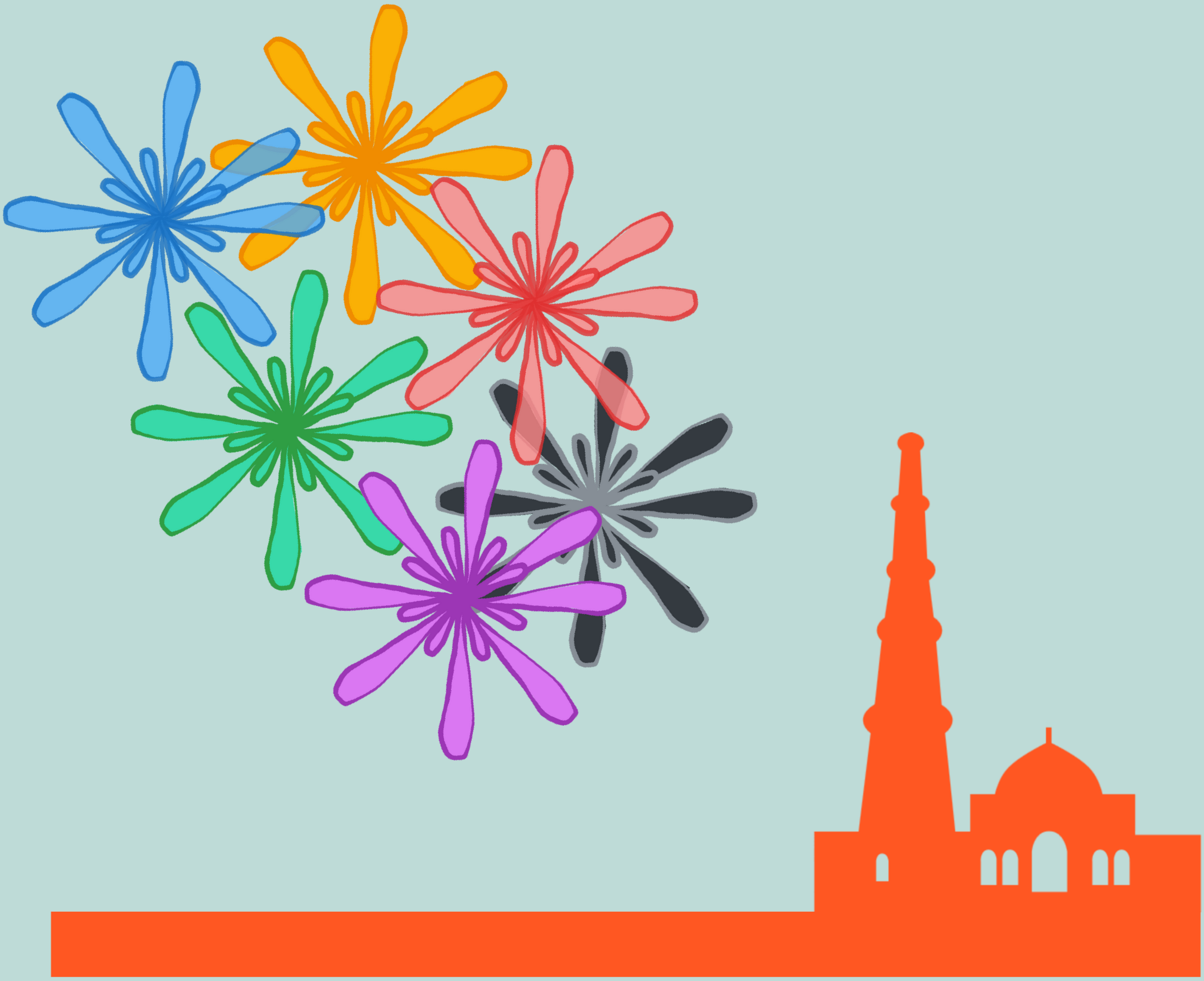
# Understanding Delhi's Diwali Emission Loads



URBAN emissions .info

Sarath Guttikunda

SIM-air working paper series # 54-2024

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- Sharing knowledge on air pollution
- Providing science-based air quality analysis
- Promoting advocacy and raising awareness on air quality management
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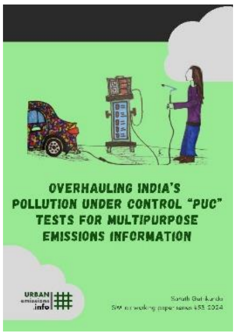

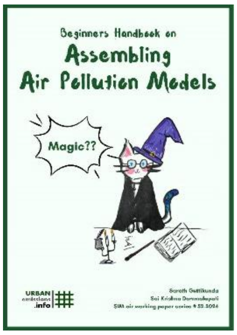

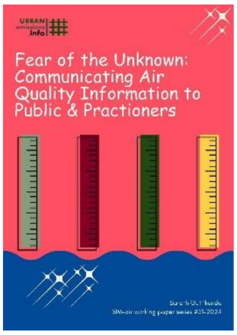

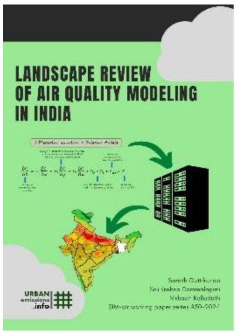

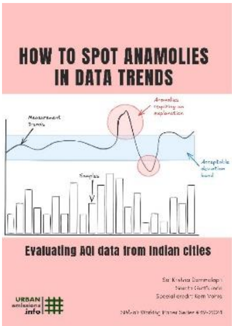


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# Disclaimer



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# List of Abbreviations

| | |
|---|---|
| AQM | Air Quality Management |
| CNG | Compressed Natural Gas |
| CPCB | Central Pollution Control Board |
| FIFA | Federation Internationale de Football Association |
| GRAP | Graded Response Action Plan |
| IGP | Indo-Gangetic Plain |
| NCR | National Capital Region |
| PESO | Petroleum and Explosives Safety Organization |
| PIL | Public Interest Litigation |

# Abstract

Air pollution in Indian cities is an escalating issue, with episodic events like Diwali intensifying seasonal pollution spikes. Despite judicial interventions aimed at limiting firecracker use, the volume of fireworks burst during Diwali remains high, contributing to hazardous short-term pollution episodes.

In Delhi, where approximately 5 million kilograms of fireworks—about 30% of the national total—are used, air quality levels average around 800 μg/m$^3$, with peaks exceeding 2000 μg/m$^3$ during Diwali. Emissions on Diwali day can account for up to 30% of daily totals, and during peak hours, these loads can surge to 90% in certain areas. Modeling studies using the WRF-CAMx system have confirmed the severe impact of firecracker emissions on Delhi's air quality, highlighting the associated health risks for the city's population.

The current approach of banning the sale of fireworks within Delhi but not extending the restriction to the entire NCR has proven ineffective. Bans that restrict both the sale and bursting of fireworks on paper, without adequate support for enforcement, are destined to fail. Without consistent enforcement and regional coordination, such measures are unlikely to yield significant reductions in firecracker usage or air pollution, leaving Delhi's air quality vulnerable to the same seasonal spikes year after year.

Recently introduced "green crackers" have been promoted as a less polluting alternative, though they have faced criticism as emissions remain comparable to conventional fireworks. Firecracker usage has likely doubled post-COVID, exacerbating air quality issues as larger celebrations resume.

These trends underscore the need for more effective regulatory measures and public awareness to address the significant health risks posed by pollutants from Diwali fireworks, especially among vulnerable populations in already pollution-stressed urban areas.

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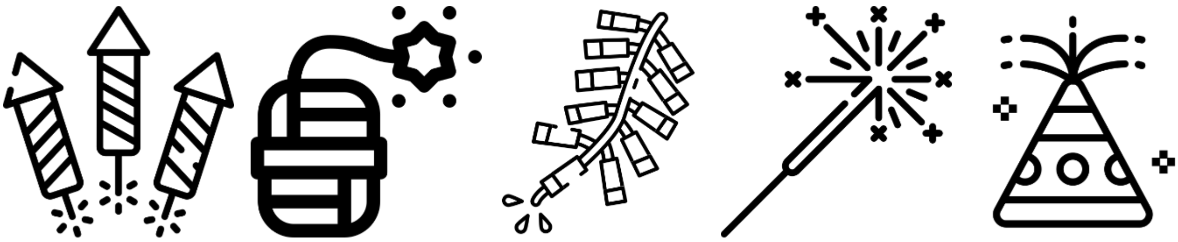
# 1. Diwali and Fireworks

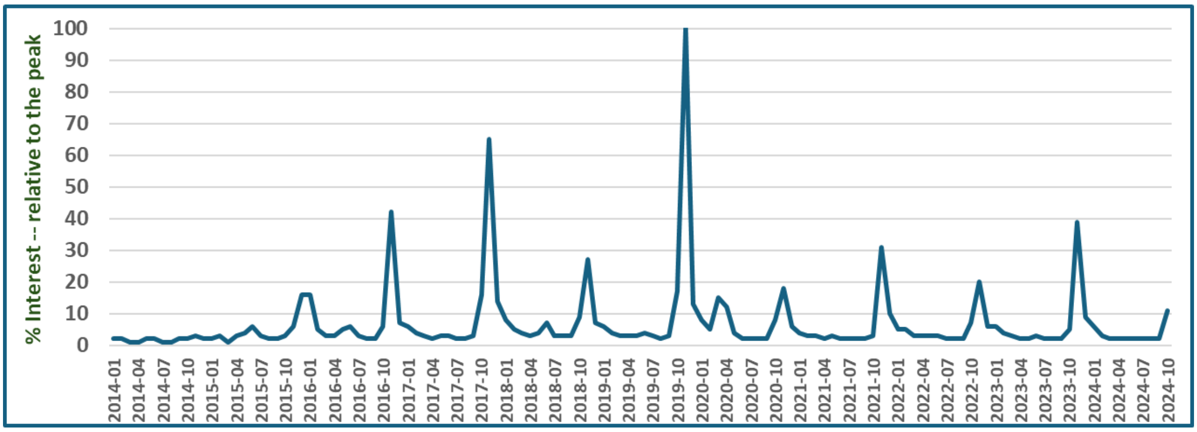
Fireworks are widely associated with celebrations worldwide, marking significant events and occasions across cultures. From global New Year's festivities to China's Spring Festival, India's Diwali, and the Fourth of July in the United States, fireworks are a central element of celebration. They are also an integral part of major ceremonies, especially at prominent international sports events. For instance, the Olympic Games, Commonwealth Games, Asian Games, and FIFA World Cup often open and close with dazzling firework displays, symbolizing unity and excitement. Additionally, national holidays and important anniversaries worldwide are marked by fireworks displays, driven by socio-cultural traditions and the communal joy that they bring to these moments.

In India, fireworks play a prominent role in the Hindu festival of Diwali, the Festival of Lights, typically celebrated in October or November each year. Diwali is also celebrated beyond India in countries like Malaysia, Fiji, Nepal, Sri Lanka, and Thailand. During Diwali, popular firecrackers include both color and light-emitting types, such as the "anar" (flowerpot/flare fountain), "chakra" (wheel/ground spinner), cobra eggs (snake pellets), "phuljadi" or pencil (sparklers), and (whistling) rockets. Sound-emitting crackers, such as garland crackers and string bombs, are also commonly used, as classified by the Petroleum and Explosives Safety Organization (PESO).



With the sparkles of fireworks comes a surge in air pollution, as these displays release fine particulate matter, heavy metals, and other harmful pollutants into the atmosphere. Since the onset of ambient air quality monitoring, Diwali in India has consistently triggered pollution alarms, with pollution levels often exceeding safe limits during the festival. This trend is not unique to India; similar spikes in pollution are observed in other countries during large celebrations that feature fireworks, such as New Year's Eve and national festivals. In recent years, however, there has been a shift towards using drone light shows to create dazzling displays without the environmental impact. Most recently, China has embraced this alternative during its nationwide Chinese New Year celebrations, showcasing how technology can offer a cleaner way to celebrate while preserving the visual grandeur of traditional fireworks displays. In India, each family celebrates Diwali independently with their immediate members. As a result, the concept of a single, large fireworks display for the entire community has not yet become a common practice.

The Diwali event and the seasonal rise in pollution levels following Diwali has also sparked a surge in public interest and discourse on air quality in Delhi and across India. This heightened attention is evident in the volume of media articles, social media posts, interviews, webinars, and workshops held each year. Discussions cover a broad range of topics, from identifying sources of air pollution and exploring ways to reduce the intensity of Diwali fireworks, to raising overall awareness about air quality. Unfortunately, however, much of this interest tends to fade within three to four weeks after Diwali, even though winter pollution levels remain severe for reasons beyond Diwali or post-harvest field fires. As a result, critical issues related to sustained air quality management often lose focus just as the peak of winter pollution begins.




Data extracted from https://trends.google.com for the topic "Delhi air pollution". The graph shows % interest in the topic based on the number of searches from India. The Y-axis is scaled 0 to 100, with 100 marked for the month with the highest number of searches and other months scaled to the peak.

The onset of winter in India is marked by a thick haze spreading across the Indo-Gangetic Plain (IGP), a seasonal phenomenon that often begins with Diwali fireworks. Pollution levels during the first week of November 2016 reached unprecedented heights, the highest recorded since continuous monitoring stations became operational in Delhi's National Capital Region (NCR) (Guttikunda et al., 2023). Anecdotally, these levels were said to be the worst in 20 years, reminiscent of the pre-CNG (compressed natural gas) days when most public and para-transit systems relied on diesel. The years following 2016, experienced more public awareness activities during this period (pre- and post-Diwali), with the interest in the topic of Delhi's air pollution peaking in 2019. This doesn't mean air pollution in Delhi got better after 2019 (Guttikunda et al., 2023).

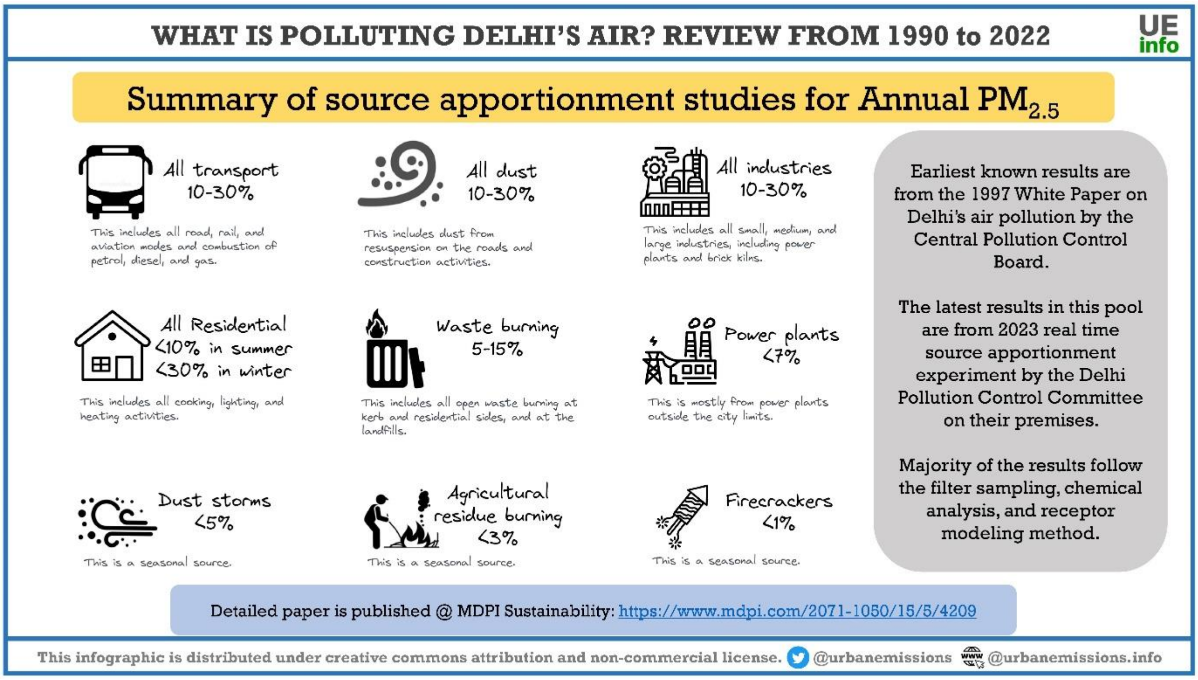
Although the 2016 episode was particularly severe and led to new interventions to address pollution, this issue extends beyond Delhi. Winter air pollution across IGP typically intensifies from late October to late March, driven by a combination of increased emissions from open field fires after harvest, higher heating demand as temperatures drop, and stagnant meteorological conditions, including low temperatures, slow-moving winds, and low mixing heights. Despite the severity and seasonal predictability of these conditions, an organized action plan to effectively control pollution in the region remains limited. While the Graded Response Action Plan (GRAP) has been introduced, its impact has yet to bring substantial relief across the region.

From both an emissions load and exposure perspective, Diwali represents a peak period and a significant event warranting further study. In this working paper, we analyzed the pollution profiles during Diwali in Delhi, focusing on how the festival contributes to seasonal peaks in emissions and heightened public exposure. We also examined how judicial interventions have played a role in raising awareness about air quality impacts associated with Diwali, leading to increased public discourse on air pollution in Delhi. Followed by a detailed comparison of emission loads on Diwali versus non-Diwali days, supported by modeled results to substantiate our emission estimates and understanding of the festival's impact on air quality.

While the study is specific to Delhi, this methodology offers a replicable approach for other cities seeking to quantify and understand the episodic influence of large-scale events like Diwali. This comparative framework is intended to serve as a resource for policymakers and researchers, contributing to the broader dialogue on targeted strategies for pollution management.

# 2. Air Pollution During Delhi's Diwali

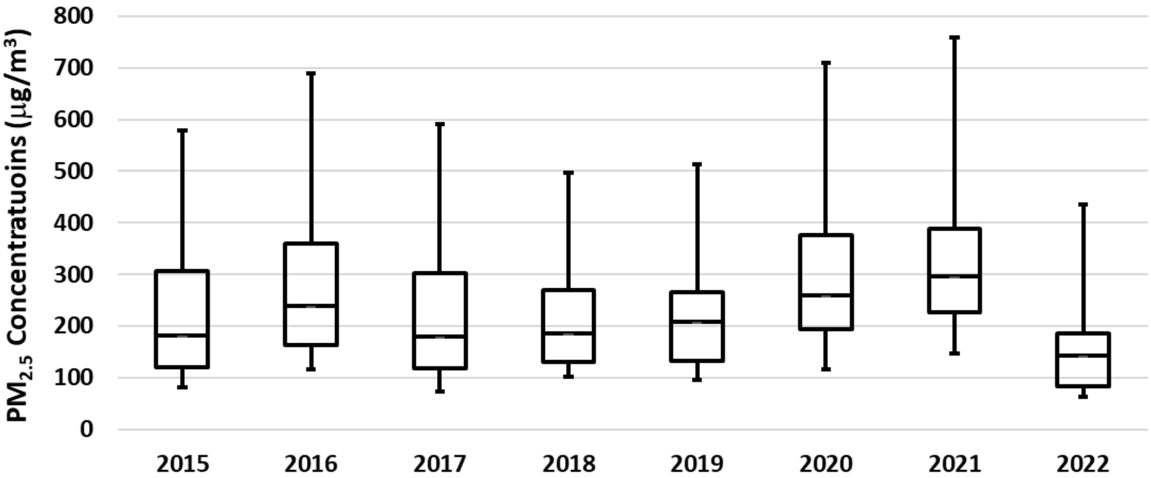
Delhi's air quality is among the most extensively studied for emissions and source apportionment (Adhikary et al., 2021; Guttikunda et al., 2023; Patel et al., 2022). There is also a consensus on the contributions of specific sources to observed particulate matter (PM) levels, based on several source apportionment studies.



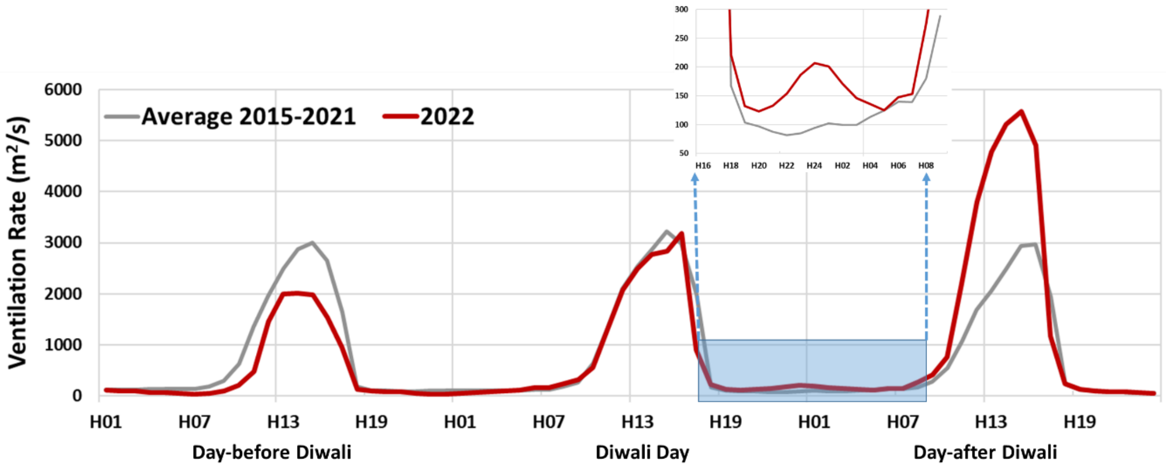

Common sources identified in previous studies include vehicle exhaust, domestic cooking and heating (using biomass, coal, and kerosene), road dust (from traffic, construction, and wind erosion), coal combustion from power generation and industrial units, diesel emissions from in-situ generator sets, waste burning, and open field burning at the onset of winter. Several ongoing studies are refining these estimates.

Numerous studies have specifically examined air quality during Delhi's Diwali (Ammasi Krishnan et al., 2020; Chauhan & Singh, 2017; Ganguly, 2015; Mushtaq et al., 2024; Pervez et al., 2016; Peshin et al., 2017; Rajagopal et al., 2024; Sateesh et al., 2018; Sati & Mohan, 2014; Shivani et al., 2018; S. Yadav et al., 2022; S. K. Yadav et al., 2022). These studies consistently demonstrate a severalfold increase in $PM_{10}$ and $PM_{2.5}$ concentrations, reporting peak concentrations crossing 2000 $\mu g/m^3$. These extreme pollution levels result in short-term exposure episodes. This is particularly concerning as these elevated concentrations contain high levels of heavy metals, such as barium (Ba), copper (Cu), strontium (Sr), and potassium (K).

The figure below summarizes all-station hourly average $PM_{2.5}$ concentrations as ranges for two days (Diwali day and the day after) between 2016 and 2022. During this period, the Supreme Court issued intermittent bans on the sale of firecrackers in Delhi (but not across the entire NCR, as detailed in the following section). However, the impact on overall median and peak pollution concentrations was limited. The peaks correspond to the hours of firecracker burning on Diwali night, spanning both days. While these peaks last only a few hours over 2–3 days, the total emissions load and the resulting severity of concentrations are significantly higher than on any other days of the year, leading to numerous acute exposure incidents and respiratory cases (Liu et al., 2019).




Data is extracted from archives maintained by https://www.earthmetry.com and the raw ambient monitoring data is from CPCB's national ambient monitoring programme. This figure is a summary of hourly data from all the stations operating in Delhi, one day before and one day after Diwali in these years. This figure is also discussed in "What is polluting Delhi's Air: A review from 1990 to 2022" (Guttikunda et al., 2023)




Ventilation rate is a product of wind-speed (m/s) and mixing height (m) – an indicator of vertical mixing and horizontal dispersion of the emissions. A higher number means more diffusivity for the emissions and less ambient concentration. The meteorological data is from ERA5 reanalysis fields and extracted from archives maintained by https://www.earthmetry.com. This figure is also discussed in "What is polluting Delhi's Air: A review from 1990 to 2022" (Guttikunda et al., 2023)

Between 2015 and 2022, the peak and average pollution levels recorded in 2022 were the lowest observed. A blanket ban on firecracker bursting was issued in 2022; however, numerous reports of noncompliance were registered across the city. Despite these violations, pollution levels remained low in 2022 Diwali period due to two key factors: (a) favorable meteorological conditions on Diwali night and the following day and (b) the timing of Diwali in 2022, which occurred at least a week before post-harvest fires began in Punjab and Haryana. Ventilation rates during this period were at least double those of previous years, resulting in nearly halved net concentrations.

While awareness of the health impacts from firecracker emissions has increased, without a clear and consistent action plan, this issue is likely to recur annually, with mitigation heavily reliant on favorable natural conditions.

At the time of this working paper, a similar ban has been issued for 2024, prohibiting the sale and bursting of firecrackers within Delhi, though this restriction does not extend to the entire NCR. Notably, in 2024, Diwali will again occur before the peak of post-harvest fires in Punjab and Haryana.

# 3. Judicial Interventions

This section is extracted from (Guttikunda et al., 2023)

The Supreme Court of India, primarily driven by public interest litigations (PILs) filed by concerned citizens, has repeatedly intervened to initiate new measures or expedite existing ones to support Delhi's air quality management. These actions, though encroaching upon the responsibilities of the elected executive and Parliament, reflect the Court's response to what it perceives as institutional apathy towards Delhi's deteriorating air quality. The Court's authority to intervene in such matters is supported by a landmark interpretation in M.C. Mehta vs. Union of India (1986), which recognized the right to clean air under Article 21 of the Indian Constitution (Dutta, 2018; Ghosh, 2018; Supreme-Court, 2017, 2018, 2019).

Through this legal foundation, the Supreme Court has issued several landmark judgments that have reshaped Delhi's regulatory framework, introducing significant policy interventions to improve air quality. However, the Court's wide-reaching actions have at times led to ad hoc and unscientific measures that may lack long-term efficacy. One such PIL is on firecrackers.


In 2015, three toddlers filed a public interest litigation at the Supreme Court, seeking a complete ban on the sale of fireworks in the period leading up to and during Diwali. While the Court acknowledged the health risks to children and vulnerable populations, it declined the request, stating that a ban would only be considered if sufficient evidence demonstrated fireworks as a major pollutant during the festive season. Instead, the Court directed the government and educational institutions to raise awareness of the harmful effects of fireworks and the pollution they cause (Supreme-Court, 2015).

In 2016, the Court again avoided a complete ban, opting instead to halve the number of licensed firework sellers in the region. However, this measure had little impact, as air quality spiked to critical levels in late October, prompting the Court to impose a temporary sales ban on November 11 (Supreme-Court, 2016a, 2016b).

In subsequent directives, the Court requested a report from the Central Pollution Control Board (CPCB) on harmful chemicals in fireworks and instructed the PESO to explore the production of “green” fireworks, designed to emit 30–35% less pollution. The Court later restricted sales to approved green fireworks and mandated a two-hour window for burning them on Diwali. Despite these efforts, compliance remained low, eventually leading to a complete ban on the sale of fireworks in Delhi in 2022, though enforcement challenges persisted (Supreme-Court, 2021).

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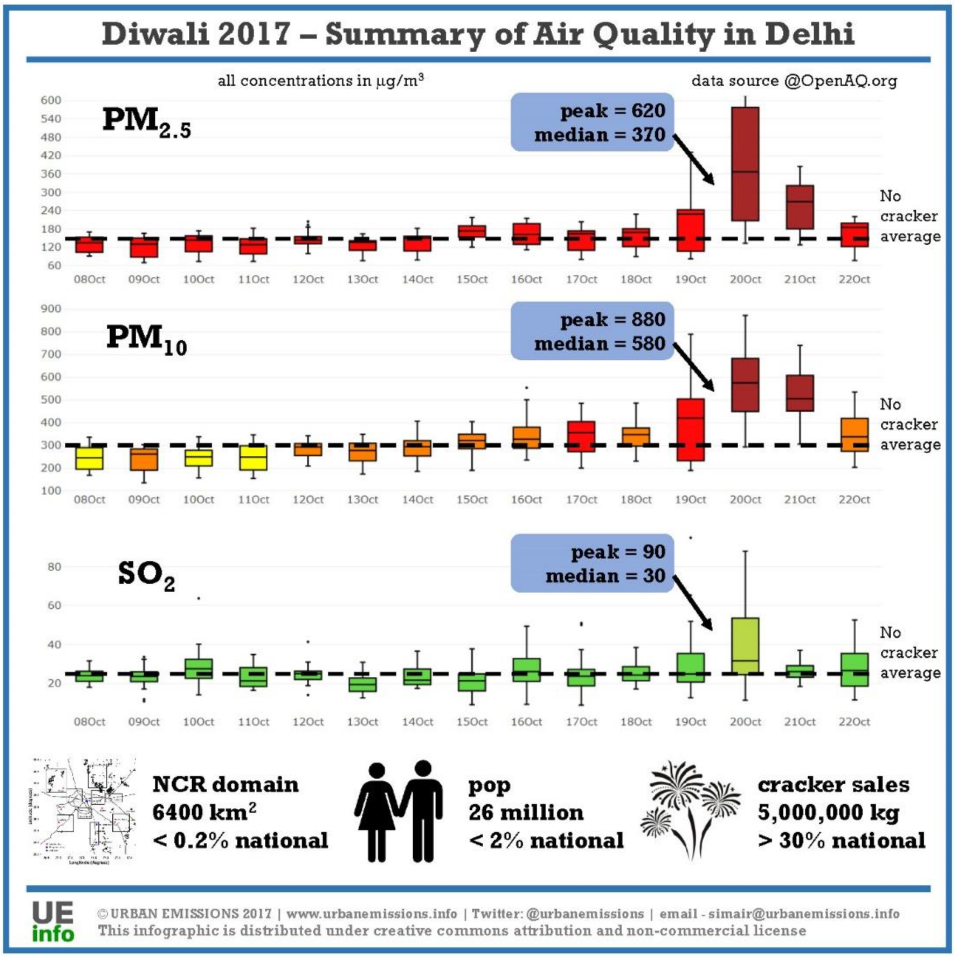
# 4. Delhi's Diwali Emission Loads

An important outcome of the judicial interventions was the disclosure of firecracker sales data for Delhi. Statements filed by firecracker manufacturers[1], distributors, and sellers in response to the 2016 ban by the Supreme Court revealed that **total firecracker sales in Delhi amounted to five million kilograms—approximately 30% of national sales**. This figure is concerning, given that Delhi's population comprises less than 2% of the national total and occupies just 0.2% of the country's land area.




This volume of firecracker sales and usage persisted in the following years, despite intermittent bans and various public awareness campaigns. The trend is evident in the concentration profiles presented in the previous section, which show consistently high pollution levels during Diwali. From a research perspective, this disclosure was a significant outcome of the PILs, as it provided

[1] The firecracker industry in India is substantial, valued at approximately ₹5,000–6,000 crore (around $600–700 million USD). Sivakasi in Tamil Nadu is the hub of firecracker production, producing over 90% of the country's fireworks. This industry provides direct and indirect employment to nearly 800,000 people at more than 1000 manufacturing units, primarily in Tamil Nadu, India.

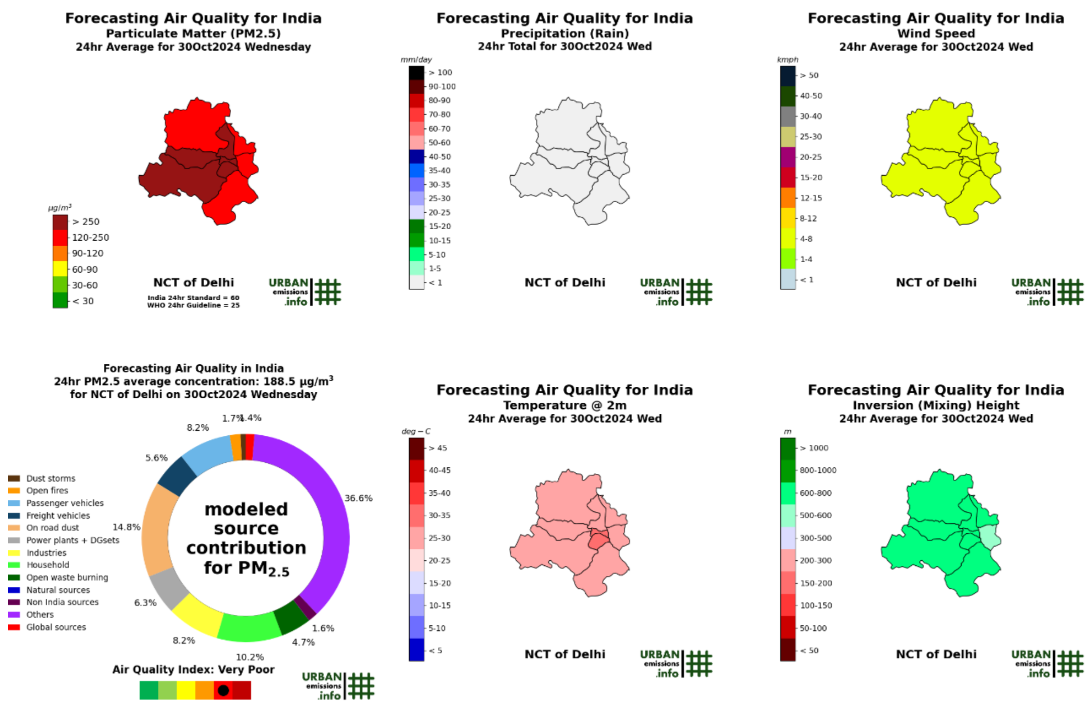
crucial data on the volume of firecrackers burst and the resulting emission load on Diwali night, enabling a better understanding of its impact on air quality.

**Delhi's Diurnal Emission Load on a Normal vs. Diwali Day**

The new information on the volume of fireworks burst in Delhi during Diwali enabled a comprehensive update to the city's emissions inventory. Using the established emissions inventory, already in place for pollution analysis and short-term forecasting at https://delhiairquality.info, we deconstructed the diurnal emission loads for a typical day and a Diwali day.

The emissions inventory for an average day is actively used in forecasting and is routinely evaluated against real-time monitoring data to maintain accuracy[2]. For operational purposes, the inventory is kept up to date through a combination of online and offline data sources. For Diwali, the new data on firecracker usage was critical for accurately modeling emissions and projecting pollution levels, with simulations run through the WRF-CAMx system.

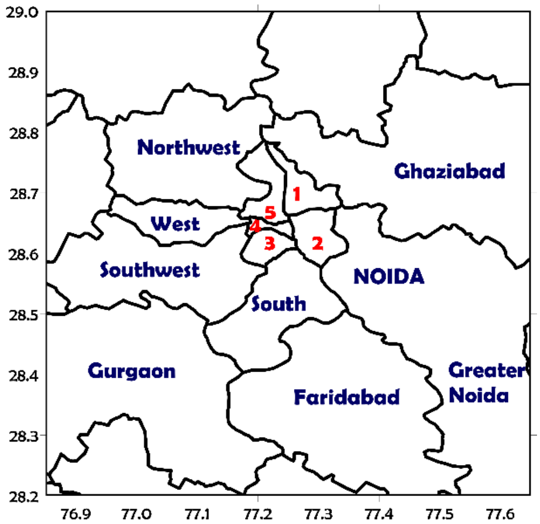
An example snapshot of the products from the forecasting system is presented below. This includes, at the district level – day-average PM2.5 concentrations source apportionment numbers, day-average meteorological fields for 2m-temperature, mixing height, and wind speeds (in the model surface layer), and day-total precipitation.




[2] For more information, refer to SIM-air working paper series #36-2011: Air quality forecasting system for cities – Modeling architecture for Delhi and SIM-air working paper series #38-2012: Multi-pollutant emissions inventory for the National Capital Region of Delhi @ https://urbanemissions.info/publications/working-papers and other publications @ https://urbanemissions.info/publications

Caution is advised when comparing the results presented below with any other emissions inventory for Delhi due to the following common differences. These distinctions highlight the importance of understanding underlying assumptions and methodologies in emissions inventories, as even slight variations can lead to substantial differences in subsequent interpretation of air quality impacts.

1. **Modeling Domain** for this analysis is distinct, covering an airshed of 80 x 80 grids (totaling 6,400 grid cells) with a spatial resolution of 0.01 degrees. This may differ significantly from the domain sizes and grid resolutions used in other inventories, potentially affecting localized emission patterns.




**1 = Northeast; 2 = East; 3 = New Delhi**
**4 = Central; 5 = North**

2. **Activity Data** employed in this inventory is unique to this study and reflects specific emission sources, types, and frequencies relevant to Delhi's context. Variations in activity data across inventories can lead to different emission load estimates for similar source categories.

3. **Emission Factors:** Our estimates are conservative, based on a vetted library of emission factors (a library of this is uploaded @ https://urbanemissions.info/tools). Other inventories may use alternative datasets, which will alter the calculated emission values, particularly for sources like vehicles, industry, and cooking.

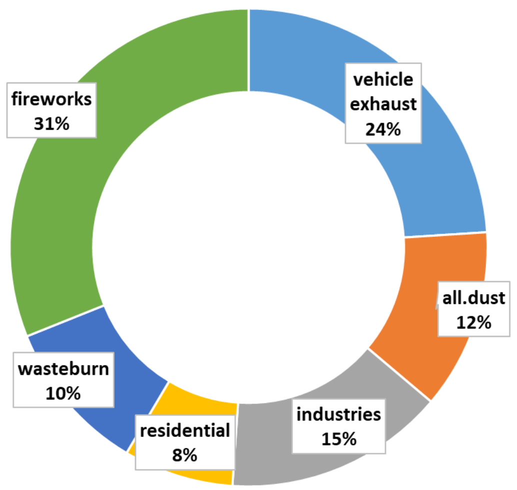
4. **Methodologies for Spatial Allocation**: The approach for spatially distributing activity data across the city may vary across inventories. We have employed a specific methodology for spatial allocation, which considers the unique distribution and density of source activities in Delhi, influencing emission concentration estimates in different areas.

5. **Temporal Time Frame**: The temporal framework of this analysis could differ from other studies. This inventory focuses on both diurnal and seasonal variations, aligning with real-time forecasting and episodic events such as Diwali. Different timeframes across studies may yield results that are not directly comparable.

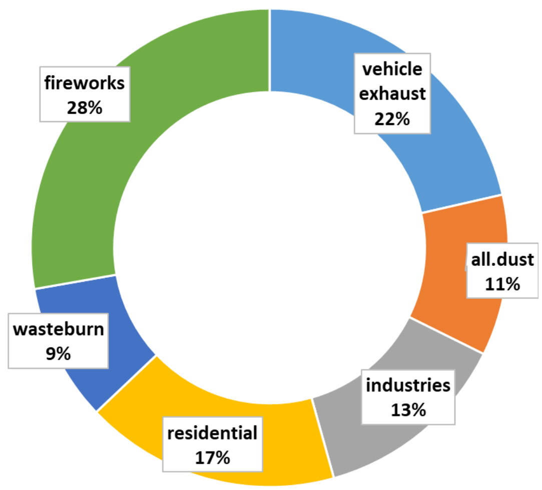
Please note that the presentation below represents only the emission loads from the defined airshed and does not include emissions from seasonal open post-harvest fires or the seasonal dust storms. Additionally, the graphs provided should not be interpreted as source apportionment for pollution or observed air concentrations.

Total $PM_{2.5}$ emission load for Delhi's airshed is calculated at 96,000 tons/year. For the volume of firecrackers burst during Diwali, will result in an estimated 150 tons of emissions, which is less than 0.1% of the annual total emissions. The graphs present four **different scenarios on a day basis** for comparison purposes.

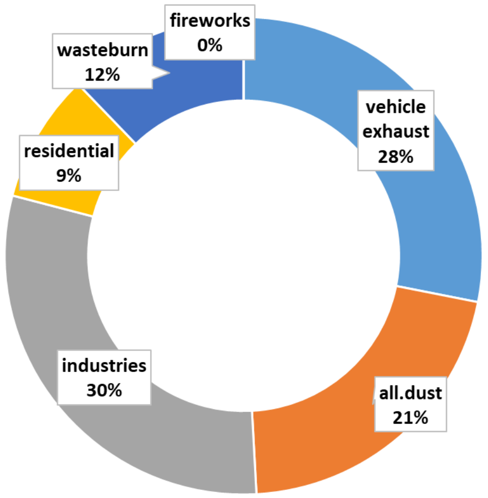
Diurnal share on a Diwali day without space heating demand activated



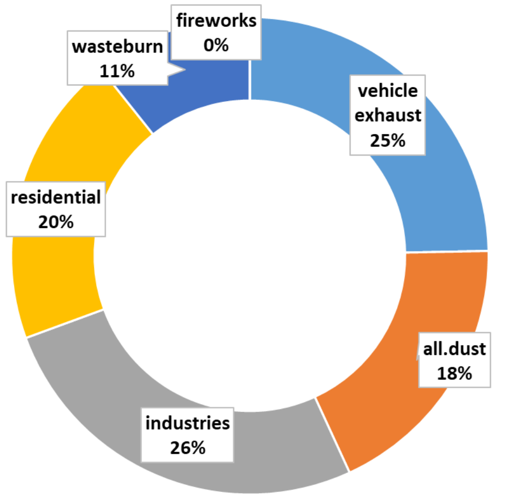

Diurnal share on a Diwali day with space heating demand activated




Diurnal share on a winter day without space heating demand activated




Diurnal share on a winter day with space heating demand activated



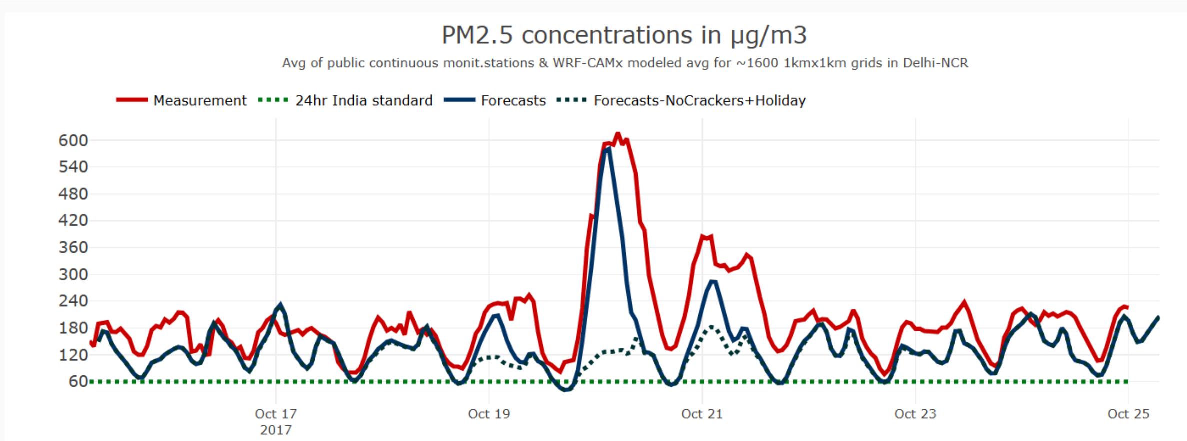

These shares represent the entire airshed, and the distribution for specific zones—whether urbanized or rural—will differ. In these areas, certain sectors may be more prominent, while others may be minimized or absent altogether.

Average emission factors used in gm/kg-fireworks are 0.045, 0.090, 0.001, 0.015, and 0.033 for $PM_{2.5}$, $PM_{10}$, $SO_2$, CO and VOC emissions, respectively.

### Validation of the Diwali emission loads

The diurnal emission loads were modeled using the WRF-CAMx meteorological and chemical transport modeling system. The comparison plot of modeled concentrations versus observed measurements, both with and without the estimated Diwali loads, confirms that Delhi's Diwali emissions are attributed to the combustion of five million kilograms of fireworks.

For Diwali 2017, we assumed three scenarios: (a) 100% of the stock would be burst, (b) 75% of the stock would be burst, and (c) 50% of the stock would be burst. The comparison of modeled data with monitoring data shows the closest match—within ±10%—when assuming a 100% stock burst scenario. The dotted forecast line represents a scenario where no firecrackers were used that week, projecting a 100% compliance with the ban and benefiting from reduced traffic due to the holiday.



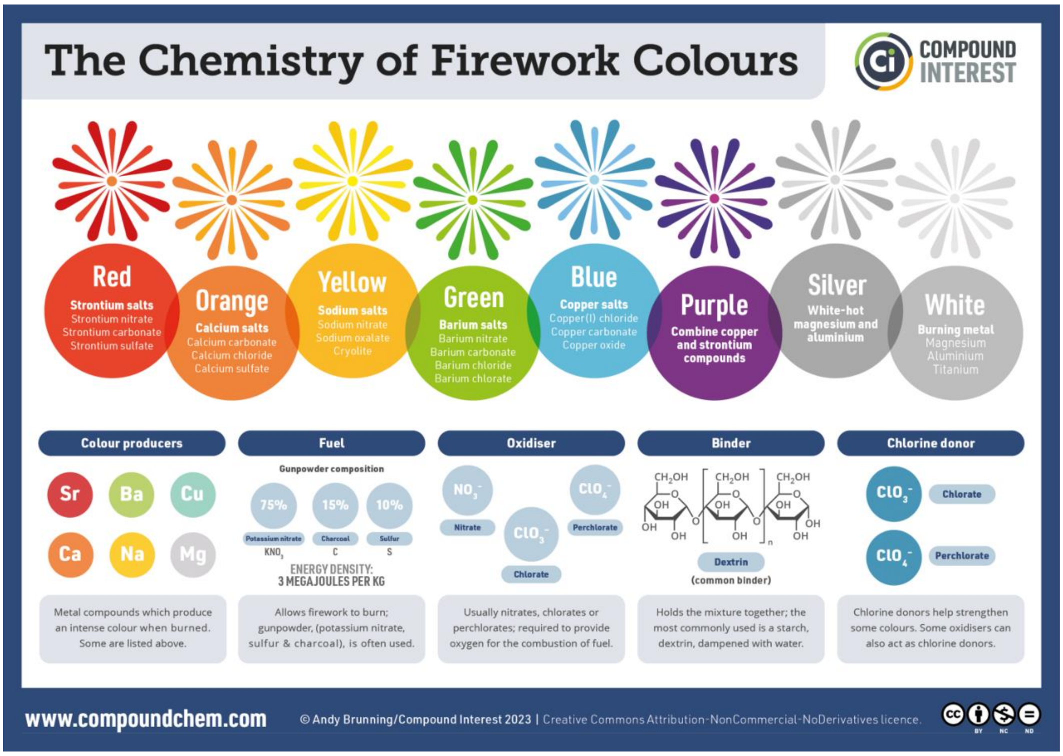

### Was the firecracker ban effective?

Reviewing data from all monitoring stations across Delhi, along with anecdotal evidence, suggests that the last-minute ban on firecracker sales—announced only two weeks before Diwali—did little to prevent their sale and use, possibly due to stockpiling prior to the ban. This is reflected in the significant pollution spikes corresponding to the estimated five million kilograms of firecrackers burned during Diwali week in 2017, indicating the ban's ineffectiveness.

Year after year, a version of this ban is announced, only to be widely violated. Even in 2020, amid the COVID-19 pandemic, anecdotal reports suggest that at least 60% of families across Delhi engaged in some form of fireworks bursting, underscoring the ongoing challenges in enforcing firecracker restrictions effectively.

# 5. In Retrospect

Air pollution in Indian cities is a serious and growing problem, with episodic events like Diwali exacerbating already high pollution levels. Despite continuous judicial interventions to curb firecracker use, the volume of fireworks burst during this single-day event remains substantial across major Indian cities, contributing significantly to seasonal pollution spikes, averaging at 800 µg/$m^3$ and peaking above 2000 µg/$m^3$.




Delhi leads in firecracker use, with an estimated 5 million kilograms burst during Diwali, representing 30% of the nation's total firecracker volume. On average, on Diwali day emissions account for 30% of the total daily emissions. However, on an hourly basis, during peak firecracker usage times—typically between 6 PM and midnight—emission loads can surge to as high as 90% in certain areas. Modeling studies using the WRF-CAMx meteorological and chemical transport system have validated the emission loads associated with this volume, demonstrating the severe impact of firecracker emissions on Delhi's air quality during the festival period.

The sheer volume of fireworks and the resulting emissions present an increasing health risk, as they contribute heavily to short-term pollution episodes. These high levels of particulate matter and toxic pollutants raise concerns, particularly for vulnerable populations, as health risks associated with Diwali emissions add to the already concerning air quality issues in Indian cities.

In recent years, "green crackers" were introduced as an alternative to traditional fireworks, purportedly to reduce pollution. However, this shift has been largely criticized as a form of greenwashing, as emissions from these so-called green crackers remain nearly as high as those from conventional fireworks. Data shows that the emission loads during Diwali have not improved significantly with their introduction. If anything, the overall volume of fireworks used has increased, potentially doubling post-COVID, as people return to larger celebrations. This growing usage exacerbates the air quality challenges, undermining efforts to reduce pollution through marginally cleaner options.

# 6. References


Adhikary, R., Patel, Z. B., Srivastava, T., Batra, N., Singh, M., Bhatia, U., & Guttikunda, S. (2021). Vartalaap: what drives# airquality discussions: politics, pollution or pseudo-science? *Proceedings of the ACM on Human-Computer Interaction*, *5*(CSCW1), 1-29.

Ammasi Krishnan, M., Devaraj, T., Velayutham, K., Perumal, V., & Subramanian, S. (2020). Statistical evaluation of PM2.5 and dissemination of PM2.5, SO2 and NO2 during Diwali at Chennai, India. *Natural Hazards*, *103*(3), 3847-3861. https://doi.org/10.1007/s11069-020-04149-8

Chauhan, A., & Singh, R. P. (2017). Poor air quality and dense haze/smog during 2016 in the indo-gangetic plains associated with the crop residue burning and diwali festival.

Dutta, R. (2018). *Twenty Years of EPCA: Lessons for the New EPCA*.

Ganguly, N. D. (2015). Short term change in relative humidity during the festival of Diwali in India [Article]. *Journal of Atmospheric and Solar-Terrestrial Physics*, *129*, 49-54. https://doi.org/10.1016/j.jastp.2015.04.007

Ghosh, S. (2018). Chapter: Environment. In *Regulation in India: Design, Capacity, Performance*. Bloomsbury Publishers.

Guttikunda, S. K., Dammalapati, S. K., Pradhan, G., Krishna, B., Jethwa, H. T., & Jawahar, P. (2023). What Is Polluting Delhi's Air? A Review from 1990 to 2022. *Sustainability*, *15*(5), 4209. https://doi.org/https://doi.org/10.3390/su15054209

Liu, J., Chen, Y., Chao, S., Cao, H., & Zhang, A. (2019). Levels and health risks of PM2.5-bound toxic metals from firework/firecracker burning during festival periods in response to management strategies. *Ecotoxicology and Environmental Safety*, *171*, 406-413. https://doi.org/https://doi.org/10.1016/j.ecoenv.2018.12.104

Mushtaq, F., Farooq, M., Lala, M. G. N., Banerjee, S., Tirkey, A. S., Shaheen, F., & Meraj, G. (2024). Analysis of spatial variability of smog episodes over National Capital Delhi during (2013–2017). *Discover Applied Sciences*, *6*(8), 413. https://doi.org/10.1007/s42452-024-06109-4

Patel, K., Adhikary, R., Patel, Z. B., Batra, N., & Guttikunda, S. (2022). *Samachar: Print News Media on Air Pollution in India* ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies (COMPASS), Seattle, WA, USA. https://doi.org/10.1145/3530190.3534812

Pervez, S., Chakrabarty, R. K., Dewangan, S., Watson, J. G., Chow, J. C., & Matawle, J. L. (2016). Chemical speciation of aerosols and air quality degradation during the festival of lights (Diwali) [Article]. *Atmospheric Pollution Research*, *7*(1), 92-99. https://doi.org/10.1016/j.apr.2015.09.002

Peshin, S. K., Sinha, P., & Bisht, A. (2017). Impact of diwali firework emissions on air quality of New Delhi, India during 2013-2015 [Article]. *Mausam*, *68*(1), 111-118. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85029009104&partnerID=40&md5=0f9f79da505bf9f96478ecbc4f5d5247

Rajagopal, K., Mohan, V., & Mishra, R. K. (2024). Are Delhi residents exposed to lesser particle number concentration due to the firework ban in the city? *Air Quality, Atmosphere & Health*, *17*(8), 1617-1627. https://doi.org/10.1007/s11869-024-01532-3

Sateesh, M., Soni, V. K., & Raju, P. V. S. (2018). Effect of Diwali Firecrackers on Air Quality and Aerosol Optical Properties over Mega City (Delhi) in India. *Earth Systems and Environment*, *2*(2), 293-304. https://doi.org/10.1007/s41748-018-0054-x

Sati, A. P., & Mohan, M. (2014). Analysis of air pollution during a severe smog episode of November 2012 and the Diwali Festival over Delhi, India [Article]. *International Journal of Remote Sensing*, *35*(19), 6940-6954. https://doi.org/10.1080/01431161.2014.960618

Shivani, Gadi, R., Saxena, M., Sharma, S. K., & Mandal, T. K. (2018). Short-term degradation of air quality during major firework events in Delhi, India. *Meteorology and Atmospheric Physics*, *131*(4), 753-764. https://doi.org/10.1007/s00703-018-0602-9

Supreme-Court. (2015). *Arjun Gopal vs Union Of India, Writ Petition(Civil) No. 728/2015*.

Supreme-Court. (2016a). *Arjun Gopal vs Union Of India, Writ Petition(Civil) No. 728/2015*.

Supreme-Court. (2016b). *Arjun Gopal vs Union Of India, Writ Petition(Civil) No. 728/2015*.
Supreme-Court. (2017). *M.C. Mehta vs Union Of India, Writ Petition(Civil) No. 13029/1985*.
Supreme-Court. (2018). *M.C. Mehta vs Union Of India, Writ Petition(Civil) No. 13029/1985*.
Supreme-Court. (2019). *M.C. Mehta vs Union Of India, Writ Petition(Civil) No. 13029/1985*.
Supreme-Court. (2021). *Arjun Gopal vs Union Of India, Writ Petition(Civil) No. 728/2015*.
Yadav, S., Tripathi, S. N., & Rupakheti, M. (2022). Current status of source apportionment of ambient aerosols in India. *Atmospheric Environment*, *274*, 118987. https://doi.org/https://doi.org/10.1016/j.atmosenv.2022.118987
Yadav, S. K., Mishra, R. K., & Gurjar, B. R. (2022). Assessment of the effect of the judicial prohibition on firecracker celebration at the Diwali festival on air quality in Delhi, India. *Environmental Science and Pollution Research*, *29*(57), 86247-86259. https://doi.org/10.1007/s11356-021-17695-w

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