RESEARCH ARTICLE

Progress or Persistence? A Comparative Analysis of Delhi's Air Quality during Diwali over the Years

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Abstract

The deteriorating air quality in Delhi is a serious cause of concern as it poses a grave danger to health. The poor air quality is attributed to many factors such as vehicular pollution, thermal power plants, construction dust and stubble burning. For the last few years, stubble burning has been implicated in the particulate matter surge and smog during the onset of winter. Diwali, the festival of light and sound, is also celebrated during October-November every year. Bursting of crackers during Diwali and the celebration of marriages and other festivals during this particular time aggravate the pollution level. The present study analyzed the data available on the CPCB (Central Pollution Control Board) portal of different sites, from east, west, north, and south Delhi. The surge in PM10 and PM2.5 levels was observed in most stations. The stubble burning incidents and the weather parameters were also studied from the available data sources. West Delhi stations (Ashok Vihar and Punjabi Bagh) showed high $PM^{2.5}$, but PM^{10} was found to be the highest in East Delhi station (Anand Vihar). Though the stubble burning was contained in Haryana, the wind direction and the speed seem to be the major causes for the surge. The present strategies adopted by the government agencies did not work as water spraying did not improve the air quality at any of the places where it was tested, and cloud seeding could not be executed.

Therefore, public transport usage, microclimatic studies, plantations at selected sites, and technological advancements are very important. Interdisciplinary research to understand the pollution-climate dynamics using mathematical models will help in planning better strategies in future.

Keywords: Green Crackers, AQI, Delhi, Diwali, Pollution, Government Strategies.

Highlights:

- Air pollution spiked in Delhi around Diwali and due to cold weather conditions.
- PM^{10} levels were much higher than PM2.5.
- Green crackers and ban lifting on bursting of crackers deteriorated air quality.
- The present mitigation measures need to be revisited.

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Introduction

Air pollution is increasingly becoming a serious global environmental issue across the globe (Cooper et al., 2011; EPA, 2022; Gajbhiye, 2023). Most of the famous cities of Southeast Asian Countries are hot spots of air pollution, and air quality in these cities falls in the poor category at one time or another of the year (Centre for Science and Environment CSE, 2024). Delhi, the capital city of India, has been at the top of the list of cities with poor air quality (Kulshrestha, 2025). As per Central Pollution Control Board (CPCB) data, the air pollution in Delhi in the past decade has increased significantly on account of fossil fuel burning, industrialization and developmental activities (Das et al., 2025). More people are being diagnosed with respiratory diseases, resulting in increased hospitalization. The increasing pollution is affecting the quality of life as children and the elderly are facing various health issues such as increasing cough and cold, lung infections, asthma and allergic rhinitis and this is seen as an escalating public health emergency (Global Air Report, 2025). Traditionally, much of Delhi's pollution has been attributed to factors like stubble burning and vehicular emissions. According to the International Council on Clean Transportation (ICCT, 2024), 30% of ambient PM 2.5 pollution is because of solid fuel combustion, complemented by more from emissions from automobiles. Thermal power plant emissions containing dust, sulphur, carbon, and soot additionally result in a compromise in the air quality (The Guardian, 2024; Ghanem et al., 2025). The emissions coming from firecrackers and thermal power plants also include heavy metals such as Pb, Cd, and Hg, Zn (Saha, 2021; EPA, 2022); however, this study focuses exclusively on PM2.5, PM10 and AQI. Despite the transition to

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renewables as a source of electricity, the reliance on Thermal Power in Delhi is projected to increase approximately 160 quadrillion British Thermal Units by the year 2040 (Vig et al., 2023). Delhi also brings in migrant and transit populations from across the country on account of various opportunities such as jobs, education and business and is thus considered the migrant capital of India (EPIC India & University of Chicago, 2024). With the increase in population, the pollution levels have seen a surge in the last decade. Migrant populations bring along different cultures, rituals, and celebrations (Sateesh, 2018). Diverse cultures from Northern parts of India, including Haryana, Punjab, Uttar Pradesh and Bihar, have resulted in an increased number of festivities and celebrations where crackers are burnt to display happiness (Kulshrestha et al., 2024; Guttikunda, 2024). Cracker bursting on marriages, festivals, mostly Diwali and Deep Diwali, is considered an auspicious ritual and people indulge in this activity with full fervor (Manchanda et al., 2020).

With an increasing population, the number of events during which the firing of crackers is carried out has increased considerably, leading to deteriorating air quality at a fast rate (Dubey et al., 2022, 2023; Times of India, 2025). Firecrackers contain higher amounts of toxic elements like Al, Cr, Ba, P, Sr, Cu, Mg, and Fe (Dubey et al., 2023). Furthermore, the manufacturing of crackers is mostly carried out by the unorganized sector, where harmful chemicals are used for making crackers (Saha, 2021).

The Diwali season is seen as most alarming in terms of depleting air quality in Delhi in the past few years (Ghei & Sane, 2018). Diwali falls in the months of October-November, the Kartik month as per the Saka calendar (Rizwan et al., 2013). Increasing particulate matter has been found to show a spike in major pollution monitoring stations during the Diwali season, which is also the onset of winter in Delhi, according to Bhola et al. (2023). The temperature starts falling in Northern India, resulting in the onset of winter. The low temperature results in a concentration of pollutants in the lower layers of the atmosphere and aggravating the problem (Das et al., 2025). Furthermore, the post-monsoon pests and pathogens are prevalent and spread infections fast, resulting in disease outbreaks (Kumar & Singh, 2025). Banning of crackers in Delhi, the penalties on stubble burning and limited construction work were some strategies that were adopted to curtail the pollution levels.

The Government of the National Capital Territory (NCT) Delhi and the Union administration have taken some steps to contain the PM levels and smoke. The 2025 surge seeks a better understanding of the reasons and trends. This study is an assessment and analysis of the various factors that have contributed to the increase in particulate matter and smog levels. This study is a comprehensive assessment of the air pollution trends, and the data has been captured from the Central Pollution Control Board Database. On the basis of the results, some recommendations have been provided with scientific outputs.

The present study aims to comprehend the AQI data of pre- and post-Diwali days to understand the root cause and compare the average AQI with previous years during Diwali in Delhi. The objective of this study is to understand the contribution of major sources like stubble burning and crackers and evaluate if existing mitigation measures are keeping pace with the current alarming situation.

Fig. 1: Map showing location of 16 sampling sites taken for the study

Methodology

The present study was carried out in the National Capital Territory of Delhi. The study captures the variation in air quality by considering 16 monitoring stations across East, West, North, and South Delhi (Fig. 1), ensuring balanced spatial coverage of the city. Major air quality parameters studied included PM2.5, PM10, NO_2, SO_2, CO, and the overall Air Quality Index (AQI). To understand the effect on the levels of particulate matter, meteorological factors such as temperature, wind velocity, and relative humidity were also considered. The data for all the parameters and factors mentioned were taken directly from the Central Pollution Control Board (CPCB) database for the month of Diwali (15 days pre- and post-Diwali) in 2025. Satellite-based fire counts were also analysed to study the contribution of stubble burning, obtained from the Consortium for Research on Agroecosystem Monitoring and Modelling from Space (CREAMS).

The analysis and visualization of the collected data were done using the statistical software R. Inter-annual variability in air quality and stubble burning trends were assessed using descriptive statistical techniques such as percentage change analysis and year-to-year comparison of AQI. In contrast, temporal trends were examined through time-series plots. Visual tools like line graphs, bar charts, etc., helped in illustrating the patterns through the collected data that the study aimed to observe. All the parameters mentioned were studied and visualized to understand the pattern for deteriorating air quality and find quality control measures.

In addition to this, student attendance records from the

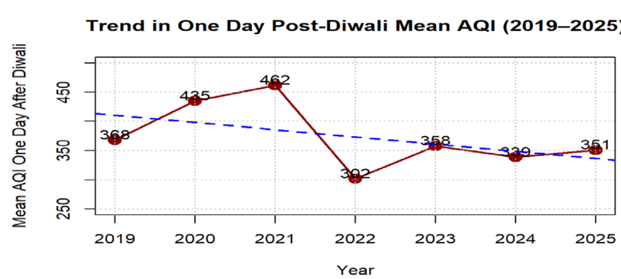

Fig. 2: Mean AQI one day post-Diwali from 2019 to 2025

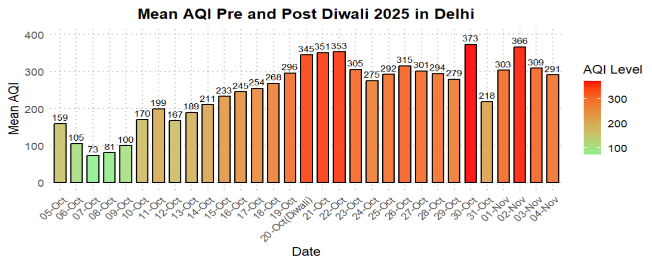

Fig. 3: Overall trend of mean AQI pre and post Diwali 2025

website of the Directorate of Education, Delhi, were also studied across the four regions of Delhi over a period of 3 months, with Diwali in between. The statistics reflected no significant absenteeism due to pollution around Diwali in Delhi schools.

16 major stations grouped by region (North, South, East, and West) are used for analysis (Fig. 1). The map is plotted using Google My Maps by importing latitude and longitude data of different stations generated in R.

Data Insights

AQI levels recorded post Diwali were analyzed over a seven-year period. Average AQI one day post-Diwali peaked in 2021 (468), indicating the worst air quality during the seven years (Fig. 2). The lowest AQI was observed in 2022 (302), making a substantial 34.6% reduction compared to 2021 - possibly due to stricter bans on firecrackers and favourable meteorological conditions. Despite year-to-year fluctuations, the trendline (blue dashed line) shows a gradual overall decline in one-day post-average AQI from 368 (2019) to 351 (2025). This suggests a moderate but consistent improvement in Delhi's AQI, considering a seven-year period from 2019 to 2025. From 2023-2025, the average AQI has stabilized near the mid-300 range, implying that while severe spikes have been controlled it still remains in the "very poor" category.

This year's air quality situation has been depicted during the days surrounding Diwali in Delhi (Fig. 3). The mean AQI 15 days pre and post Diwali 2025 was monitored and it was seen that the air quality deteriorated slowly as the festival approached. The mean AQI pre-Diwali before 19 October remained relatively moderate, ranging from 73 to 254. However, critical levels were reached when AQI values peaked between 345 and 373 around the festival from 19 October to 22 October, due to widespread firecracker combustion and meteorological conditions that hindered pollutant dispersion. In the post-Diwali phase, AQI values were observed to be around 270-373, showing a marginal decline but still remained in the "very poor" to "severe" category. This persistence suggests that calm winds and low mixing heights typical of late October did not affect the dispersion of particulate matter and gaseous pollutants accumulated in the lower atmosphere.

Over the period (2020-25), stubble burning incidents in Haryana and Punjab dropped by 95.85% and 96.15%, respectively, according to satellite-based fire counts obtained from the Consortium for Research on Agroecosystem Monitoring and Modelling from Space (CREAMS), ICAR, in the window from 15 September to 21 October. This shows that two core paddy-growing states have made significant progress in terms of limiting farm-fire events. Table 1 below clearly shows the year-wise variations for the same. In contrast, Uttar Pradesh recorded 660 incidents, which is nearly 37% higher than Punjab (415) this year over the same window, which suggests a shift in the pattern of crop-residue burning. It also underscores the significance of broadening policy attention beyond just the "Punjab-Haryana axis".

Results And Discussion

Delhi has a subtropical climate, and the air quality often deteriorates sharply during the post-monsoon season, particularly around Diwali, due to the combined effects of fireworks, unfavorable meteorological conditions, and local emissions. This year too, PM2.5 and PM10 levels started increasing days before Diwali and reached their peaks around Diwali only. Station-wise variations in different parameters have been shown (Fig. 4 and Fig. 5). The peaks for PM2.5 were observed to be 298 (Sonia Vihar), 385.68 (Punjabi Bagh), 290.25 (Nehru Nagar), and 353.13 (Ashok Vihar) while for PM10, it was 617.3 (Anand Vihar), 496.2 (Punjabi Bagh), 394.97 (Nehru Nagar), and 501.88 (Alipur) (as shown in Table 2). Awasthi et al. (2024) conducted in-situ source apportionment and chemical analyses during severe winter smog in 2022-23. Results indicated that nearly 45% of PM2.5 originated from biomass burning, while 60% of VOCs were produced by vehicular and industrial sources, intensifying secondary aerosol and ozone buildup. Total VOC levels climbed beyond 150 ppb at times of limited air dispersion, reflecting high pollutant buildup (Awasthi et al., 2024).

Ghosh et al. (2024) analysed air-pollution trends during the years 2019-2022 across major Indian cities, highlighting substantial elevation in PM2.5 and PM10 concentrations during and after Diwali, especially during covid year 2020. The study introduced a new quality assessment indicator referred to as HAQI (Health Hazard-based Air Quality Index). This captures the health risks more accurately than existing conventional air

Table 1: Year-wise Paddy Burning Incidents (2020-2025)

Haryana			*Punjab*	
Year	*No. of Incidents*	*Year-on-Year Variation*	*No. of Incidents*	*Year-on-Year Variation*
2020	1326	-	10791	-
2021	1367	3%	4327	-60%
2022	771	-44%	3114	-28%
2023	689	-11%	1764	-43%
2024	655	-5%	1510	-14%
2025	55	-92%	415	-73%

Table 2: Station wise max-min levels of different parameters

East-Delhi Stations

Anand Vihar Delhi - DPCC			*Patparganj Delhi - DPCC*	
Parameters	*Max*	*Min*	*Max*	*Min*
$PM^{2.5}$	253.04	30.38	255.12	20.59
PM^{10}	617.3	60.38	423	49.18
Humidity	79.1	55.13	83.6	62.28
Temperature	27.1	23.27	29.14	25.14
Wind Speed	0.79	0.3	1.31	0.3
Sonia Vihar Delhi - DPCC			Vivek Vihar Delhi - DPCC	
Parameters	Max	Min	Max	Min
$PM^{2.5}$	298	26.4	272.33	28.15
PM^{10}	353.09	46.62	387.44	50.64
Humidity	83.67	67.25	75.77	55.52
Temperature	30.45	24.82	29.71	25.91
Wind Speed	1.53	0.3	1.75	0.54

West-Delhi Stations

Dwarka-Sector 8 Delhi - DPCC			*Mundka Delhi*	
Parameters	*Max*	*Min*	*Max*	*Min*
$PM^{2.5}$	255.06	17.08	269.2	17.83
PM^{10}	432.53	50.29	451.39	49.42
Humidity	85.46	61.23	82	58.88
Temperature	28.44	24.59	30.83	26.63
Wind Speed	0.96	0.43	1.46	0.47
Punjabi Bagh Delhi - DPCC			Shadipur Delhi - CPCB	
Parameters	Max	Min	Max	Min
$PM^{2.5}$	385.68	21.25	281.88	23.63
PM^{10}	496.2	47.87	413.76	39.9
Humidity	78.45	54.96	97.77	28.4
Temperature	31.8	19.7	31.8	19.7
Wind Speed	0.71	0.3	0.48	0.05

North-Delhi Stations

Alipur Delhi - DPCC			*Ashok Vihar Delhi - DPCC*	
Parameters	*Max*	*Min*	*Max*	*Min*
$PM^{2.5}$	267.38	23.54	353.13	28
PM^{10}	501.88	56.66	468.45	44.82
Humidity	78.43	58.95	82.05	61.74
Temperature	29.98	25.83	29.53	25.9
Wind Speed	199	1.9	2.28	0.48
Jahangirpuri Delhi DPCC			Narela Delhi DPCC	
Parameters	Max	Min	Max	Min
$PM^{2.5}$	325.36	30	257.34	23.99
PM^{10}	482.24	44.42	383.1	49.62
Humidity	88.2	83.1	81.02	59.57
Temperature	28.04	24.24	27.76	25.41
Wind Speed	1.99	1.9	0.64	0.3

South-Delhi Stations

Najafgarh Delhi DPCC			*Nehru Nagar Delhi DPCC*	
Parameters	*Max*	*Min*	*Max*	*Min*
$PM^{2.5}$	244.27	17.13	290.25	17.96
PM^{10}	26551	265.51	394.97	39.88
Humidity	89.35	61	64.39	44.95
Temperature	28.49	21.67	28.15	22.28
Wind Speed	0.78	0.4	0.9	0.3
Okhla Phase 2 Delhi DPCC			RK Puram Delhi DPCC	
Parameters	Max	Min	Max	Min
$PM^{2.5}$	282.98	16.07	281.02	24.24
PM^{10}	370.53	49.41	372.06	41.56
Humidity	81.18	54.6	87.29	63.4
Temperature	29.46	25.72	25.9	19.28
Wind Speed	0.89	0.3	0.71	0.35

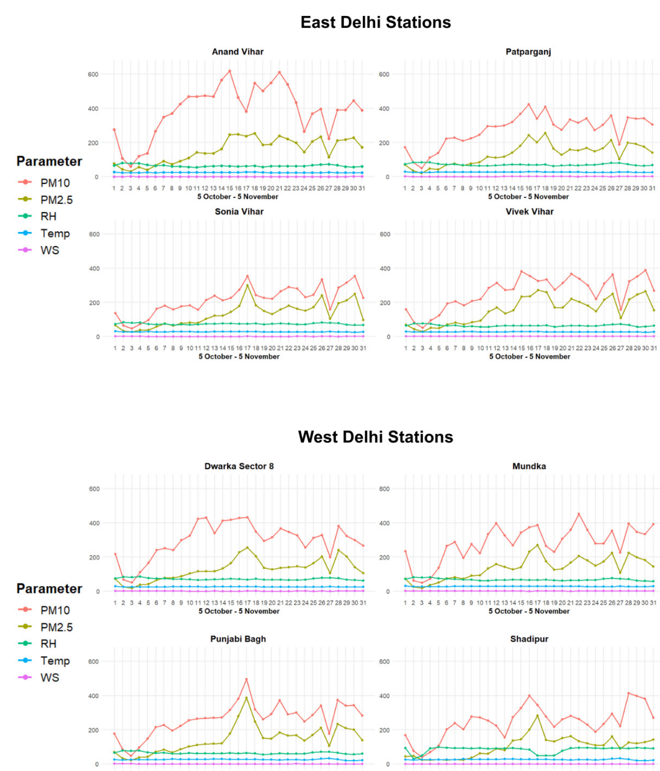

Fig. 4: Pollutants and weather conditions contributing to pollution 15 days pre and post Diwali 2025 in East and West Delhi stations

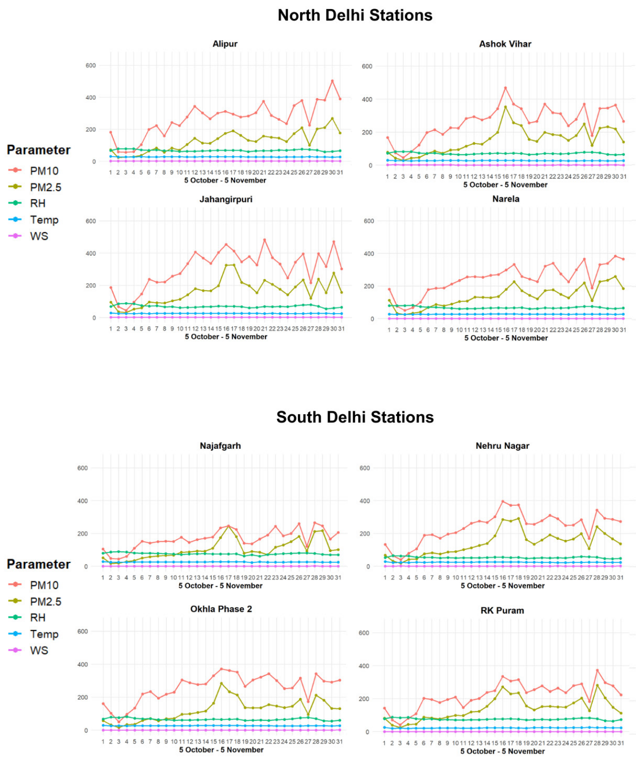

Fig. 5: Pollutants and weather conditions contributing to pollution 15 days pre- and post Diwali 2025 in North and South Delhi stations

quality assessment parameters presently in use, such as AQI. It has been observed that diseases caused by deteriorating air quality increased in urban centres, including Delhi, suggesting the need for novel innovative strategies to mitigate and control the pollution levels (Ghosh et al., 2024). Pal et al. (2023) performed a spatial analysis of air quality during the Diwali festival from 2017 to 2021. Researchers compared the air quality during the pandemic (2020-21) and compared that to the quality of air during the non-pandemic years (2017-19). This study found that anthropogenic activities enhanced the pollution levels and when humans were mostly indoors, the air quality improved. Air quality not only varies with human activity but also with the timing of festival occurrence in October versus November last year which notably influenced dispersion of pollutants depending on temperature, wind speed and mixing height. It was observed that in November 2020, when winter was stagnant, increased stubble burning coincided with the air poor and very poor category of AQI (Pal et al., 2023).

A decadal perspective from 2014-24 on air quality was provided by Tewari & Jindal (2025), who suggested that despite various policy interventions, Delhi's Mean AQI remained in the "very poor" category. Crop-residue burning in Punjab/ Haryana has been implicated as a major cause of Delhi's severe air pollution and health issues (Saxena et al., 2021). This year, however, even after a drastic drop in stubble burning in these states, no major improvement in the air quality was observed. The study suggested vehicular emissions, industrial activities, and population growth as dominant contributors to low air quality standards (Tewari & Jindal, 2025). The decade-long span gives a temporal perspective that highlights how previously dominant sources may decline while others rise. This is important as it calls for a dynamic policy despite government intervention. In 2025, the Government launched various mitigation plans, and the Supreme Court allowed green crackers to burst during festival time to respect the sentiments of the students. However, lifting the ban on crackers and allowing the burning of green crackers does not seem to improve the situation. Green crackers manufactured in and around Delhi have also been found to emit pollutants (Times of India, 2025). This year, Diwali was celebrated on 20 October, 2025. The average AQI in Delhi before Diwali was 183 and after Diwali was 308, showing a huge jump. Garg and Singh (2022) found that during winter, PM2.5 concentrations exceeded 250 (4 times the permissible 60 limit), after analyzing the CPCB data from the years 2015-2021. About 39% of total emissions were observed from vehicles, 23% by industries and 18% by biomass burning. Despite cracker bans and "odd-even" schemes, AQI values remained in the "very poor" range (320-360), suggesting that short-term benefits can be seen through fragmented interventions (Garg & Singh, 2022). This is also true for this year's PM trends in Delhi, as small interventions such as water sprays and vehicular exhaust reduction have only been able to offer temporary relief. Furthermore, Kumar and Foster (2009) analysed daily PM10 and NO2 data (1996-2007) as well as spatial meteorological parameters. It was shown by their GIS (Geographical Information Systems) assessment that PM10 levels dropped by 15-20% in central Delhi but rose again in suburban areas due to cross-boundary transport and industrial relocation after the 2001 CNG (Compressed Natural Gas) transition. Strong pollutant diffusion between neighboring districts was indicated by the correlation coefficients (Kumar & Foster, 2009). This suggests that besides the ambient pollutant levels, there are a plethora of factors, including meteorological parameters, human activities and regional microclimatic factors. Steps such as odd-even practices also reported a surge in vehicles in households, calling for yet another debate. Sharma and Kumar (2025) analysed 15 years of CPCB monitoring data to evaluate temporal changes in fine particulate concentrations using regression and time-series models. Their results indicated an annual decline of about 1.8% in PM2.5 levels post 2019 due to BS-VI vehicle norms and cleaner fuel policies. However, WHO standards were exceeded by over 16 times due to mean winter concentrations (165-190) (Sharma & Kumar, 2025). Interestingly, Delhi is also a market hub with major centres and mandis where agricultural and horticultural produce is coming in through trucks and vehicles running on diesel (Times of India, 2024). Sahu, Beig, and Parkhi (2015) took the 2010-2011 data from vehicular, industrial, and domestic sectors and developed a 1 km X 1 km gridded emission inventory. Total emission was 170 Gg/yr of NOx and 990 Gg/yr of CO, alongside traffic, which contributed to nearly 56% of NOx and 80% of CO loads. Emission hotspots were found along major transport corridors and industrial clusters using spatial mapping (Sahu et al., 2015).

Balyan et al. (2018) reviewed over 40 papers on air pollution and exposure-based studies on air pollution and health outcomes in Delhi. They observed a consistent association between PM2.5 and PM10 concentrations and increased respiratory ailments (28-35%), cardiovascular hospitalizations

(20-25%), and asthma exacerbation. Exposure to PM2.5 above 150 was seen to impact vital lung capacity and performance.

Yadav et al. (2020) studied Σ_{16}PAH concentrations that ranged from 122 to 245 ng/m^3, with winter levels nearly three times higher than in monsoon months. Vehicular emissions and biomass burning were found to be the dominant contributors. Delhi residents face significant long-term cancer risks due to persistent exposure to these particulates (Yadav et al., 2020). This has affected the children and elderly more as they are most vulnerable (Balietti et al., 2022). Reports of increased absenteeism on account of chest and lung infections have been found to be increasing (IQAir, 2022). It is therefore important to monitor air quality during the Diwali season and understand the trends so that there is more preparedness. However, there is a lack of well-curated information that can help in designing mitigation measures.

Conclusion

Delhi's post-Diwali air quality has shown slight improvement and greater stability since 2019, yet it continues to remain quite below healthy standards. This year, post Diwali, the Punjabi Bagh area showed the highest PM$^{2.5}$ levels, followed by Ashok Vihar, whereas PM^{10} peaked in Anand Vihar. All the stations showed air to be of poor quality with slight changes at peak periods. While the Delhi government planned to implement a lot of strategies, such as promoting electric mobility (EV vehicles and policies), cloud seeding, sprinkling water to curb dust, limiting biomass burning, management of construction and demolition waste, and abating industrial pollution under their Air Pollution Mitigation Plan 2025, several shortcomings persisted. It was expected that cloud seeding would decrease the pollution levels this year, but it was not successful due to the lack of moisture in clouds. Lifting the ban on green crackers needed to be better implemented, as many crackers were burnt, thinking that these are zero-polluting. This, however, is not true as they were found to be emitting the same pollutants responsible for deteriorating air quality. Water sprayers or anti-smog guns were used to suppress the dust and pollutant particles under the "Pollution Control and Emergency Measures" project by the Government, but that was also not effective, as there was no significant reduction in PM^{10} or PM$^{2.5}$ levels in the data provided by CPCB. This year, the stubble burning was comparatively lower in Punjab and Haryana than in the previous years, but a major change in trend was observed in Uttar Pradesh. It is increasingly becoming clear that for achieving improved air quality, a single tailor-made solution will not work. Despite all these preventive measures, the main reason behind the accumulation of pollutants after Diwali may be associated with the weather conditions, as the wind speed became very low, due to which the dispersal of pollutants in the air may have stopped, leading to the aggravation of the problem. It is therefore important to monitor the pollutants at various places and account for microclimatic variables as well while planning any strategies. Besides, the use of scrubbers, dust traps, plantation of trees, climbers and shrubs that have the ability to clean the air and trap the dust can be other suggested alternatives. An interdisciplinary approach using the knowledge of weather fluctuations, mathematical modelling of the data and predicting the surges using the data may help in preparedness to handle the problem.

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Author's Contributions

JB, RB and MK designed the work and guided the students. Disha and Pawni worked on data collection, data curation and analysis. Pawni and Disha worked on the first draft. MK, JB and RB revised the manuscript. All the authors contributed equally in completing the work.

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