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COMPARATIVE ANALYSIS OF AQI ON DIWALI FESTIVAL IN METROPOLITAN AND NON-METROPOLITAN CITIES

Asst. Prof. Prachi Singh
Department of Environmental Science
Mewar University
Chittorgarh, Rajasthan, India

Mr. Praveen Kumar Tiwari
Department of Environmental Science
Mohanlal Sukhadia University
Udaipur, Rajasthan, India

Mr. Shreyanshish Pratyush
Department of Biotechnology
Mewar University
Chittorgarh, Rajasthan, India

Abstract -**Air pollution remains a critical environmental and public health challenge in Indian cities, with Delhi experiencing some of the worst air quality levels globally. Among various contributing factors, Diwali festivities—characterized by widespread firecracker usage—lead to a significant deterioration in air quality. Additionally, the annual practice of stubble burning in the neighboring states of Punjab and Haryana further exacerbates pollution levels, particularly in the post-Diwali period. This study aims to comprehensively assess the impact of Diwali-related emissions on air quality by comparing AQI levels in metropolitan cities (Delhi and Jaipur) and non-metropolitan cities (Chittorgarh and Sirohi) before and after the festival. Air quality data for the period from October 21 to November 10, 2024, was collected from the Central Pollution Control Board (CPCB). The study examines AQI fluctuations, identifies key pollutants responsible for air quality degradation, and evaluates the role of meteorological factors such as wind speed, temperature, and atmospheric stability in pollution dispersion. Findings reveal a stark contrast between metropolitan and non-metropolitan cities in terms of air quality deterioration. Prior to Diwali (October 20–30), Delhi recorded an average AQI of 376.08 (Very Poor), while Jaipur stood at 184.71 (Moderate to Poor). In contrast, non-metropolitan cities such as Chittorgarh (119.78 AQI) and Sirohi (89.65 AQI) maintained relatively better air quality. However, post-Diwali (October 31–November 9), AQI levels in metropolitan cities surged dramatically, with Delhi peaking at a hazardous 412.22 AQI (Severe) and Jaipur at 290.90 AQI (Poor). The sharp rise in pollution levels is attributed to firecracker emissions, increased vehicular and industrial activity, and unfavorable meteorological conditions leading to pollutant accumulation. In non-metropolitan cities, the increase in AQI was less pronounced, with Chittorgarh reaching 156.60 AQI (Moderate to Poor) and Sirohi slightly increasing to 99.93 AQI (Satisfactory to Moderate). The comparatively lower pollution levels in non-metropolitan areas highlight the significant impact of urbanization, population density, and anthropogenic activities in worsening air quality. Additionally, the study observes the formation of haze and smog in Delhi, exacerbated by high levels of PM2.5 and PM10, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and other suspended particulate matter emitted during Diwali celebrations. The findings of this study emphasize the urgent need for stringent regulatory measures, effective implementation of firecracker bans, and public awareness campaigns promoting eco-friendly alternatives. Additionally, long-term policy interventions, including restrictions on stubble burning, enhanced vehicular emission controls, and sustainable urban planning, are essential to curb air pollution. Future research could focus on multi-year AQI trends, health impacts of pollution spikes, and the efficacy of government policies in mitigating seasonal air quality deterioration. By fostering collective action from policymakers, environmental agencies, and citizens, it is**

possible to mitigate the adverse environmental and health effects of air pollution during Diwali and beyond.

Keywords – **Air Pollution, AQI, Diwali, Metropolitan and non-metropolitan cities.**

I. INTRODUCTION

The issue of air pollution in Indian cities, particularly Delhi, has gained significant attention on both national and international platforms, especially from 2000-2020 and onwards (Cropper et al., 2011; Rizwan et al., 2013; Khan, 2023). Delhi consistently grapples with pervasive ambient air pollution, which intricately influences diverse facets of development (Chaudhary, 2023). Understanding the factors behind the poor air quality index (AQI) is crucial for safeguarding public health, shaping effective policies, optimizing resource allocation, and fostering community engagement (Liu et al., 2016). Curbing air pollution is imperative for advancing environmental sustainability and enhancing emergency preparedness (Kotze, 2015; Nayak and Chaudhary, 2018). Diwali is celebrated throughout the subcontinent, marked by lavish celebrations featuring an elaborate presentation of fireworks and pyrotechnic displays on a nationwide scale (Wise, 2019; Yadav et al., 2022). The national capital, New Delhi, adheres to this tradition with equal fervor and over the last three decades, fireworks and crackers have integrated with the festival. Cracker bursting probably is also seen as a display of wealth and an increase in the purchasing power of the residents. Diwali is observed annually in either October or November (Kumar, 2020; Yadav, 2022). These fireworks are composed of paper tubes filled with a combination of various harmful metal salts, soot-charcoal, sulfur dust, and a few binding agents. Upon ignition, they release dense plumes of smoke and vibrant illuminations (Yadav et al., 2022). Fireworks consist of various chemicals, including arsenic, sulfur, and manganese, besides oxalates and salts that are bound in many metal complexes (Wang et al., 2007; Ajith et al., 2019). Upon ignition, these fireworks emit a plethora of pollutants, including some greenhouse gases and suspended particles with a size below 10 micrometers in diameter. Metals such as Al, Cd, Pb, Si and As, which pose significant health risks also show a spike (Nasir and Brahmaiah, 2015). According to a study conducted in Thiruvananthapuram, India, there was a significant increase in atmospheric black carbon during the fireworks display on Diwali compared to normal days (Nasir and Brahmaiah, 2015). Similarly, studies conducted in Nagpur and Kolkata have also revealed the adverse effects of firecracker burning during Diwali on air quality (Verma and Deshmukh, 2014; Deka and Haque, 2014**;** Khaparde et al., 2011). Additionally, data shows that the concentration of air pollutants such as PM10 and SO2 significantly increased during Diwali, attributed to adverse changes in the meteorological parameters such as a decrease in the 24-hour average mixing height, temperature, and wind speed conditions and the burning of firecrackers (Nasir and Brahmaiah, 2015). Furthermore, the issue of stubble burning in neighboring states of Punjab and Haryana is seen as a potential contributor to the deteriorating air quality in Delhi during the post-Diwali period (Tripathi, 2019). Stubble burning is a common agricultural practice where farmers burn leftover crop residue after harvesting their crops (Jethva et al., 2018). Crop residue incineration releases a substantial number of pollutants into the air, including fine particulate matter and gases like carbon monoxide and volatile organic compounds (Oanh et al., 2018; Deshpande et al., 2023). These pollutants can travel long distances and contribute to the already high levels of air pollution in Delhi. Several studies have been conducted throughout India to evaluate the impact of Diwali emissions on air quality (Ravindra et al., 2022; Mandal et al., 2022). These studies have consistently reported higher concentrations of pollutants during the days of Diwali, including increased levels of respirable particulate matter, sulfur dioxide, nitrogen dioxide, and volatile organic compounds. These pollutants have been linked to various health issues, including respiratory tract infections, worsening of asthma and chronic obstructive pulmonary disease, cardiovascular complications, and other serious health hazards (Rizwan et al., 2013; Kumar et al., 2023). Additionally, the inhalation of smoke emanating from fireworks induces symptoms that cause chronic respiratory, nasal and cardio-vascular problems (Hirai et al., 2000). The combustion of firecrackers was further linked to markedly elevated levels of personal exposure to PM 2.5, indicating a potential for significant health issues and disease burden, particularly in children (Saxena et al., 2020). Delhi also witnesses a phenomenon of haze-fog pollution that causes low visibility, formation of dust clouds, reduced plant, and crop growth, compromised human and animal health and global climate dynamics (Jenamani, 2007; Mohan and Payra, 2009). The confluence of heightened air pollutant levels and stagnant atmospheric conditions, characterized by low wind speeds (below 2 m/s) and a shallow boundary layer height (approximately 500–800 m), promotes the formation of haze. The deteriorating AQI (air quality index) severely impacts human health and well-being, especially young children and adults, resulting in chronic respiratory problems. Over the last few years, various awareness drives have been carried out through print, electronic, and social media on stopping the crackers from bursting, banning the crackers from bursting after a particular time, and other political initiatives (Yadav et al., 2022; Jain et al., 2022). Therefore, it is important to understand the reasons and factors that adversely affect the air quality in the National Capital. The present study's central objective was to comprehensively compare Metropolitan and Non-Metropolitan cities air quality index (AQI) levels, specifically focusing on the before and after days leading up to and succeeding the Diwali celebration. This investigation

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aims to discern the primary causative factors behind the deterioration of AQI, exploring the potential contributions from pollutants emitted by firecrackers and agricultural stubble burning. In addition to this comparative analysis, the study endeavors to identify and analyze the specific atmospheric conditions that may have played a role in influencing the observed fluctuations in AQI levels during this critical period. Through this multifaceted examination, we aspire to contribute valuable insights into the complex dynamics of associated air quality variations.

II. PROPOSED WORK

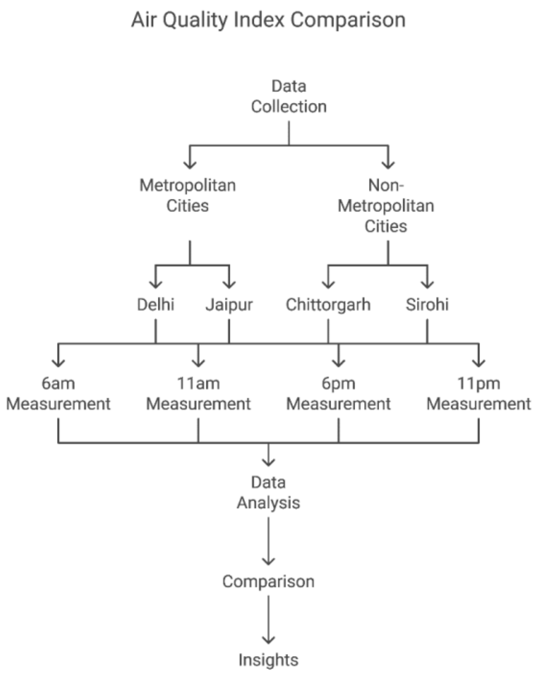
A. Data set used

The data has been collected from CPCB. A snapshot of the dataset is shown in figure 1. The dataset contains City, Date, AQI Average Index. AQI Index describes the air quality index. The data has been collected from 21 October 2024 to 10 November 2024 for analysis.

	A	B	C	D	E	F	G	H	I
1	DATE	LOCATION OF CITY	AVERAGE AQI	LOCATION OF CITY	AVERAGE AQI	LOCATION OF CITY	AVERAGE AQI	LOCATION OF CITY	AVERAGE AQI
2	21.10.24	Anand Vihar,Delhi	360	Mansarovar,Jaipur	120.75	Sirohi, Rajasthan	78.5	Chittorgarh,Rajasthan	98.5
3	22.10.24	Anand Vihar,Delhi	394.25	Mansarovar,Jaipur	113.25	Sirohi, Rajasthan	56	Chittorgarh,Rajasthan	91.5
4	23.10.24	Anand Vihar,Delhi	415.5	Mansarovar,Jaipur	160	Sirohi, Rajasthan	56	Chittorgarh,Rajasthan	111
5	24.10.24	Anand Vihar,Delhi	378	Mansarovar,Jaipur	214.5	Sirohi, Rajasthan	73.75	Chittorgarh,Rajasthan	105
6	25.10.24	Anand Vihar,Delhi	384.25	Mansarovar,Jaipur	187.75	Sirohi, Rajasthan	110	Chittorgarh,Rajasthan	NA
7	26.10.24	Anand Vihar,Delhi	380.5	Mansarovar,Jaipur	218.75	Sirohi, Rajasthan	102.75	Chittorgarh,Rajasthan	155.25
8	27.10.24	Anand Vihar,Delhi	394.25	Mansarovar,Jaipur	251	Sirohi, Rajasthan	102.5	Chittorgarh,Rajasthan	115.75
9	28.10.24	Anand Vihar,Delhi	343.5	Mansarovar,Jaipur	235.33	Sirohi, Rajasthan	98.75	Chittorgarh,Rajasthan	157.5
10	29.10.24	Anand Vihar,Delhi	317.25	Mansarovar,Jaipur	163	Sirohi, Rajasthan	102.75	Chittorgarh,Rajasthan	130
11	30.10.24	Anand Vihar,Delhi	393.25	Mansarovar,Jaipur	182.75	Sirohi, Rajasthan	115.5	Chittorgarh,Rajasthan	113.5
12	31.10.24	Anand Vihar,Delhi	406.75	Mansarovar,Jaipur	222	Sirohi, Rajasthan	123	Chittorgarh,Rajasthan	117
13	1.11.24	Anand Vihar,Delhi	386	Mansarovar,Jaipur	270.25	Sirohi, Rajasthan	174.75	Chittorgarh,Rajasthan	194.5
14	2.11.24	Anand Vihar,Delhi	396	Mansarovar,Jaipur	300.5	Sirohi, Rajasthan	88	Chittorgarh,Rajasthan	148.5
15	3.11.24	Anand Vihar,Delhi	428.5	Mansarovar,Jaipur	286.75	Sirohi, Rajasthan	76.25	Chittorgarh,Rajasthan	148.5
16	4.11.24	Anand Vihar,Delhi	437	Mansarovar,Jaipur	230.75	Sirohi, Rajasthan	86.5	Chittorgarh,Rajasthan	137.5
17	5.11.24	Anand Vihar,Delhi	432	Mansarovar,Jaipur	285.5	Sirohi, Rajasthan	96.5	Chittorgarh,Rajasthan	153
18	6.11.24	Anand Vihar,Delhi	NA	Mansarovar,Jaipur	335.75	Sirohi, Rajasthan	101.25	Chittorgarh,Rajasthan	183.25
19	7.11.24	Anand Vihar,Delhi	428.5	Mansarovar,Jaipur	344.25	Sirohi, Rajasthan	91.25	Chittorgarh,Rajasthan	177.5
20	8.11.24	Anand Vihar,Delhi	412.5	Mansarovar,Jaipur	325	Sirohi, Rajasthan	81	Chittorgarh,Rajasthan	155
21	9.11.24	Anand Vihar,Delhi	382.75	Mansarovar,Jaipur	308.25	Sirohi, Rajasthan	80.75	Chittorgarh,Rajasthan	151.25
22	10.11.24	Anand Vihar,Delhi	353	Mansarovar,Jaipur	276.5	Sirohi, Rajasthan	70.75	Chittorgarh,Rajasthan	168.5

B. Methodology

The following methodology was used to tackle the problem at hand. Across these steps, the pool of prospective cities that could be provided the funding was continuously shortened in order to narrow down to the metropolitan city and non- metropolitan city.



III. RESULTS

1. The AQI comparison table **between** Metropolitan (Delhi & Jaipur) and Non-Metropolitan (Chittorgarh & Sirohi) cities **for** 10 days after October 30, 2024 **(figure 2):**

Date	**Metropolitan AQI (Delhi & Jaipur)**	**Non-Metropolitan AQI (Chittorgarh & Sirohi)**
2024-10-31	314.38	120.00
2024-11-01	328.13	184.63
2024-11-02	348.25	118.25
2024-11-03	357.63	112.38
2024-11-04	333.88	112.00
2024-11-05	358.75	124.75
2024-11-06	NaN (Missing Data)	142.25
2024-11-07	386.38	134.38
2024-11-08	368.75	118.00
2024-11-09	345.50	116.00

Table.1. AQI trends for metropolitan and non- metropolitan cities

The analysis of AQI trends before and after Diwali 2024 reveals a stark contrast between metropolitan and non-metropolitan cities, highlighting **Metropolitan cities, particularly Delhi and Jaipur, recorded significantly higher AQI levels compared to non-metropolitan cities like Chittorgarh and Sirohi.** Before Diwali (October 20–30, 2024), Delhi had an average AQI of **376.08** (Very Poor), while Jaipur stood at **184.71** (Moderate to Poor). In contrast, non-metropolitan cities remained in the **Moderate category**, with Chittorgarh at **119.78 AQI** and Sirohi at **89.65 AQI**. However, post-Diwali (October 31–November 9, 2024), **AQI levels spiked significantly in metropolitan cities**, with **Delhi reaching a hazardous 412.22 AQI (Severe) and Jaipur rising to 290.90 AQI (Poor),** indicating the adverse effects of increased firecracker use, stagnant weather conditions, and urban pollution retention. Non-metropolitan cities also experienced an increase but to a much lesser extent, with **Chittorgarh rising to 156.60 AQI (Moderate to Poor) and Sirohi slightly increasing to 99.93 AQI (Satisfactory to Moderate).**

Comparison between **Metropolitan Cities (Delhi & Jaipur)** and **Non-Metropolitan Cities (Chittorgarh & Sirohi)** for their **Average AQI Index**, focusing on the**10 days before and after October 30, 2024**(i.e., from October 20 to November 9).

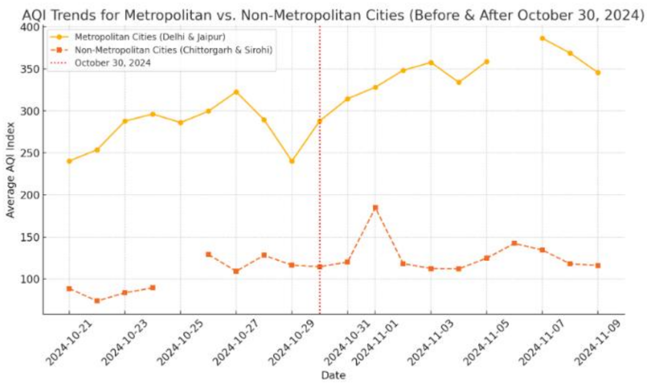


Fig.3. AQI trends **Metropolitan Cities** and **Non-Metropolitan Cities** (**before and after October 30, 2024)**

AQI trends between **Metropolitan (Delhi & Jaipur) and Non-Metropolitan (Chittorgarh & Sirohi) cities** for the **10 days before October 30, 2024** (i.e., from October 20 to October 30, 2024).

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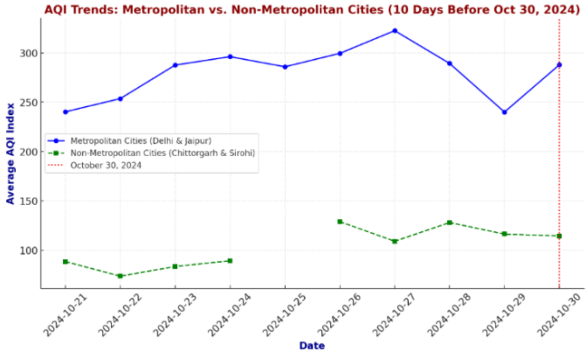

Fig.4. AQI trends for **Metropolitan and Non-Metropolitan cities** for the **10 days before October 30, 2024**

AQI trends between **Metropolitan (Delhi & Jaipur) and Non-Metropolitan (Chittorgarh & Sirohi) cities**for the**10 days after October 30, 2024**(i.e., from October 31 to November 9, 2024).

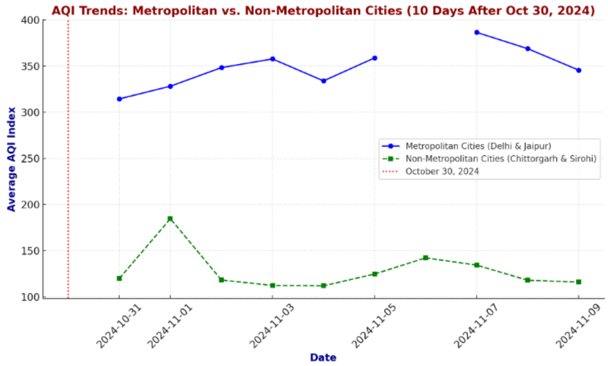

Fig.5. **AQI trends** for **Metropolitan and Non-Metropolitan cities** for the **10 days after October 30, 2024**

IV. CONCLUSION AND FUTURE SCOPE

The analysis of AQI levels during the Diwali festival presents a striking contrast between metropolitan and non-metropolitan cities, shedding light on the significant impact of urbanization, industrialization, and festive activities on air quality. Metropolitan cities like Delhi and Jaipur witnessed a sharp rise in pollution levels, with Delhi averaging 391.19 AQI and Jaipur 239.65 AQI, both falling into the "poor" to "very poor" air quality categories. These numbers indicate a substantial deterioration in air quality, primarily driven by heavy vehicular emissions, industrial pollutants, construction dust, and the widespread bursting of firecrackers. During Diwali, the combination of stagnant atmospheric conditions and increased particulate matter further exacerbated pollution, leading to the formation of thick smog that lingered over urban areas, significantly reducing visibility and increasing respiratory discomfort among residents. On the other hand, non-metropolitan cities like Sirohi (93.64 AQI) and Chittorgarh (140.63 AQI) experienced relatively lower pollution levels, remaining in the "moderate" category for most of the period. These cities, with lower population density, fewer industries, and reduced vehicular congestion, did not exhibit the severe air quality degradation seen in metropolitan areas. The findings highlight how factors such as urban infrastructure, industrial presence, and human activities influence pollution levels, making metro cities more vulnerable to severe air quality deterioration during festive seasons. The disparity in AQI values between urban and rural areas further emphasizes the growing environmental concerns surrounding air pollution, climate change, and public health, necessitating immediate and long-term intervention strategies.

To develop sustainable solutions for tackling air pollution, it is essential to expand the scope of this study by analyzing multi-year AQI trends across variouscities to identify recurring patterns and assess the long-term impact of Diwali festivities on air quality. Additionally, correlating AQI data with public health records, such as hospital admissions for respiratory issues, can provide crucial insights into the direct consequences of increased pollution on human health. Future research could also focus on evaluating the effectiveness of government policies, such as firecracker bans, odd-even vehicle schemes, and industrial emission regulations, to determine their success in reducing pollution levels.

Public awareness campaigns promoting eco-friendly celebrations can play a pivotal role in reducing pollution, particularly in metropolitan areas. Encouraging the use of green crackers, community firework displays, and alternative celebrations such as laser lightshows can help mitigate pollution levels while preserving festive traditions. Additionally, investing in air purification infrastructure, forestation initiatives, and stricter enforcement of pollution control measures can significantly contribute to improving air quality, not just during Diwali but throughout the year. Addressing the issue of air pollution requires a collective effort from policymakers, environmental agencies, industries, and the public to ensure cleaner air and a healthier environment for future generations.

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