particulate matter (PM), during Diwali festivities. This escalation is primarily attributed to the widespread ignition of firecrackers, leading to a myriad of health complications including respiratory problems and cardiovascular diseases (Guttikunda et al., 2014).

However, the repercussions of air pollution extend beyond the outdoor environment. Research indicates that poorly ventilated homes can serve as reservoirs for these pollutants, resulting in significant indoor air exposure (Mittal et al., 2020). This phenomenon is particularly alarming in Lucknow City, which frequently grapples with "very poor" air quality during winter, as reported by the Central Pollution Control Board (CPCB) (Lawrence et al., 2020). Understanding the specific trends in air pollution during Diwali in Lucknow, alongside the factors influencing indoor exposure and associated health impacts, is paramount for devising effective mitigation strategies.

The primary objective of this study is to conduct a comprehensive assessment of air pollution trends in Lucknow City during the Diwali festival. Through rigorous analysis, we aim to scrutinize outdoor pollutant concentrations, dissect factors influencing indoor exposure, and evaluate the potential health effects on the city's residents. By delving deeper into this multifaceted issue, we endeavour to furnish policymakers and citizens with invaluable insights, thereby fostering a healthier and more sustainable celebration of Diwali.

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

1.2 Area of the study

The study area encompasses Lucknow, a bustling metropolitan city located in the northern Indian state of Uttar Pradesh. As the capital and largest city of Uttar Pradesh, Lucknow serves as a cultural, economic, and political hub, renowned for its rich history, vibrant heritage, and bustling urban landscape. With a rapidly growing population and expanding urbanization, Lucknow faces various environmental challenges, including air pollution exacerbated during festive periods like Diwali. The city's diverse socio-economic fabric, characterised by a mix of urban, suburban, and rural localities, provides an ideal backdrop for examining the nuances of air pollution exposure across different community settings. By focusing on Lucknow, this study aims to generate insights that are not only relevant to the city's residents but also applicable to other urban centres grappling with similar environmental concerns in India and beyond.

1.3 Objectives

1. To analyse the Air pollution levels for the festival days of Diwali 2023 in Lucknow city.
2. To study the association between types 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. To investigate the perspective of doctors regarding the demographic characteristics of children who are more susceptible to health issues associated with air pollution.
4. To identify the most pressing Health Effects of Air Pollution on Children from the perspective of doctors.

2. Research Methodology

The present study employs an exploratory survey design and uses a quantitative approach. The study utilizesboth 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.

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. Doctorsinclude 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 spreadingquestionnairesfor two months (January-February 2024)tonearly 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 beforeFurther, 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

3.1 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 areatotal of 179 respondents (doctors), out of which 49.7% are General physicians, 43.6% are paediatricians and only 6.7% are pulmonologists.

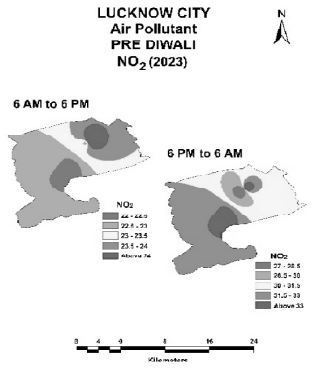
3.2 Air pollution survey results for the festival days of Diwali 2023 in Lucknow city.

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. /http://iitrindia.org/Admin/EnviromentalReport/2f34591f. Accessed on 12-01-2024 at 11.30 PM.

Map-1



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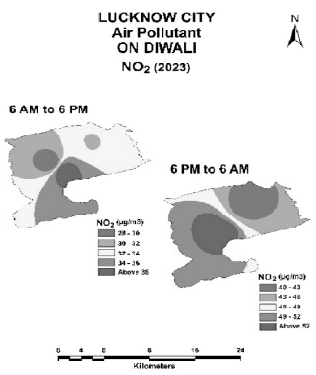

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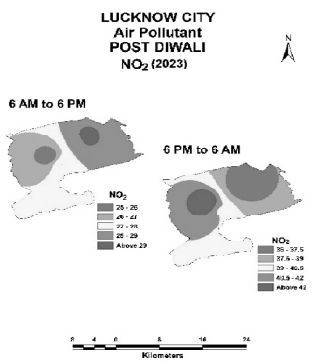
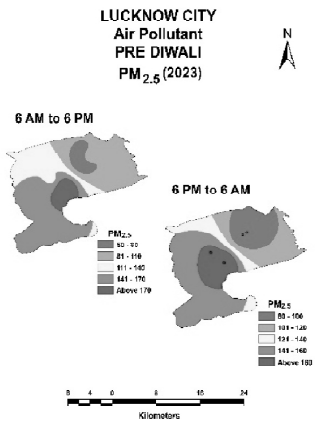


Map-4



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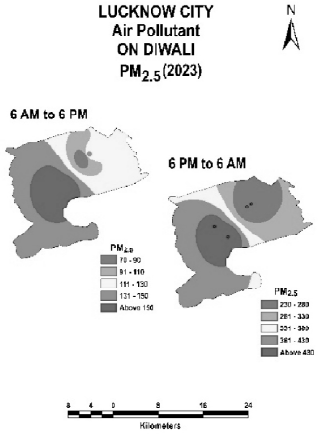

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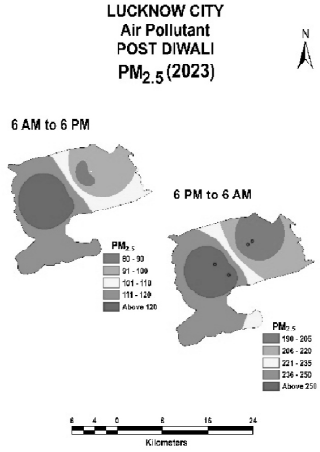

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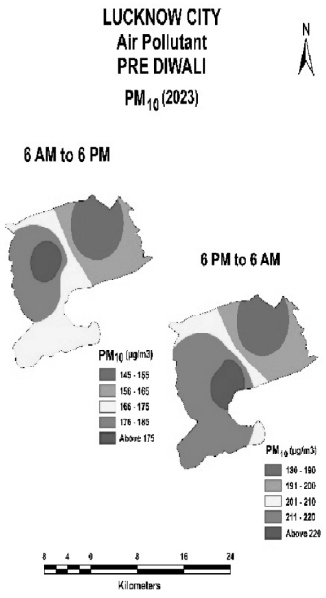
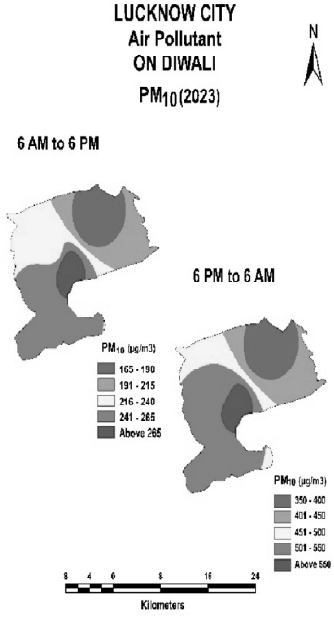


Map-8



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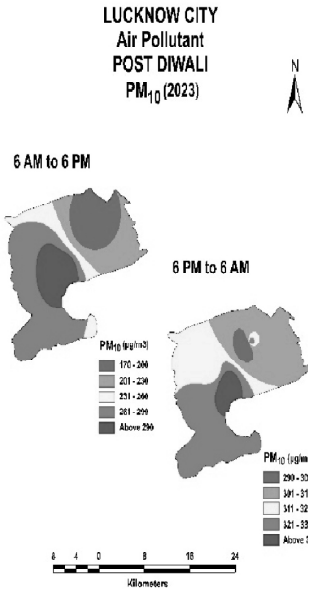

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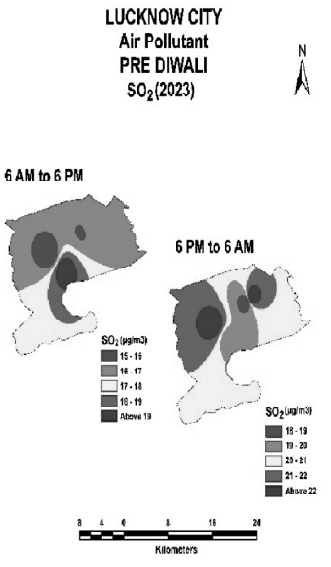

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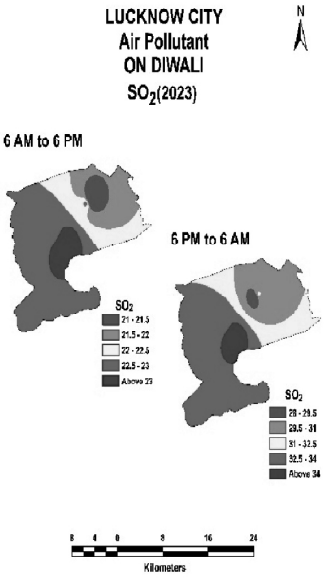
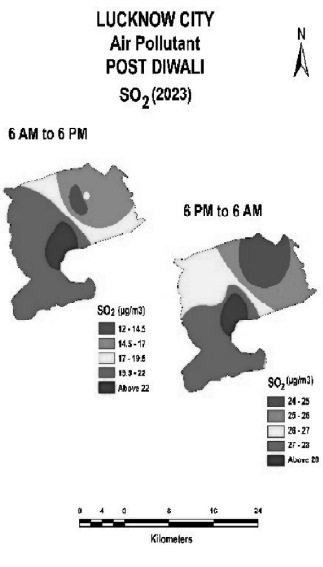


Map-12



Interpretation : The data shows a significant spike in air pollutant concentrations, particularly PM10 and PM2.5, during Diwali in all four locations (Aliganj, Vikas Nagar, Aminabad, Chowk) compared to pre-Diwali levels. This rise is most prominent at night, suggesting an

influence from firecrackers burning. SO2 and NO2 levels also show a slight increase during Diwali, potentially due to additional fuel combustion. Overall, the data highlights the substantial impact of Diwali celebrations on air quality in Lucknow City.

3.3Chi-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.

Table 2.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

3.4 Doctors' Perspective onDemographic Profile of Children More prone to health issues related to Air Pollution.

F 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.

F 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.

F 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.

F 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.

F 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.

F 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?

F 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.

F 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 thatlead to a higher risk of developing complications due to air pollution exposure.

F 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.

F 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

F 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.

F 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

F 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.

F 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

F 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.

F 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 respiratory infections in children

F 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.

F 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.

F 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.

F 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.

F 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 from the perspective of doctors.

Thedata is adequate as the KMO measure ofSampling Adequacy is 0.547 and also there is enough correlation between the variables (0.000) to proceed with the analysis.

Table 3.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

Interpretation- Based on the initial eigenvalues less than 1 or equal to 1, output has identified 7 linear components explaining13.624%, 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 PM10 and PM2.5, 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 SO2 and NO2 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.

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