Winter is here: Overview of impending air quality crisis in Delhi-NCR

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As Delhi and the National Capital Region (NCR) braces for the upcoming winter
it remains to be seen if the seasonal average of PM2.5 during winter that had improved during pandemic but stagnated post pandemic, will further bend or increase. This winter season is also starting from a much cleaner benchmark due to rains in September and October.

This has emerged from the latest winter analysis of the Urban Lab at Centre for Science and Environment (CSE). The objective has been to understand the trend and the starting line of the onset of the winter pollution season or pre-winter levels in this region. This also captures the longer term context of seasonal variation and annual trends in particulate pollution. This is the first analysis of the third edition of Urban Lab's Air Quality Tracker Initiative which was started in 2020-21 winter to study the impact of pandemic lockdown on air quality of Delhi and NCR.

The intensity of winter pollution and severity of smog episodes will depend on the effectiveness of the long term multi-sector action so far in the entire region of Delhi and NCR and also on the enforceability of the short term emergency action. Only the effectiveness of the air pollution control measures targeting all key sources will determine if the winter pollution trend that had stabilised post pandemic, will continue to hold and improve or worsen further.

The onset of the winter has been much cleaner this year due to the rains. But the intensity of the early winter pollution will depend a lot on the trend in the crop fires and also the impact of Diwali. Though Diwali is happening during the warmer part of the early winter, prolonged rains can delay and lead to concentrated burning later compounding the problem.

This is an assessment of annual and seasonal trends in PM2.5 concentration for the period 1 January 2015 to 17 October 2022 (winter is defined as from October 1 to February 28). This captures seven successive winter seasons and pre-winter trends in Delhi and the National Capital Region. This analysis is based on the real time data available from the current working air quality monitoring stations in Delhi-NCR. A huge volume of data points have been cleaned and data gaps have been addressed based on USEPA method for this analysis. This analysis covers 81 continuous ambient air quality monitoring stations (CAAQMS) spread across cities of Delhi-NCR. Meteorological data for the analysis is sourced from the Palam weather station of Indian Meteorological Department (IMD). Fire count data is sourced from NASA's Fire Information for Resource Management System, specifically Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) product is used. Estimate of contribution of farm stubble fire smoke to Delhi's air quality is sourced from Ministry of Earth Science's System of Air Quality and Weather Forecasting and Research (SAFAR).

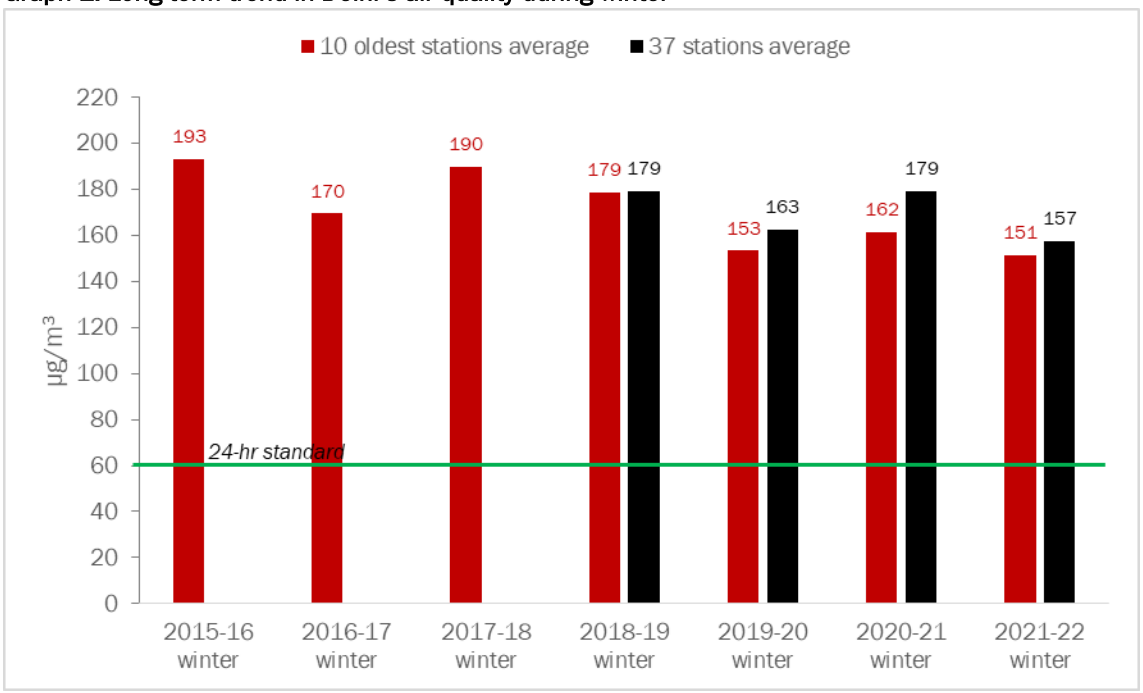
Key findings

Recent winters show about 20 per cent improvement in seasonal air quality compared to winters of 2015-18, but progress seems to have stagnated since pandemic: Delhi's seasonal air quality for winter (1 Oct to 28 Feb) used hover around 180-190 µg/m³ before pandemic and for last three winters it has come down to 150-160 µg/m³ (See *Graph 1: Long term trend in Delhi's air quality during winter)*. Despite the improvement the seasonal average is still over 150 per cent above the 24-hr standard and almost 4-times the annual standard.

Peak pollution shows similar trend as seasonal average. Peak pollution (worst 24-hr average) used to cross 800 µg/m³ at individual stations pre-pandemic, it has been hovering in 700-800 µg/m³ range during last three winters (See *Graph 2: Long term trend in Delhi's peak pollution level during winter*). These peak pollution numbers should be taken with caution as CPCB introduced at 1,000 µg/m³ cap on reported real-time data in 2016-17, which has greatly compromised the assessment of peak pollution level. Actual peak levels must be higher than what CPCB data shows.

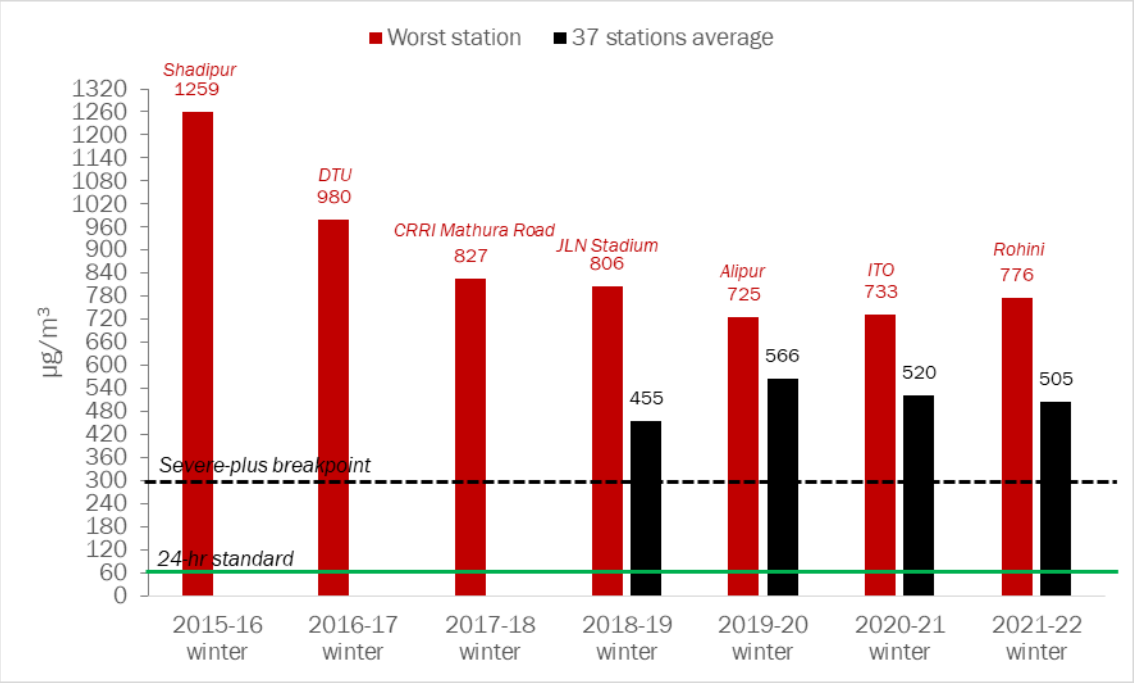
It must also be noted that the worst station for peak pollution has change 7 times in last seven winters. Shadipur, DTU, CRRI Mathura Road, JLN Stadium, Alipur, ITO and Rohini have occupied the worst peak pollution title in last seven winters. These are spread across the city with no clear pattern. This indicates that the winter pollution is regional in nature and short-term peak build-up can happen anywhere based on local meteorology and pollution sources.

Graph 1: Long term trend in Delhi's air quality during winter



Note: 10 oldest stations of Delhi are Anand Vihar, CRRI Mathura Road, IGI Airport T3, IHBAS, Mandir Marg, DU North Campus, NSIT Dwarka, Punjabi Bagh, RK Puram and Shadipur. 37 station average includes all the Delhi stations except Lodhi Road IITM, Chandni Chowk IITM and East Arjun Nagar. Seasonal average is based on mean of monthly averages. Winter season is defined as October to February.
Source: CSE analysis of CPCB realtime data

Graph 2: Long term trend in Delhi's peak pollution level during winter

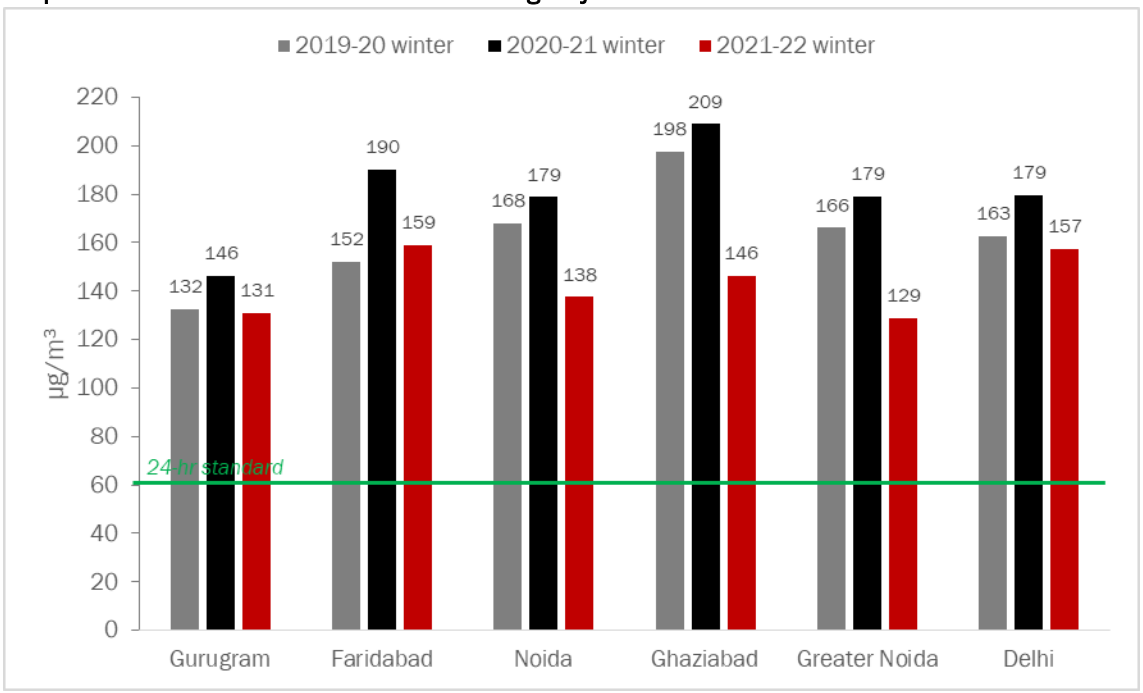


Note: 37 station average includes all the Delhi stations except Lodhi Road IITM, Chandni Chowk IITM and East Arjun Nagar. Peak level is based on 24-hour averages calculated from midnight to midnight. Winter season is defined as October to February.
Source: CSE analysis of CPCB realtime data

Last winter was 10-30 per cent less polluted compared to 2020-21 winter for most major NCR cities, Ghaziabad and Faridabad have had worst winter air among major NCR cities: Winter of 2021-22 was relatively less polluted compared to winter of 2020-21 for most NCR cities. Ghaziabad registered 30 per cent improvement that was highest among major cities but it's PM2.5 level was still about 2.5-times the 24-hr standard (See *Graph 3: Last three winter's PM2.5 level among major cities of core NCR*). Greater Noida (28 per cent), Noida (23 per cent) and Faridabad (16 per cent) also registered improvement in excess of Delhi that registered 12 per cent improvement. Gurugram with 11 per cent improvement was the worst performer among the core NCR cities. In absolute concentration terms, Faridabad with seasonal average of 159 µg/m^3 was the most polluted city of NCR last winter.

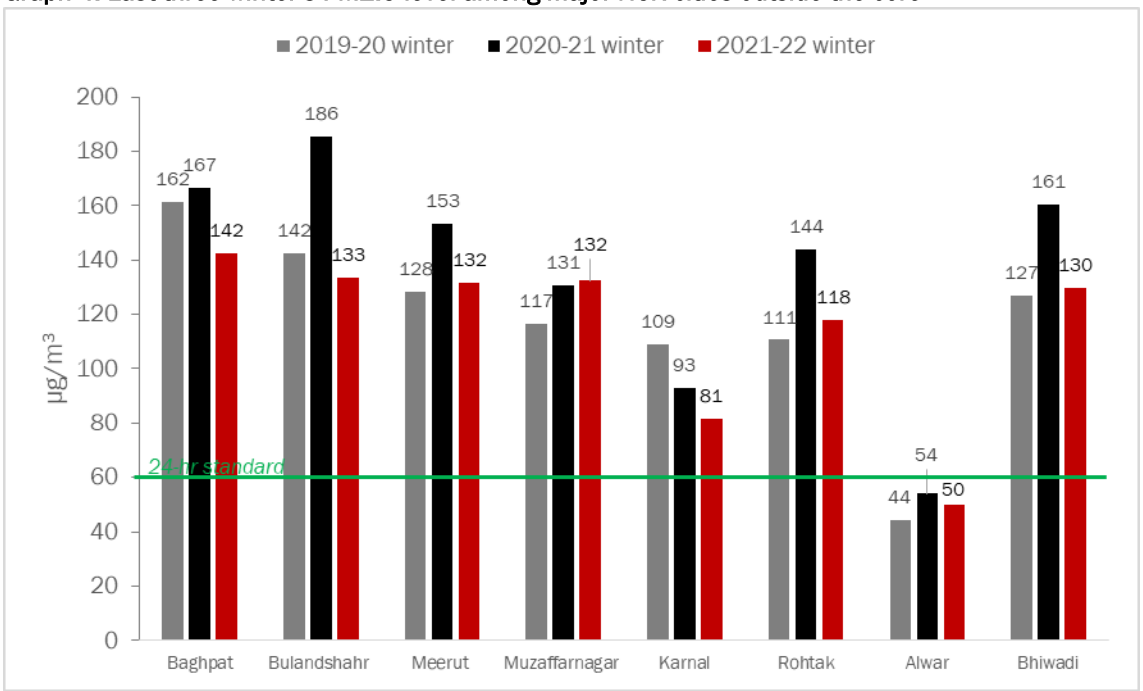
Across the larger NCR, Muzaffarnagar was worst performer as it registered one per cent increase in winter level (See *Graph 4: Last three winter's PM2.5 level among major NCR cities outside the core*). Bulandshahr with 28 per cent improvement was the best performer among major non-core NCR cities. Baghpat with seasonal average of 142 µg/m^3 was the most polluted city outside the core-NCR. Alwar with winter average of 50 µg/m^3 was the only major city in NCR that registered a seasonal level lower than the 24-hr standard.

Graph 3: Last three winter's PM2.5 level among major cities of core NCR



Note: Seasonal average is based on mean of monthly averages recorded at CAAQM stations in the city that have adequate data for all three winters. Delhi is represented by its 10 oldest stations (Anand Vihar, CRRI Mathura Road, IGI Airport T3, IHBAS, Mandir Marg, DU North Campus, NSIT Dwarka, Punjabi Bagh, RK Puram and Shadipur). Gurugram by Gwal Pahari and Vikas Sadan stations; Faridabad by Sector 16A station; Noida by Sector 125 and Sector 62 stations; Ghaziabad by Vasundhara station; and Greater Noida by KP-III station. Winter season is defined as October to February.
Source: CSE analysis of CPCB realtime data

Graph 4: Last three winter's PM2.5 level among major NCR cities outside the core



Note: Seasonal average is based on mean of monthly averages recorded at CAAQM stations in the city that have adequate data for all three winters. Except Meerut all cities have only one station and are represented by them. Meerut is represented by mean of its three stations. Winter season is defined as October to February.
Source: CSE analysis of CPCB realtime data

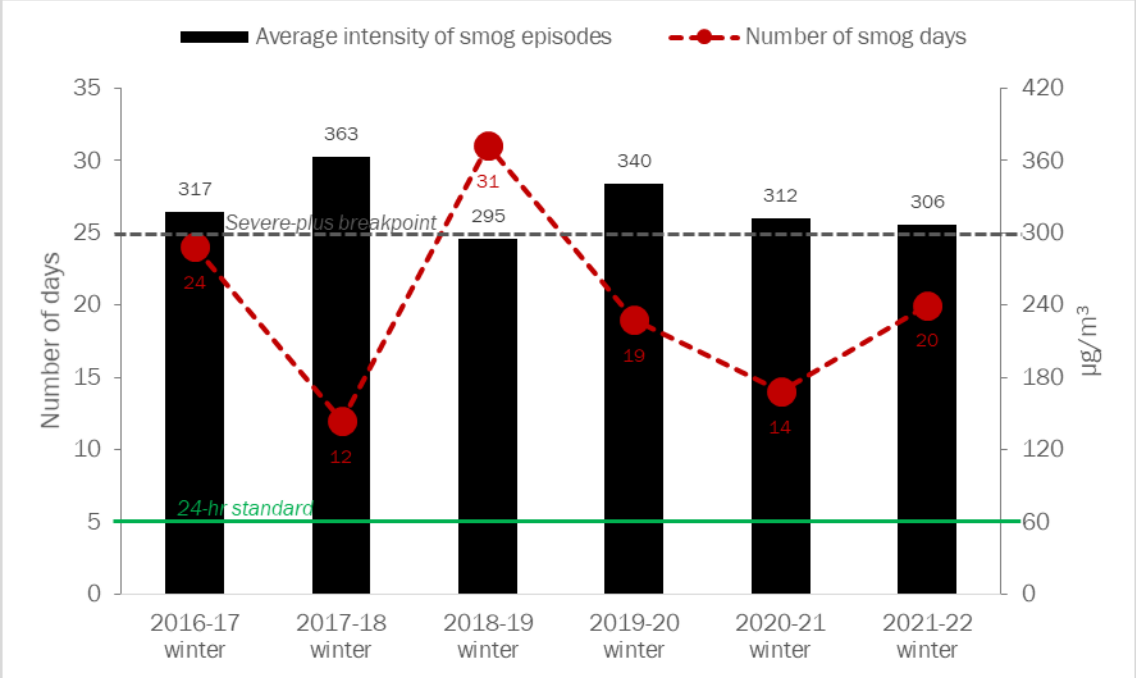
Smog days and intensity remain worrisome: A smog episode is defined for the purpose of emergency action under Delhi's Graded Response Action Plan when the levels of PM2.5 remain in "severe" category for three consecutive days. In this study, if two consecutive smog episodes are separated by only one day and the PM2.5 level of that day doesn't drop below 200 µg/m³ then the whole period is considered a single extended smog episode. Last winter season, there were three distinct smog episodes totally 20 smog days (See *Table 1: Smog episodes in Delhi*). This was more than previous two winters. 2020-21 winter had 14 smog days while 2019-20 winter had 19 smog days (See *Graph 5: Trend in winter smog duration and intensity in Delhi*). Most smog days were observed in 2018-19 winter when 4 smog episodes were recorded with total of 31 smog days. Average intensity of smog episode last winter was 306 µg/m³ which lower than previous two winter smog episodes but this marginally lower intensity is negated by the longer duration of the smog episodes. It must be noted that winters with relatively lower seasonal averages have longer and more smog episodes (See *Table 1: Smog episodes in Delhi*). Which is a fascinating occurrence and requires deeper investigation.

Table 1: Smog episodes in Delhi

Winter	Seasonal PM2.5 average	Total smog days	1st smog episode	2nd smog episode	3rd smog episode	4th smog episode
2016-17	170 µg/m³	24	27 Oct-11 Nov	29 Nov-2 Dec	6-9 Dec	
2017-18	190 µg/m³	12	7-14 Nov	30 Dec-2 Jan		
2018-19	179 µg/m³	31	8-13 Nov	20 Dec-5 Jan	11-13 Jan	16-20 Jan
2019-20	153 µg/m³	19	28 Oct-4 Nov	11-15 Nov		
2020-21	162 µg/m³	14	4-10 Nov	4-7 Dec	22-24 Dec	
2021-22	151 µg/m³	20	4-13 Nov	25-28 Dec	21-26 Dec	

Note: A smog episode is defined for the purpose of emergency action under Delhi's Graded Response Action Plan when the levels of PM2.5 remain in "severe" category for three consecutive days. In this study, if two consecutive smog episodes are separated by only one day and the PM2.5 level of that day doesn't drop below 200 µg/m³ then the whole period is considered a single extended smog episode.
Source: CSE analysis of CPCB realtime data

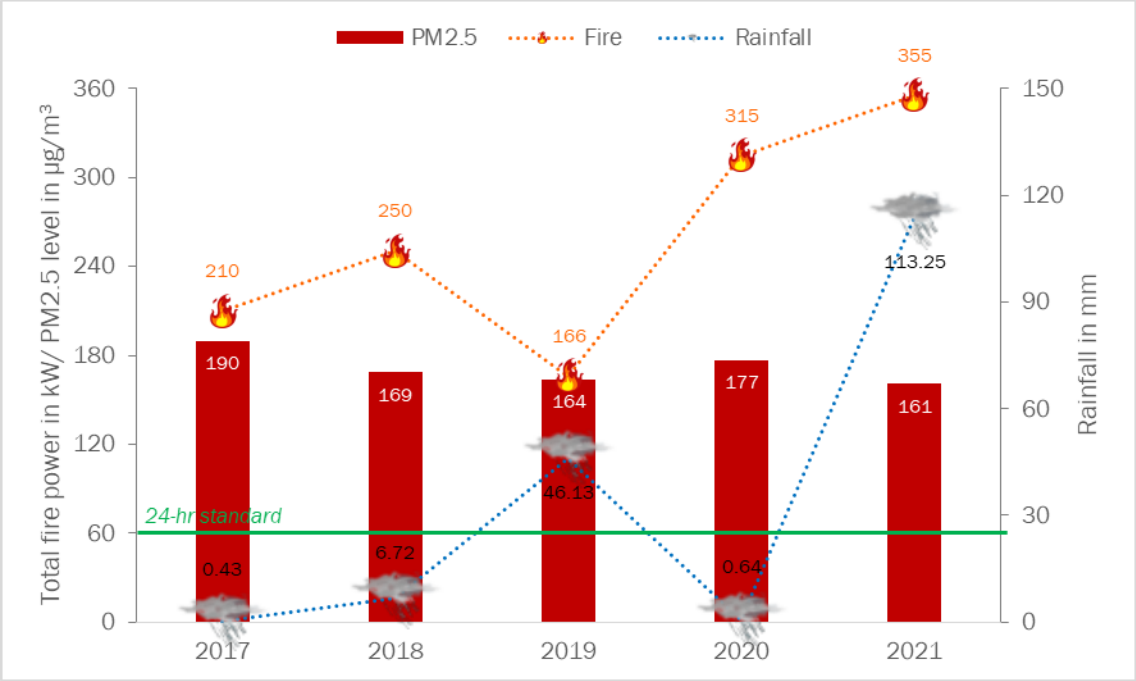
Graph 5: Trend in winter smog duration and intensity in Delhi



Note: Based on 10 oldest stations of Delhi are Anand Vihar, CRRI Mathura Road, IGI Airport T3, IHBAS, Mandir Marg, DU North Campus, NSIT Dwarka, Punjabi Bagh, RK Puram and Shadipur. A smog episode is defined for the purpose of emergency action under Delhi's Graded Response Action Plan when the levels of PM2.5 remain in "severe" category for three consecutive days. In this study, if two consecutive smog episodes are separated by only one day and the PM2.5 level of that day doesn't drop below 200 µg/m³ then the whole period is considered a single extended smog episode.
Source: CSE analysis of CPCB realtime data

Impact of rain and farm stubble fire smoke on the air quality is highly pronounced: Each year air in October and November become unbreathable due to unfortunate clustering of pollution causing and compounding events. Festive season leads to increase in local pollution due to traffic chaos and firecrackers which is compounded by cooling of weather that lower mixing height and sets in inversion. Burning of crop waste in Punjab and Haryana further adds to the pollution load, which is compounded by retreating monsoon which transports the smoke down the Gangetic Plains. Only sobering element during these two months is rain, which can wash down the pollution if the downpour is strong and prolonged. Albeit it is only a temporary relief. This relationship is evident from the data (See *Graph 6: Relationship among rain, farm stubble fires, and Delhi's air quality in October-November*).

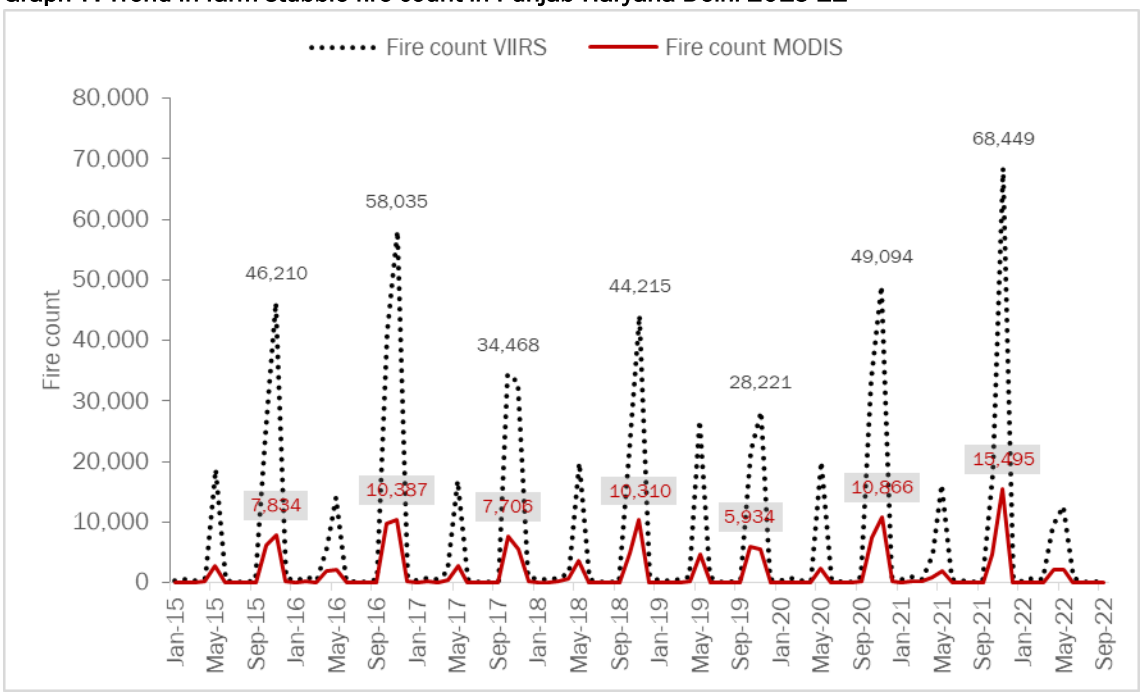
Graph 6: Relationship among rain, farm stubble fires, and Delhi's air quality in October-November



Note: PM2.5 level is based on 10 oldest stations of Delhi are Anand Vihar, CRRI Mathura Road, IGI Airport T3, IHBAS, Mandir Marg, DU North Campus, NSIT Dwarka, Punjabi Bagh, RK Puram and Shadipur. Fire data is based on NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) product and is for Punjab, Haryana and Delhi. Rainfall data is from IMD's station at Palam.
Source: CSE analysis

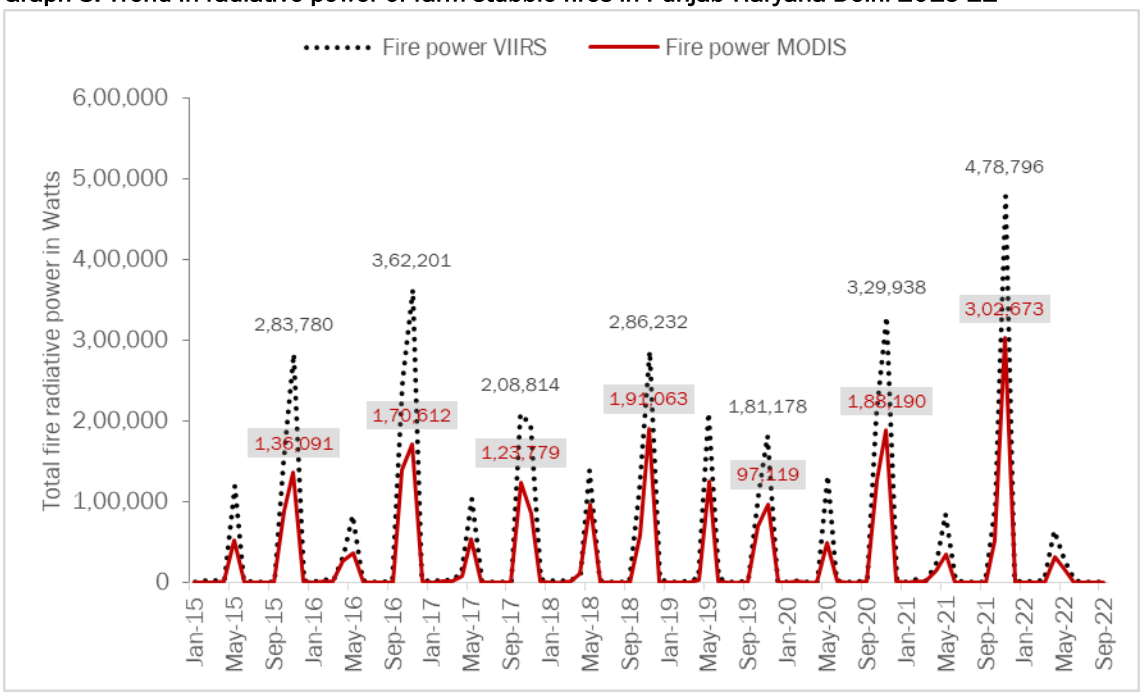
Farm stubble fires of Punjab-Haryana-Delhi are increasing both in numbers and intensity: Last year registered highest instances of farm stubble fire in last seven years. 2021 October-November saw 10 per cent increase in observed fire count by MODIS and 5 per cent increase by VIIRS compared to 2020 October-November (See *Graph 7: Trend in farm stubble fire count in Punjab-Haryana-Delhi 2015-22*). Similarly, the total fire radiative power from these fires were 13 per cent and 7 per cent higher compared to 2020 October-November fire as observed by MODIS and VIIRS respectively (See *Graph 8: Trend in radiative power of farm stubble fires in Punjab-Haryana-Delhi 2015-22*). In fact there is a consistence increase in fire instances and intensity since 2019.

Graph 7: Trend in farm stubble fire count in Punjab-Haryana-Delhi 2015-22



Note: Fire data is based on NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) products. It covers Punjab, Haryana and Delhi. Data up till 1 October 2022.
Source: CSE analysis

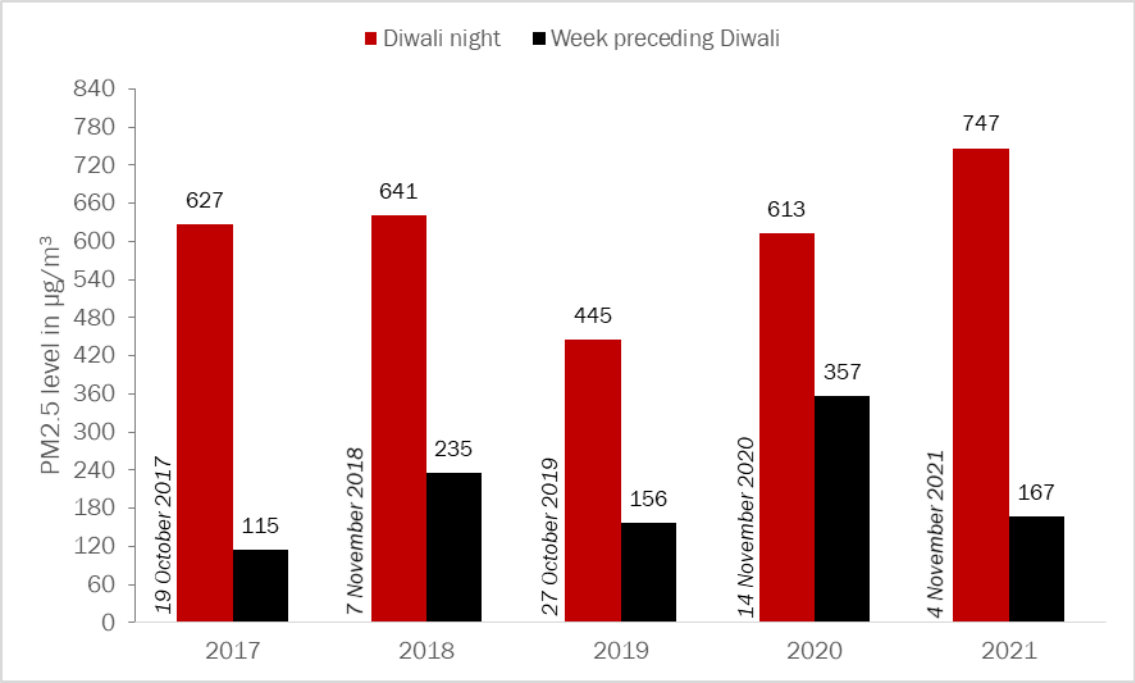
Graph 8: Trend in radiative power of farm stubble fires in Punjab-Haryana-Delhi 2015-22



Note: Fire data is based on NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) products. It covers Punjab, Haryana and Delhi. Data up till 1 October 2022.
Source: CSE analysis

Diwali night pollution continues to remain high: PM2.5 concentration at the Diwali night (8pm to 8am) last year stood at 747 µg/m³, 22 per cent higher than 2020 Diwali night. The levels on Diwali night were 4.5 times the average night-time levels recorded in the week preceding Diwali (See *Graph 9: PM2.5 levels Diwali-night (8pm-8am) vs average of nights in the week preceding Diwali*). Please note that this Diwali night value is an undercount as CPCB caps PM2.5 data at 1,000 µg/m³. It is noted that hourly concentrations can go beyond 1,000 µg/m³. This year 26 of 38 operational monitoring stations hit the 1,000 µg/m³ mark. In 2020, 23 out of 38 station had hit the 1000 µg/m³ mark while in 2019 the number stood at 22 stations.

Graph 9: PM2.5 levels Diwali-night (8pm-8am) vs average of nights in the week preceding Diwali

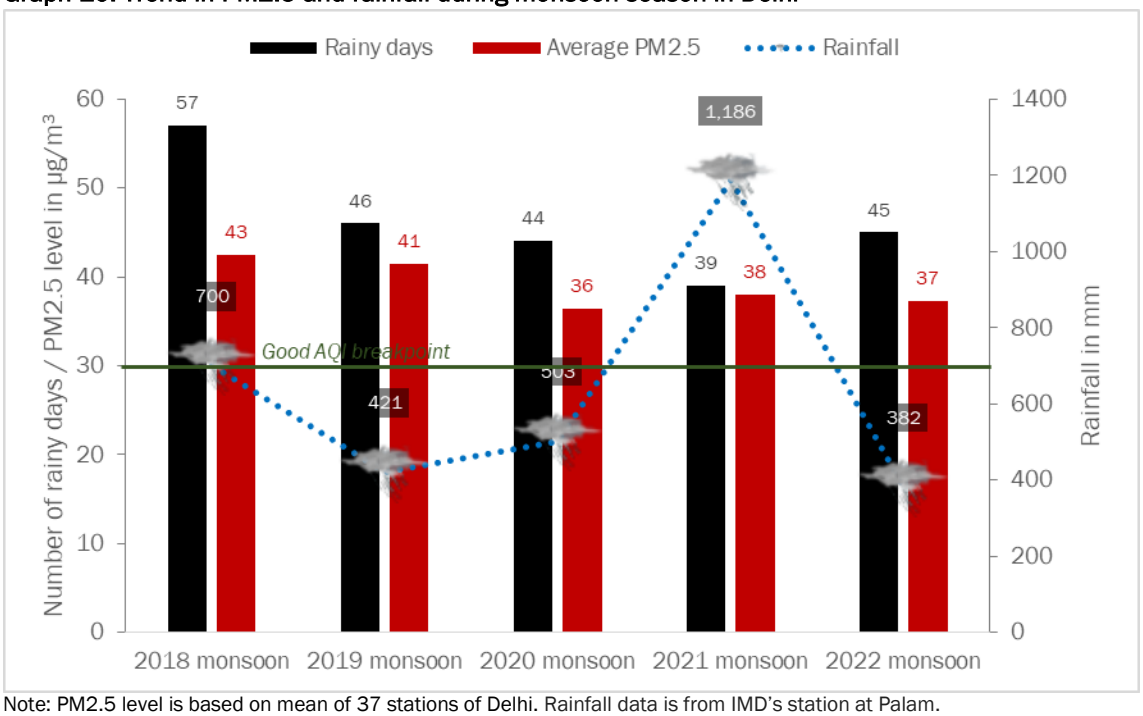


Note: Average PM2.5 concentration is based on mean of 12hr values recorded at Delhi's 37 CAAQM stations (2017 Diwali data is based on lesser number of stations). Nighttime is 8pm to 8am. Pre-diwali night average is mean of nighttime levels of seven preceding nights.
Source: CSE analysis of CPCB's real time air quality data

What is happening this year!

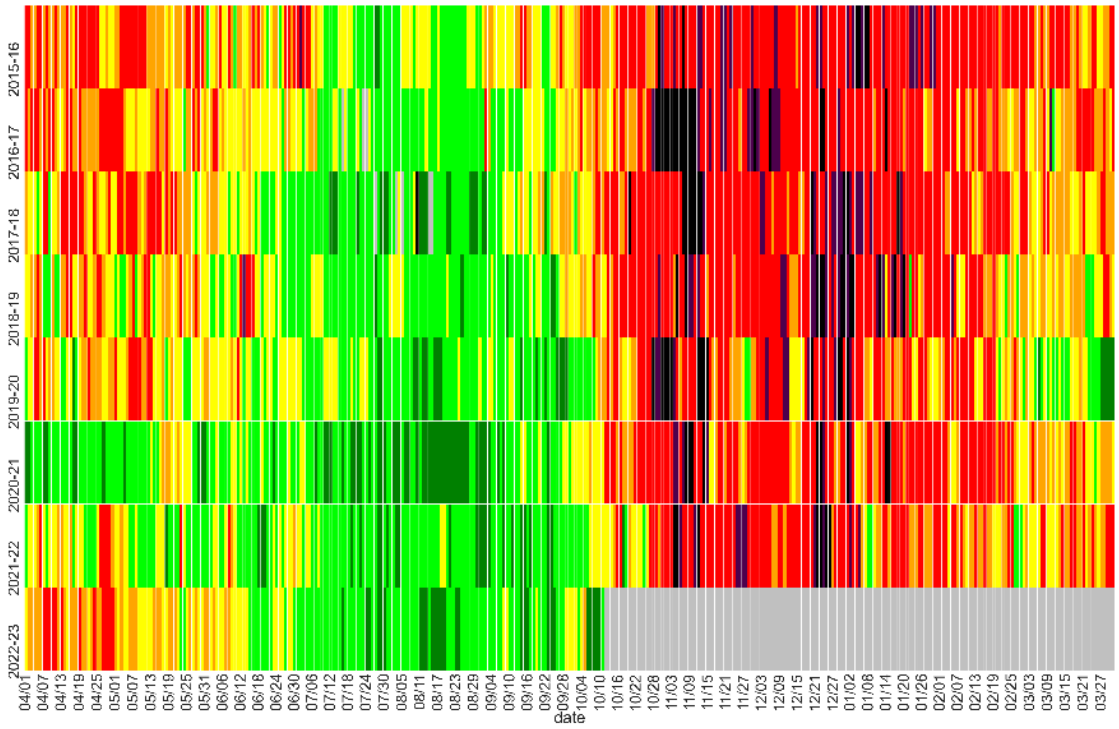
2022 monsoon was the second cleanest in last 8 years despite relatively lesser rain and unusually polluted summer: The seasonal average for the monsoon (July, August and September) this year stood at 37 µg/m³ which is only marginally higher than lowest monsoon average of 36 µg/m³ that was recorded during 2020 monsoon (See *Graph 10: Trend in PM2.5 and rainfall during monsoon season in Delhi*). The ultra-low pollution level recorded during the 2020 monsoon were preceded by cleanest ever summer (March-May) due to extraordinary conditions created because of hard pandemic lockdowns. But this monsoon has been preceded by one of the most polluted summer, therefore it important to understand what aided in cleaning up the Delhi air. Looking at the rainfall data it becomes evident that distribution of rainfall has relatively higher impact on seasonal air quality than the absolute quantity of rainfall. This monsoon there have been 45 rainy days compared to just 39 rainy days in the previous monsoon. These six extra rainy days helps keep the seasonal average low despite total rainfall this monsoon have been just one-third of previous monsoon. These additional rainy days also pushed the regular start of bad air quality days further down the month of October (See *Graph 11: Air quality heatmap of Delhi*).

Graph 10: Trend in PM2.5 and rainfall during monsoon season in Delhi



Note: PM2.5 level is based on mean of 37 stations of Delhi. Rainfall data is from IMD's station at Palam.
Source: CSE analysis

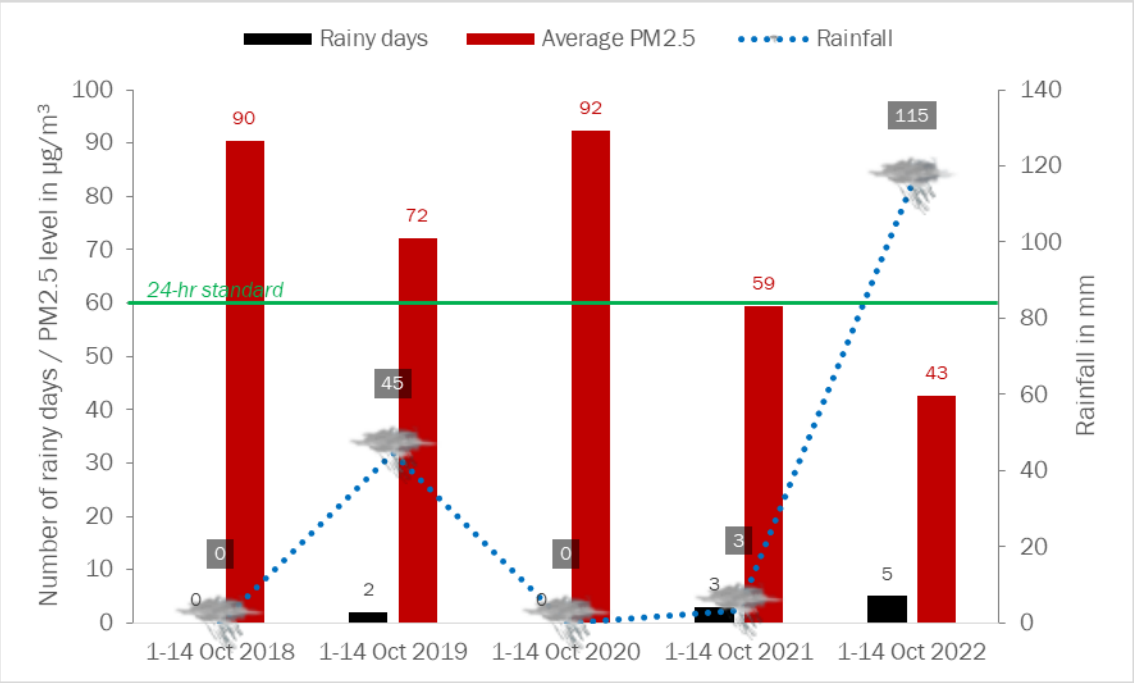
Graph 11: Air quality heatmap of Delhi



Note: PM2.5 level is based on 10 oldest stations of Delhi are Anand Vihar, CRRI Mathura Road, IGI Airport T3, IHBAS, Mandir Marg, DU North Campus, NSIT Dwarka, Punjabi Bagh, RK Puram and Shadipur. Cell colour is based on the official colour-scheme of AQI sub-categories.
Source: CSE analysis

Rains kept air quality in check during first two weeks of October: Delhi received unprecedented 115 mm of rainfall in the first two weeks of October this year, this translated in cleanest start to winter since wide-scale monitoring started in 2018. PM2.5 average for the first two weeks of October stood at 43 µg/m³ which is less than half of the level recorded in 2020 for same period (See *Graph 12: Trend in PM2.5 and rainfall during 1-14 October in Delhi*). This October so far five days of "Good" AQI (PM2.5 sub-category) which is most recorded in last eight winter seasons. All these "good" AQI days fell on the rainy days. Last year two "good" AQI days were recorded for entire winter season, previous winters had no "good" AQI days.

Graph 12: Trend in PM2.5 and rainfall during 1-14 October in Delhi

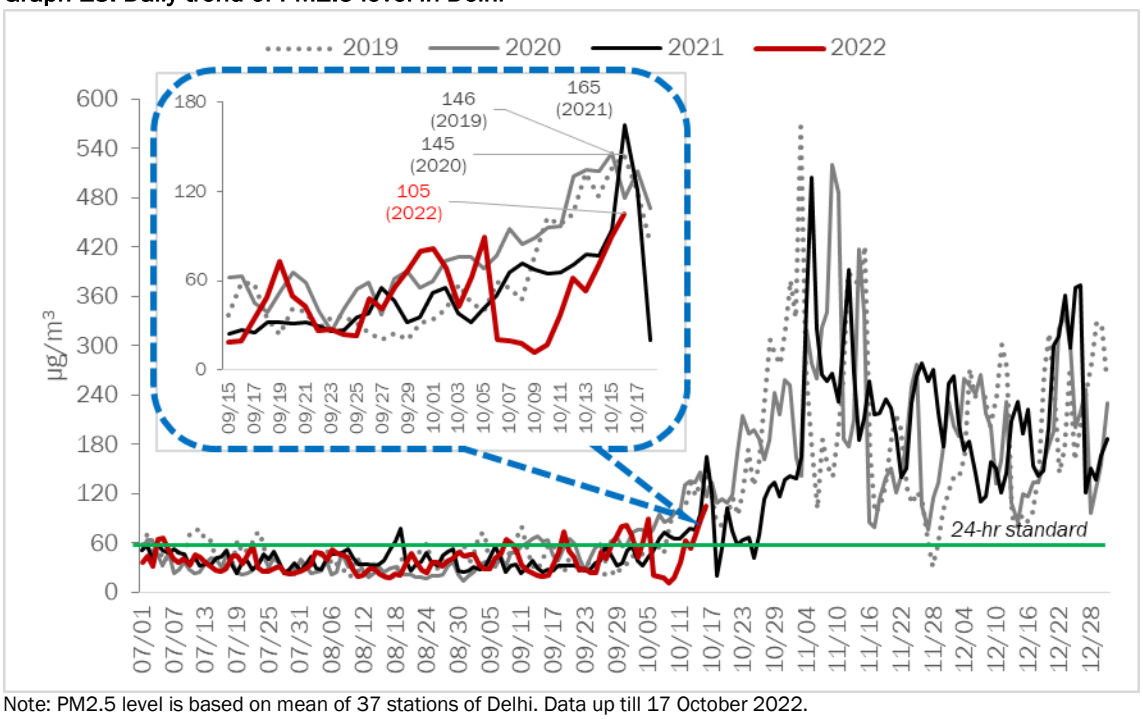


Note: PM2.5 level is based on mean of 37 stations of Delhi. Rainfall data is from IMD's station at Palam.
Source: CSE analysis

Air quality is starting to deteriorate: Relief given by extended rainfall period has come to an end as PM2.5 level have risen above 100 µg/m³ on 16th October (See *Graph 13: Daily trend of PM2.5 level in Delhi*). This is still low compared to previous years but it is expected to rise quickly. This rise is being driven by smoke from the farm stubble fires starting to enter the region. As per SAFAR, this smoke contributed about 3 per cent to Delhi's PM2.5 level on 17th October. This is relatively low contribution compared to previous years for this time of the year (See *Graph 14: Daily trend of farm stubble fire smoke's contribution to PM2.5 level in Delhi*). This is happening now because burning activities have picked up in Punjab-Haryana-Delhi. The total radiative fire power of these fires in Punjab-Haryana-Delhi breeched 2,000 Watt on 16th October, which is less than half of the value recorded in 2020 and 2021 for same period (See *Graph 15: Daily trend of farm stubble fire's radiative power, Punjab-Haryana-Delhi*). Based on previous years' observation it can be said that situation will worsen dramatically if business as usual scenario continues. In fact, Diwali celebrations next week will accelerate this deterioration.

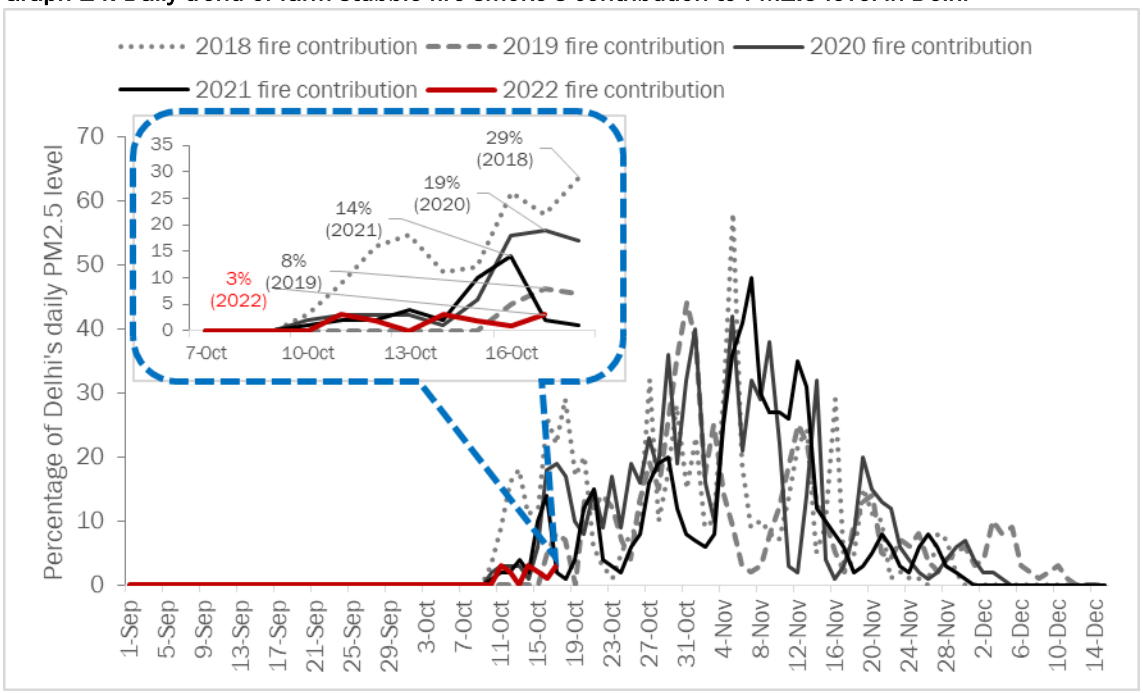
This Diwali might yet again trigger a deadly smog episode: This year Diwali is falling relatively early in the season which means the warmer and windier conditions will help dilute the pollution that is staple of Diwali night celebrations. Unlike previous two years, the smoke from the farm stubble fires has not overwhelmed the air quality of the region yet and rains in early October have also kept the air relatively clean so far. But based on previous years data it is expected that Diwali night can add 300-600 µg/m³ of PM2.5 to Delhi's air if business as usual scenario continues. There is very high likelihood that farm stubble fire will drastically increase as well during the days leading to Diwali and will continue post Diwali. Delay start of the burning season in past has resulted in concentration of burning activities which will intensify the smoke-fall in the region. In short, conditions are ripe for a severe smog episode to start from Diwali night.

Graph 13: Daily trend of PM2.5 level in Delhi



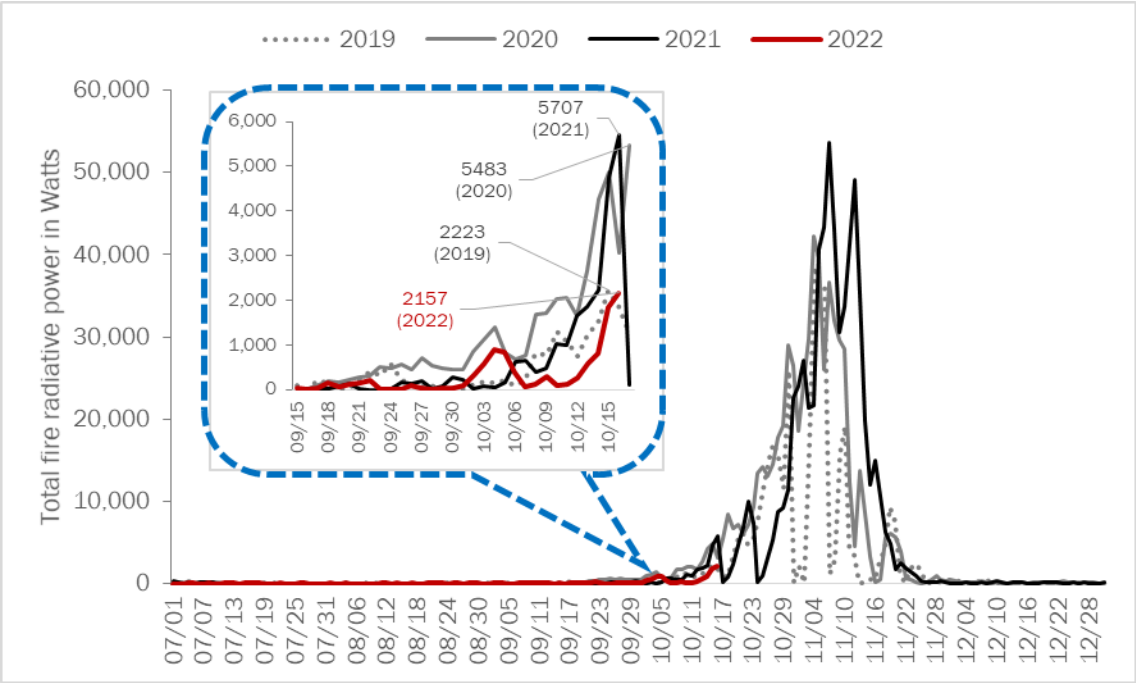
Note: PM2.5 level is based on mean of 37 stations of Delhi. Data up till 17 October 2022.
Source: CSE analysis

Graph 14: Daily trend of farm stubble fire smoke's contribution to PM2.5 level in Delhi



Note: Farm stubble fire smoke contribution to Delhi's PM2.5 level based on the SAFAR India publication. Data up till 17 October 2022.
Source: CSE analysis

Graph 15: Daily trend of farm stubble fire's radiative power, Punjab-Haryana-Delhi



Note: Fire data is based on NASA's Visible Infrared Imaging Radiometer Suite (VIIRS) product. It covers Punjab, Haryana and Delhi. Data up till 17 October 2022.
Source: CSE analysis

Next steps

This early winter alert is a wake-up call for more stringent pre-emptive and preventive measures to avert the smog episodes that cause excessive exposure and health risk during winter. The enforcement of the graded response action plan needs to be equally stringent with zero tolerance across Delhi and NCR. This requires preparedness in all concerned departments to ensure:

- All waste streams are collected, segregated and transported to prevent accumulation of waste in the open. Ongoing legacy waste management needs additional measures to ensure that dumpsites do not catch fire.
- Access to clean fuels in industry needs to be scaled up and units without air pollution control equipment or consent to operate are not allowed to function.
- Intensify public transport strategies and enforce parking controls and pricing as a demand management measure to reduce vehicle usage. Incentivise use of electric vehicles.
- Identify key commercial areas in Delhi and NCR towns that can be pedestrianized and be declared low emission zones.
- Dust control in construction sites and management of construction and demolition waste is implemented with zero tolerance.
- Disclose data on the truck movement based on the RFID data set to inform and control the intensity of the heavy duty traffic in the city.
- Identify all unpaved roads and dust hotspots for immediate action and paving.
- Equally stringent measures are needed to control fugitive dust and industrial waste burning and the mechanism need to be put in place for all industrial areas.
- Step up action to provide access to LPG and electricity to all eateries and households to prevent burning of solid fuels.
- Ensure access to reliable electricity supply in all residential and commercial/industrial areas to minimize use of diesel generator sets. Make DISCOMS liable and accountable for the outages in Delhi and entire NCR.

Annexure: Winter PM2.5 averages for cities of Delhi NCR

City	1-14 Oct 2022	2021-22 winter	2020-21 winter
Dharuhera, HR	62	106	142
Baghpat, RJ	59	142	166
Meerut, RJ*	59	134	159
Ghaziabad, UP*	55	167	213
Bhiwadi, RJ	55	130	161
Manesar, HR	49	143	123
Gurugram, HR*	49	137	148
Bulandshahr, RJ	48	133	185
Greater Noida, UP*	47	128	185
Delhi, DL*	47	157	179
Charkhi Dadri, HR	46	116	127
Muzaffarnagar, RJ	46	133	126
Hapur, RJ	46	135	61
Faridabad, HR*	44	152	156
Bahadurgarh, HR	43	122	142
Bhiwani, HR	43	102	41
Noida, UP*	40	141	188
Jind, HR	39	125	145
Ballabgarh, HR	39	128	109
Narnaul, HR	36	82	95
Rohtak, HR	34	118	143
Panipat, HR	32	73	88
Palwal, HR	30	44	48
Karnal, HR	28	81	93
Alwar, RJ	26	50	54
Sonipat, HR	24	66	84
Mandikhera, HR	17	57	80

Note: Seasonal average is based on mean of monthly averages. Winter season is defined as October to February. All values are in $\mu g/m^3$.
*Cities with multiple stations, average of all stations is used to represent the city.
Source: CSE analysis of CPCB realtime data