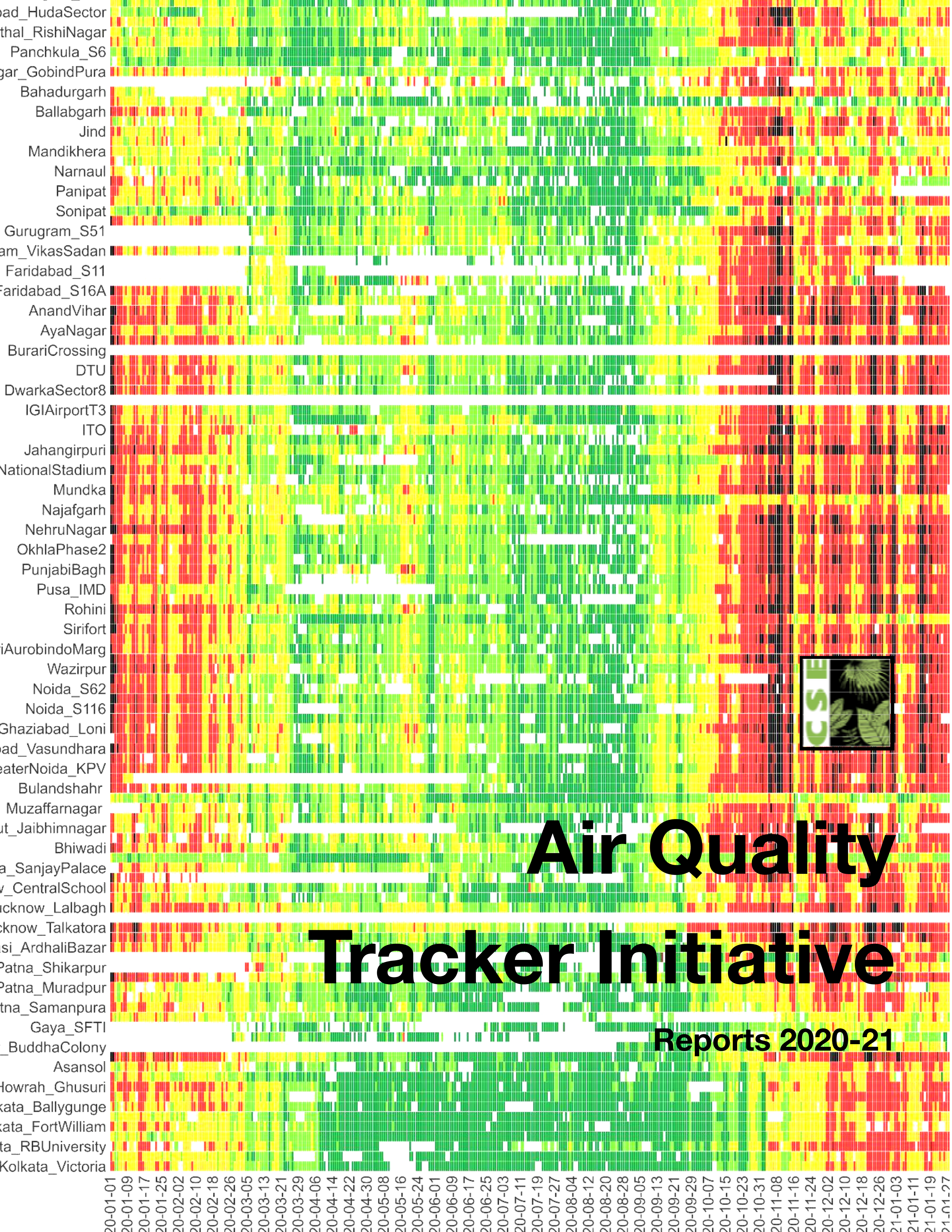

Air Quality Tracker Initiative

Reports 2020-21

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Data analytics: Avikal Somvanshi

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Material from this publication can be used, but with acknowledgement.
Cover graphics is a heatmap (calendar) of daily PM2.5 levels at all air quality monitoring stations in cities of Indo-Gangetic plains. Amritsar is at the top while Kolkata is at the bottom. Color signifies sub-air quality index for PM2.5. Data is from 1 January 2020 to 28 February 2021.

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0 About Air Quality Tracker Initiative

Air quality tracker initiative was started in 2020 by the Urban Data Analytics Lab of Centre for Science and Environment (CSE) to understand the nature of air pollution in the cities and various regions of India and how it has been impacted by the extraordinary pandemic year of 2020 that has witnessed one of the biggest disruptions in the recent times. This is an inflexion point but also an indicator of what may change and yet not changed despite the disruption. This initiative is designed to provide quick but empirically robust analysis to address some of the basic public curiosities related to air pollution in cities.

The initiative leverages publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management.

The initiative put out eight reports in the 2020-21 winter. Two additional reports were released in the 2021 summer. The reports use data from 249 official stations under the Continuous Ambient Air Quality Monitoring System (CAAQMS) and have covered 115 cities in 22 states and union territories.

1. Decoding winter smog so far to expose new patterns

numita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, December 2, 2020

New analysis of the winter pollution until November this year by the Centre for Science and Environment (CSE) shows how clean air gains of the lockdown and monsoon period were lost with the reopening of the economy and hostile winter weather. While this was expected, the deep dive analysis of the realtime data from monitoring stations across Delhi NCR and Delhi expose the changing pattern of winter pollution.

Even though the overall average level of $PM_{2.5}$ for the 11 months in 2020 is considerably lower than the previous year, the $PM_{2.5}$ levels in winter spiked to very poor to severe levels across Delhi NCR. This is a typical and predictable winter trend when continuous emissions from local sources and episodic pollution from biomass burning get trapped due to meteorological changes. But this year there is a change in the pattern that shows up in lesser number of smog episodes compared to last year, wider variation on location-wise concentration with more lower bound ranges compared to last year, higher number of days with greater contribution from the stubble burning among others. There are also days when pollution levels have dropped to moderate level even without rains but better wind conditions.

This only indicates towards the fact that the deep dive reforms and action in key sectors of pollution – vehicles, industry, power plants and waste management – will have to be scaled up at speed across the region to further bend the annual air pollution curve.

Data used in the analysis

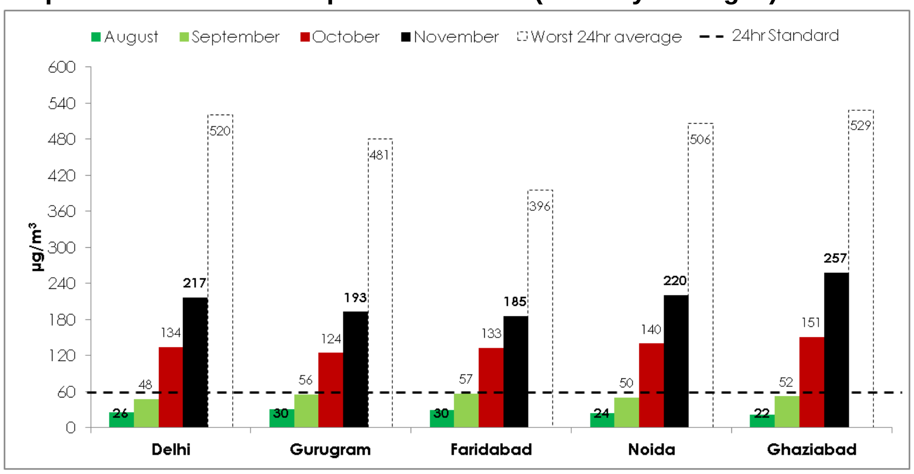
The analysis is based on publically available data from various government agencies. Most granular data (15-minute averages) has been sourced from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management - All India (https://app.cpcbccr.com/). This has analysed data recorded by 79 air quality monitoring stations or cent per cent of the current NCR network under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Farm stubble fire data has been sourced from System of Air Quality and Weather Forecasting and Research (SAFAR). Weather data has been sourced from the Palam weather station of Indian Meteorological Department (IMD).

Key highlights

Lower average level of $PM_{2.5}$ throughout the year due to the lockdown could not prevent the winter spike: The overall $PM_{2.5}$ average this year (until November) has been predictably lower compared to the previous year largely because of the unprecedented economic disruption during the summer lockdown and monsoon. But reopening of the economy coinciding with the onset of the winter trapping pollution made $PM_{2.5}$ levels spiral during October and November.

From the cleanest weeks of August (the cleanest month on record so far) the levels rose dramatically to one of the dirtiest November in recent years. This rise varied from 9.5 times increase in Delhi to 11 times in Ghaziabad; followed by Noida – 9.2 times, Gurugram by 6.4 times and Faridabad by 6.2 times (See *Graph 1: Pollution build-up in 2020 winter (monthly averages)*). The transient change of the lockdown phases could not be sustained without the systemic changes needed to control pollution from vehicles, industry, power plants, and waste.

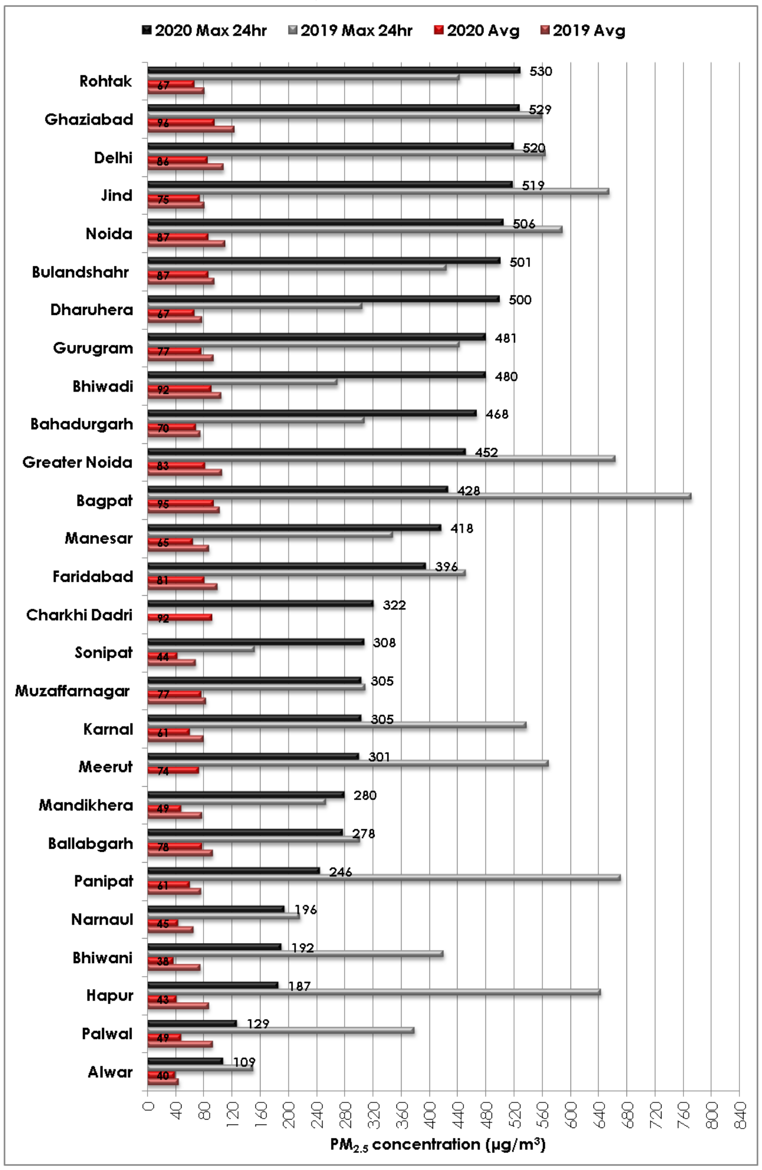
Graph 1: Pollution build-up in 2020 winter (monthly averages)



Note: Worst 24hr average is based on mean of all CAAQM stations in the city, not including Diwali day. Average $PM_{2.5}$ concentration for a month is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's realtime air quality data

Even with comparatively cleaner air round the year other towns in the NCR have recorded spikes as high as those observed in Delhi and big four NCR cities: CSE has compared the annual averages of the cities and towns of the larger NCR region with that of Delhi and the big four including Gurugram, Faridabad, Noida and Gaziabad. This shows that even with much lower annual average level of $PM_{2.5}$ other smaller cities and towns in NCR experience almost same maximum levels during winter when the entire region is in airlock (See *Graph 2: Pollution among NCR cities and towns*). In fact, even Delhi that has in the recent times witnessed decline in annual average levels year-on-year basis have experienced high pollution build up during winter. This brings out the deadly combination of regional influence with local pollution when meteorology is adverse.

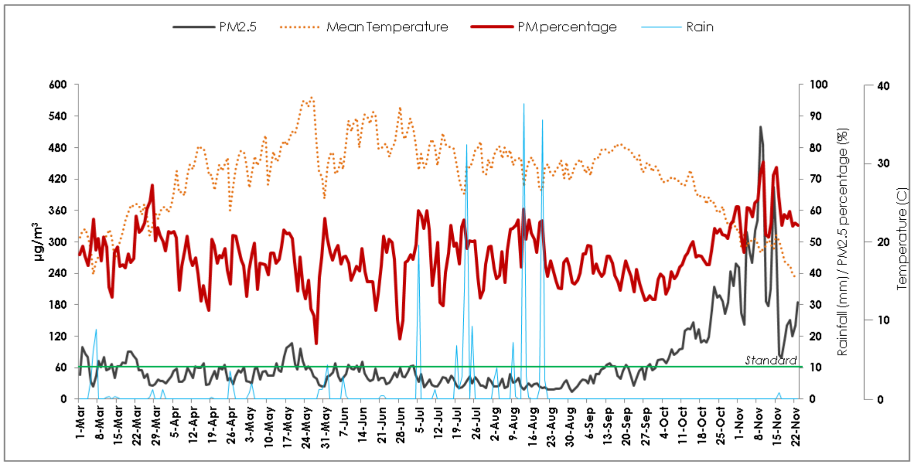
Graph 2: Pollution among NCR cities and towns



Note: 2020 numbers are based on data up to 30 Nov 2020. Data labels are for 2020 only.
Source: CSE analysis of CPCB's realtime air quality data

Air quality gets more toxic with the onset of winter - share of tinier $PM_{2.5}$ in the PM_{10} increases: The share of tinier and finer particles in the overall coarser PM_{10} concentration determines the toxicity of air. Interestingly, during lockdown, when the overall suspended coarser particles had settled down reducing the PM_{10} levels, the $PM_{2.5}$ had also come down but its share was 47 per cent – higher than its usually noted during summer. But with the onset of winter the percentage share of $PM_{2.5}$ in the overall PM_{10} rose to over 70 per cent during the smog episodes in early November, and remained high at 50-60 per cent during most of November (See Graph 3: Percentage of PM2.5 in Delhi (1 Mar – 29 Nov, 2020)). The share of $PM_{2.5}$ in PM_{10} was highest on Diwali reaching over 80 per cent at many locations. Tinier particles are more dangerous as they can penetrate deep inside the lungs and through blood barriers increasing health risk.

Graph 3: Percentage of $PM_{2.5}$ in Delhi (1 Mar – 29 Nov, 2020)

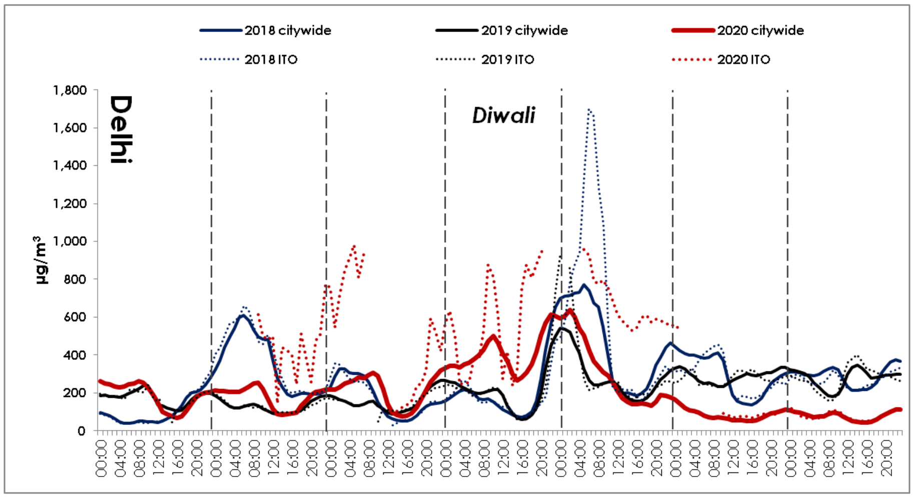


Data: CPCB (PM_{10} and $PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Pattern of smog episode is different this year: Technically, smog episode is defined for the purpose of emergency action under Graded Response Action Plan when the levels of $PM_{2.5}$ remain in severe category for three consecutive days. By that logic the region has experienced one severe smog episode this year (7-10 Nov, 2020) compared to two episodes last year until November (31 Oct-3 Nov, 2019 and 12-15 Nov, 2019). This year the episode preceded Diwali that also much later in November compared to end of October last year. In fact, last year Diwali had catalyzed the first big smog episode of the season.

But this year Diwali pollution from fire crackers combined with smoke from stubble burning and local pollution to start a buildup of severe-plus and extremely hazardous level on day of Diwali itself (14 Nov 2020). But this did not last long to become another smog episode as meteorology along with short rain spell helped to dissipate it quicker. The average $PM_{2.5}$ level on Diwali day in Delhi was 404 µg/m^3 and it dropped to 308 µg/m^3 the next day in contrast the trend in the previous years when the levels increased next day. This year pollution was able to disperse faster due to meteorology. But like previous years, there was dramatic change in hourly $PM_{2.5}$ concentration between afternoon and night of Diwali due to excessive firecracker busting (See *Graph 4: Impact of Diwali on hourly pollution*). The change in hourly $PM_{2.5}$ concentration between afternoon and night of Diwali was 370 µg/m^3, down from 480 µg/m^3 in 2019 and 698 µg/m^3 in 2018.

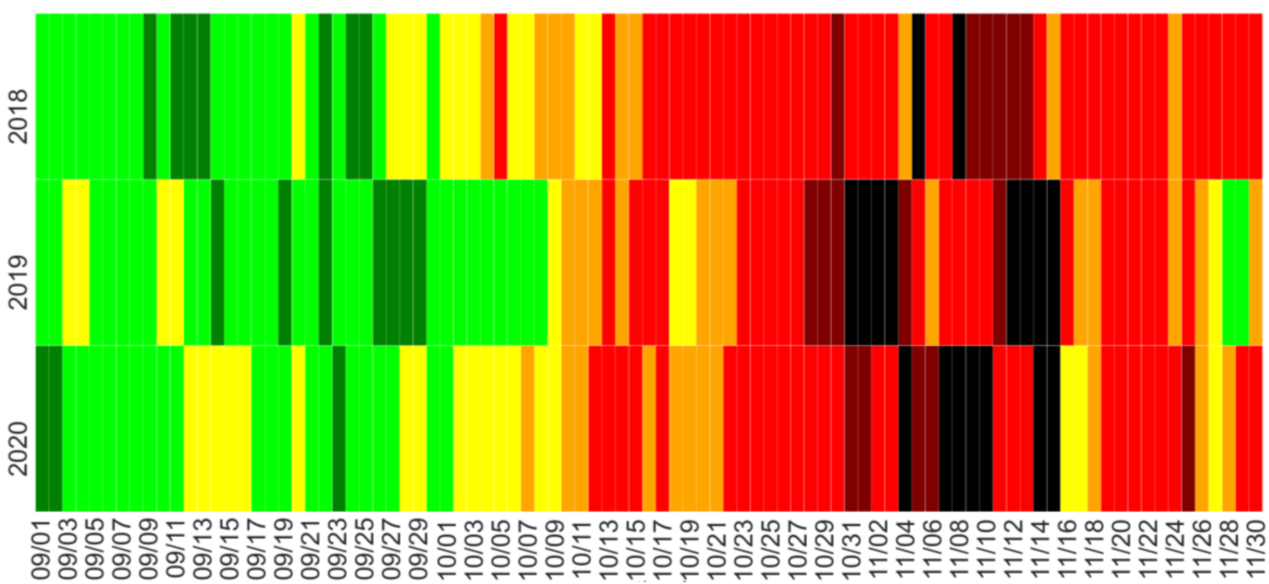
Graph 4: Impact of Diwali on hourly pollution in Delhi



Note: Diwali dates are 7 Nov 2018, 27 Oct 2019, and 14 Nov 2020. Citywide is based on average $PM_{2.5}$ concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations. CPCB portal since 2019 has a cap of 1,000 µg/m^3, i.e. when the $PM_{2.5}$ concentration peaks beyond 999 µg/m^3 (very common on Diwali night) the portal data entry goes blank, therefore the broken line in the graph at Diwali night should be read as concentration beyond 1,000 µg/m^3 instead of being generic missing data.
Source: CSE analysis of CPCB's real time air quality data

Levels are more volatile recording quicker ups and downs and dispersal aided by overall downward trend in annual trends and meteorology: The cyclical ups and down of pollution this winter is more volatile – showing quicker rise and fall than pervious winter (See *Graph 5: Heatmap of Delhi's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20*). This could also be a reflection of changes in local pollution pattern and overall downward trend while aided by the meteorology.

Graph 5: Heatmap of Delhi's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20

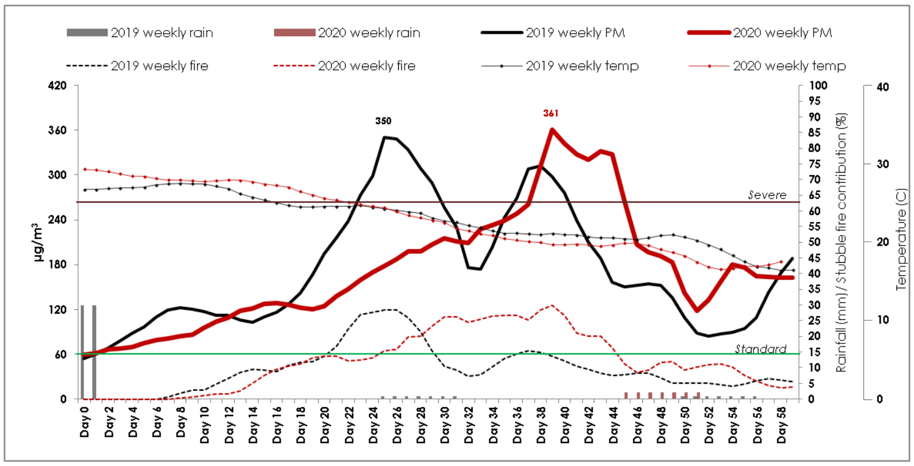


Note: Average $PM_{2.5}$ concentration for a day is based on mean of 36 CAAQM stations of Delhi. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

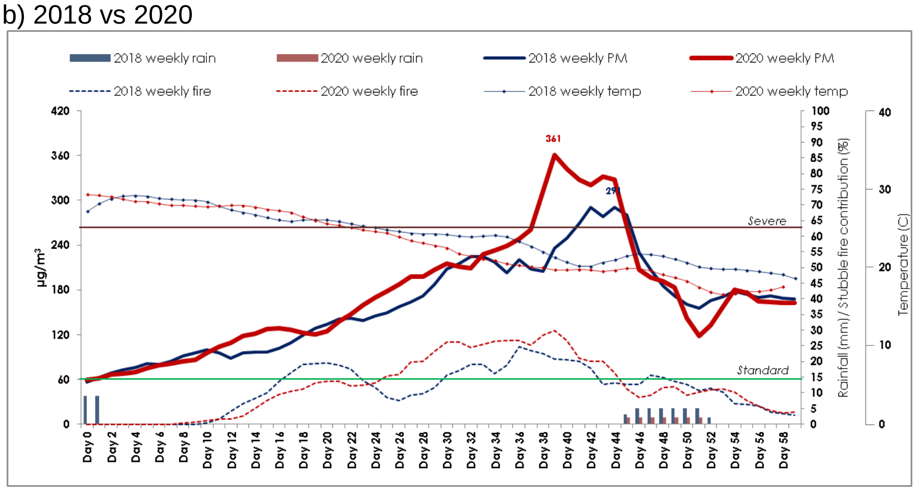
Firstly, an interesting observation is that there are days this November when air quality improved substantially without the rains but with overall improvement in wind pattern. There are three days during the second half of November in 2020 when the air quality improved to “moderately polluted” AQI category in Delhi. This is same as 2019 but the clean up in 2019 was induced by rains. In 2018, the citywide average never dropped below “poor” AQI category in November. This winter the daily citywide average dropped down even to 76 µg/m^3 on November 27, without any rain to help aid in the cleaning process. In fact, five stations in Delhi met the 24hr standard with Shadipur registering 41 µg/m^3. Gurugram (68 µg/m^3), Faridabad (58 µg/m^3), and Noida (73 µg/m^3) had even lower citywide average than Delhi, in fact Faridabad met the standard. Ghaziabad had a relatively higher 84 µg/m^3 . This is quite different compared to previous winter.

Graph 6: Rate of increase in $PM_{2.5}$ in Delhi a) 2019 vs 2020, b) 2018 vs 2020

a) 2019 vs 2020



b) 2018 vs 2020



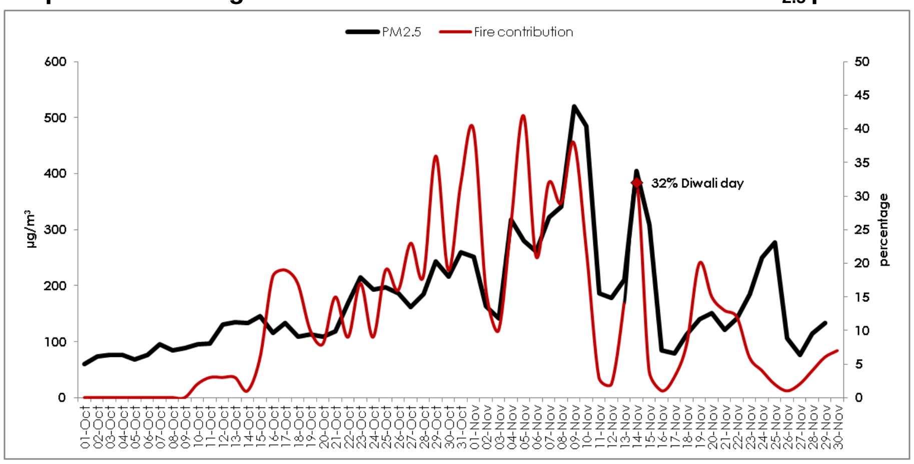
Note: All values are rolling weekly average. Day 0 is the last day when the rolling weekly average was below the standard (60ug/m3). Day 0 for each year is week ending on 30 Sept 2018, 9 Oct 2019, and 2 Oct 2020.
Data: CPCB ($PM_{2.5}$), SAFAR (Stubble fire contribution), IMD (Temperature and rainfall)
Source: CSE analysis

Secondly, this year local pollution across the monitoring locations of Delhi shows wider variation between lower and upper range of pollution. This is in contrast to the range of variation noted last year that was more upper bound. Even on the peak smog day in November this year, the PM2.5 levels in several stations varied from a lower bound 108 µg/m^3 at NSIT to 699 µg/m^3 at Mundaka. But last year the variation was noted at a higher range – between 351 µg/m^3 at Shadipur to 725 µg/m^3 at Alipur – while the overall level stayed above 374 µg/m^3 . In fact, the standard deviation among the 36 stations of Delhi this November on an average is 60 per cent higher compared to last year across. This indicates somewhat clearing up of local pollution though meteorology plays a part.

Even the rolling weekly average rose slower this year compared to last year (See *Graph 6: Rate of increase in PM$_{2.5}$ in Delhi a) 2019 vs 2020, b) 2018 vs 2020*). It took 37 days to reach the severe category (250 µg/m^3) from the week that last met the standard of 60 µg/m^3 in early October (week ending on 2nd October, 2020). This is considerably slower rise compared to 2019 when it took 23 days. In 2018, it took 40 days but weather was also about 3^{o}C warmer compared to this November. This November is also among the coldest in the recent years according to IMD.

Contribution of crop burning to the region's pollution was volatile and higher number of days recorded higher share: CSE has analysed the data provided by SAFAR on daily percentage contribution of the stubble burning to the PM$_{2.5}$ concentration in Delhi-NCR depending on the direction and speed of the wind. This shows that the smoke from crop stubble fire started impacting Delhi more discerningly from 10, October 2020 onwards. This was a week earlier than last year when it started on 16 October, 2019 (See *Graph 7: Percentage contribution of stubble fire to Delhi's PM$_{2.5}$ pollution in 2020*).

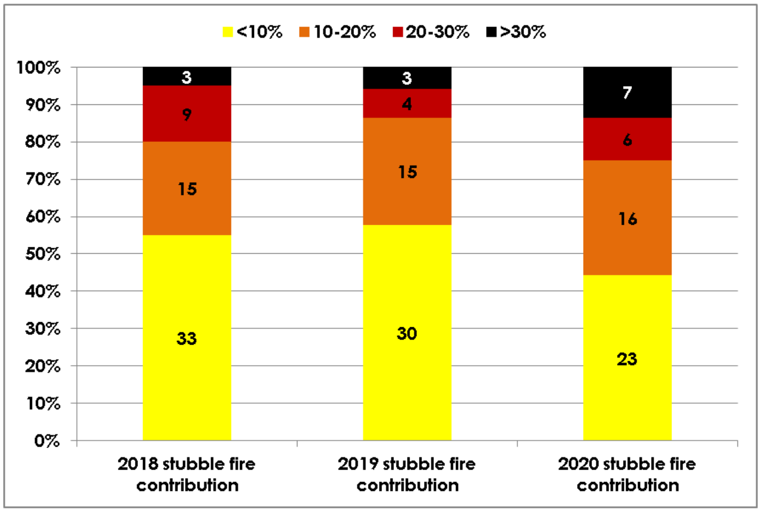
Graph 7: Percentage contribution of stubble fire to Delhi's PM$_{2.5}$ pollution in 2020



Note: Data up till 30 Nov 2020.
Source: CSE analysis of CPCB and SAFAR data

CSE analysed classified days (uptill 30 November) based on daily percentage contribution – less than 10 per cent, 10-20 per cent, 20-30 per cent and above 30 per cent. This shows there were 7 days this year when the contribution of smoke to Delhi's PM$_{2.5}$ concentration exceeded 30 per cent in contrast to 3 days in 2019 and 2018 (See *Graph 8: Day-wise breakup of farm stubble fire contribution to Delhi's PM$_{2.5}$ pollution load*). There were 6 days when contribution was between 20-30 per cent, (up from 4 days in 2019) and 16 days of 10-20 per cent contribution (up from 15 days in 2019) and 23 days with less than 10 per cent contribution (down from 30 days in 2019). This year Diwali pollution was also compounded by the heightened contribution of smoke from crop stubble fire as the contribution increased to 32 per cent.

Graph 8: Day-wise breakup of farm stubble fire contribution to Delhi's $PM_{2.5}$ pollution load

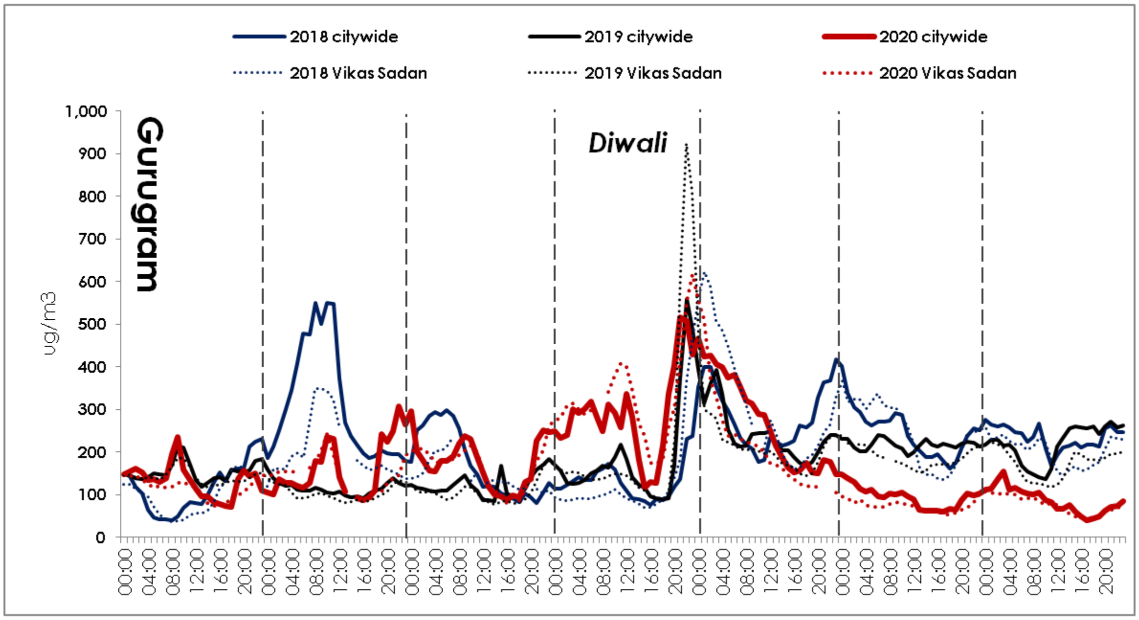


Note: For 10 Oct – 30 Nov of 2018, 2019, and 2020.
Source: CSE analysis of SAFAR data

Need deep cuts
How the pollution level will play out during the rest of the winter remains to be seen. But it is clear that the region cannot afford to lose the wins already made and at the same time, raise the level of ambition to drive action across all key sectors of pollution and the entire region. Enforce power plant standards, eliminate coal from the industry, scale up public transport and vehicle restraint measures and manage waste to have a zero waste and zero landfill strategy.

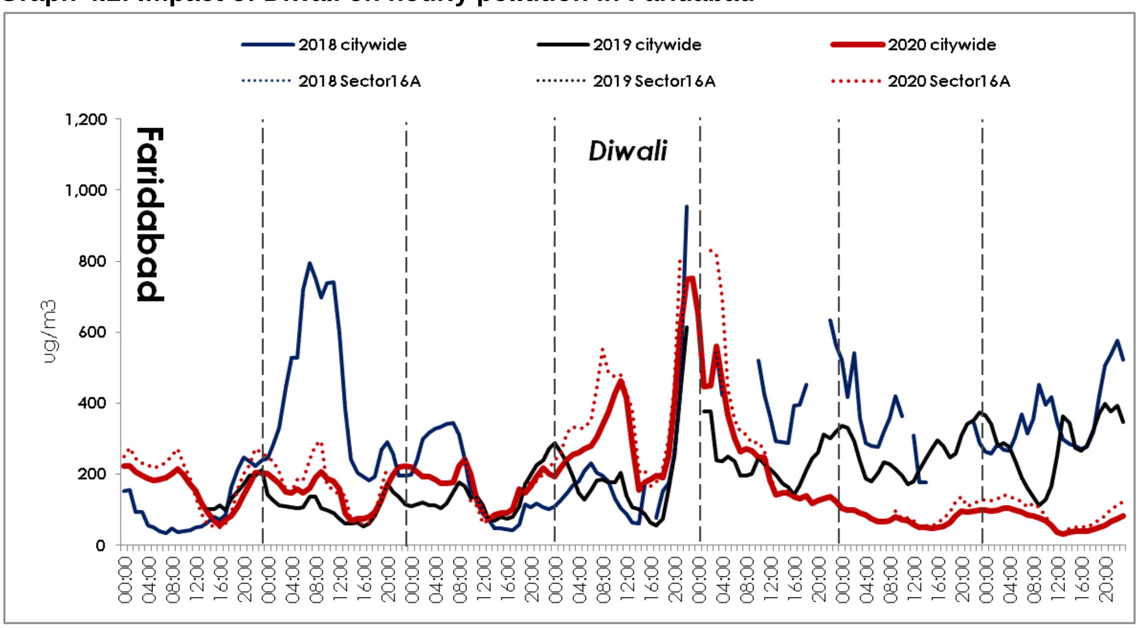
Additional graphs for NCR cities

Graph 4.1: Impact of Diwali on hourly pollution in Gurugram



Note: Diwali dates are 7 Nov 2018, 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations. CPCB portal has a cap of 1,000 µg/m^3, i.e. when the $PM_{2.5}$ concentration peaks beyond 999 µg/m^3 (very common on Diwali night) the portal data entry goes blank, therefore the broken line in the graph at Diwali night should be read as concentration beyond 1,000 µg/m^3 instead of being generic missing data.
Source: CSE analysis of CPCB's real time air quality data

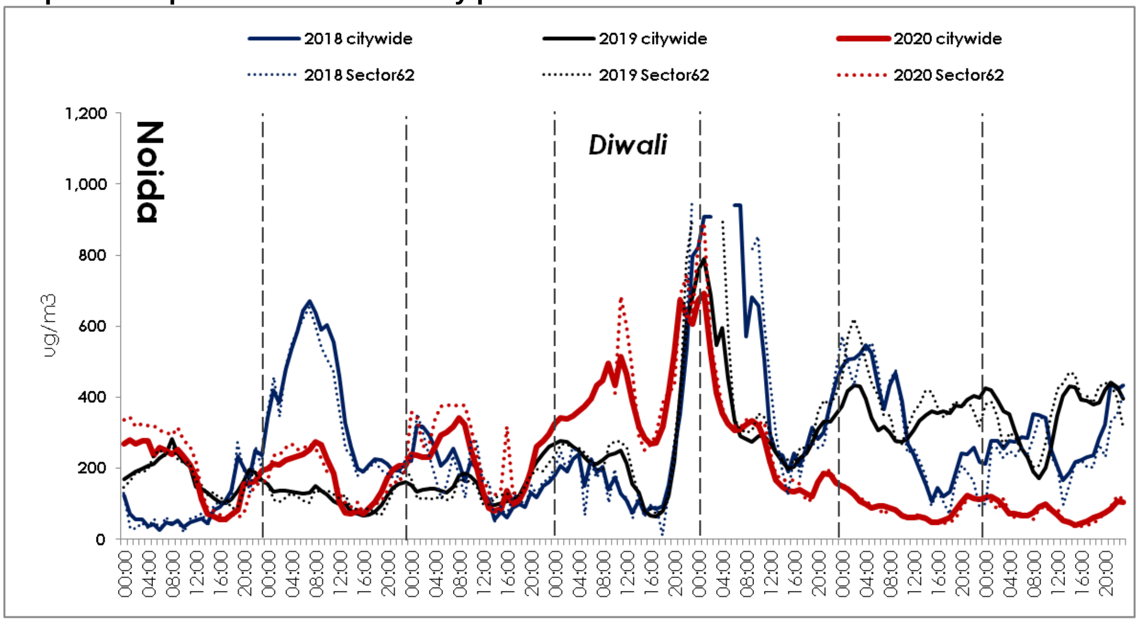
Graph 4.2: Impact of Diwali on hourly pollution in Faridabad



Note: Diwali dates are 7 Nov 2018, 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations. CPCB portal has a cap of 1,000 µg/m^3, i.e. when the $PM_{2.5}$ concentration peaks beyond 999 µg/m^3 (very common on Diwali night) the portal data entry goes blank, therefore the broken

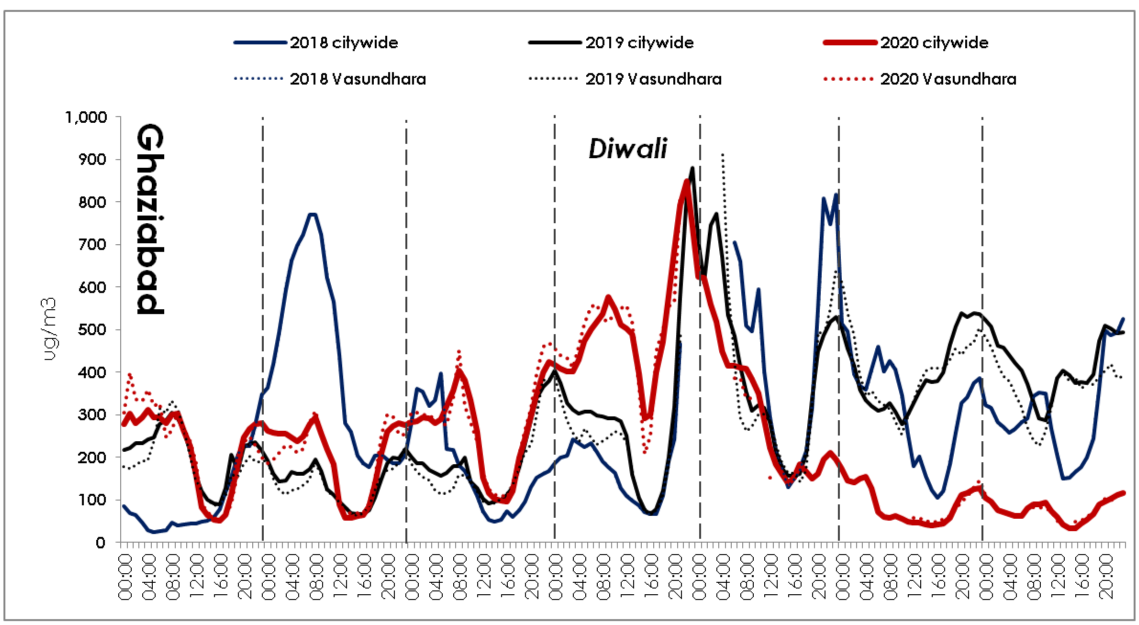
line in the graph at Diwali night should be read as concentration beyond 1,000 µg/m^3 instead of being generic missing data.
Source: CSE analysis of CPCB's real time air quality data

Graph 4.3: Impact of Diwali on hourly pollution in Noida



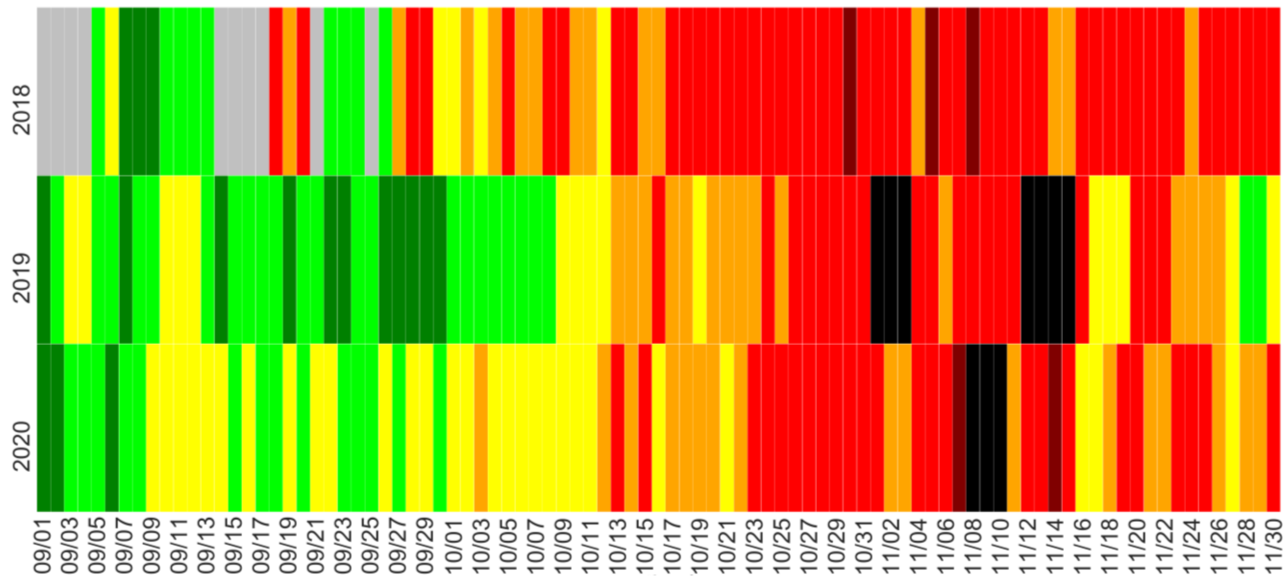
Note: Diwali dates are 7 Nov 2018, 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations. CPCB portal has a cap of 1,000 µg/m^3, i.e. when the $PM_{2.5}$ concentration peaks beyond 999 µg/m^3 (very common on Diwali night) the portal data entry goes blank, therefore the broken line in the graph at Diwali night should be read as concentration beyond 1,000 µg/m^3 instead of being generic missing data.
Source: CSE analysis of CPCB's real time air quality data

Graph 4.4: Impact of Diwali on hourly pollution in Ghaziabad



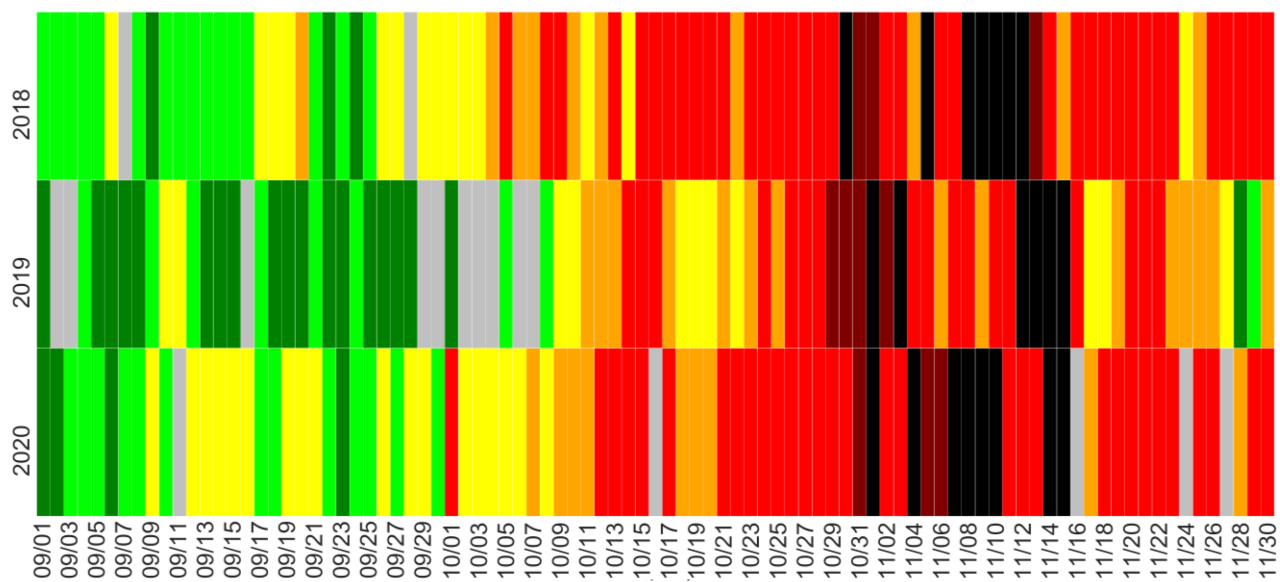
Note: Diwali dates are 7 Nov 2018, 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations. CPCB portal has a cap of 1,000 µg/m^3, i.e. when the $PM_{2.5}$ concentration peaks beyond 999 µg/m^3 (very common on Diwali night) the portal data entry goes blank, therefore the broken line in the graph at Diwali night should be read as concentration beyond 1,000 µg/m^3 instead of being generic missing data.
Source: CSE analysis of CPCB's real time air quality data

Graph 5.1: Heatmap of Gurugram's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



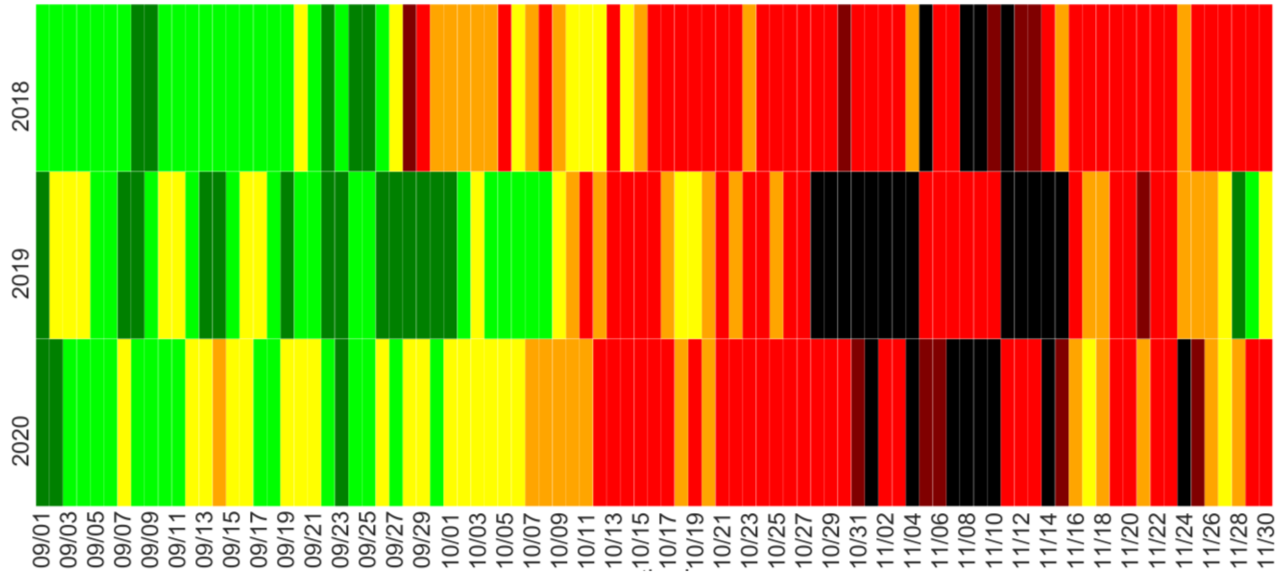
Note: Average $PM_{2.5}$ concentration for a day is based on mean of Vikas Sadan and Gwal Pahari CAAQM stations in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.2: Heatmap of Faridabad's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



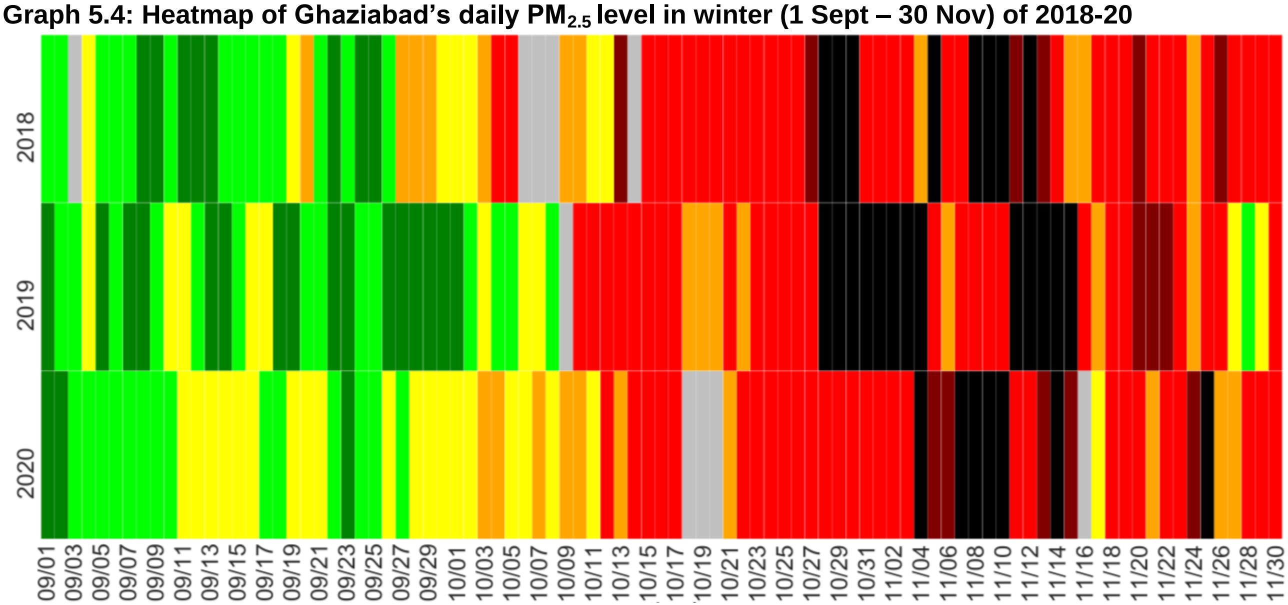
Note: Average $PM_{2.5}$ concentration for a day is based on Faridabad Sector 16A CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.3: Heatmap of Noida's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



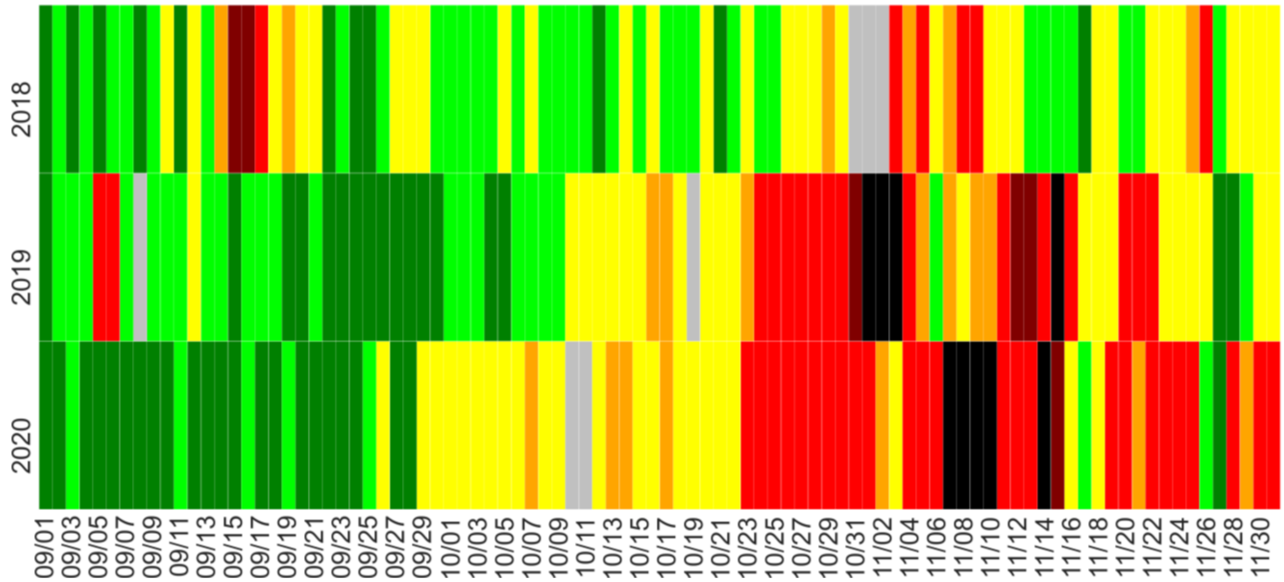
Note: Average $PM_{2.5}$ concentration for a day is based on mean of Sector 125 and Sector 62 CAAQM stations in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.4: Heatmap of Ghaziabad's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



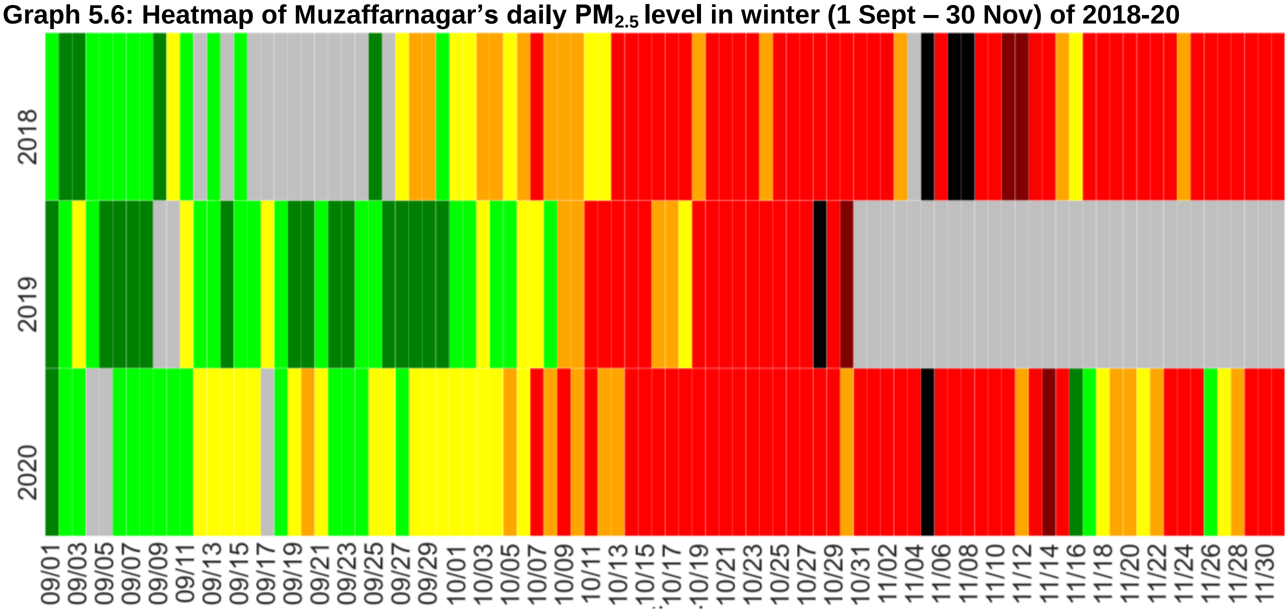
Note: Average $PM_{2.5}$ concentration for a day is based on Varundhara CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.5: Heatmap of Rohtak's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



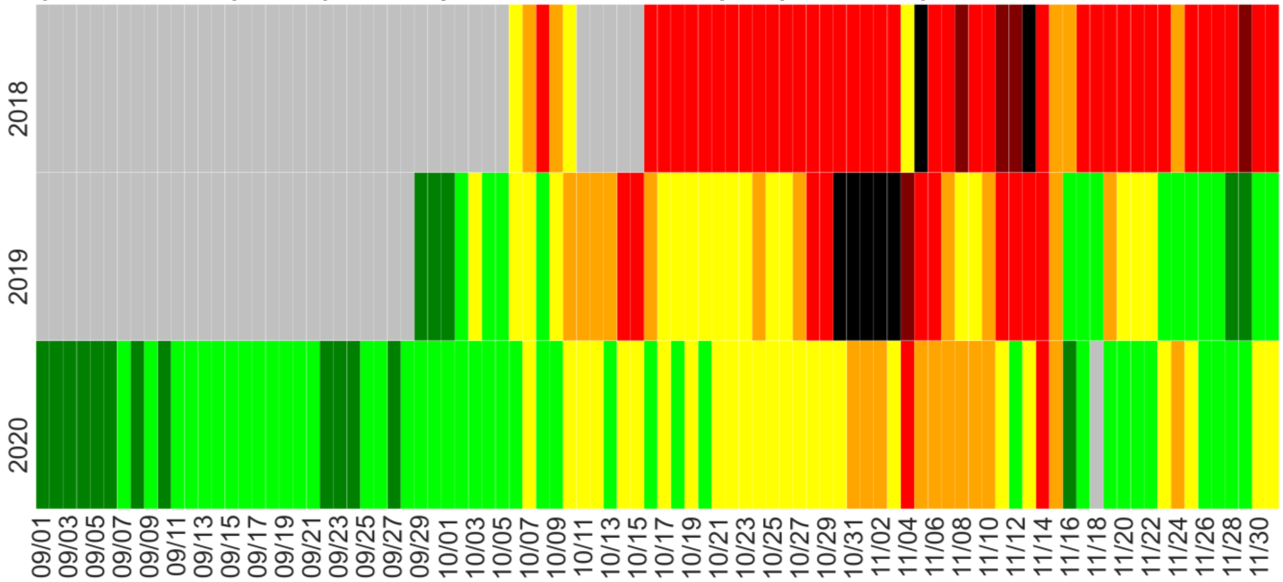
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.6: Heatmap of Muzaffarnagar's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



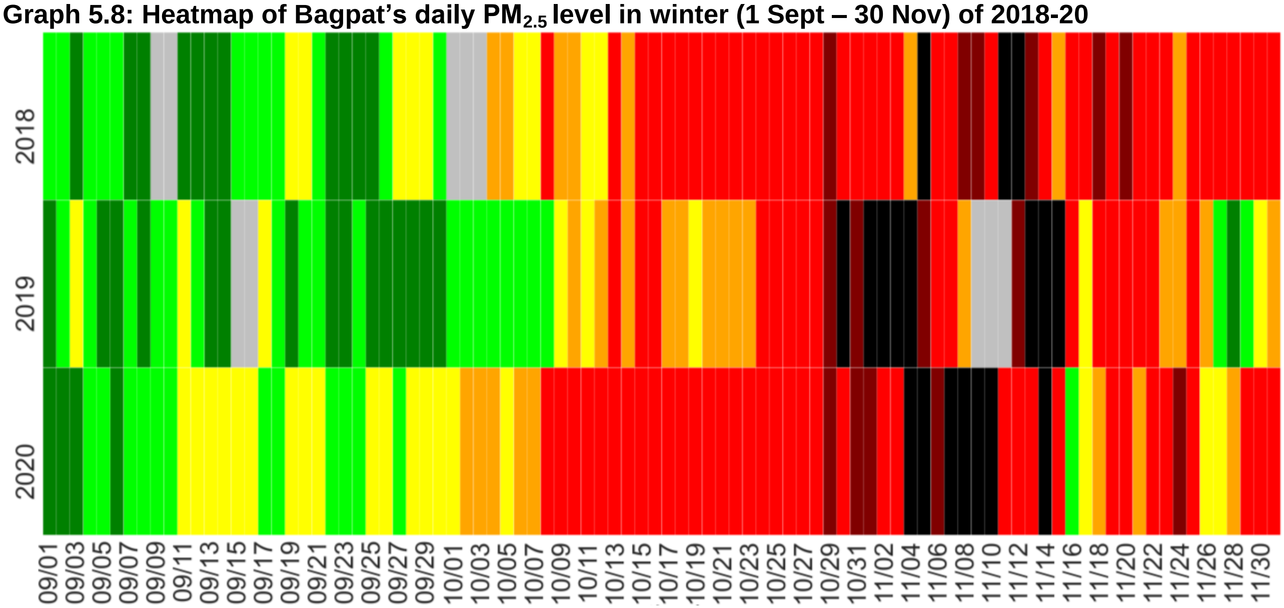
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.7: Heatmap of Hapur's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



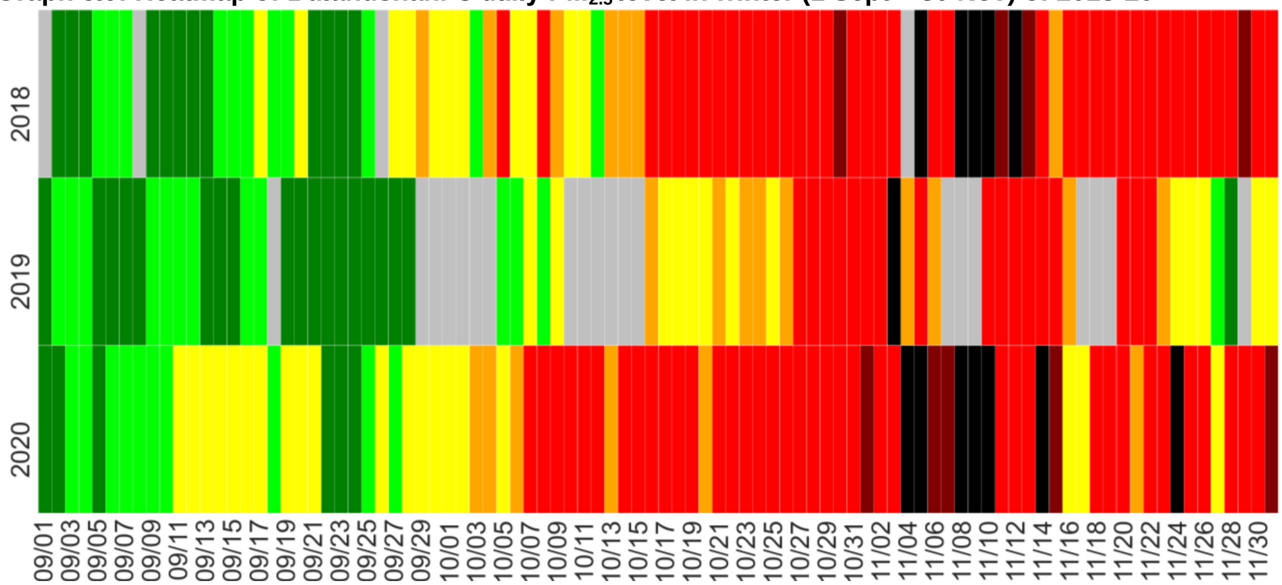
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.8: Heatmap of Bagpat's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



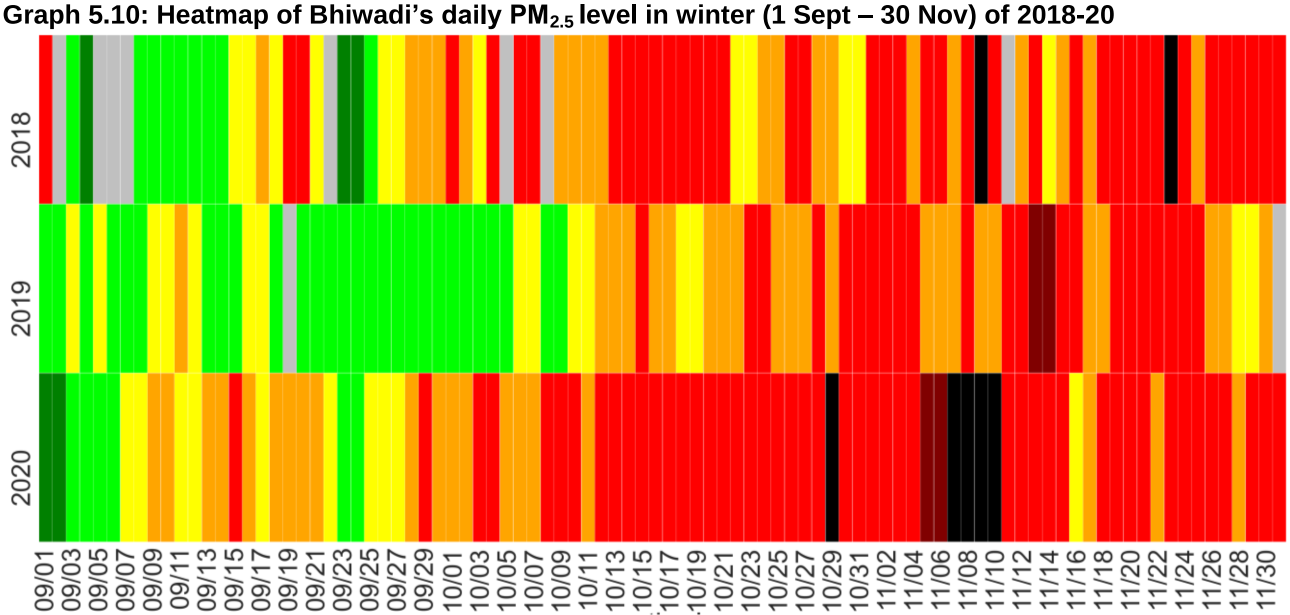
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.9: Heatmap of Bulandshahr's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



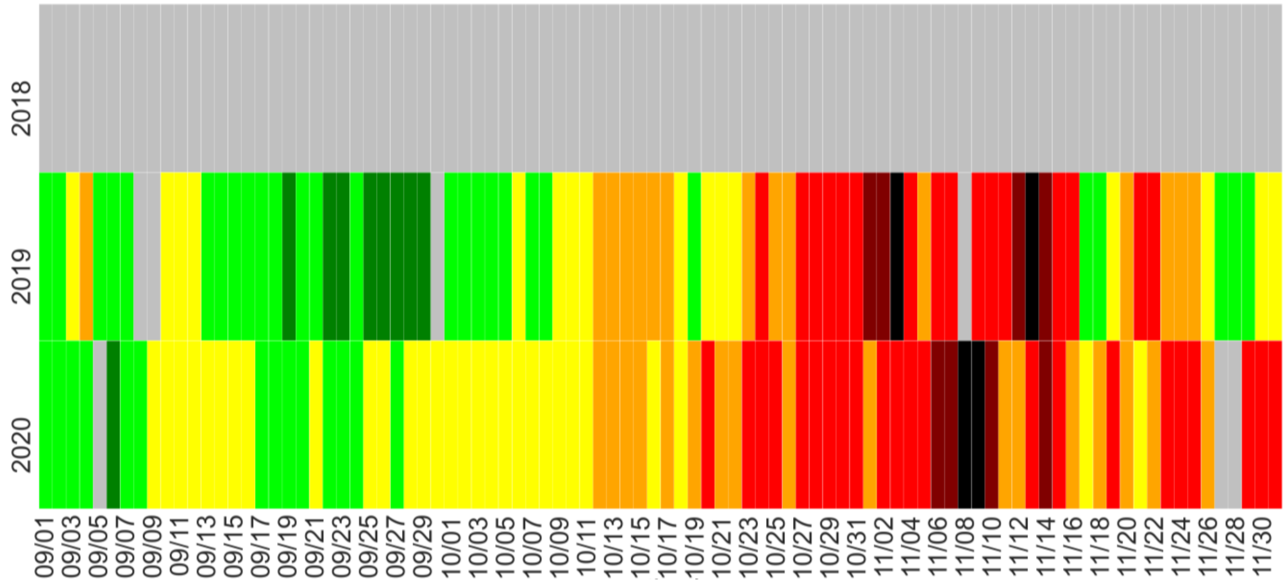
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.10: Heatmap of Bhiwadi's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



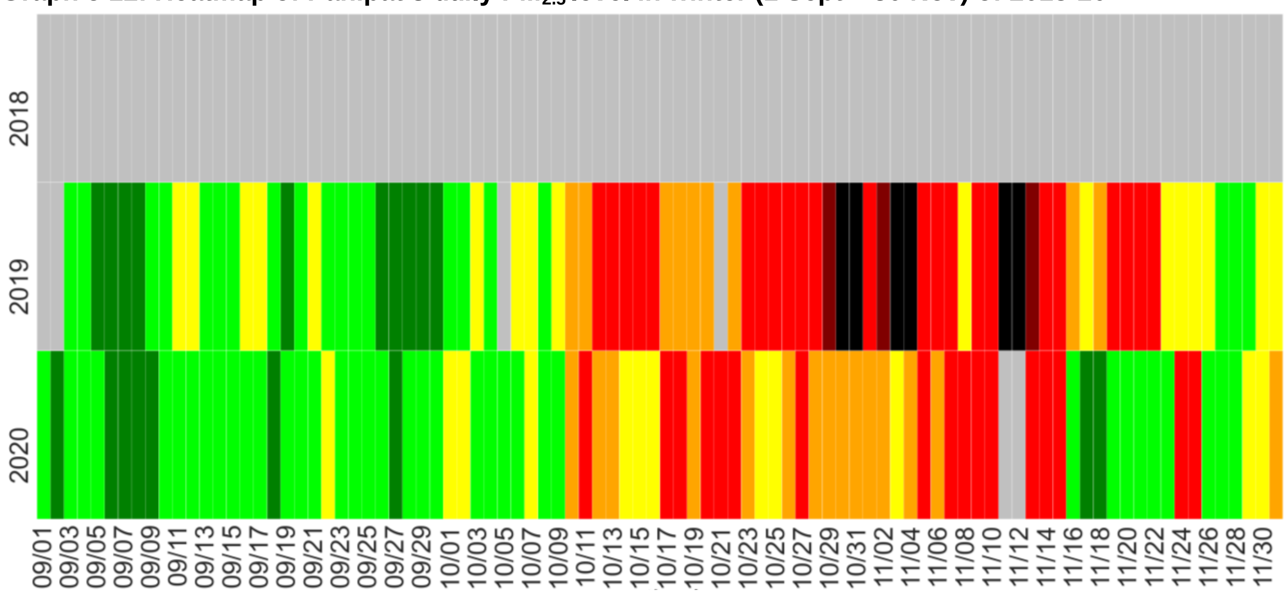
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.11: Heatmap of Manesar's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



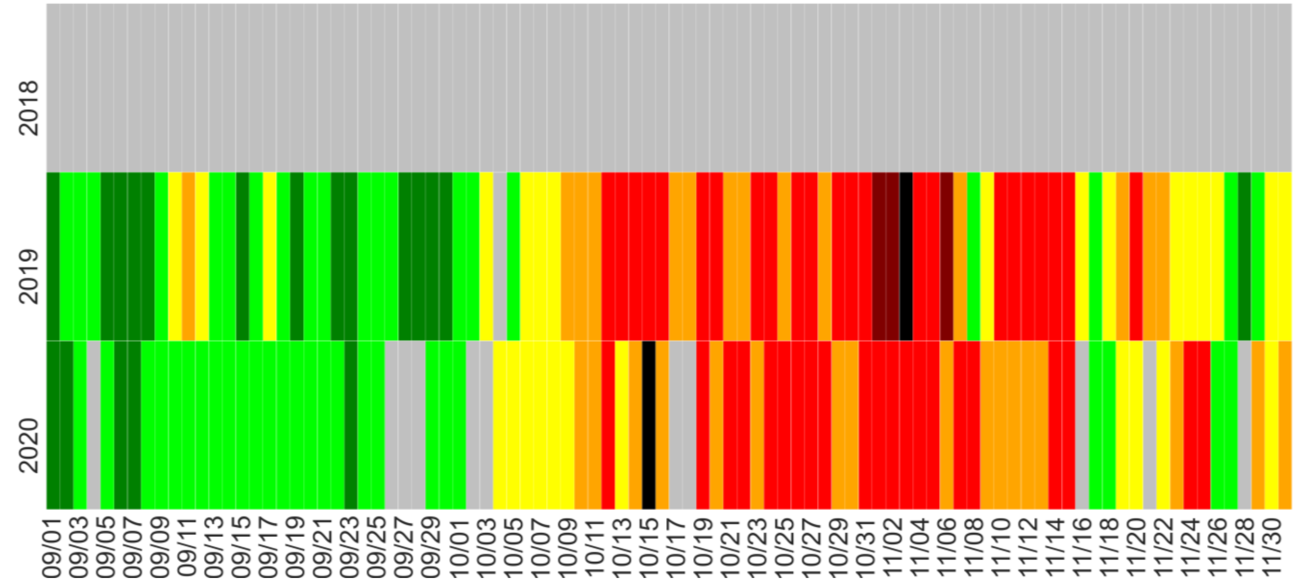
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.12: Heatmap of Panipat's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



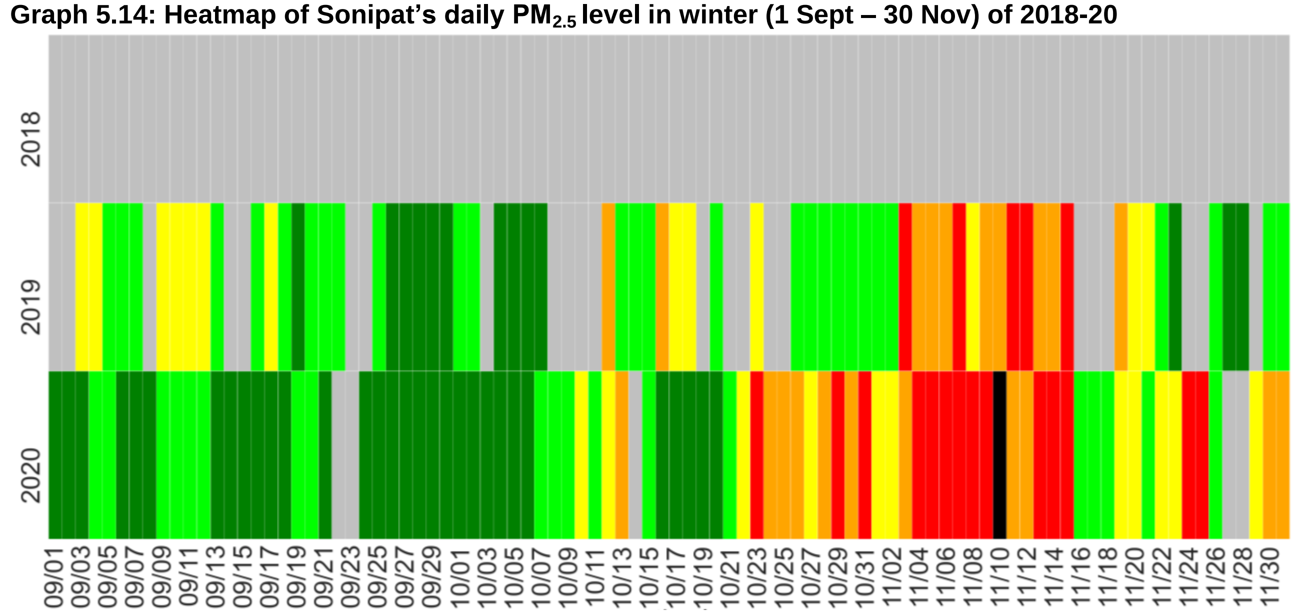
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.13: Heatmap of Karnal's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



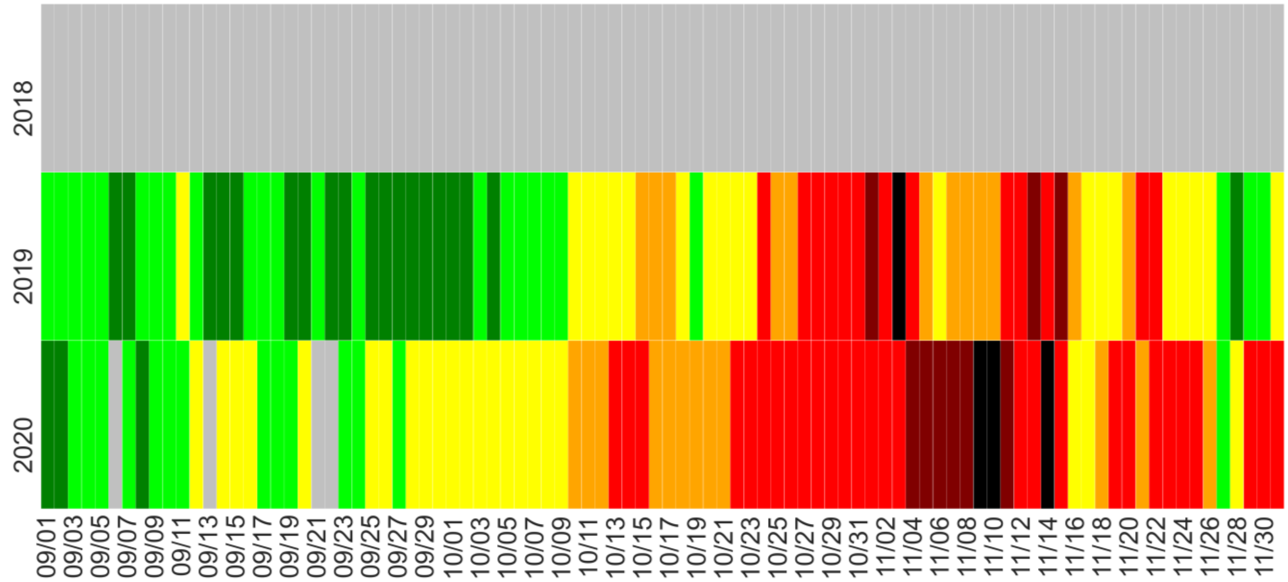
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.14: Heatmap of Sonipat's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



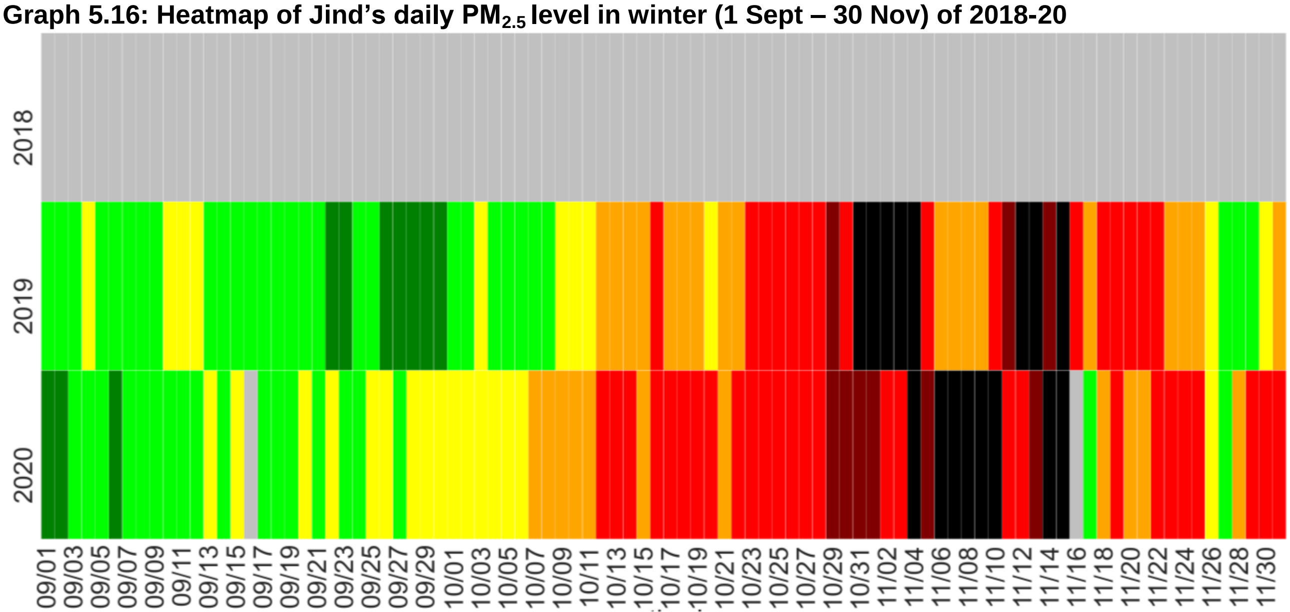
Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.15: Heatmap of Bahadurgarh's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 5.16: Heatmap of Jind's daily $PM_{2.5}$ level in winter (1 Sept – 30 Nov) of 2018-20



Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

2. Winter air pollution in Kolkata-Howrah spikes

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, December 7, 2020

New analysis of winter pollution until December first week this year, done by Centre for Science and Environment (CSE), shows how clean air gains of the lockdown and monsoon period were lost with the reopening of the economy and hostile winter weather. While this was expected, the analysis of the real-time data from monitoring stations across Kolkata-Howrah as well as Asansol and Siliguri show the changing pattern in winter pollution this year.

Even though the overall average level of $PM_{2.5}$ for the 11 months in 2020 is considerably lower than the previous year, the $PM_{2.5}$ levels in winter spiked to "very poor" levels in the twin cities of Kolkata and Howrah. This is a typical and predictable winter trend when continuous emissions from local sources including vehicles, industry, construction, and episodic pollution from biomass burning get trapped due to meteorological changes. But this year, there is higher pollution peak and substantial jump due to reopening of the economy.

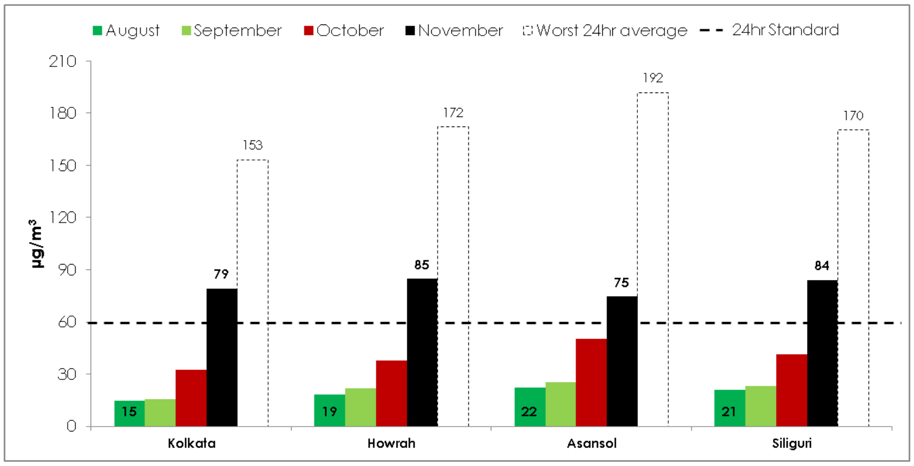
Reforms and action in key sectors of pollution – vehicles, industry, power plants and waste management – will have to be scaled up at speed across the region to further bend the annual air pollution curve.

Data used in the analysis: The analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. Four cities – Kolkata, Howrah, Asansol and Siliguri have been selected for this analysis because real time data is available for these cities. This has analysed data recorded by 7 air quality monitoring stations at Kolkata, 3 stations in Howrah, one station each Asansol and Siliguri under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Weather data has been sourced from the Dum Dum weather station of Indian Meteorological Department (IMD). The reason

Key highlights

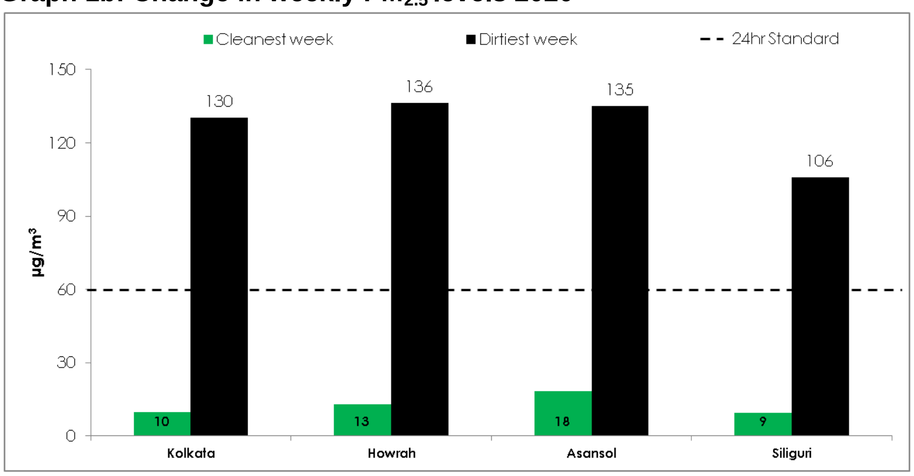
Average level of $PM_{2.5}$ has been lower during this year due to the lockdown but could not prevent the winter spike: The overall $PM_{2.5}$ average this year (until first week of December) has been predictably lower compared to the previous year largely because of the unprecedented economic disruption during the summer lockdown and monsoon. But reopening of the economy coinciding with the onset of the winter trapping pollution made $PM_{2.5}$ levels spiral upward starting November hitting record high in early December. From the respective cleanest week weekly average of $PM_{2.5}$ in Kolkata rose 13 times, in Howrah 11 times, Asanasol 7 times and in Siliguri 11 times (See *Graph 1a: Pollution build-up in 2020 winter (monthly averages)*; and *Graph 1b: Change in weekly $PM_{2.5}$ levels*). The transient change of the lockdown phases could not be sustained without the systemic changes needed to control pollution from vehicles, industry, power plants, and waste.

Graph 1a: Pollution build-up in 2020 winter (monthly averages)



Note: Average $PM_{2.5}$ concentration for a month is based on mean of all CAAQM stations in the city. Worst 24hr average at the citywide level recorded between 1 March- 6 December, 2020.
Source: CSE analysis of CPCB's real time air quality data

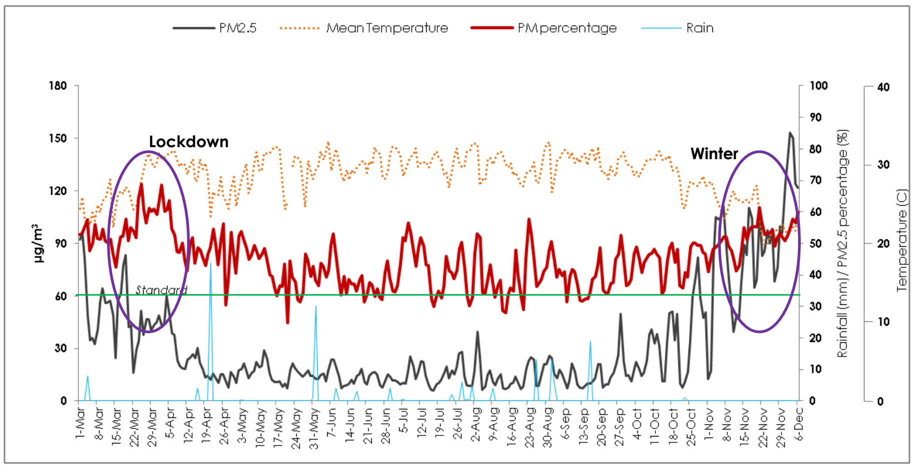
Graph 1b: Change in weekly $PM_{2.5}$ levels 2020



Note: Average $PM_{2.5}$ concentration for a week is based on mean of all CAAQM stations in the city. Dirtiest week for Kolkata, Howrah, and Asansol was the week ending on 6 December, 2020. Siliguri's dirtiest week was the week ending 8 November, 2020.
Source: CSE analysis of CPCB's real time air quality data

Air quality gets more toxic with the onset of winter - share of tinier $PM_{2.5}$ in the PM_{10} increases: The share of tinier and finer particles in the overall coarser PM_{10} concentration determines the toxicity of air. When the overall share of tinier $PM_{2.5}$ in the overall coarser PM_{10} is higher, the air is more toxic as the tiny particles penetrate deep inside the lungs and cut through the blood barrier increasing health risk. Interestingly, during lockdown, when the overall suspended coarser particles had settled down reducing the PM_{10} levels, the $PM_{2.5}$ had also come down. But its share was 50 per cent – higher than its usually noted during summer. But with the onset of winter the overall level of both have gone up and also the percentage share of $PM_{2.5}$ in the overall $PM_{10.}$ This rose to over 60 per cent during the high pollution episode following Diwali in mid November, and remained high over 50 per cent since (See *Graph 2: Percentage of $PM_{2.5}$ in Kolkata (1 Mar – 6 Dec, 2020)*). The share of $PM_{2.5}$ in PM_{10} is generally highest on Diwali reaching over 80 per cent in 2019 but due to lesser busting of firecracker this year it remained in mid 50s.

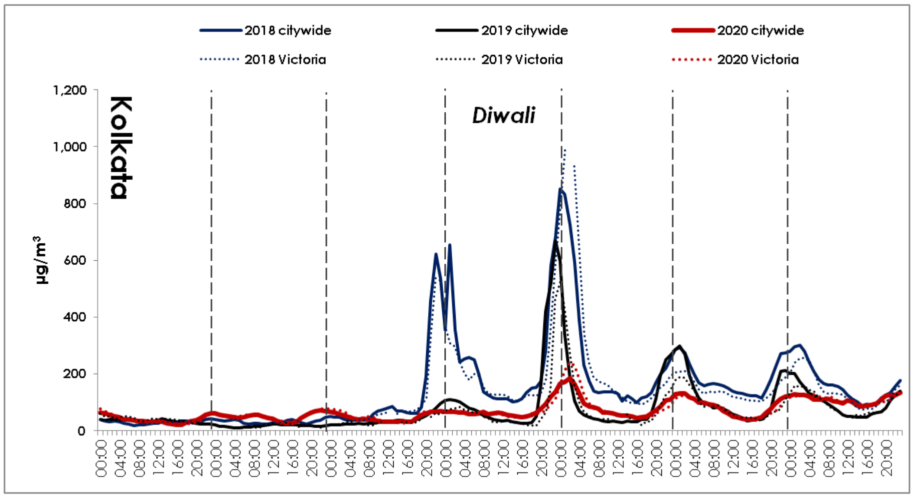
Graph 2: Percentage of $PM_{2.5}$ in Kolkata (1 Mar – 6 Dec, 2020)



Data: CPCB (PM_{10} and $PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Cleaner Diwali in Kolkata this year: This year Diwali pollution from firecrackers was considerably lower. The average $PM_{2.5}$ level on Diwali day in Kolkata was 89 µg/m^3 down from 123 µg/m^3 recorded in 2019. This year pollution did not disperse but grew to 110 µg/m^3 on 17 November due to meteorology. Unlike previous years, there was about 80 per cent lesser change in hourly $PM_{2.5}$ concentration between afternoon and night of Diwali that is mostly caused due to firecracker busting (See *Graph 3: Impact of Diwali on hourly pollution*). The change in hourly $PM_{2.5}$ concentration between afternoon and night of 2020 Diwali was 136 µg/m^3, down from 642 µg/m^3 in 2019 and 751 µg/m^3 in 2018.

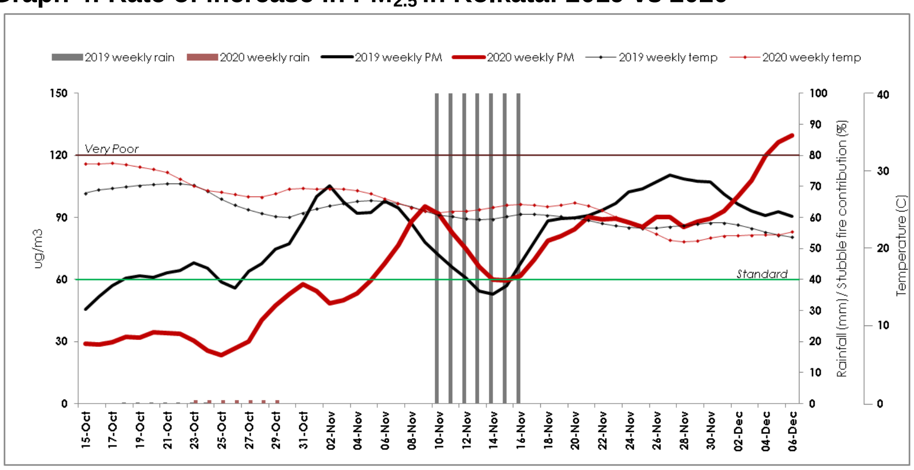
Graph 3: Impact of Diwali on hourly pollution in Kolkata



Note: Diwali dates are 7 Nov 2018, 27 Oct 2019, and 14 Nov 2020. Citywide is based on average $PM_{2.5}$ concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Kolkata -- November 2020 cleaner but first week of December more polluted: The rolling weekly average rose to "very poor" or 120 µg/m^3 on December 4, but it never did so last year (See *Graph 4: Rate of increase in $PM_{2.5}$ in Kolkata: 2019 vs 2020*). In fact, Rabindra Bharati University station's 24hr average slipped into "severe" category on December 4. This is quite different compared to previous winter even when there was no significant change in city's average temperature.

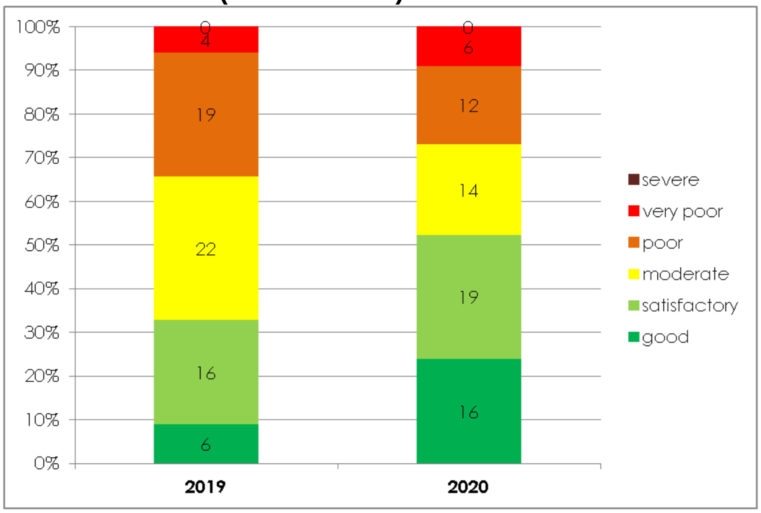
Graph 4: Rate of increase in $PM_{2.5}$ in Kolkata: 2019 vs 2020



Note: All values are rolling weekly average.
Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Kolkata -- Number of days with $PM_{2.5}$ concentration in good and satisfactory categories higher this winter; but very poor days have also increased a little: There have been 16 days of "good" air days this winter compared to just 6 recorded last year. But the "very poor" days have climbed from 4 days to 6 days this year (See *Graph 5: Distribution of AQI days in Kolkata's $PM_{2.5}$ level in winter (1 Oct – 6 Dec) 2019 and 2020*).

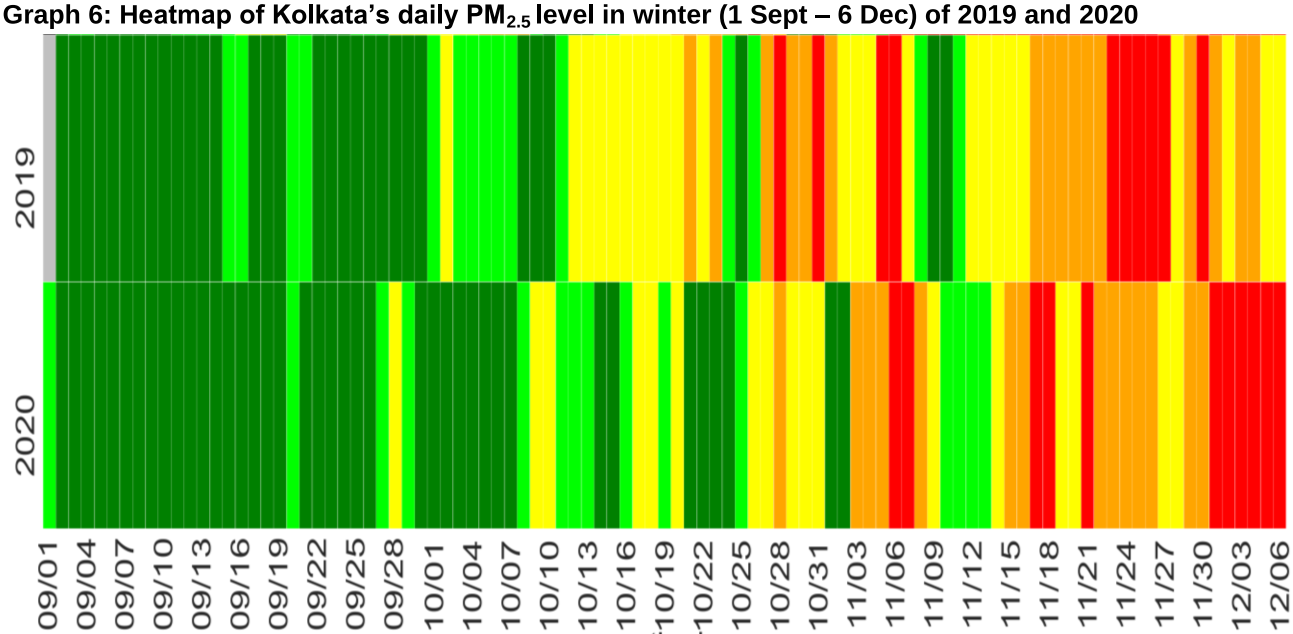
Graph 5: Distribution of days with $PM_{2.5}$ concentration according to AQI category of $PM_{2.5}$ level in Kolkata in winter (1 Oct – 6 Dec) 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on mean of all 7 CAAQM stations of Kolkata.
Source: CSE analysis of CPCB's realtime air quality data

Kolkata: The cyclical ups and down of pollution this winter is more volatile – showing quicker rise and fall than pervious winter: This could also be a reflection of changes in local pollution pattern and overall lower pollution load in the air-shed while aided by the meteorology. (See *Graph 6: Heatmap of Kolkata's daily $PM_{2.5}$ level in winter (1 Sept – 6 Dec) of 2018-20*).

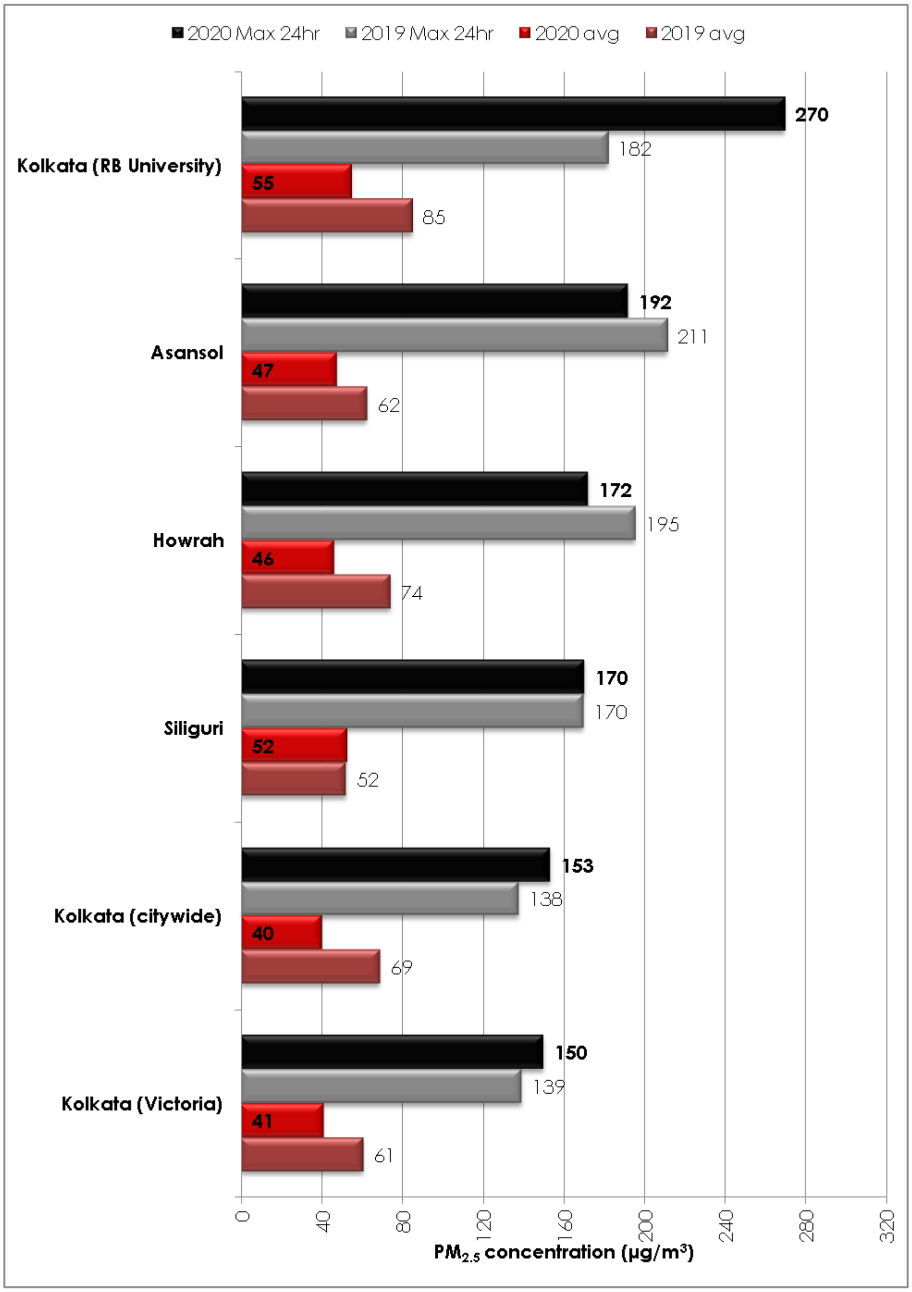
Graph 6: Heatmap of Kolkata's daily $PM_{2.5}$ level in winter (1 Sept – 6 Dec) of 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on mean of RB University and Victoria CAAQM stations of Kolkata. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Even with comparatively cleaner air during this year, four cities recorded daily spikes even higher than those observed in 2019: There is another interesting trend. CSE has compared the annual averages and peak 24hr averages of in these cities of West Bengal between 2019 and 2020. This shows that these cities even with much lower annual average levels of $PM_{2.5}$ have experienced almost same or higher maximum daily levels during winter when the entire region got air locked (See *Graph 7: Pollution among West Bengal cities and towns*). This shows substantial reduction in longer term annual trends are needed to eliminate winter smog.

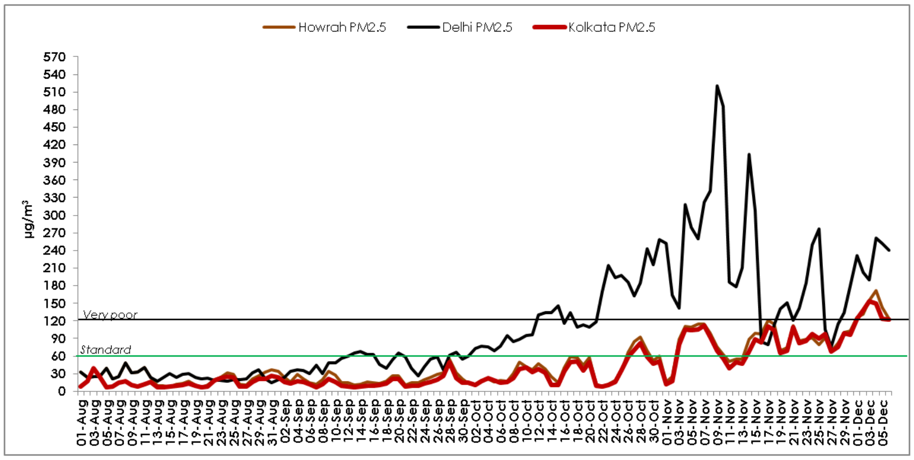
Graph 7: Pollution among West Bengal cities and towns



Note: 2020 numbers are based on data up to 6 Dec 2020.
Source: CSE analysis of CPCB's realtime air quality data

Kolkata's air cleaner than Delhi but on a few days comes close and even exceeds: CSE has compared Kolkata's winter pollution so far (until December 6) with that of Delhi and found both cities to have a similar pollution buildup pattern but Kolkata and Howrah have considerably lower absolute concentration. But as the weather gets colder and more adverse, the average pollution in Kolkata continues to climb when Delhi's pollution levels seems to have plateaued (See *Graph 8: Kolkata vs Delhi's $PM_{2.5}$ pollution in 2020*). This year on November 16, 17, and 18, Kolkata and Howrah have higher $PM_{2.5}$ levels than Delhi. On those days winter peak pollution in Delhi had got lower.

Graph 8: Kolkata vs Delhi's $PM_{2.5}$ pollution in 2020



Note: Data up till 6 Dec 2020.
Source: CSE analysis of CPCB's realtime air quality data

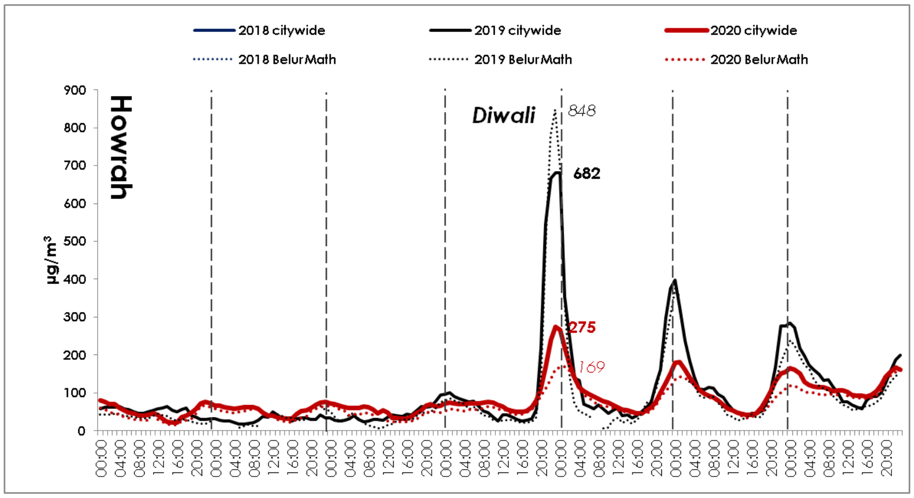
Need deep cuts

It may be noted that these cities require deep cuts in the average $PM_{2.5}$ levels. Kolkata has to reduce by 41 per cent from the base level of three year average, Howrah by 42 per cent, Asansol by 32 per cent and Siliguri by 28 per cent to meet the national ambient air quality standards.

How the pollution level will play out during the rest of the winter remains to be seen. But it is clear that the region cannot afford to lose the wins already made and at the same time, raise the level of ambition to drive action across all key sectors of pollution and the entire region. Enforce power plant standards, eliminate coal from the industry, scale up public transport and vehicle restraint measures and manage waste to have a zero waste and zero landfill strategy. But this also brings out that in addition to the round the year clean air action, cities also need Graded Response Action Plans for emergency response to slow down the peaking of winter pollution.

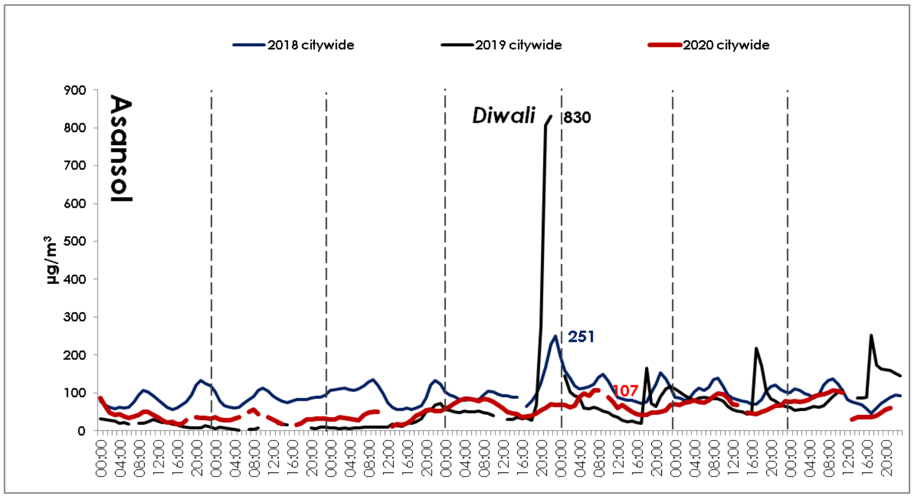
Additional graphs for West Bengal cities

Graph 3a: Impact of Diwali on hourly pollution in Howrah



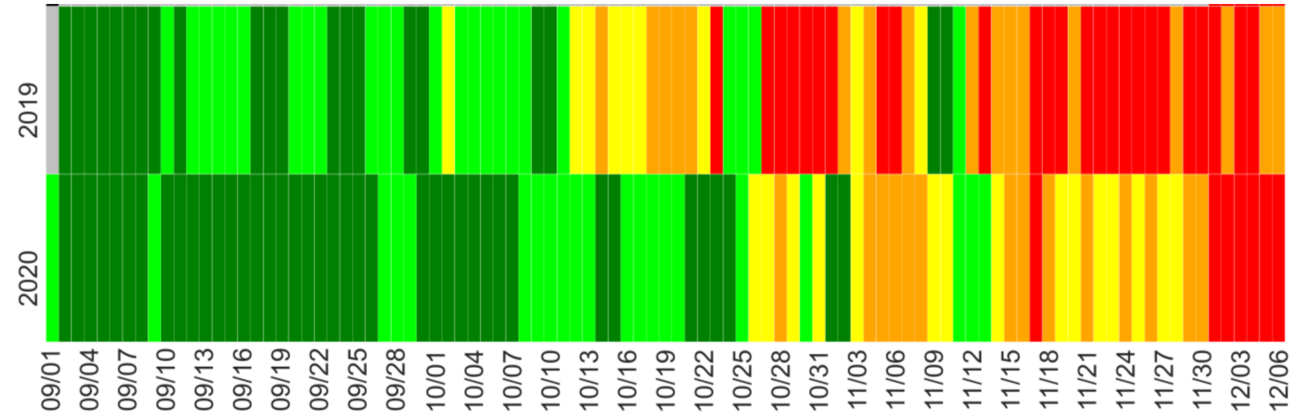
Note: Diwali dates are 7 Nov 2018, 27 Oct 2019, and 14 Nov 2020. Citywide is based on average $PM_{2.5}$ concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Graph 3b: Impact of Diwali on hourly pollution in Asansol



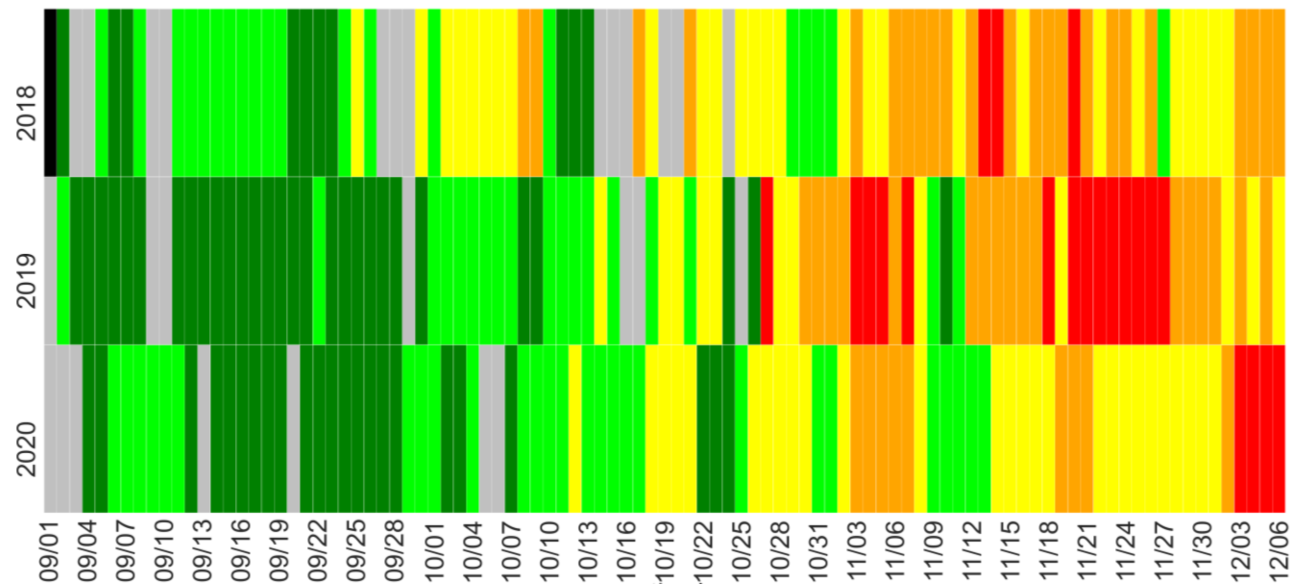
Note: Diwali dates are 7 Nov 2018, 27 Oct 2019, and 14 Nov 2020. Citywide is based on average $PM_{2.5}$ concentration of one CAAQM station operational in the city on a given day.
Source: CSE analysis of CPCB's real time air quality data

Graph 6a: Heatmap of Howrah's daily $PM_{2.5}$ level in winter (1 Sept – 6 Dec) of 2019 and 2020



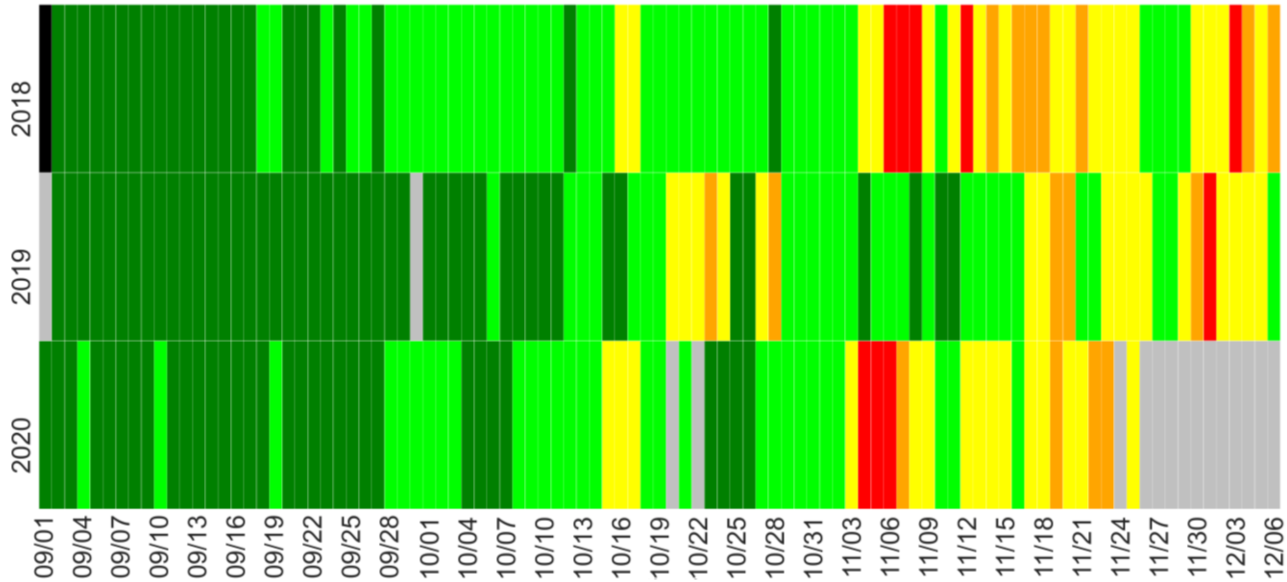
Note: Average $PM_{2.5}$ concentration for a day is based on mean of two CAAQM stations of Howrah. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 6b: Heatmap of Asansol's daily $PM_{2.5}$ level in winter (1 Sept – 6 Dec) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 6b: Heatmap of Siliguri's daily $PM_{2.5}$ level in winter (1 Sept – 6 Dec) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on one CAAQM station in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

3 ■Decoding winter air pollution in Mumbai region and other cities of Maharashtra

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, December 10, 2020

New analysis of winter pollution until December first week this year, done by Centre for Science and Environment (CSE), shows how clean air gains of the lockdown and monsoon period were lost with the reopening of the economy and hostile winter weather. While this was expected, the analysis of the real-time data from monitoring stations across Greater Mumbai Region as well as other major cities in Maharashtra show the changing pattern in winter pollution this year. Even though trapping of winter pollution in Greater Mumbai region is not as high as that of the Indo Gangetic Plain due to its proximity to sea and improved ventilation, the levels increase despite the geographical advantages and favourable meteorology.

Even though the overall average level of $PM_{2.5}$ for the 11 months in 2020 is considerably lower than the previous year due to the pandemic related to summer lockdown, the $PM_{2.5}$ levels in winter rose beyond the standard in Greater Mumbai Region and rest of Maharashtra. This is a typical and predictable winter trend when continuous emissions from local sources including vehicles, industry, construction, and episodic pollution from biomass burning get trapped due to meteorological changes. But this year, this trend has set in almost two weeks earlier in the season and the average $PM_{2.5}$ levels in October and November have been 25-30 per cent higher in Greater Mumbai Region compared to previous October and November. Combination of the reopening of the economy and changing meteorology is responsible. But the region cannot rely only on its advantage of being close to the sea. This demands speed and scale of action.

This detailed data analysis points to the fact that the air pollution is a more pervasive problem in the Mumbai region and beyond and this requires quicker reforms and action in key sectors of pollution – vehicles, industry, power plants and waste management to control winter pollution and further bend the annual air pollution curve.

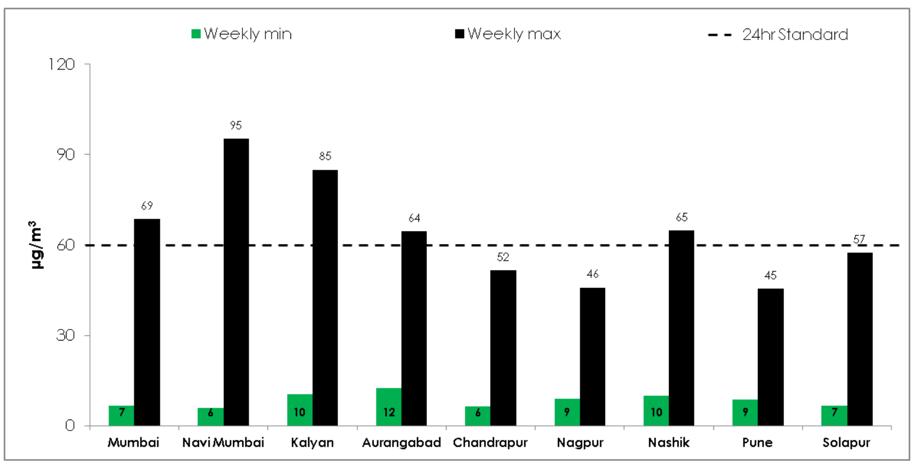
Data used in the analysis: The analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. Ten cities – Mumbai, Navi Mumbai, Thane, Kalyan, Pune, Nagpur, Nashik, Aurabgabad, Solapur, and Chandrapur have been selected for this analysis because real time data is available for these cities. This has analysed data recorded by 10 air quality monitoring stations at Mumbai, 3 stations in Navi Mumbai, 2 stations in Chandrapur, one station each Thane, Kalyan, Pune, Nagpur, Nashik, Aurangabad, and Solapuri under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Recently, new stations owned and operated by Indian Institute Of Tropical Meteorology, Pune have been added to CAAQMS network but they don't have adequate data available needed for this analysis therefore they have not been used. Weather data for Mumbai has been sourced from the Santa Cruz weather station of Indian Meteorological Department (IMD).

Key highlights

Average level of $PM_{2.5}$ has been lower during this year due to the lockdown but could not prevent the winter spike: The overall $PM_{2.5}$ average this year (until first week of December) has been predictably lower compared to the previous year largely because of the unprecedented economic disruption during the summer lockdown and monsoon. But reopening of the economy coinciding with the onset of the winter trapping pollution made $PM_{2.5}$ levels rose starting October. From the respective cleanest week the weekly average of $PM_{2.5}$ in Mumbai rose 10 times, in Navi Mumbai 16 times, Kalyan 8 times, Pune 5 times, Nagpur 5 times, Nashik 6 times, Aurangabad 5 times, Chandrapur 8 times and Solapuri 9 times to the dirtiest week.

Cleanest week for Mumbai, Navi Mumbai, Kalyan and Solapur was the week ending on 5 July, 2020. Nagpur, Nashik, Pune, and Solapur had their cleanest week in August 2020. Aurangabad had its cleanest week on the week ending 25 May 2020. The most polluted weeks this winter so far are week ending on 15 Nov, 2020 in Mumbai and Kalyan; week ending on 29 Nov, 2020 Navi Mumbai, Nagpur, Nashik, the week ending on 8 Nov in Pune, week ending on 1 November in Chandrapur, week ending on 22 November in Aurangabad and week ending on 6 Dec Solapur (See *Graph 1: Change in weekly PM2.5 levels 2020 – Difference between cleanest and most polluted week*). The transient change of the lockdown phases could not be sustained without the systemic changes needed to control pollution from vehicles, industry, power plants, and waste.

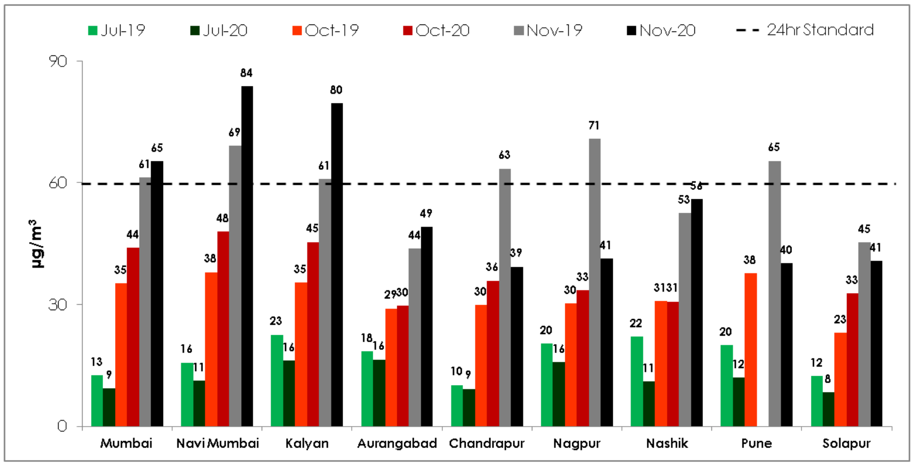
Graph 1: Change in weekly $PM_{2.5}$ levels 2020 – Difference between cleanest and most polluted week



Note: Average $PM_{2.5}$ concentration for a week is based on mean of all CAAQM stations in the city. Dirtiest week for all cities were in November except Solapur had its dirtiest week on the week ending on 6 December 2020. Cleanest week for Mumbai, Navi Mumbai, Kalyan and Solapur was the week ending on 5 July, 2020. Nagpur, Nashik, Pune, and Solapur had their cleanest week in August 2020. Aurangabad had its cleanest week on the week ending 25 May 2020.
Source: CSE analysis of CPCB's real time air quality data

Average October-November $PM_{2.5}$ level has been considerably higher this year: October this year was dirtier across all cities in Maharashtra and it was worst among Greater Mumbai Region. The $PM_{2.5}$ average this October was 25 per cent higher in Mumbai, 26 per cent in Navi Mumbai and 28 per cent in Kalyan compared to corresponding time in 2019. Thane doesn't have a working $PM_{2.5}$ monitor (See *Graph 2: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages)*). November was also dirtier with monthly average higher by 7 per cent in Mumbai, 21 per cent in Navi Mumbai, and 31 per cent in Kalyan. Cities outside Greater Mumbai Region had similar or lower November average as last year.

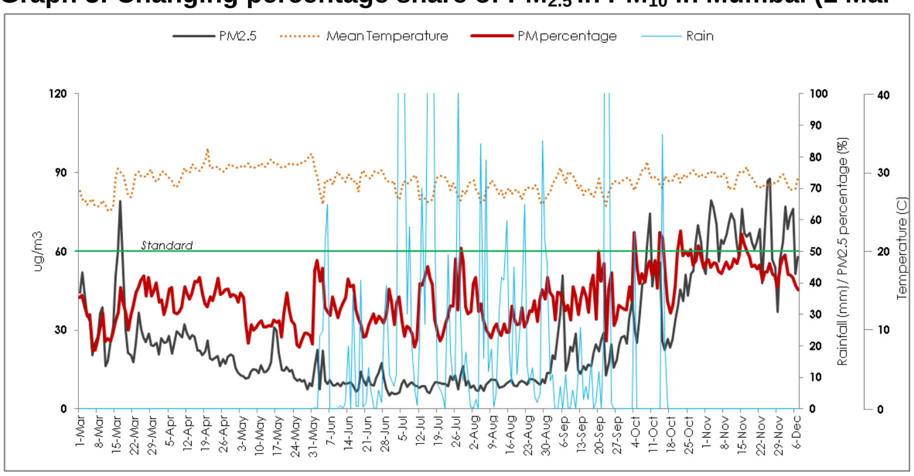
Graph 2: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages)



Note: Average $PM_{2.5}$ concentration for a month is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

Air quality gets more toxic with the onset of winter - share of tinier $PM_{2.5}$ in the PM_{10} increases: The share of tinier and finer particles in the overall coarser PM_{10} concentration determines the toxicity of air. When the overall share of tinier $PM_{2.5}$ in the overall coarser PM_{10} is higher, the air is more toxic as the tiny particles penetrate deep inside the lungs and cut through the blood barrier increasing health risk. Interestingly, during lockdown, when the overall suspended coarser particles had settled down reducing the PM_{10} levels, the $PM_{2.5}$ had also come down. But its share was 36 per cent – higher than it's usually noted during summer (below 30 per cent). But with the onset of winter the overall level of both have gone up and also the percentage share of $PM_{2.5}$ in the overall $PM_{10.}$ This rose to high 40s during October and remained high through November averaging at 46 per cent (See *Graph 3: Changing share of percentage share of $PM_{2.5}$ in PM_{10} in Mumbai (1 Mar – 8 Dec, 2020)*). The share of $PM_{2.5}$ in PM_{10} is generally highest on Diwali and it reached 60 per cent this year.

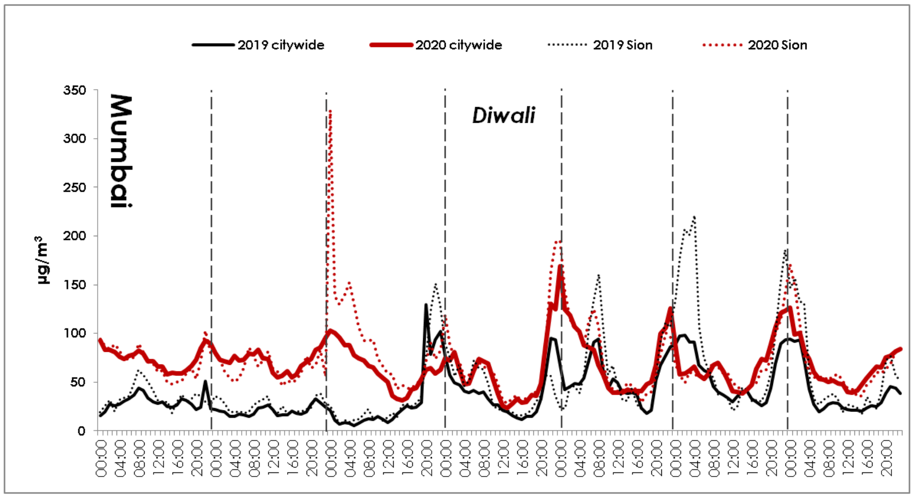
Graph 3: Changing percentage share of $PM_{2.5}$ in PM_{10} in Mumbai (1 Mar – 8 Dec, 2020)



Data: CPCB (PM_{10} and $PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Dirtier Diwali in Mumbai this year: The average $PM_{2.5}$ level on Diwali day in Mumbai was 76 µg/m^3 up from 53 µg/m^3 recorded in 2019. This year there was about 75 per cent higher rise in hourly $PM_{2.5}$ concentration between afternoon and night of Diwali that is mostly caused due to firecracker busting (See *Graph 4: How hourly pollution changed on Diwali day in Mumbai*). The change in hourly $PM_{2.5}$ concentration between afternoon and night of 2020 Diwali was 145 µg/m^3, up from 83 µg/m^3 in 2019. Diwali also occurred later in November than the previous year.

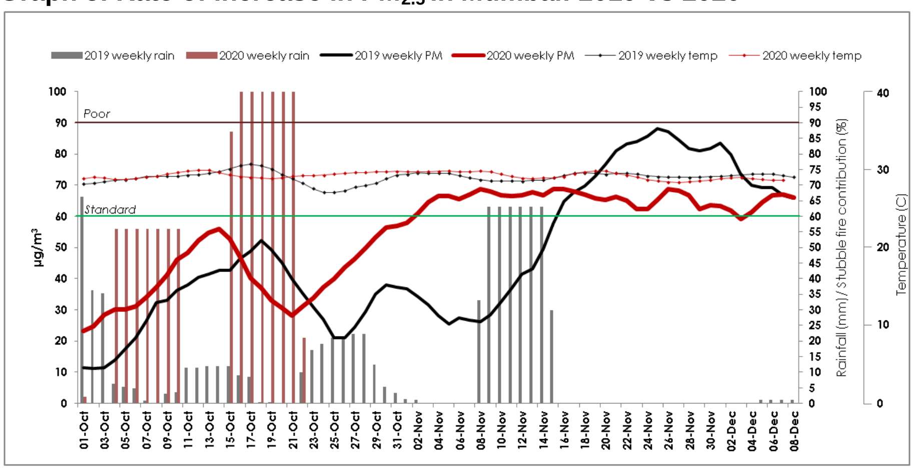
Graph 4: How hourly pollution changed on Diwali day in Mumbai



Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Mumbai –November 2020 dirtier but peak is lower: The rolling weekly average rose over the 24hr standard or 60 µg/m^3 on November 2, but it did so on November 16 last year (See *Graph 5: Rate of increase in $PM_{2.5}$ in Mumbai: 2019 vs 2020*).

Graph 5: Rate of increase in $PM_{2.5}$ in Mumbai: 2019 vs 2020

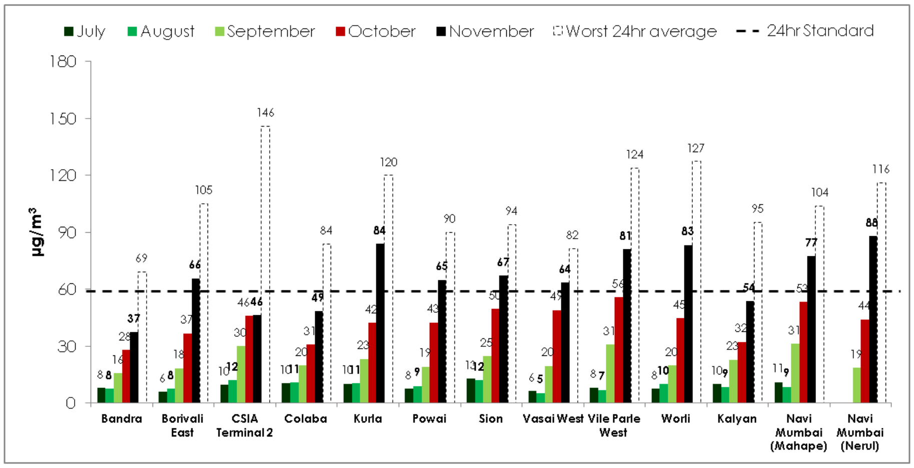


Note: All values are rolling weekly average.
Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Variation within Mumbai shows some locations are highly polluted: In fact, Worli, Vile Parle, Kurla, and CSIA stations' 24hr average has slipped into "very poor" category on multiple days this November even though citywide average remains moderately polluted category. This is quite different compared to previous November when no station registered a "very poor" day even when there was no significant change in city's average temperature or rainfall in second half of the month. There is wider variation in $PM_{2.5}$ levels within the city; standard deviation among city's 10 stations is 80 per cent higher this November on average, difference between upper and lower bound has increased to 53 µg/m^3 from 33 µg/m^3 last November. Air quality in the city usually at its worst around Christmas and New Year, last year it got to "very poor" category across all stations; going by the trend similar if not worse can be expected this year.

Kurla and Worli have the highest November average in the city, while Bandra, CSIA and Colaba have the lowest. Nerul in Navi Mumbai is the most polluted in greater Mumbai region. CSIA despite one of the lowest monthly concentration has the highest daily spikes (see *Graph 6: Variation in local pollution build-up in different locations of Mumbai during 2020 winter (monthly averages)*).

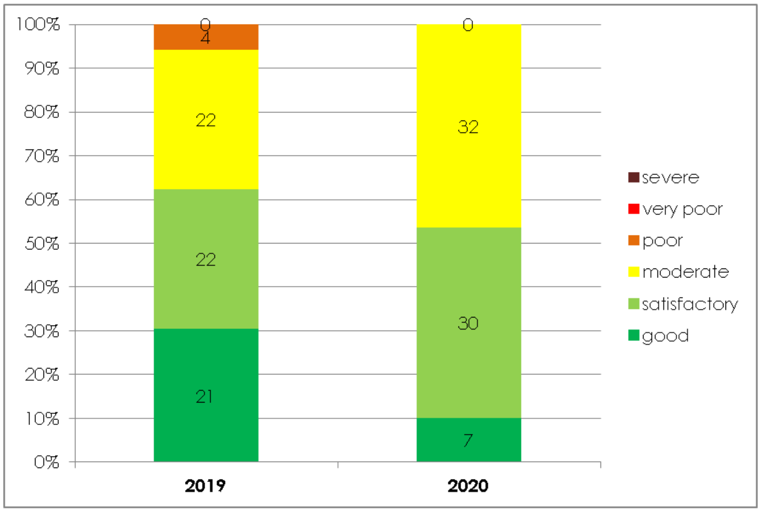
Graph 6: Variation in local pollution build-up in different locations of Mumbai during 2020 winter (monthly averages)



Note: Worst 24hr average based on data upto 8 Dec, 2020
Source: CSE analysis of CPCB's realtime air quality data

Mumbai – City-wide number of days with $PM_{2.5}$ concentration in good category was considerably lower this winter; but no poor days: There have been 7 days of "good" air days this winter compared to just 21 recorded last year. But the "poor" days have come down to 0 days from 4 days last year (See *Graph 7: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Mumbai during winter (1 Oct – 8 Dec) 2019 and 2020*).

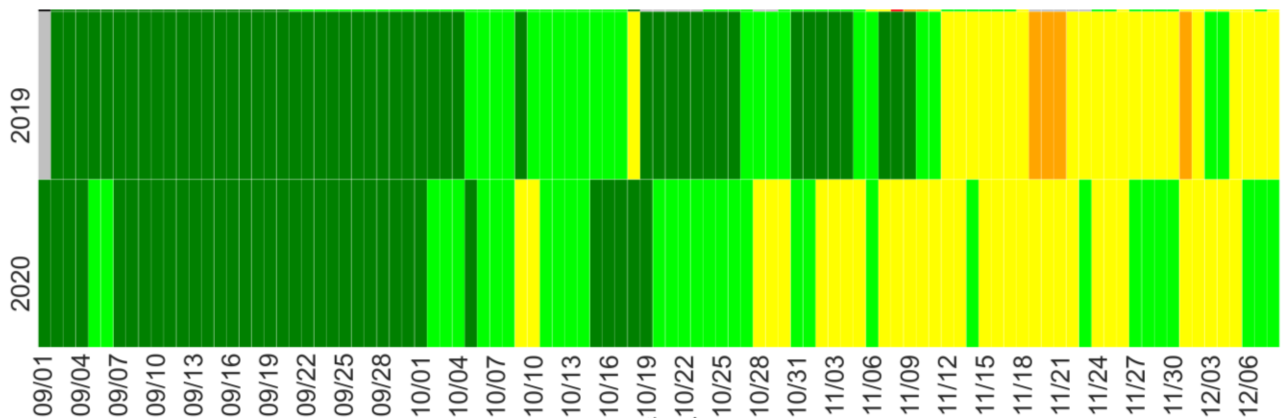
Graph 7: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Mumbai during winter (1 Oct – 8 Dec) 2019 and 2020.



Note: Average $PM_{2.5}$ concentration for a day is based on mean of all 10 CAAQM stations of Mumbai.
Source: CSE analysis of CPCB's realtime air quality data

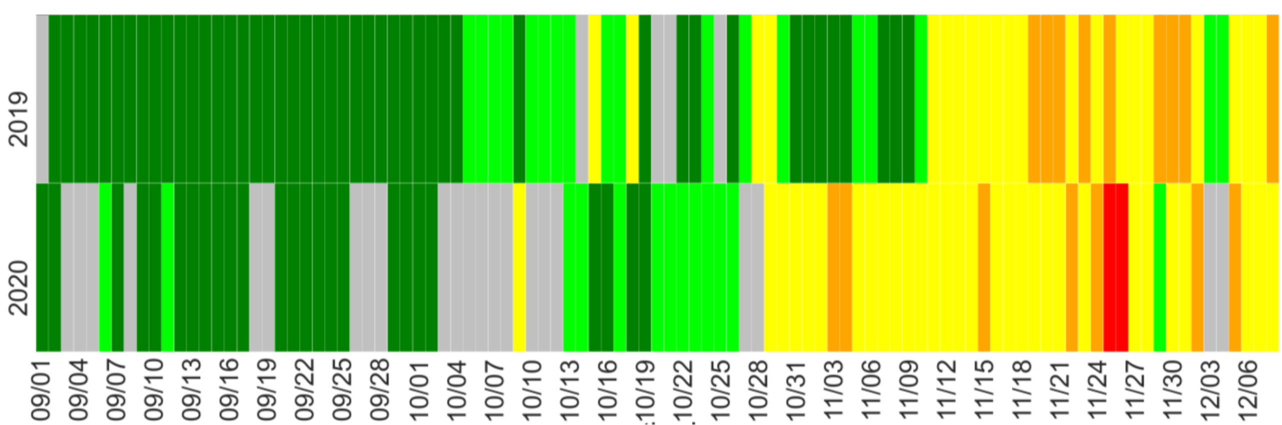
Mumbai: The cyclical ups and down of pollution this winter is less volatile – showing slower rise and fall than pervious winter: This inelastic behavior of $PM_{2.5}$ levels in Mumbai is in contrast to the trend seen in Delhi-NCR and Kolkata-Howrah where the trend has been more volatile during winter with frequent quicker rise and drop (*See Graph 8: Heatmap of Mumbai's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2019-20*). This can be the impact of changed meteorology but more investigation is needed to understand the reasons for this.

Graph 8a: Heatmap of Mumbai's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on mean of all CAAQM stations of Mumbai. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

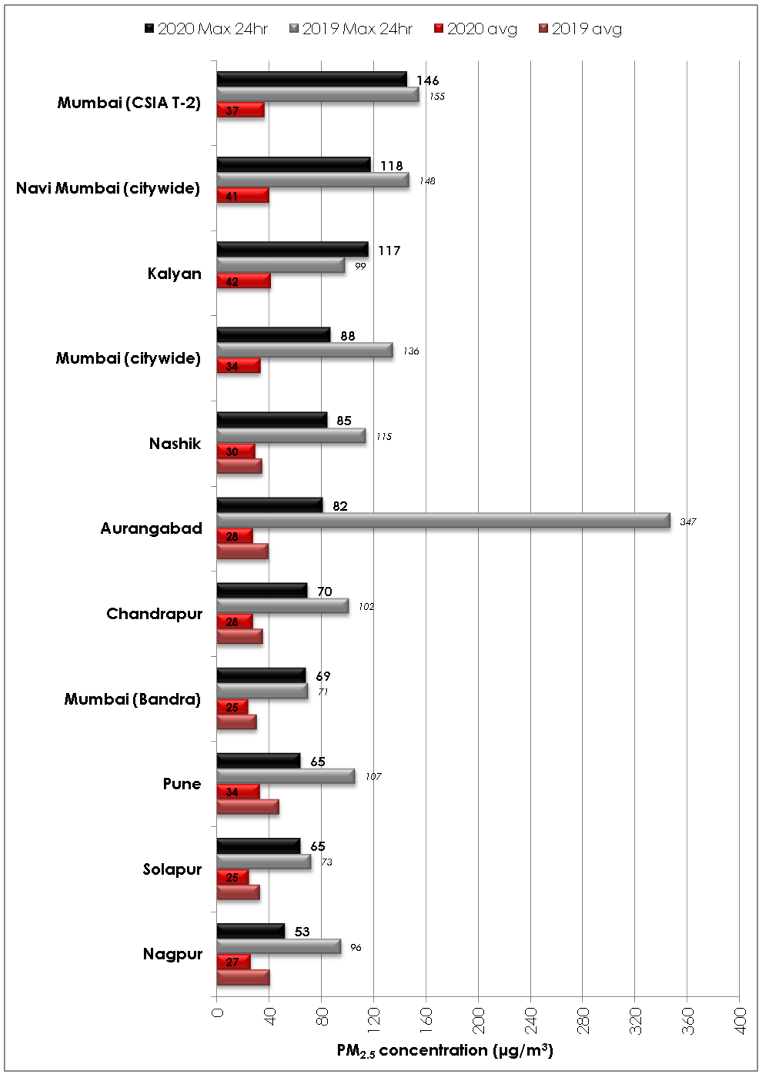
Graph 8b: Heatmap of Worli's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on Worli CAAQM station of Mumbai. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's real time air quality data

Even with comparatively cleaner air during this year, Greater Mumbai cities recorded daily spikes similar to those observed in 2019: CSE has compared the annual averages and peak 24hr averages in these cities of Maharashtra between 2019 and 2020. This shows that the Greater Mumbai cities even with much lower annual average levels of $PM_{2.5}$ have experienced almost same or higher maximum daily levels during winter when the entire region got air locked (See *Graph 9: How annual average and maximum level changed in cities and towns of Maharashtra – comparison of 2019 and 2020*). Cities outside Greater Mumbai region have registered much lower daily spikes.

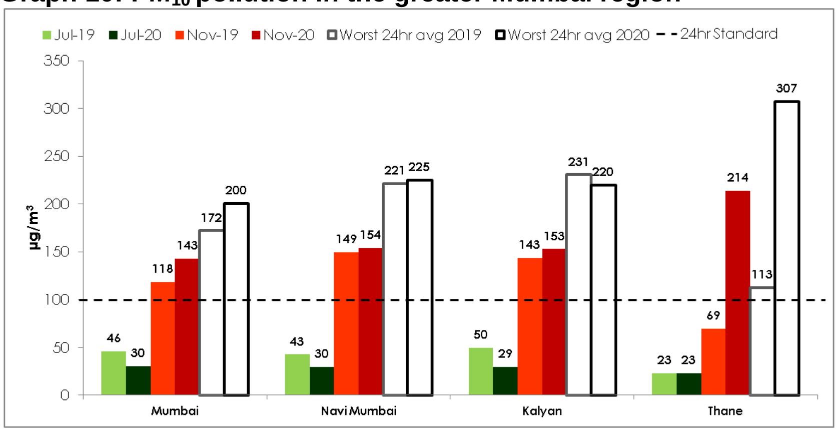
Graph 9: How annual average and maximum level changed in cities and towns of Maharashtra – comparison of 2019 and 2020



Note: 2020 numbers are based on data up to 8 Dec 2020.
Source: CSE analysis of CPCB’s realtime air quality data

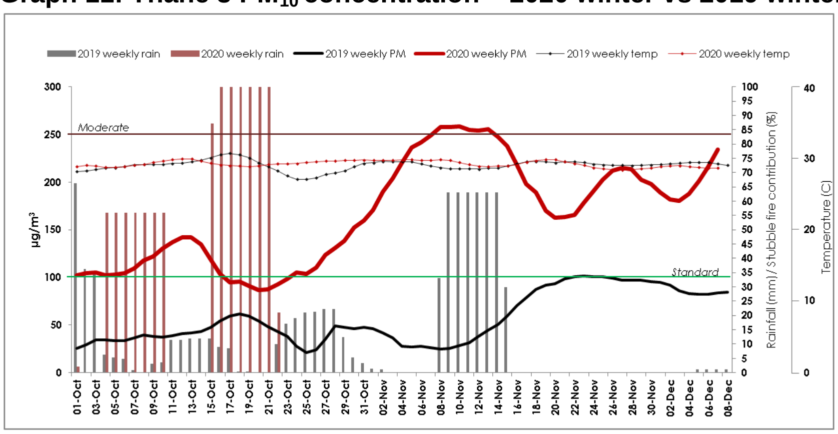
Thane's air dirtiest in the region: CSE has also compared PM_{10} levels during winter months (until December 8) in cities of greater Mumbai region and found Thane (which does not have a working $PM_{2.5}$ monitor) to have the highest levels of PM_{10} (See *Graph 10: PM_{10} pollution in the greater Mumbai region*). Other cities had similar curvature trend in PM_{10} concentration as noted for $PM_{2.5}$ levels. In fact, Thane's annual average for 2020 (uptill Dec 8) is 85 µg/m^3 which is already higher than 2019 average of 84 µg/m^3. This increase in PM_{10} levels from 2019 in Thane is driven by extraordinary dirtier October and November this year (See *Graph 11: Thane's PM_{10} concentration – 2020 winter vs 2019 winter*).

Graph 10: PM_{10} pollution in the greater Mumbai region



Note: Average PM_{10} concentration for a month is based on mean of all CAAQM stations in the city. Worst 24hr average at the citywide level recorded between 1 March- 8 December, 2020.
Source: CSE analysis of CPCB's real time air quality data

Graph 11: Thane's PM_{10} concentration – 2020 winter vs 2019 winter



Note: All values are rolling weekly average. Data: CPCB (PM_{10}), IMD (Temperature and rainfall)
Source: CSE analysis

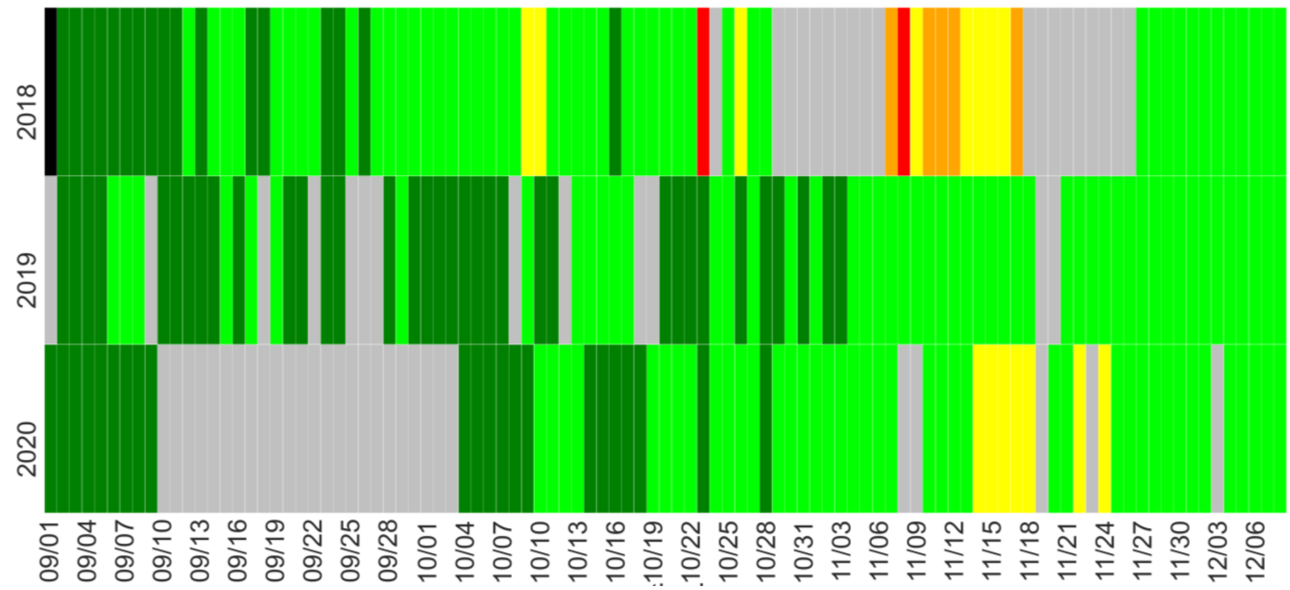
Need deep cuts

To avoid winter pollution peaks all cities of Maharashtra will have to reduce the annual average level of pollution to meet the national ambient air quality standards and even bring it further down to be closure to health based guidelines of the World Health Organisation.

How the pollution level will play out during the rest of the winter remains to be seen. But it is clear that the region has to take forward its wins so far and raise the level of ambition to drive action across all key sectors of pollution and in the entire region. Enforce power plant standards across the state, minimise use of coal and other dirt fuels in the industry while improving emissions control, scale up public transport and vehicle restraint measures and manage waste to have a zero waste and zero landfill strategy.

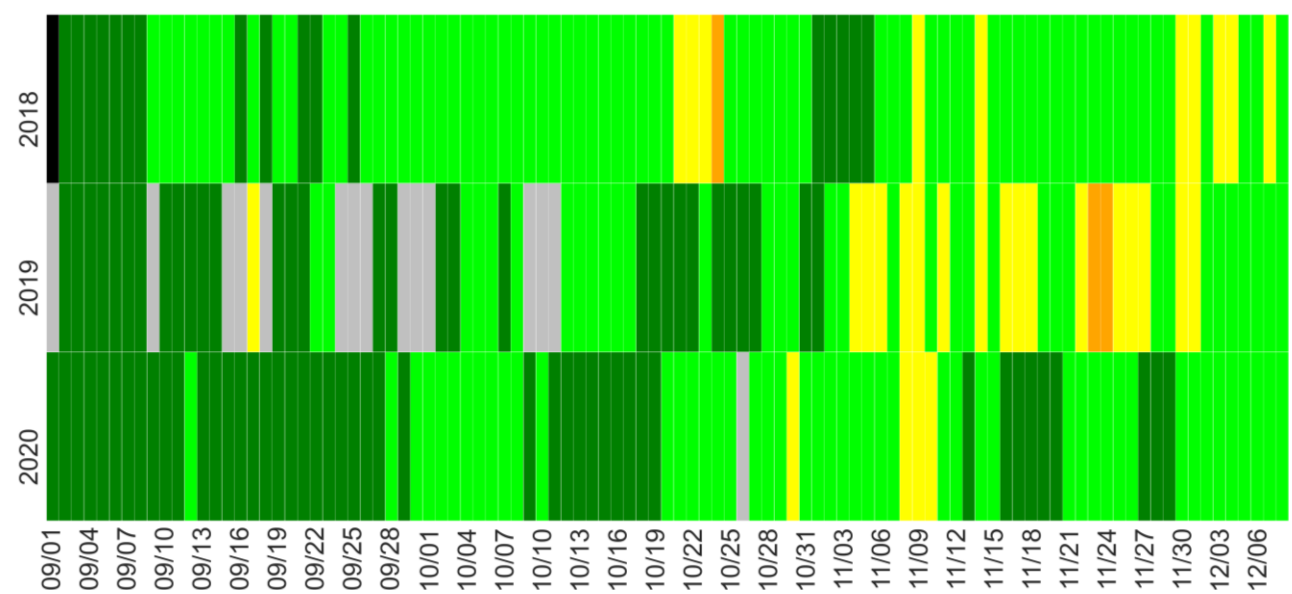
Additional graphs for Maharashtra cities

Graph 8c: Heatmap of Aurangabad's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2018, 2019 and 2020



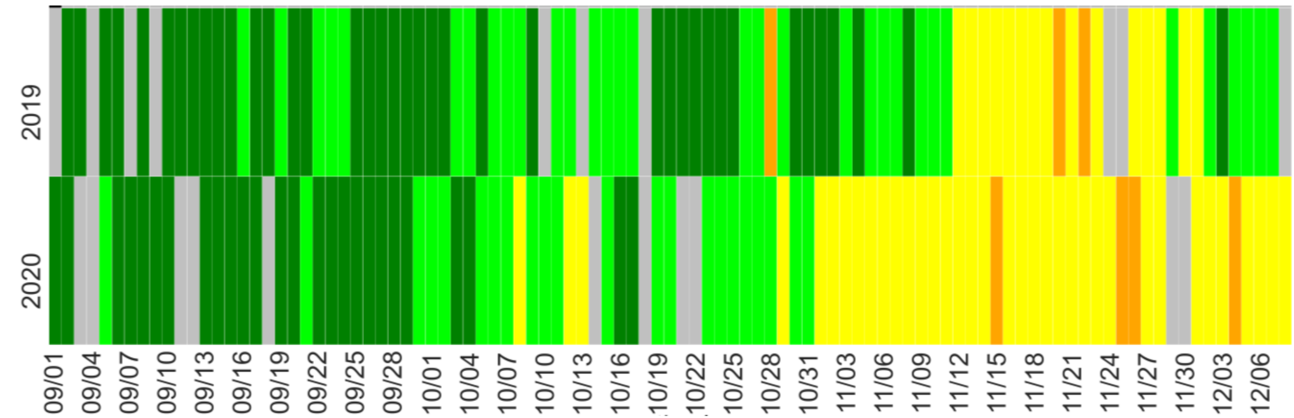
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8d: Heatmap of Chandrapur's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2018, 2019 and 2020



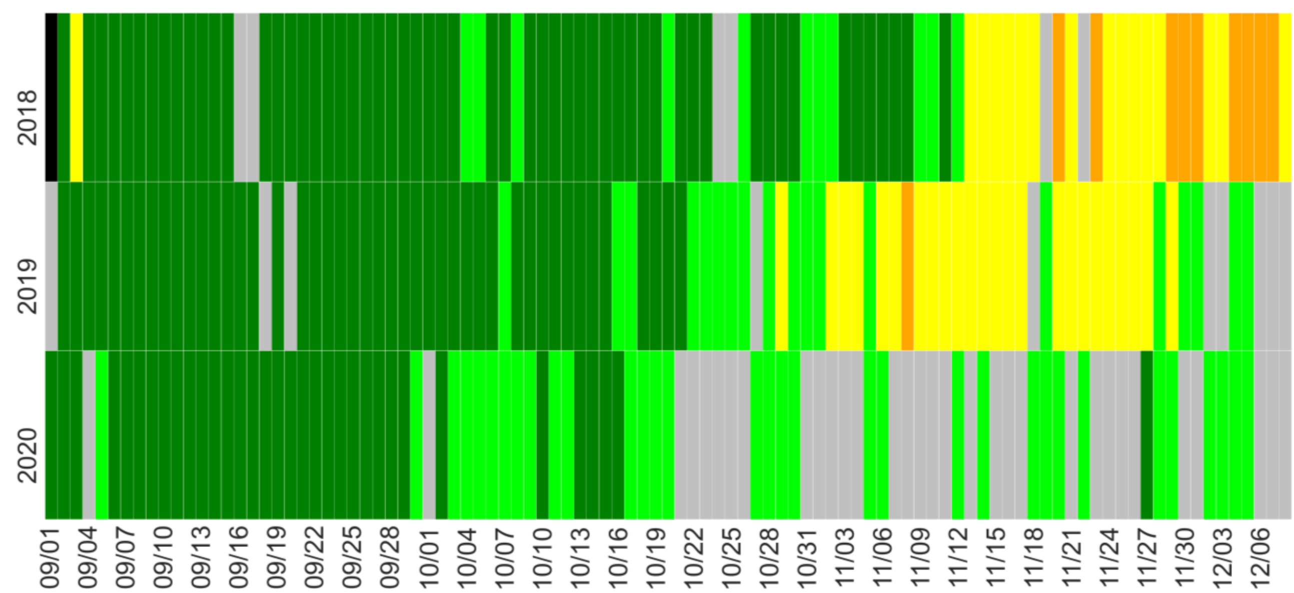
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3 and is based on mean of two CAAQM stations in the city. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8e: Heatmap of Kalyan's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2019 and 2020



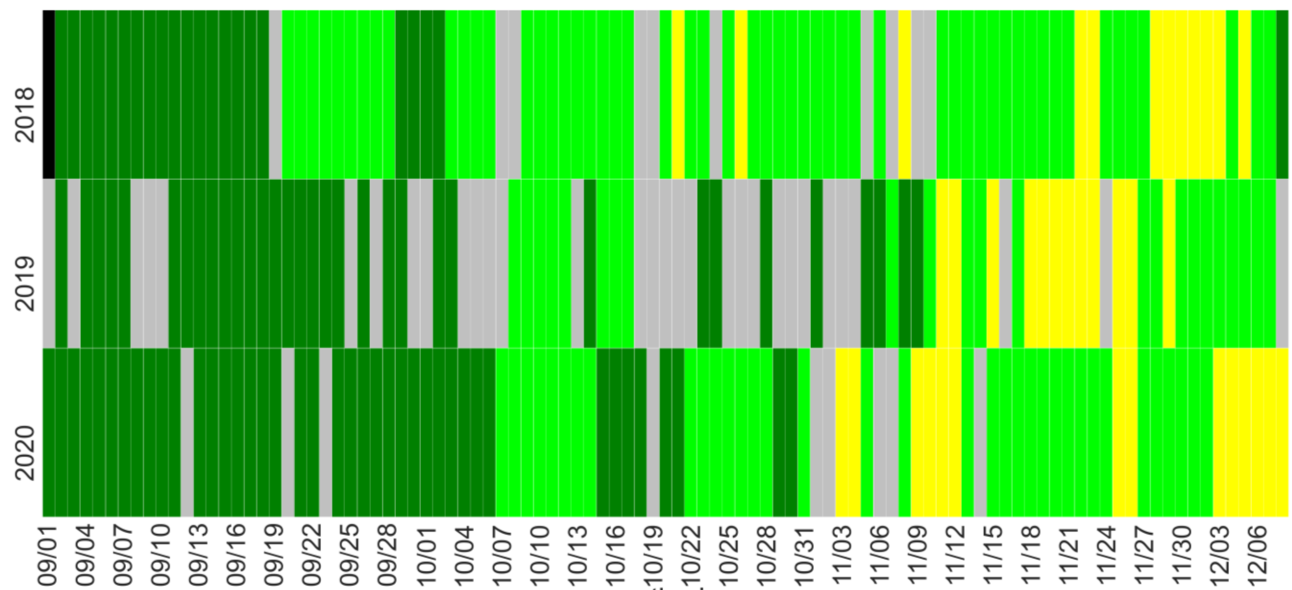
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8f: Heatmap of Nagpur's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2018, 2019 and 2020



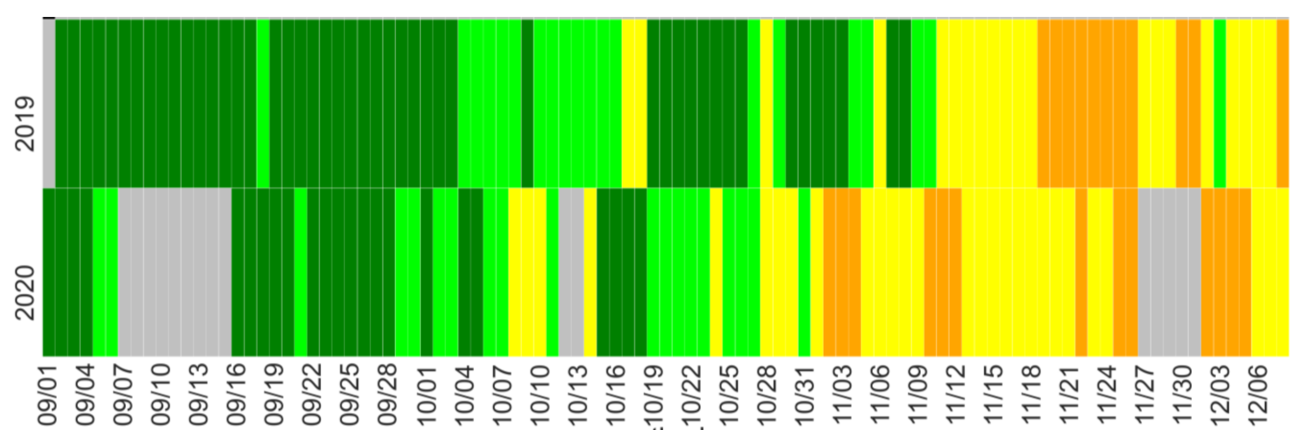
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8g: Heatmap of Nashik's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2018, 2019 and 2020



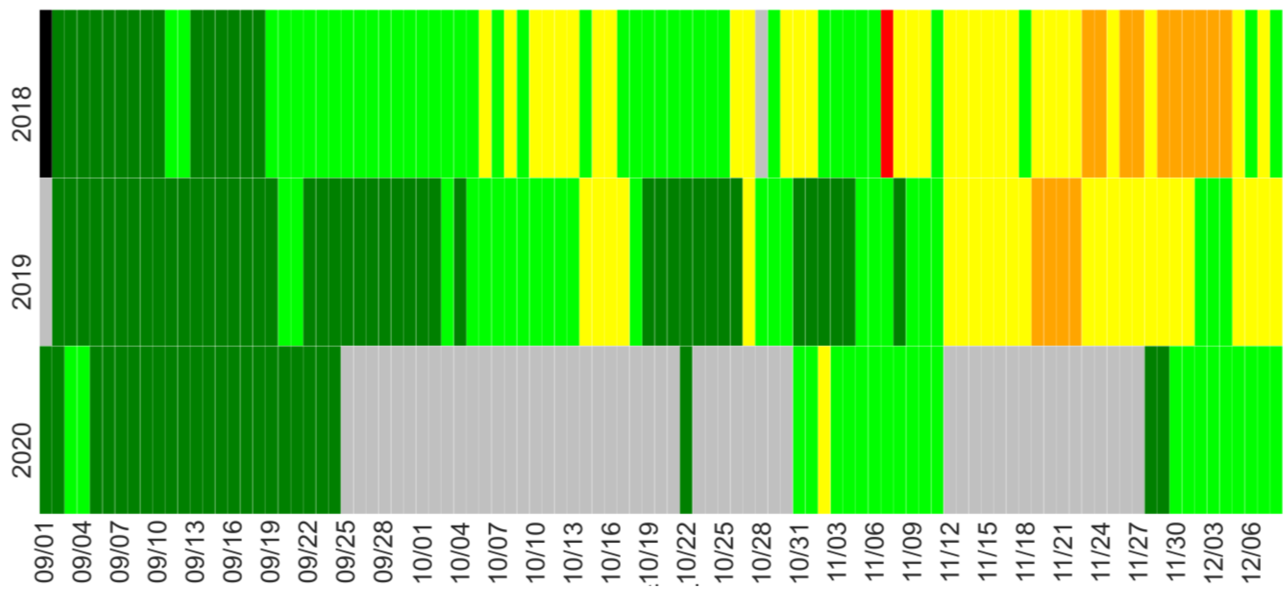
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8g: Heatmap of Navi Mumbai's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2019 and 2020



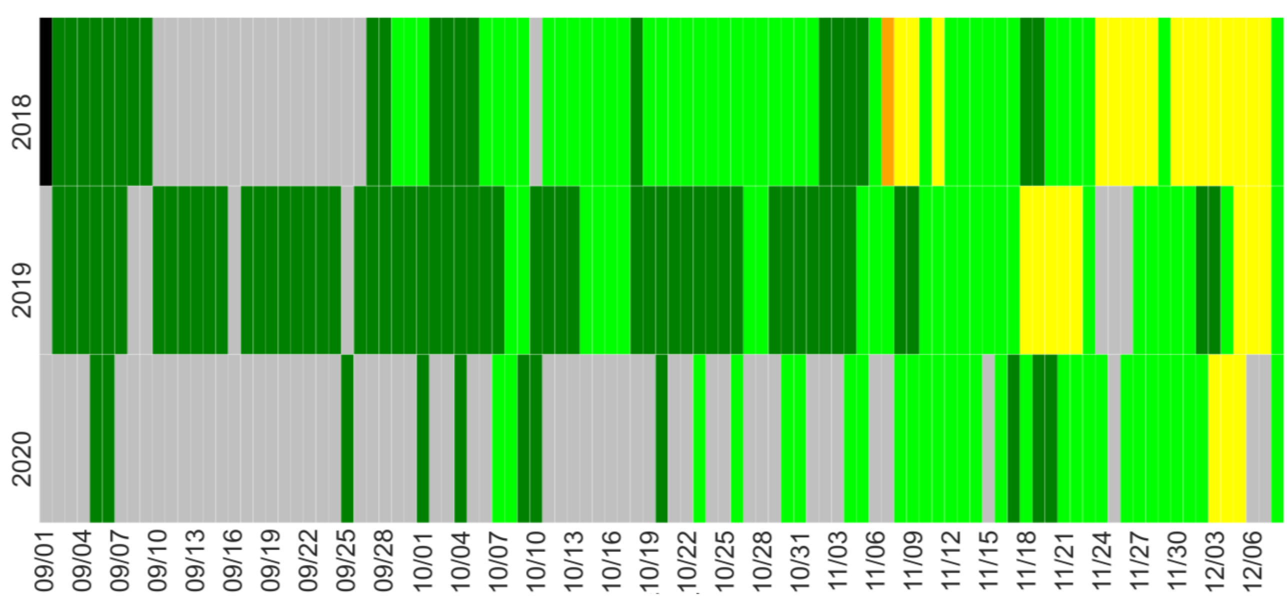
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3 and based on mean of the two CAAQM stations in the city. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8h: Heatmap of Pune's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8i: Heatmap of Solapur's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

4. Decoding winter air pollution in Jaipur region and other cities of Rajasthan

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, December 23, 2020

New analysis of winter pollution until 20 December of this year, done by Centre for Science and Environment (CSE), shows how clean air gains of the lockdown and monsoon period were lost with the reopening of the economy and hostile winter weather. While this was expected, the analysis of the real-time data from monitoring stations across Jaipur division as well as other major cities in Rajasthan show the changing pattern in winter pollution this year. Even though trapping of winter pollution in Rajasthan is not as high as that of the Indo Gangetic Plain but it seems to be catching up, the levels increase this year in identical fashion despite the geographical and meteorological advantage.

Even though the overall average level of $PM_{2.5}$ for the 2020 (uptill 20 Dec) is lower than the previous year due to the pandemic related to summer lockdown, the $PM_{2.5}$ levels in winter rose beyond the standard in Jaipur and rest of Rajasthan. This is a typical and predictable winter trend when continuous emissions from local sources including vehicles, industry, construction, and episodic pollution from biomass burning get trapped due to meteorological changes. But this year, this trend has set in almost a week earlier in the season and the average $PM_{2.5}$ levels in November have been 26-33 per cent higher in Jaipur division compared to previous November. Combination of the reopening of the economy and changing meteorology is responsible. But the region cannot rely only on its advantage of being close to the sea. This demands speed and scale of action.

This detailed data analysis points to the fact that the air pollution is a more pervasive problem in the Jaipur region and beyond and this requires quicker reforms and action in key sectors of pollution – vehicles, industry, power plants and waste management to control winter pollution and further bend the annual air pollution curve.

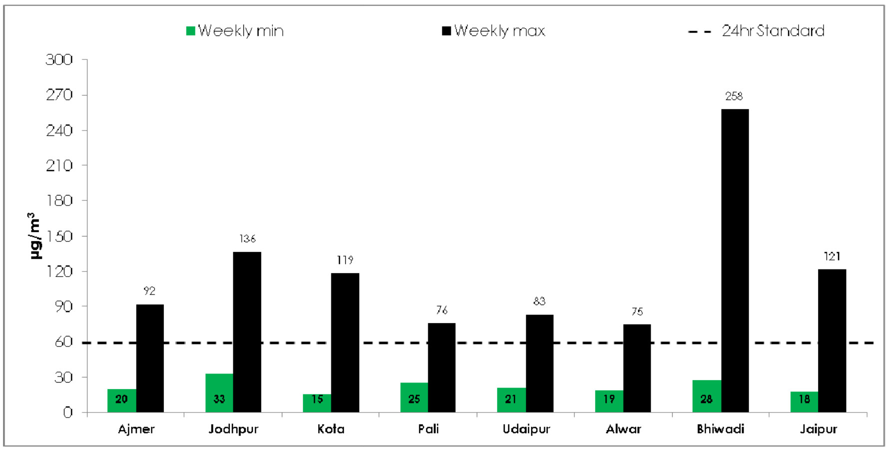
Data used in the analysis: The analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. Eight cities – Ajmer, Jodhpur, Kota, Pali, Udaipur, Alwar, Bhiwadi, and Jaipur have been selected for this analysis because real time data is available for these cities. This has analysed data recorded by three air quality monitoring stations at Jaipur and one station each Ajmer, Jodhpur, Kota, Pali, Udaipur, Alwar, and Bhiwadi under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Weather data for Jaipur has been sourced from the Sanganer weather station of Indian Meteorological Department (IMD).

Key highlights

Average level of $PM_{2.5}$ has been lower during this year due to the lockdown but could not prevent the winter spike: The overall $PM_{2.5}$ average this year (until 20 December) has been predictably lower compared to the previous year largely because of the unprecedented economic disruption during the summer lockdown and monsoon. But reopening of the economy coinciding with the onset of the winter trapping pollution made $PM_{2.5}$ levels rose starting October. From the respective cleanest week the weekly average of $PM_{2.5}$ in Jaipur rose 7 times, in Ajmer 5 times, Alwar 4 times, Bhiwadi 9 times, Kota 8 times, Jodhpur 4 times, Pali 3 times, and Udaipur 4 times to the dirtiest week.

Dirtiest week for all cities was on the week ending on 15 November 2020 except in Bhiwadi which was a week earlier. Cleanest week for Alwar and Pali was in the early April, 2020. Ajmer and Kota had their cleanest week on the week ending 12 July 2020. Udaipur, Jaipur and Bhiwadi had their cleanest week in August 2020. Jodhpur had its cleanest week on the week ending 6 September 2020 (See *Graph 1: Change in weekly PM2.5 levels 2020 – Difference between cleanest and most polluted week*). The transient change of the lockdown phases could not be sustained without the systemic changes needed to control pollution from vehicles, industry, power plants, and waste.

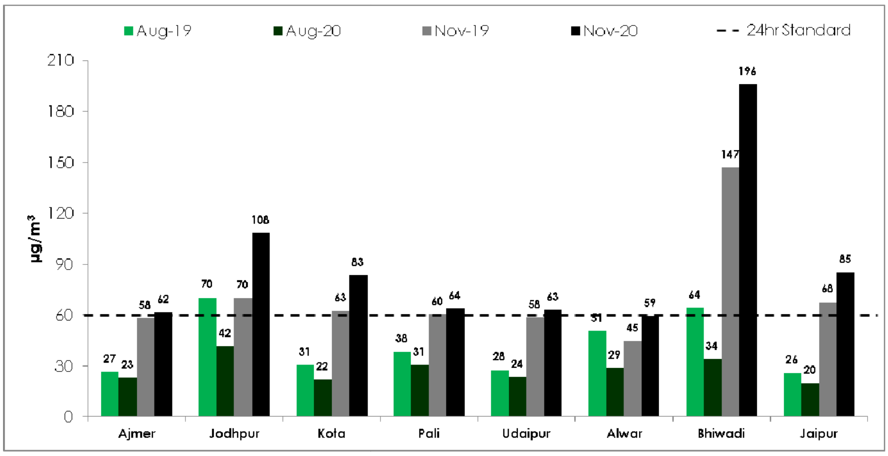
Graph 1: Change in weekly $PM_{2.5}$ levels 2020 – Difference between cleanest and most polluted week



Note: Average $PM_{2.5}$ concentration for a week is based on mean of all CAAQM stations in the city. Dirtiest week for all cities was on the week ending on 15 November 2020 except in Bhiwadi which was a week earlier. Cleanest week for Alwar and Pali was in the early April, 2020. Ajmer and Kota had their cleanest week on the week ending 12 July 2020. Udaipur, Jaipur and Bhiwadi had their cleanest week in August 2020. Jodhpur had its cleanest week on the week ending 6 September 2020.
Source: CSE analysis of CPCB's real time air quality data

Average November $PM_{2.5}$ level has been considerably higher this year: November this year was dirtier across all cities in Rajasthan. The $PM_{2.5}$ average this November was 26 per cent higher in Jaipur, 33 per cent in Alwar and Bhiwadi compared to November 2019. November was also dirtier in other cities 6 per cent in Pali, 6 per cent in Ajmer, 8 per cent in Udaipur, 33 per cent in Kota and 55 per cent in Jodhpur. August this year was 13-47 per cent cleaner in these cities compared to August 2019 (See *Graph 2: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages)*).

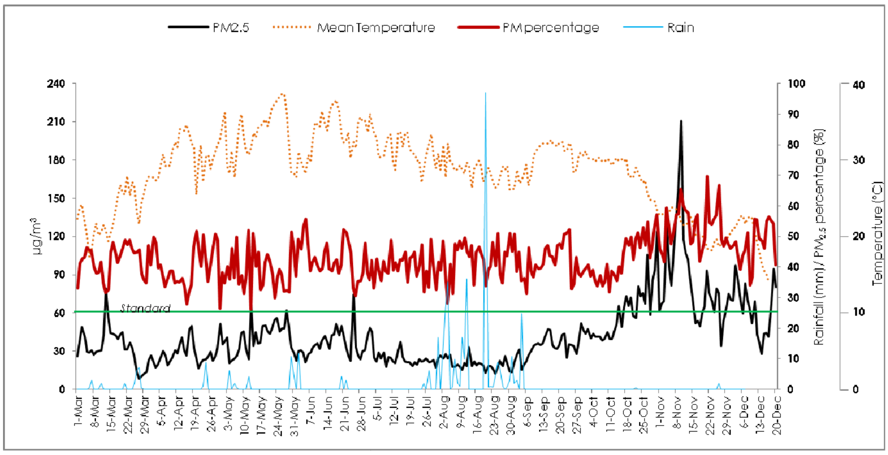
Graph 2: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages)



Note: Average $PM_{2.5}$ concentration for a month is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

Air quality gets more toxic with the onset of winter - share of tinier $PM_{2.5}$ in the PM_{10} increases: The share of tinier and finer particles in the overall coarser PM_{10} concentration determines the toxicity of air. When the overall share of tinier $PM_{2.5}$ in the overall coarser PM_{10} is higher, the air is more toxic as the tiny particles penetrate deep inside the lungs and cut through the blood barrier increasing health risk. Interestingly, during lockdown, when the overall suspended coarser particles had settled down reducing the PM_{10} levels, the $PM_{2.5}$ had also come down. But its share was 40 per cent in April – higher than it's usually noted during summer (April 2019 was 35 per cent). But with the onset of winter the overall level of both have gone up and also the percentage share of $PM_{2.5}$ in the overall $PM_{10.}$ This rose to above 50 per cent during mid-October and remained high through November averaging at 53 per cent (See *Graph 3: Changing share of percentage share of $PM_{2.5}$ in PM_{10} in Jaipur (1 Mar – 8 Dec, 2020)*). The share of $PM_{2.5}$ in PM_{10} is generally highest on Diwali and it peaked at 70 per cent this year but it was a week before Diwali.

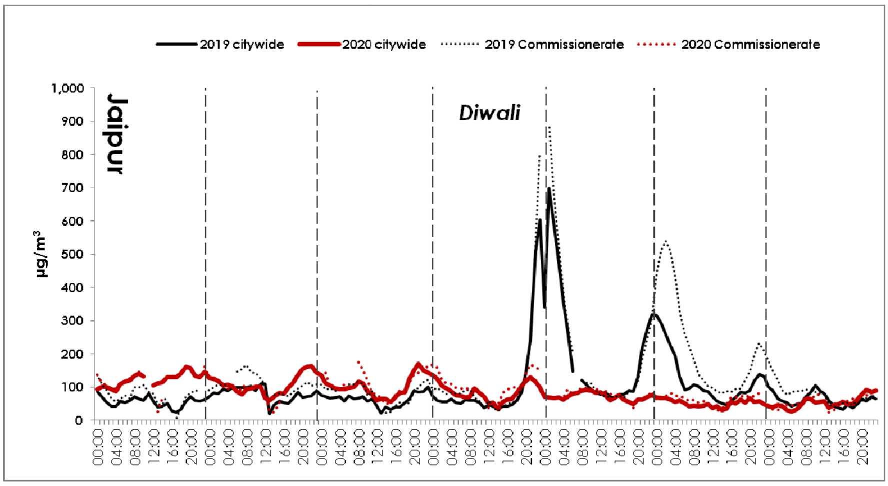
Graph 3: Changing percentage share of $PM_{2.5}$ in PM_{10} in Jaipur (1 Mar – 20 Dec, 2020)



Data: CPCB (PM_{10} and $PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

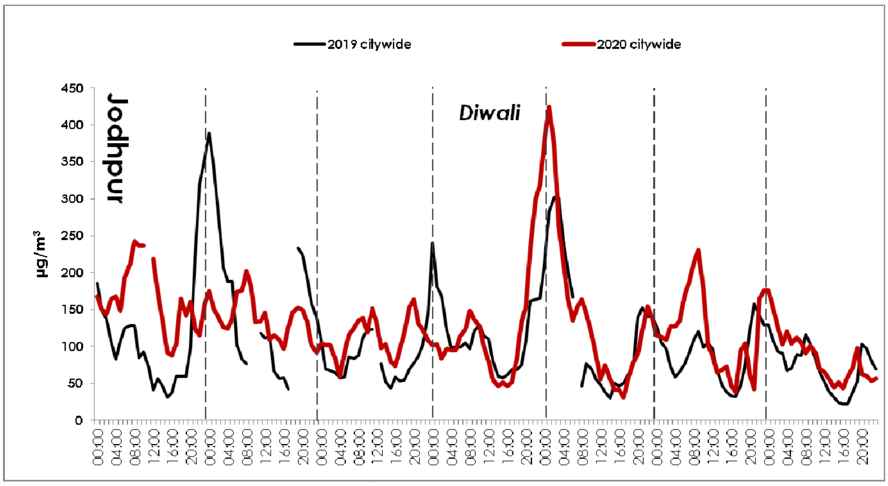
Diwali was cleaner in Jaipur but dirtier in Jodhpur this year: The average $PM_{2.5}$ level on day after Diwali in Jaipur was 72 µg/m^3 down from 211 µg/m^3 recorded in 2019, 66 per cent decline. This year there was about 85 per cent lower rise in hourly $PM_{2.5}$ concentration between afternoon and night of Diwali that is mostly caused due to firecracker busting (See *Graph 4a: How hourly pollution changed on Diwali day in Jaipur*). But story was different in Jodhpur where the change in hourly $PM_{2.5}$ concentration between afternoon and night of 2020 Diwali was 379 µg/m^3, up from 244 µg/m^3 in 2019 (See *Graph 4b: How hourly pollution changed on Diwali day in Jodhpur*). The average $PM_{2.5}$ level on day after Diwali in Jodhpur was 149 µg/m^3 up from 123 µg/m^3 recorded in 2019, 21 per cent increase. This Diwali also occurred later in November than the previous year.

Graph 4a: How hourly pollution changed on Diwali day in Jaipur



Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

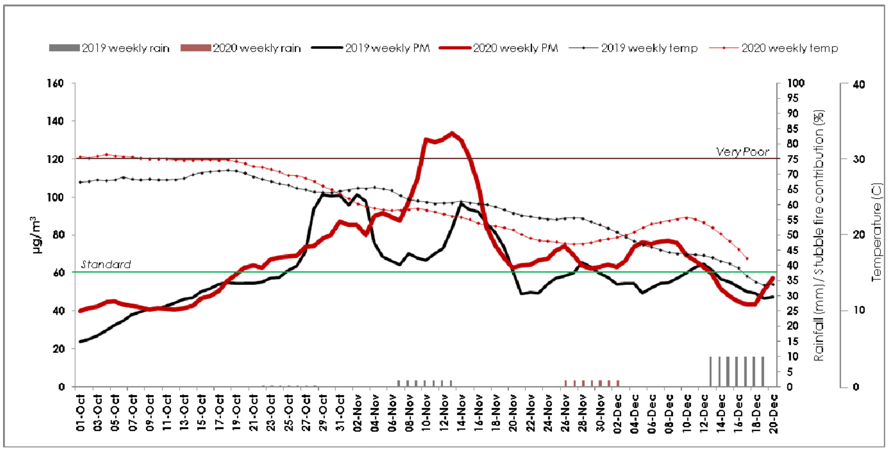
Graph 4b: How hourly pollution changed on Diwali day in Jodhpur



Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Jaipur –this winter had the dirtiest week in three year: The rolling weekly average rose over the 24hr standard or 60 µg/m^3 on October 20, but it did so on October 25 last year. This year the rolling weekly average crossed "Very Poor" level or 120 µg/m^3 on November 10 and remained over till November 15. Rolling weekly average had never crossed 120 µg/m^3 in 2018 or 2019 (See *Graph 5: Rate of increase in PM$_{2.5}$ in Jaipur: 2019 vs 2020*).

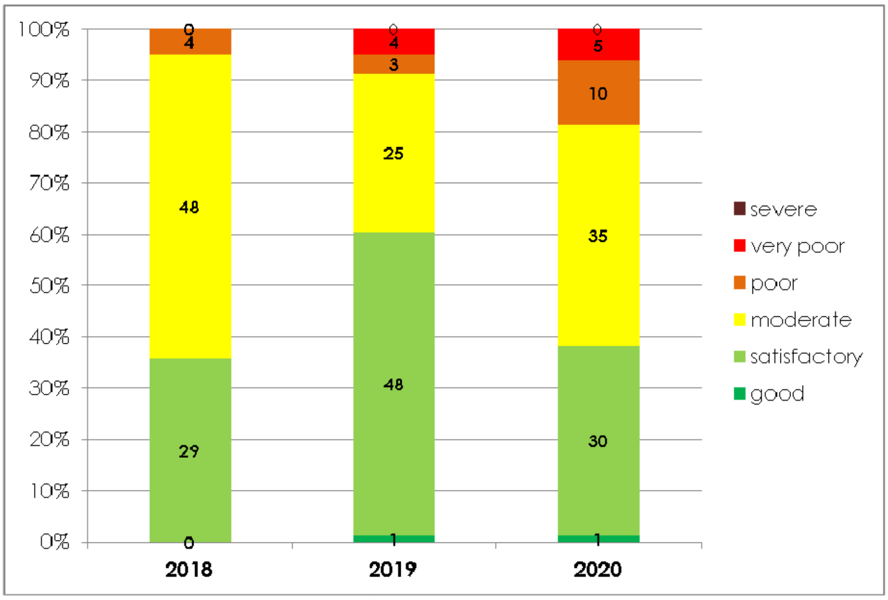
Graph 5: Rate of increase in PM$_{2.5}$ in Jaipur: 2019 vs 2020



Note: All values are rolling weekly average.
Data: CPCB (PM$_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Jaipur – City-wide number of days with PM$_{2.5}$ concentration in poor or worse category was considerably higher this winter: There have been 5 days of "very poor" air days this winter compared to just 4 recorded last year and zero in 2018. The "poor" days have also increased to 10 days from 3 days last year (See *Graph 6: Distribution of days based on PM$_{2.5}$ concentration and classified according to National Air Quality Index in Jaipur during winter (1 Oct – 20 Dec) 2018, 2019 and 2020*).

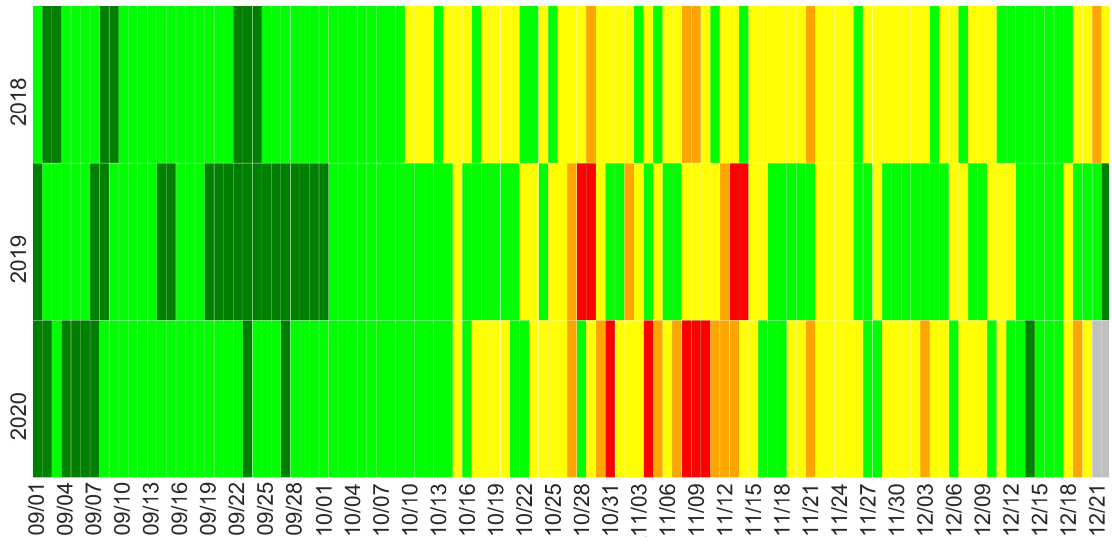
Graph 6: Distribution of days based on PM$_{2.5}$ concentration and classified according to National Air Quality Index in Jaipur during winter (1 Oct – 20 Dec) 2018, 2019 and 2020.



Note: Average PM$_{2.5}$ concentration for a day is based on mean of all 3 CAAQM stations of Jaipur.
Source: CSE analysis of CPCB's realtime air quality data

Jaipur: Episodes of bad air quality are becoming increasingly longer and severe in Jaipur during winter: This inelastic behavior of $PM_{2.5}$ levels in Jaipur is in contrast to the trend seen in Delhi-NCR where the trend has been more volatile during winter with frequent quicker rise and drop (*See Graph 7: Heatmap of Jaipur's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018-20*). This can be the impact of changed meteorology but more investigation is needed to understand the reasons for this.

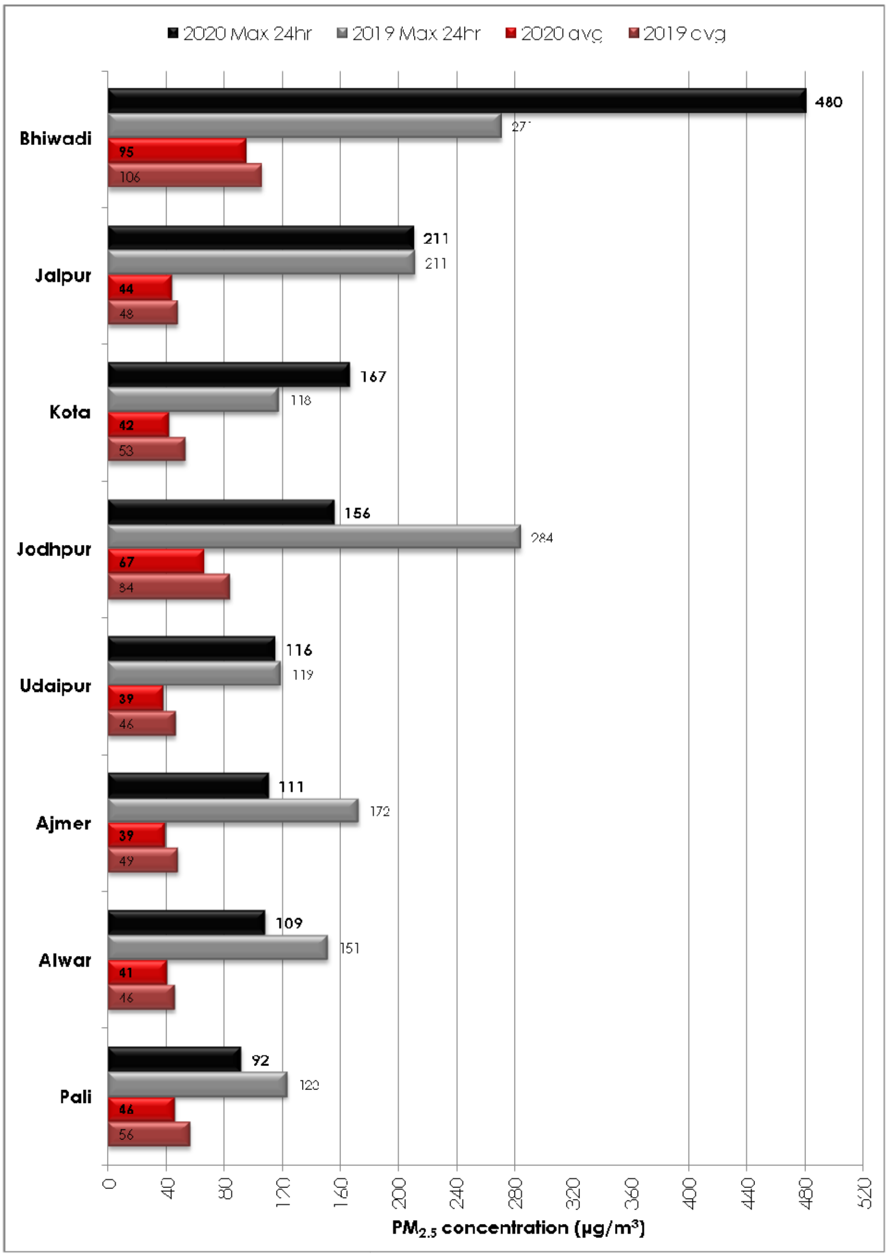
Graph 7: Heatmap of Jaipur's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on mean of all CAAQM stations of Jaipur. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Even with comparatively cleaner air during this year, Rajasthan cities recorded daily spikes similar to those observed in 2019: CSE has compared the annual averages and peak 24hr averages in these cities of Rajasthan between 2019 and 2020. This shows that eastern Rajasthan cities even with much lower annual average levels of $PM_{2.5}$ have experienced almost same or higher maximum daily levels during winter when the entire region got air locked (See *Graph 8: How annual average and maximum level changed in cities and towns of Rajasthan – comparison of 2019 and 2020*). Cities in western and central Rajasthan have registered much lower daily spikes.

Graph 8: How annual average and maximum level changed in cities and towns of Rajasthan – comparison of 2019 and 2020

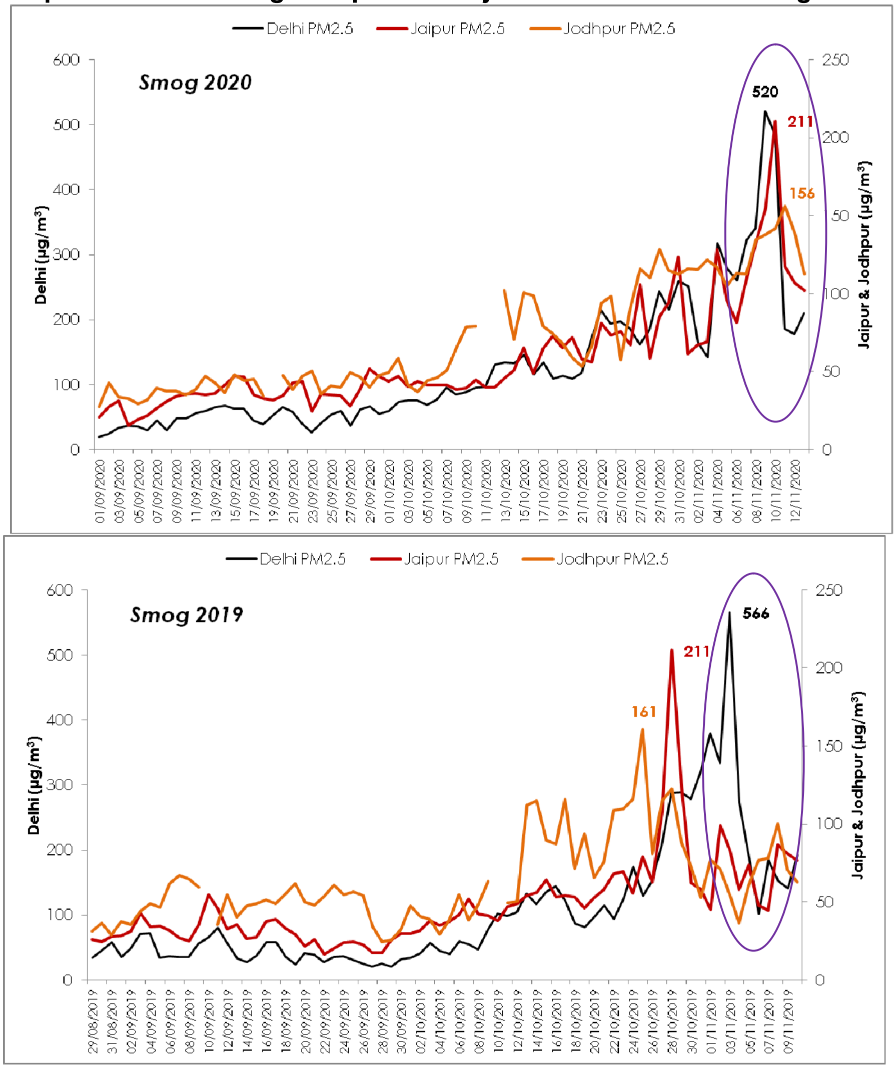


Note: 2020 numbers are based on data up to 8 Dec 2020.
Source: CSE analysis of CPCB's realtime air quality data

Jaipur and showed impact of stubble smoke smog this year: CSE tracked stubble fire smog movement down the Indo-Gangetic Plain by looking for unusual spike in $PM_{2.5}$ levels at CAAQM stations in the region. Last year when peak smog hit IGP in first week of November Rajasthan cities showed no unusual spike in their $PM_{2.5}$ except Bhiwadi which is very close to Delhi. In fact, the peak $PM_{2.5}$ in Jaipur and Jodhpur in 2019 happened before smog started in IGP. But this year the peak $PM_{2.5}$ in Jaipur and Jodhpur aligned smog. Peak of smog happened on 9 November in Delhi with $PM_{2.5}$ at 520 µg/m^3

interestingly Jaipur recorded its peak (211 µg/m^3) a day later on 10 November and Jodhpur registered its peak (156 µg/m^3) on 11 November. This is highly unusual and needs further investigation (that is beyond the scope of this analysis) as the regular wind patterns are not known to blow the stubble smoke towards Thar Desert. (See *Graph 9: Stubble smog's impact on Rajasthan cities – 2020 smog vs 2019 smog*).

Graph 9: Stubble smog's impact on Rajasthan cities – 2020 smog vs 2019 smog



Note: Average $PM_{2.5}$ concentration is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

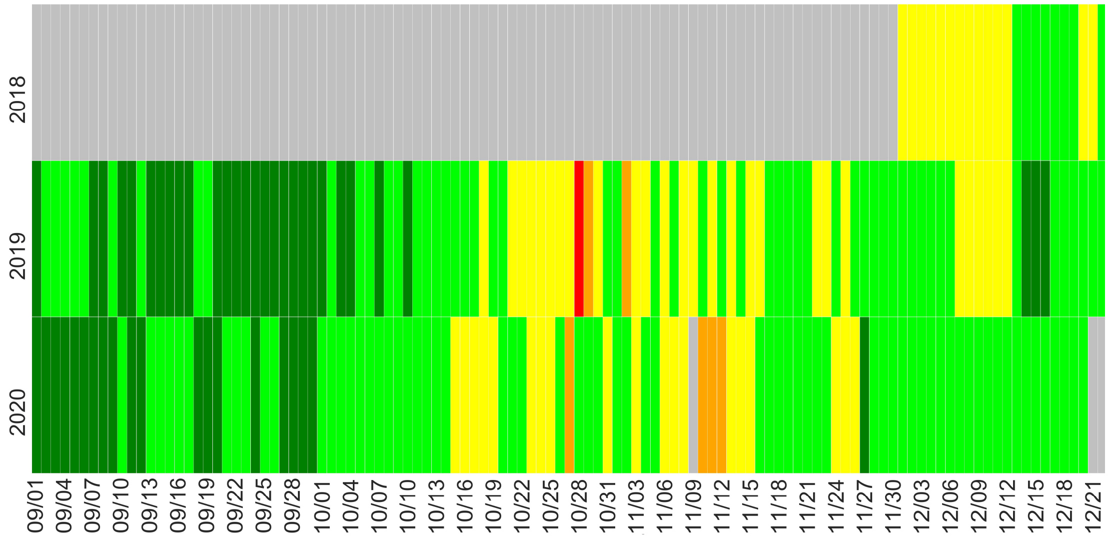
Need deep cuts

To avoid winter pollution peaks all cities of Rajasthan will have to reduce the annual average level of pollution to meet the national ambient air quality standards and even bring it further down to be closure to health based guidelines of the World Health Organisation.

How the pollution level will play out during the rest of the winter remains to be seen. But it is clear that the region has to take forward its wins so far and raise the level of ambition to drive action across all key sectors of pollution and in the entire region. Enforce power plant standards across the state, minimise use of coal and other dirt fuels in the industry while improving emissions control, scale up public transport and vehicle restraint measures and manage waste to have a zero waste and zero landfill strategy.

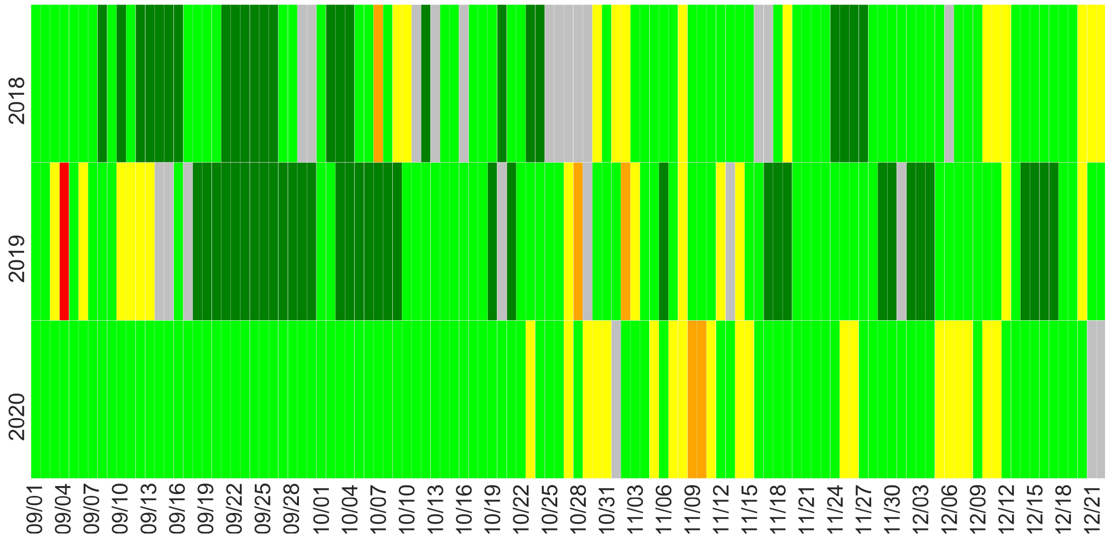
Additional graphs for Rajasthan cities

Graph 7b: Heatmap of Ajmer's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018, 2019 and 2020



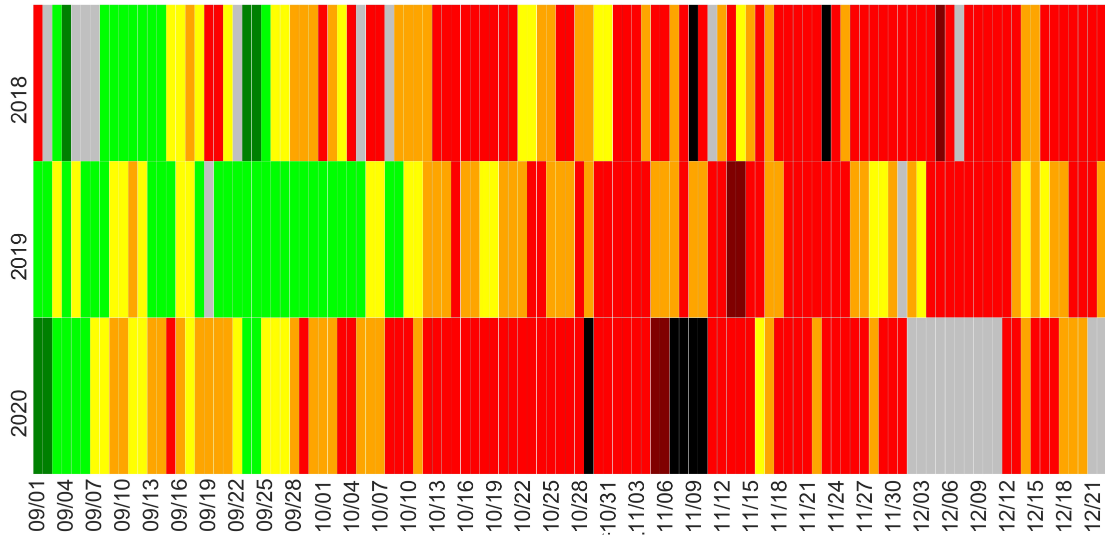
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8c: Heatmap of Alwar's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018, 2019 and 2020



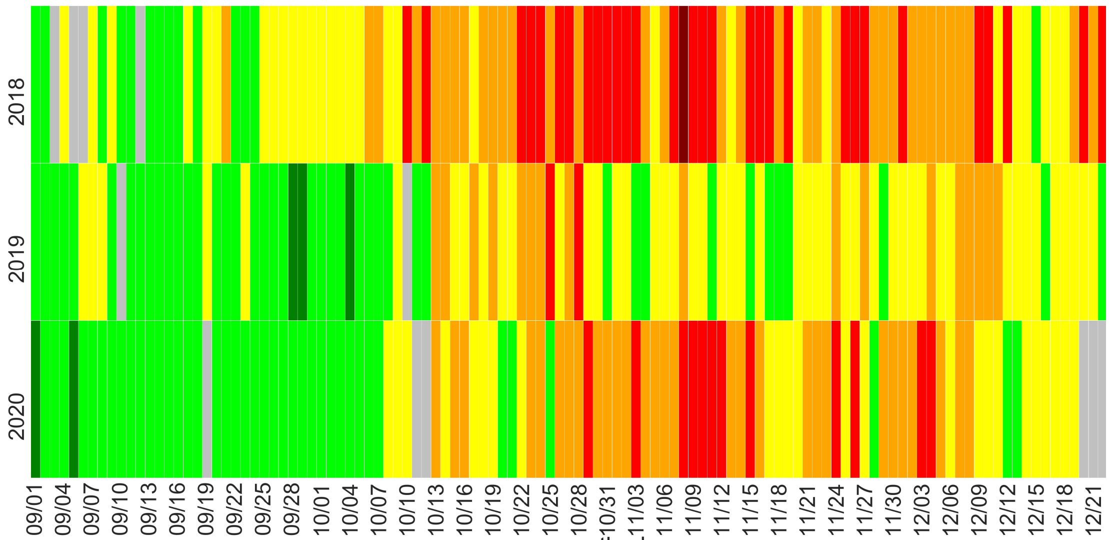
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8d: Heatmap of Bhiwadi's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018, 2019 and 2020



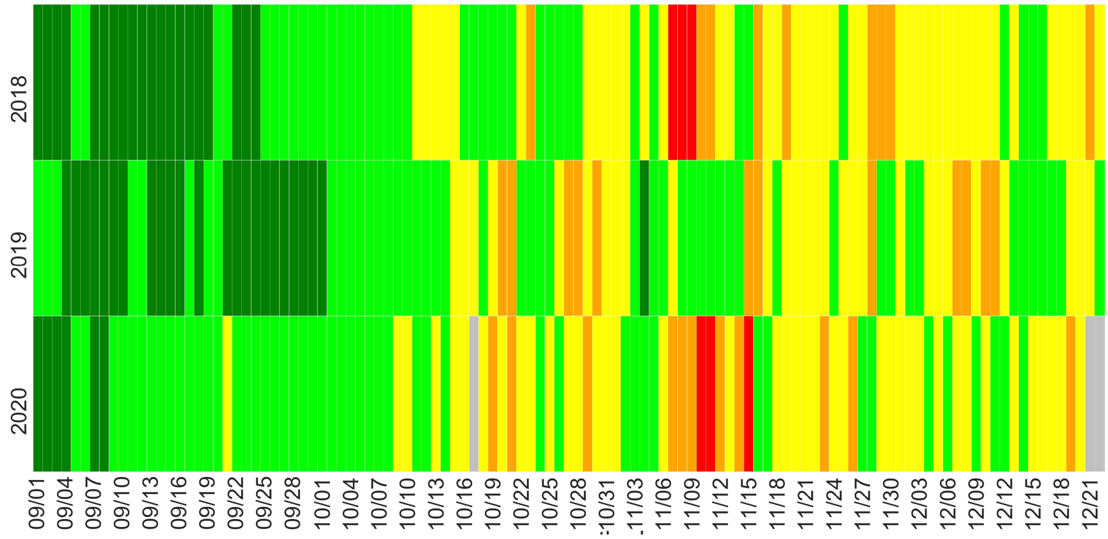
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8e: Heatmap of Jodhpur's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018, 2019 and 2020



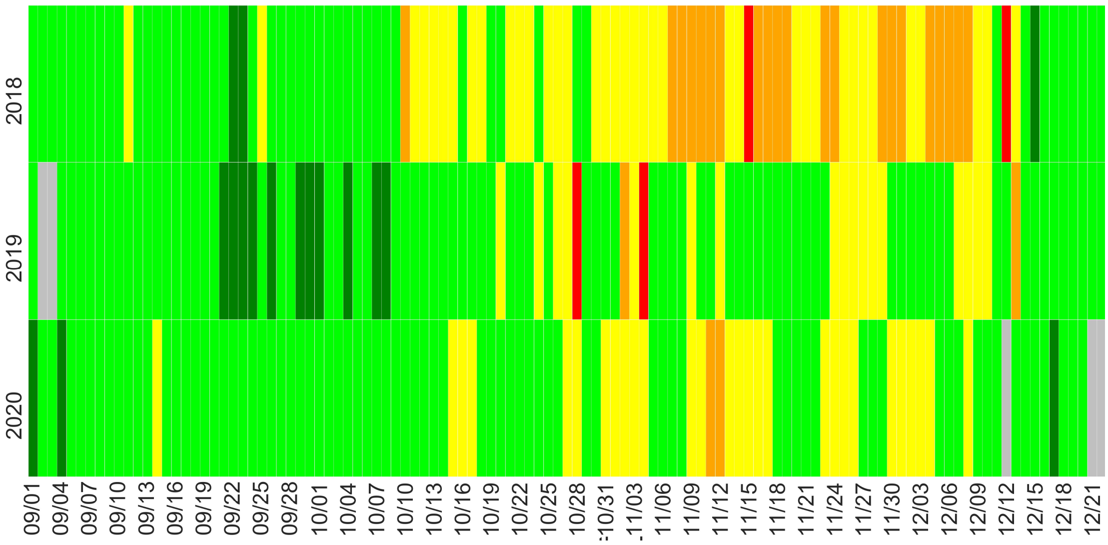
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8f: Heatmap of Kota's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018, 2019 and 2020



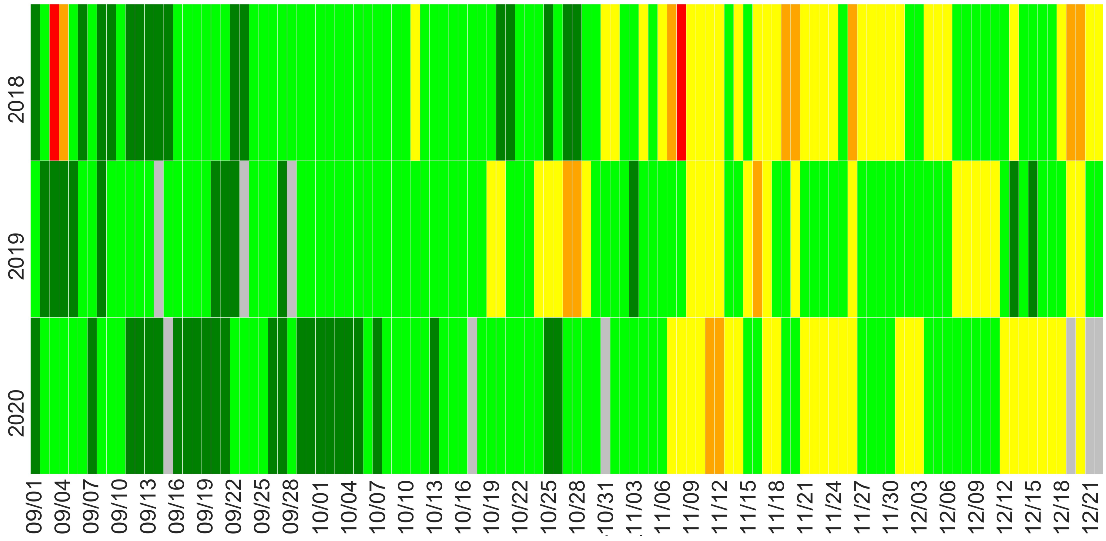
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8g: Heatmap of Pali's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8h: Heatmap of Udaipur's daily $PM_{2.5}$ concentration in winter (1 Sept – 20 Dec) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

5 Decoding winter air pollution in Indo-Gangetic Plain: Pollution beyond NCR

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, January, 2021

As part of its air quality tracker initiative the Centre for Science and Environment (CSE) has carried out a series of air quality analysis for different regions of the country to get a deeper view of the changing patterns of air quality trends. This seeks to understand the impact of the extraordinary year 2020 that has witnessed one of the biggest disruptions in the recent times. This is an inflexion point but also an indicator of what may change and yet not change despite the disruption. This helps to address some of the basic curiosities related to how low the pollution can get with stopping of activities, regional influence on local air quality, and deeper seasonal patterns that unmask the high local pollution despite the forced change during the lockdown phases. After analyzing the changing trends in Delhi and National Capital region, Rajasthan, Maharashtra, and West Bengal, this analysis unravels the pattern in the Indo-Gangetic Plain – the most vulnerable and difficult region from air quality perspective.

New analysis of winter pollution until 11 January of this year, carried out shows how clean air gains of the lockdown and monsoon period were lost with the reopening of the economy and hostile winter weather like all other regions. While this was expected, the analysis of the real-time data from monitoring stations outside NCR in the larger Indo-Gangetic Plain show newer pattern in winter pollution this year. Even though trapping of winter pollution in the larger Indo Gangetic Plain is high compared to other regions, it was not as high as that of the NCR but it was alarmingly high and synchronized despite large distances. This is the challenge of this landlocked region.

Higher $PM_{2.5}$ levels is a typical and predictable winter trend when continuous emissions from local sources including vehicles, industry, construction, and episodic pollution from biomass burning get trapped due to meteorological changes. But this year, this trend has set in almost two weeks earlier in the season. There is clear difference in winter pollution pattern between IGP regions north and south of NCR. Even though the average level of $PM_{2.5}$ for the summer and monsoon months in 2020 is considerably lower than the previous year due to the pandemic related to summer lockdown, the $PM_{2.5}$ levels this winter have risen beyond the 2019 in almost all monitored cities in Punjab and Haryana (region north of NCR. Cities in central and eastern UP and Bihar (region south of NCR) also show high winter pollution but levels are similar or lower compared to 2019. Combination of the reopening of the economy and changing meteorology is responsible for high winter pollution but this regional variation calls out for more nuanced and robust pollution control strategy. The region cannot rely only on action being taken in Delhi-NCR. This demands speed and scale of action.

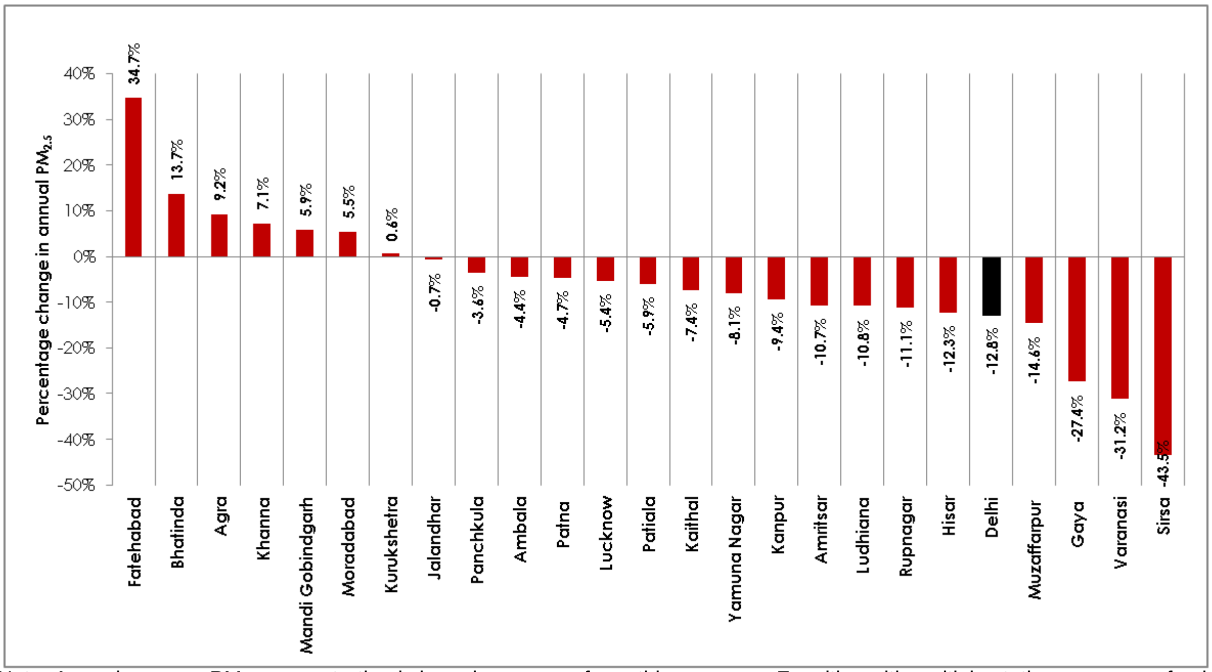
This detailed data analysis points to the fact that the air pollution is an IGP wide problem and this requires quicker reforms and action in key sectors of pollution – vehicles, industry, power plants and waste management to control winter pollution and further bend the annual air pollution curve.

Data used in the analysis: The analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. 26 cities – Amritsar, Bhatinda, Jalandhar, Khanna, Ludhiana, Mandi Gobindgarh, Patiala, Rupnagar, Chandigarh, Ambala, Fatehabad, Hisar, Kaithal, Kurukshetra, Panchkula, Sirsa, Yamuna Nagar, Agra, Kanpur, Moradabad, Varanasi, Lucknow, Patna, Gaya, Muzaffarpur, and Hajipur have been selected for this analysis because real time data is available for these cities. This has analysed data recorded by 6 air quality monitoring stations at Patna, 5 stations in Lucknow, 2 stations in Gaya and Muzaffarpur, one station each rest of the cities under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Weather data for Amritsar, Ambala, Chandigarh, Lucknow, and Patna has been sourced from the weather stations of Indian Meteorological Department (IMD) located at the airport of each city.

Key highlights

Annual average level of $PM_{2.5}$ not lower in many cities this year despite the lockdown – while several bigger cities have witnessed reduction, smaller towns and cities have experienced increase: The 2020 average $PM_{2.5}$ level in many cities in upper IGP has climbed up to breach the average concentration recorded in 2019. Fatehabad in northern Haryana is the worst performer with 35 per cent increase from 2019 level. It is followed by Bhatinda at 14 per cent, Agra at 9 per cent, Khanna at 7 per cent, Mandi Gobindgarh at 6 per cent, Moradabad at 5.5 per cent and Kurukshetra at about 1 per cent increase. Jalandhar registered less than one per cent change. Most improvement is noted in Sirsa which is closing 2020 with a 44 per cent lower $PM_{2.5}$. Varanasi at 31 per cent, Gaya at 27 per cent, Muzaffarpur at 15 per cent and Hisar at 12 per cent are other best performers in the pool. Rest of the cities show improvement in range of 4-12 per cent (See *Graph1: Percentage change in $PM_{2.5}$ annual average in IGP cities*). For context, Delhi's 2020 average is 13 per cent lower than its 2019 level.

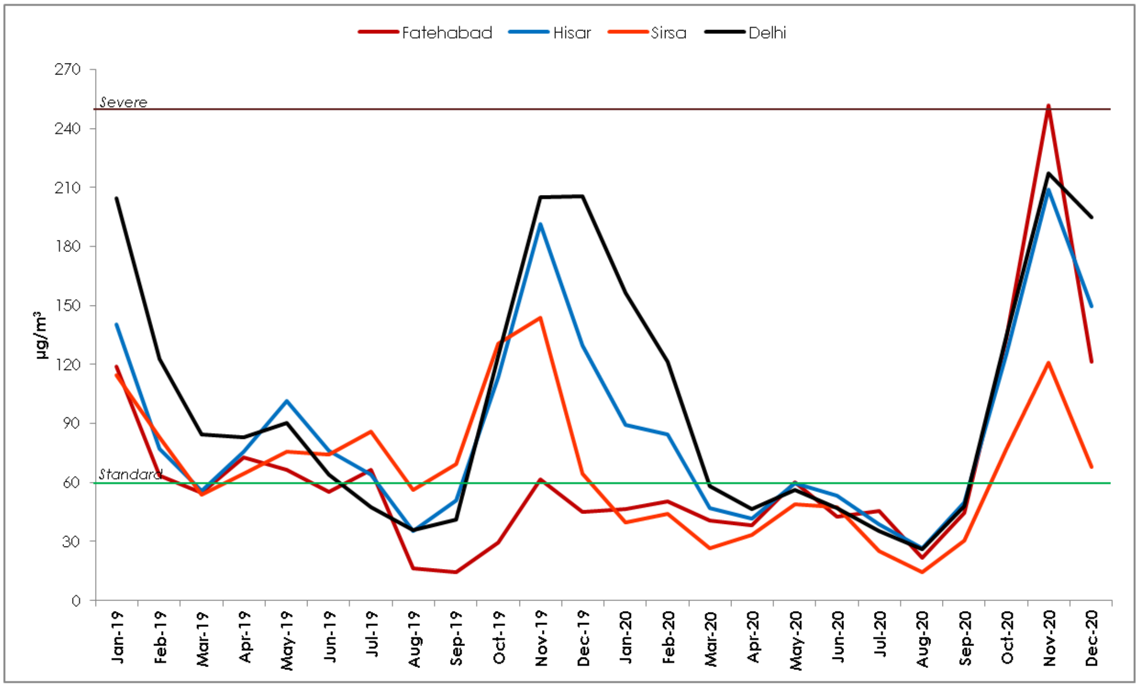
Graph1: Percentage change in $PM_{2.5}$ annual average in IGP cities



Note: Annual average $PM_{2.5}$ concentration is based on mean of monthly averages. For cities with multiple stations average of only those stations are used which were working in both 2019 and 2020 for all 12 months. Data uptill 31 December 2020.
Source: CSE analysis of CPCB's real time air quality data

Bad November indicates influence of stubble burning: In must be noted that Fatehabad (the worst performer) and Sirsa (the best performer) are neighboring towns; just 40 kms apart. Therefore, this massive variation can't be attributed to meteorology and has to do with local factors. The annual average of these towns along with other smaller towns like Hisar and Jind in the north-west are heavily influenced episodic pollution caused burning of crop stubbles. Influence is so pronounced that it can elevate their monthly $PM_{2.5}$ level for November to Delhi's level but unlike Delhi these towns are directly exposed to the smoke. The elevated November levels don't linger on for rest of winter in these towns as noted in Delhi (See *Graph 2: Smaller Haryana towns have bad November similarly as Delhi*). Therefore, any change in stubble burning pattern skews their annual average dramatically and which may possibly be the reason for observed trend in data but further field investigation is needed to determine the real reasons.

Graph 2: Smaller Haryana towns have bad November similarly as Delhi



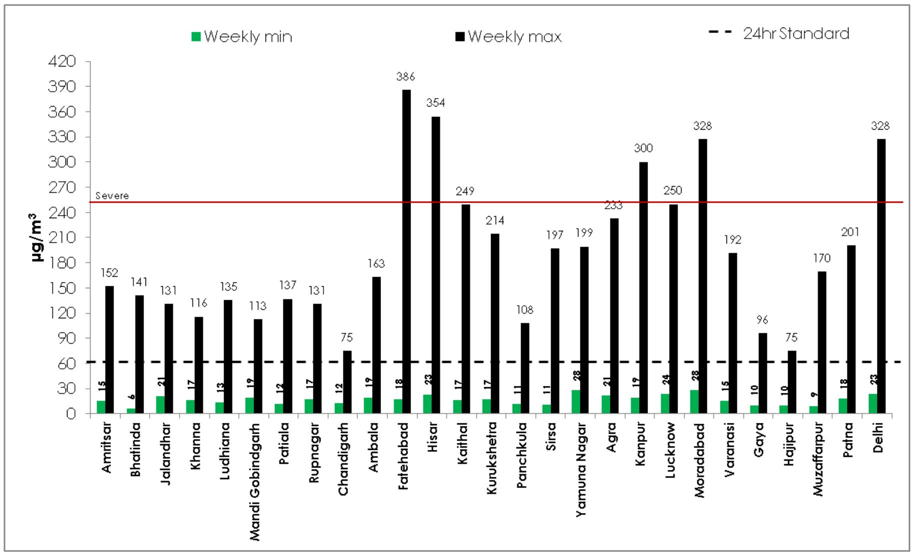
Note: Average $PM_{2.5}$ concentration for a month is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

Average level of $PM_{2.5}$ has been lowest during this summer and monsoon due to the lockdown but could not prevent the winter spike: The overall $PM_{2.5}$ average this summer and monsoon has been predictably lower compared to the previous year largely because of the unprecedented economic disruption during the summer lockdown and phased unlocking. But reopening of the economy coinciding with the onset of the winter trapping pollution made $PM_{2.5}$ levels rose starting October. From the respective cleanest week the weekly average of $PM_{2.5}$ in Amritsar rose 10 times, in Ambala 9 times, Chandigarh 6 times, Lucknow 11 times, and Patna 11 times to the dirtiest week. These major cities recorded lesser deterioration than Delhi where weekly air quality worsened 14 times but smaller towns beat the capital. Bhatinda deteriorated 23 times, Fatehabad 22 times, Muzaffarpur 19 times, Sirsa 17 times, and Kanpur 16 times. It deteriorated 15 times in Hisar and Kaithal.

There is marked difference between northern cities and eastern cities. The cities in northern recorded their dirtiest week in first half of November same as Delhi-NCR, while eastern cities had their dirtiest week in December.

Dirtiest week for Khanna, Mandi Gobindgarh, Patiala, Rupnagar, Chandigarh, Ambala, Kaithal, Kurukshetra, Yamuna Nagar, Agra, and Moradabad was week ending on 8 November 2020. For Delhi, Amritsar, Bhatinda, Jalandhar, Ludhiana, Fatehabad, Hisar, Panchkula, and Sirsa the dirtiest week on the week ending on 15 November 2020. Hajipur, Patna, and Muzaffarpur the dirtiest week on the week ending on 6 December 2020. Kanpur, Varanasi, and Lucknow the dirtiest week on the week ending on 27 December 2020. Dirtiest week for Gaya was the new year's week. Cleanest week for Khanna, Rupnagar, Ludhiana, and Panchkula was the week ending on 29 March, 2020. Amritsar and Jalandhar had their cleanest week in April. Patna had its cleanest week in June and July was the cleanest for Agra and Moradabad. Patiala, Chandigarh, Ambala, Kaithal, Kurukshetra, Yamuna Nagar, Delhi, Hisar, Kanpur, Varanasi, Lucknow, and Muzaffarpur had their cleanest week ending on 23 August 2020. Mandi Gobindgarh and Fatehabad had its cleanest week on the week ending 30 August 2020. Bhatinda and Sirsa had their cleanest week ending on 6 September 2020. Hajipur and Gaya had their cleanest week ending on 27 September 2020 (See *Graph 3: Change in weekly $PM_{2.5}$ levels 2020 – Difference between* *cleanest and most polluted week*). The transient change of the lockdown phases could not be sustained without the systemic changes needed to control pollution from vehicles, industry, power plants, and waste.

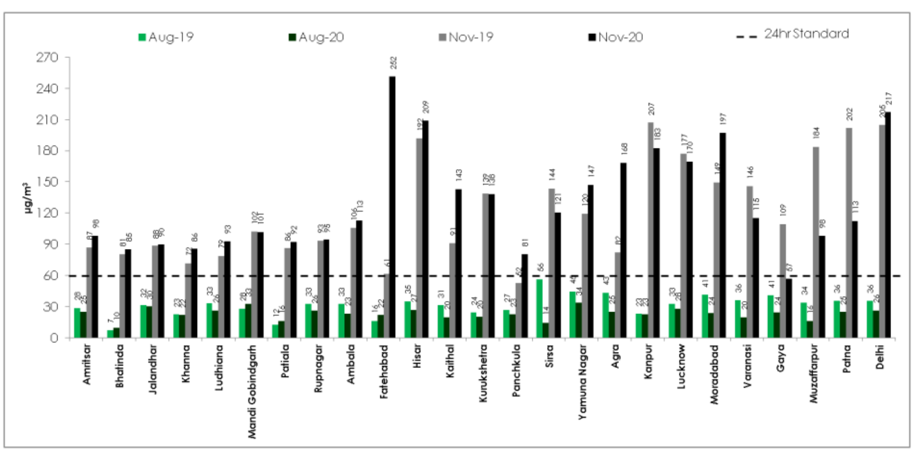
Graph 3: Change in weekly $PM_{2.5}$ levels 2020 – Difference between cleanest and most polluted week



Note: Average $PM_{2.5}$ concentration for a week is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

Average November $PM_{2.5}$ level has been considerably higher in northern cities this year: November this year was dirtier across most cities in IGP. The $PM_{2.5}$ average this November was 310 per cent higher in Fatehabad, 104 per cent in Agra and 57 per cent in Kaithal compared to November 2019. November was also same or dirtier in all Punjab and Haryana cities except Sirsa that registered 16 per cent cleaner November. All cities in central and eastern UP and Bihar had a 4-48 per cent cleaner November. August this year cleaner in all these cities compared to August 2019 except in Bhatinda, Mandi Gobindgarh, Patiala, and Fatehabad (See *Graph 4: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages)*).

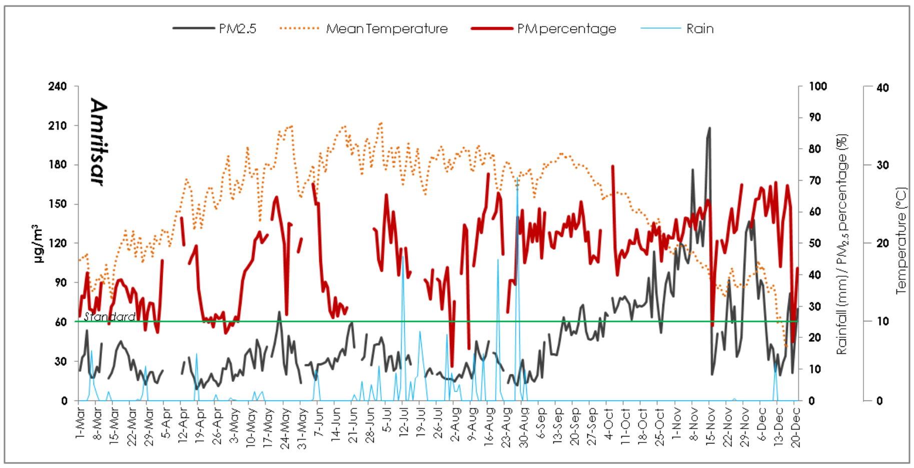
Graph 4: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages)



Note: Average $PM_{2.5}$ concentration for a month is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

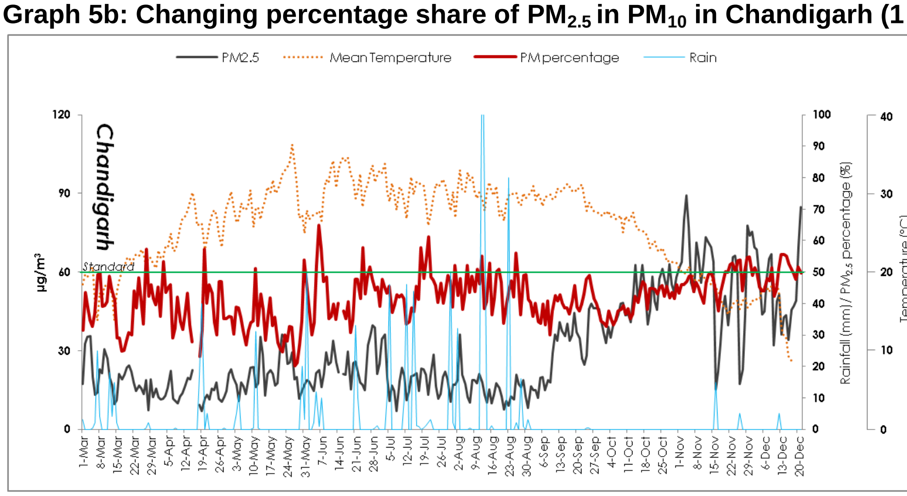
Air quality gets more toxic with the onset of winter - share of tinier $PM_{2.5}$ in the PM_{10} increases: The share of tinier and finer particles in the overall coarser PM_{10} concentration determines the toxicity of air. When the overall share of tinier $PM_{2.5}$ in the overall coarser PM_{10} is higher, the air is more toxic as the tiny particles penetrate deep inside the lungs and cut through the blood barrier increasing health risk. Interestingly, during lockdown, when the overall suspended coarser particles had settled down reducing the PM_{10} levels, the $PM_{2.5}$ had also come down. But its share was 33 per cent in Amristsar, 39 per cent in Chandigarh, 38 per cent in Patna – higher than it's usually noted during summer (low 30s). But with the onset of winter the overall level of both have gone up and also the percentage share of $PM_{2.5}$ in the overall $PM_{10.}$ This rose to high 40s during October and remained high through November averaging at 55 per cent in Amritsar, 48 per cent in Chandigarh, 53 per cent in Patna (See *Graph 5: Changing share of percentage share of $PM_{2.5}$ in PM_{10} in a) Amritsar b) Chandigarh c) Patna (1 Mar – 8 Dec, 2020)*). The share of $PM_{2.5}$ in PM_{10} is generally highest on Diwali and it reached 64 per cent in Amritsar, 69 per cent in Chandigarh, and 62 per cent in Patna this year.

Graph 5a: Changing percentage share of $PM_{2.5}$ in PM_{10} in Amritsar (1 Mar – 21 Dec, 2020)



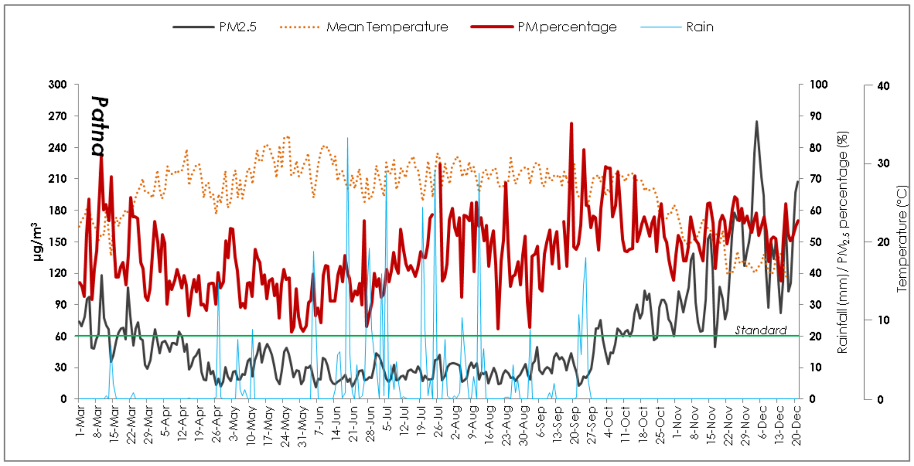
Data: CPCB (PM_{10} and $PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Graph 5b: Changing percentage share of $PM_{2.5}$ in PM_{10} in Chandigarh (1 Mar – 21 Dec, 2020)



Data: CPCB (PM_{10} and $PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

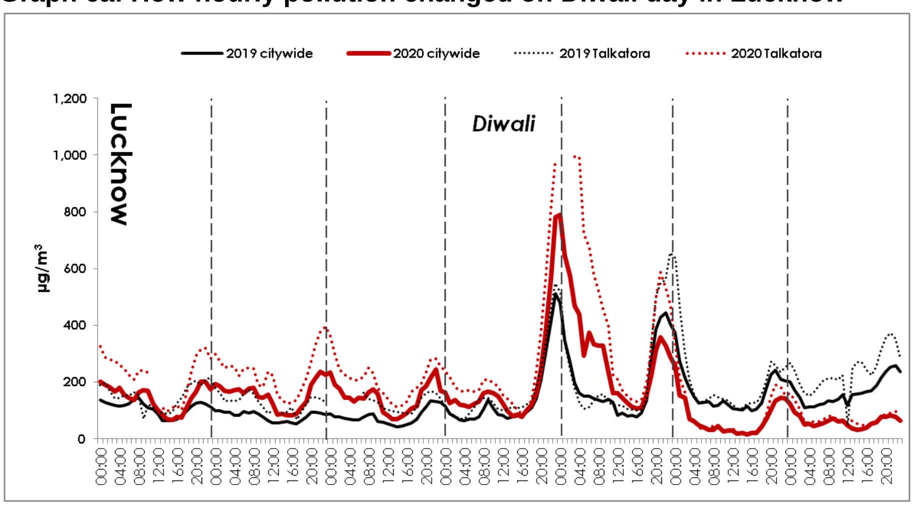
Graph 5c: Changing percentage share of $PM_{2.5}$ in PM_{10} in Patna (1 Mar – 21 Dec, 2020)



Data: CPCB (PM_{10} and $PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

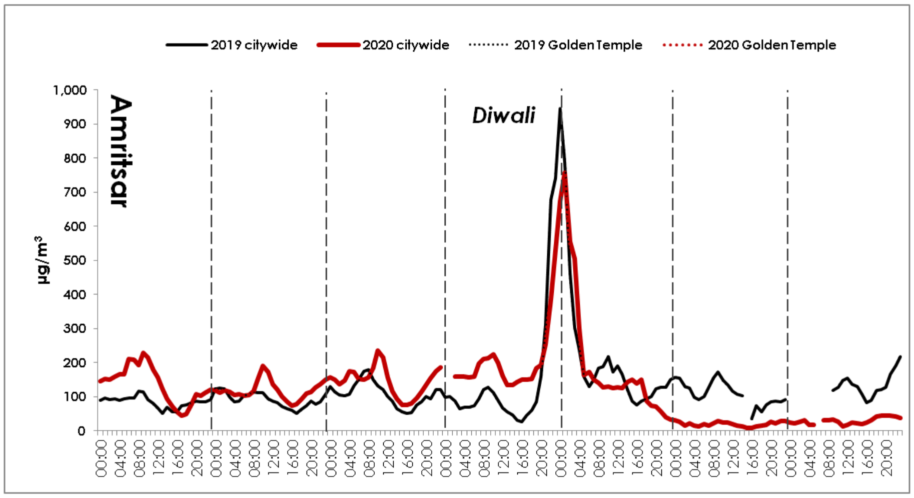
Dirtier Diwali in Lucknow this year but Amritsar, Ambala, Chandigarh, and Patna were cleaner: The average $PM_{2.5}$ level on Diwali day at Talkatora in Lucknow was 434 µg/m^3 up from 237 µg/m^3 recorded in 2019. This year there was over 100 per cent higher rise in hourly $PM_{2.5}$ concentration between afternoon and night of Diwali that is mostly caused due to firecracker busting (See *Graph 6: How hourly pollution changed on Diwali day in Mumbai*). Amritsar was 7 per cent, Chandigarh was 56 per cent, Ambala was 57 per cent, and Patna was 22 per cent cleaner. Diwali also occurred later in November than the previous year.

Graph 6a: How hourly pollution changed on Diwali day in Lucknow



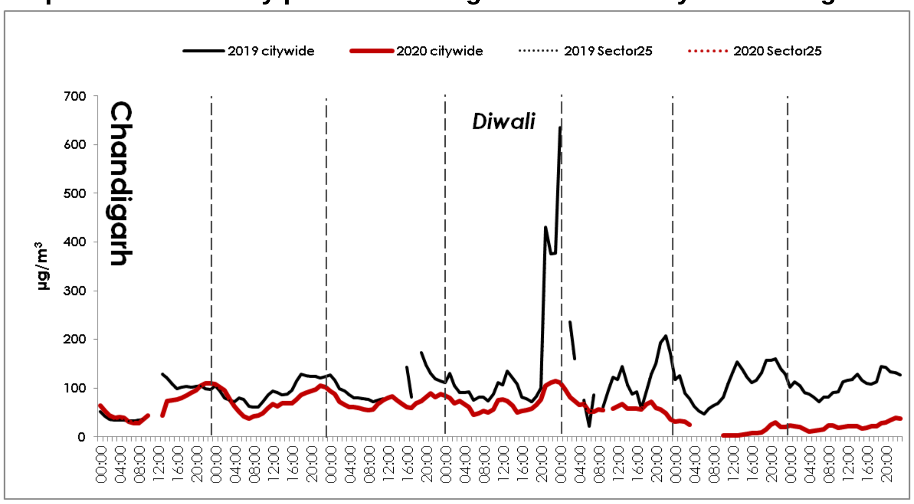
Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Graph 6b: How hourly pollution changed on Diwali day in Amritsar



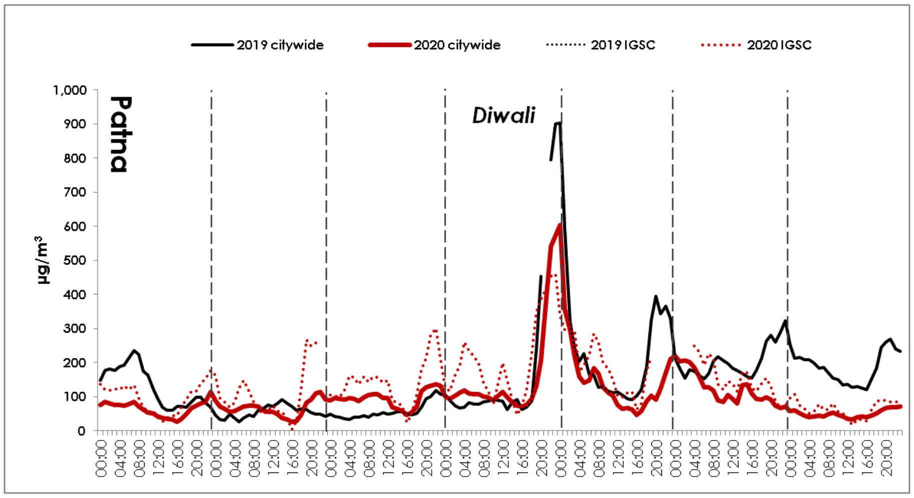
Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Graph 6c: How hourly pollution changed on Diwali day in Chandigarh



Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

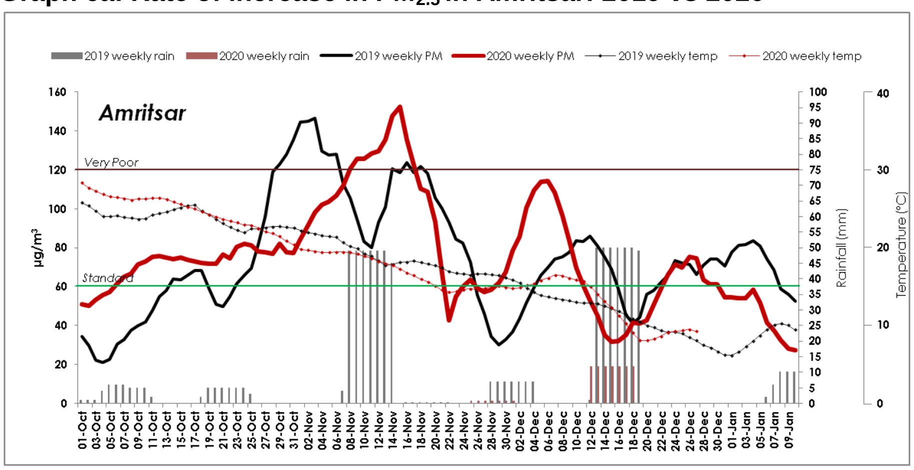
Graph 6d: How hourly pollution changed on Diwali day in Patna



Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

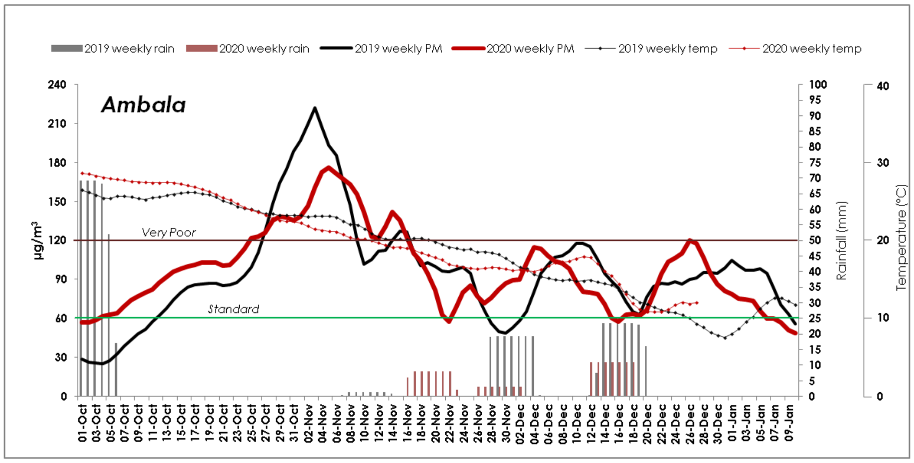
Bad air days started earlier in 2020 winter: The rolling weekly average rose over the 24hr standard or 60 µg/m^3 in Amritsar on October 6 (8 days earlier), Ambala on October 4 (8 days earlier), Lucknow on September 10 (29 days earlier), and Patna on October 1 (14 days earlier). Overall the winter has been dirtier across. Chandigarh has had a relatively cleaner November with bad air setting in later this year compared to 2019 (See *Graph 7: Rate of increase in $PM_{2.5}$ in a) Amritsar, b) Ambala, c) Lucknow, d) Patna, e) Chandigarh: 2019 vs 2020*).

Graph 6a: Rate of increase in $PM_{2.5}$ in Amritsar: 2019 vs 2020



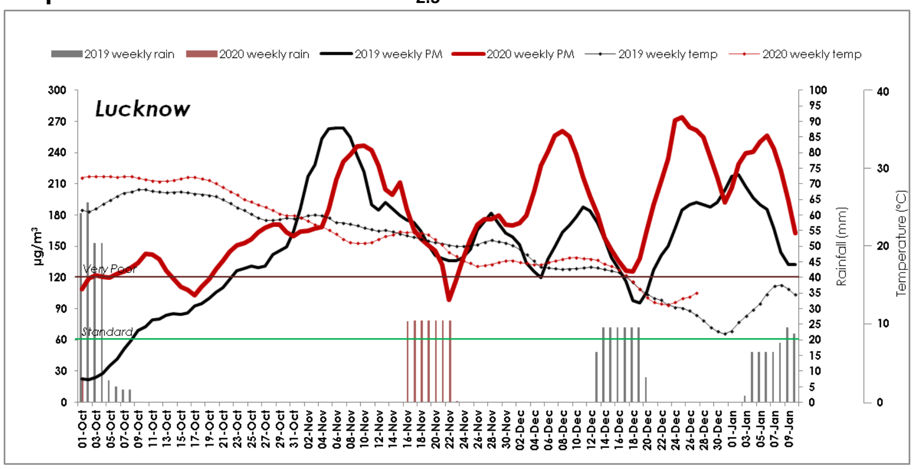
Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Graph 6b: Rate of increase in $PM_{2.5}$ in Ambala: 2019 vs 2020



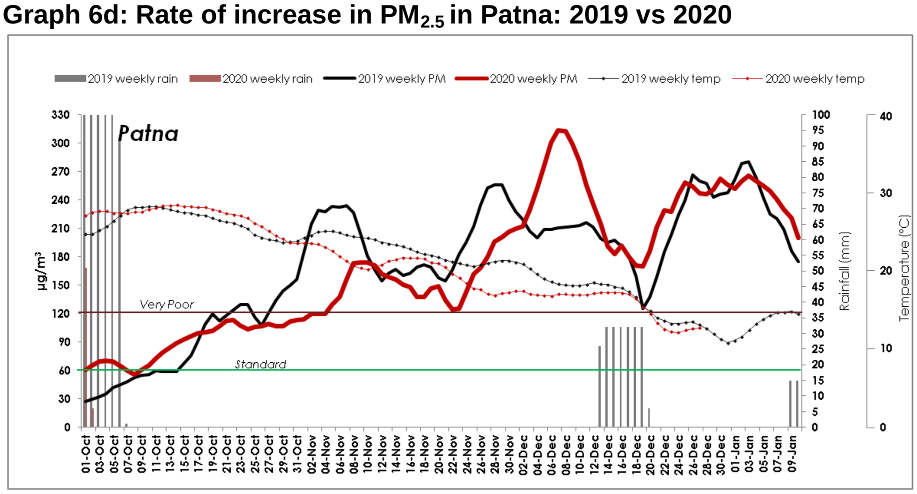
Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Graph 6c: Rate of increase in $PM_{2.5}$ in Lucknow: 2019 vs 2020



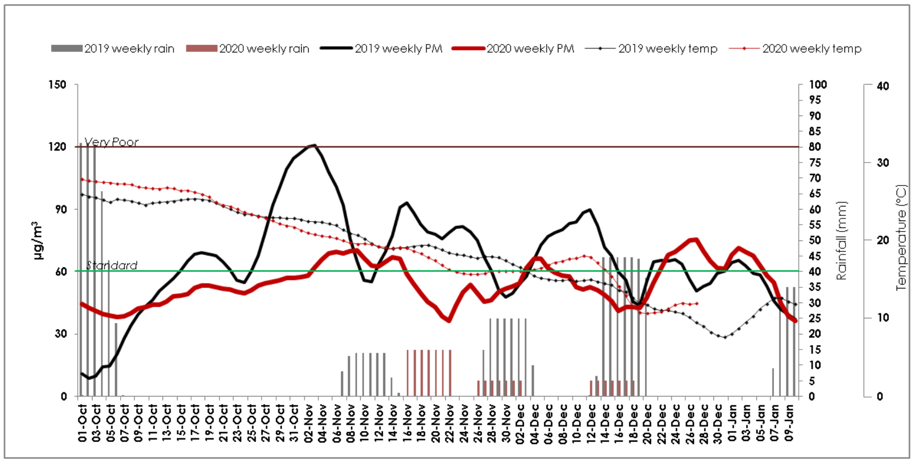
Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Graph 6d: Rate of increase in $PM_{2.5}$ in Patna: 2019 vs 2020



Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

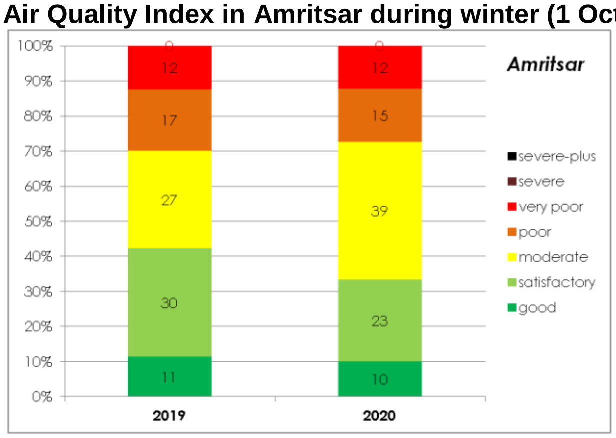
Graph 6e: Rate of increase in $PM_{2.5}$ in Chandigarh: 2019 vs 2020



Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

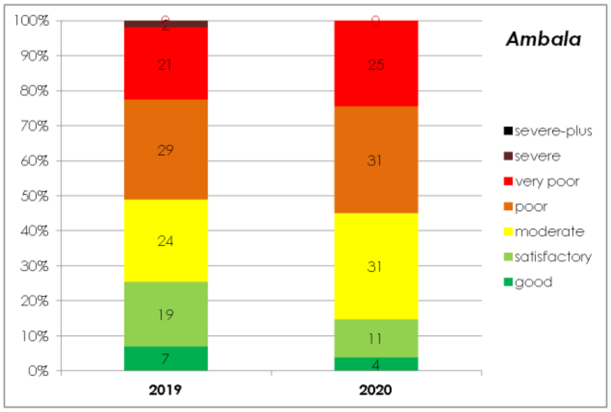
Number of days with $PM_{2.5}$ concentration meeting standard was considerably lower this winter; more poor or worse days: There have been 33 days of standard air days this winter compared to 41 recorded last year in Amritsar. Similarly standard days have been lesser by 11 days in Ambala, 4 days in Lucknow and Patna (See *Graph 7: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in a) Amritsar, b) Ambala, c) Lucknow, d) Patna, e) Chandigarh during winter (1 Oct –10 Jan) 2019 and 2020*). In fact, in Lucknow not a single day met the standard since start of October this winter and 19 days of severe or worse air quality up from 5 days in last winter. Chandigarh bucks the trend and recorded 18 more days this winter with air quality meeting the standard.

Graph 7a: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Amritsar during winter (1 Oct – 10 Jan) 2019 and 2020.



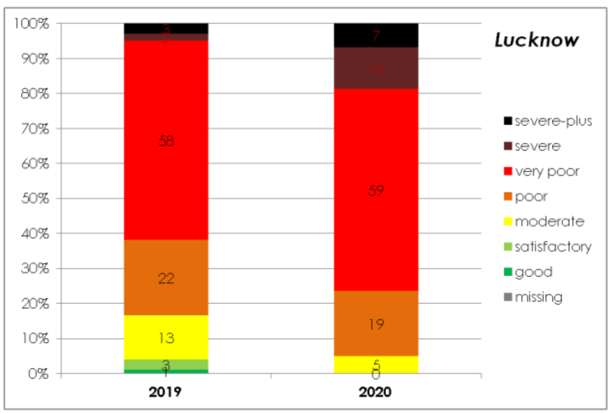
Note: Average $PM_{2.5}$ concentration for a day is based on single CAAQM station.
Source: CSE analysis of CPCB's realtime air quality data

Graph 7b: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Ambala during winter (1 Oct – 10 Jan) 2019 and 2020.



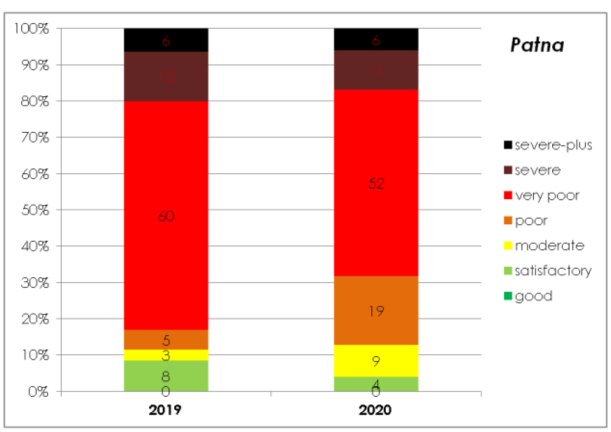
Note: Average $PM_{2.5}$ concentration for a day is based on single CAAQM station.
Source: CSE analysis of CPCB's realtime air quality data

Graph 7c: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Lucknow during winter (1 Oct – 10 Jan) 2019 and 2020.



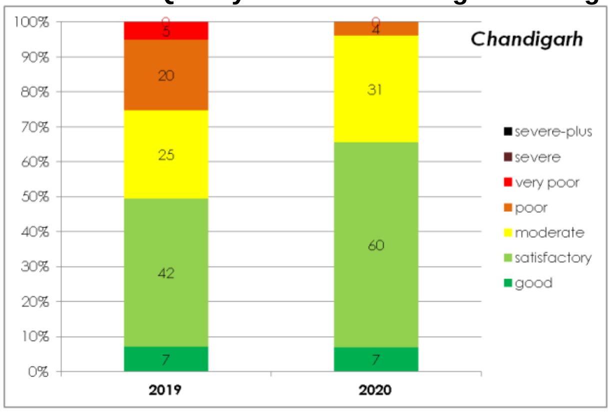
Note: Average $PM_{2.5}$ concentration for a day is based on mean of 3 CAAQM stations of Lucknow.
Source: CSE analysis of CPCB's realtime air quality data

Graph 7d: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Patna during winter (1 Oct – 10 Jan) 2019 and 2020.



Note: Average $PM_{2.5}$ concentration for a day is based on single CAAQM station at IGSC, Patna.
Source: CSE analysis of CPCB's realtime air quality data

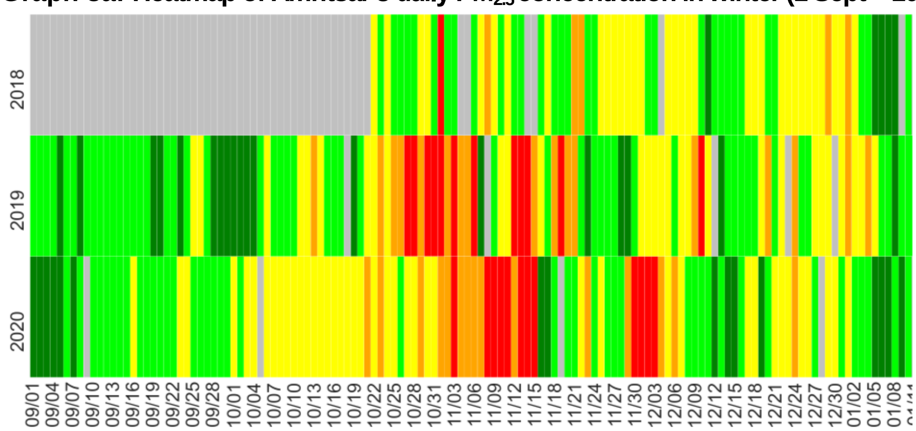
Graph 7e: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Chandigarh during winter (1 Oct – 10 Jan) 2019 and 2020.



Note: Average $PM_{2.5}$ concentration for a day is based on single CAAQM station.
Source: CSE analysis of CPCB's realtime air quality data

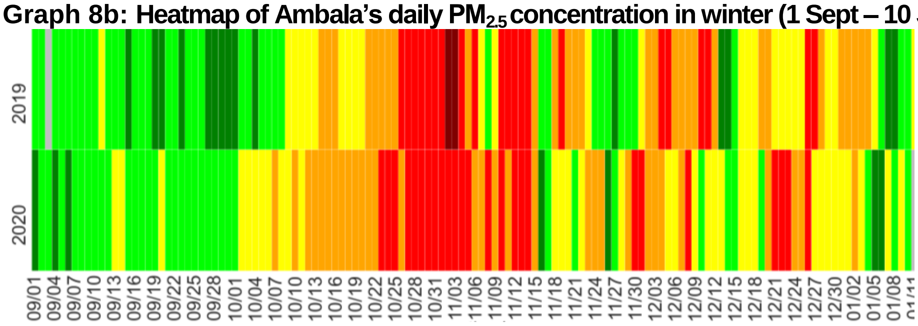
The cyclical ups and down of pollution this winter is less volatile – showing slower rise and fall than pervious winter: This inelastic behavior of $PM_{2.5}$ levels in IGP cities is in contrast to the trend seen in Delhi-NCR where the trend has been more volatile during winter with frequent quicker rise and drop (*See Graph 8: Heatmap of daily $PM_{2.5}$ concentration in winter a) Amritsar, b) Ambala, c) Lucknow, d) Patna, e) Chandigarh (1 Sept – 21 Dec) of 2018-20*). This can't be the impact of meteorology as Delhi-NCR is exhibiting different trend, therefore it might be due to poor pollution control action among these cities but more investigation is needed to understand the reasons for this.

Graph 8a: Heatmap of Amritsar's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



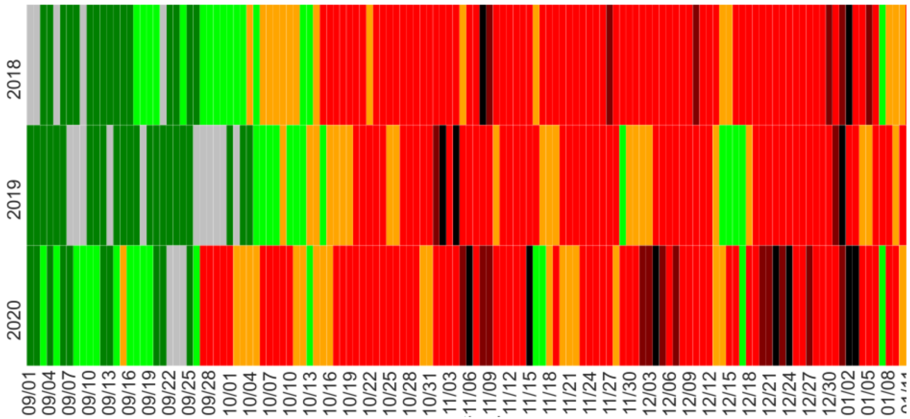
Note: Average $PM_{2.5}$ concentration for a day is based on a single CAAQM station. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8b: Heatmap of Ambala's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2019 and 2020



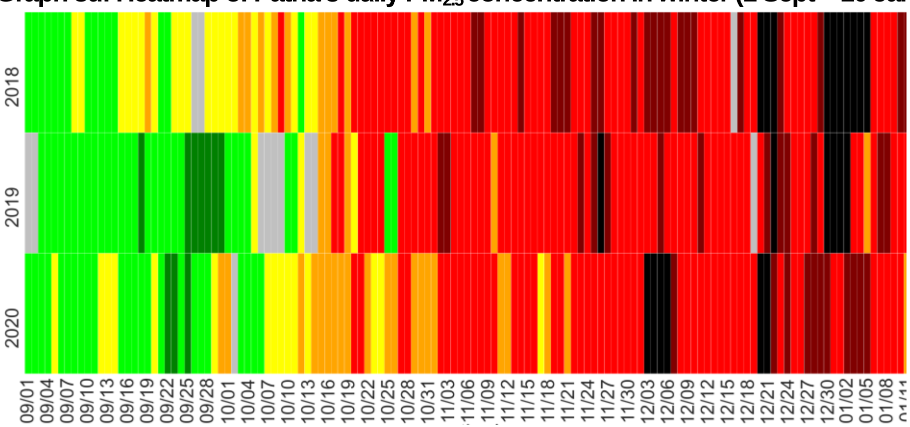
Note: Average $PM_{2.5}$ concentration for a day is based on a single CAAQM station. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8c: Heatmap of Lucknow's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



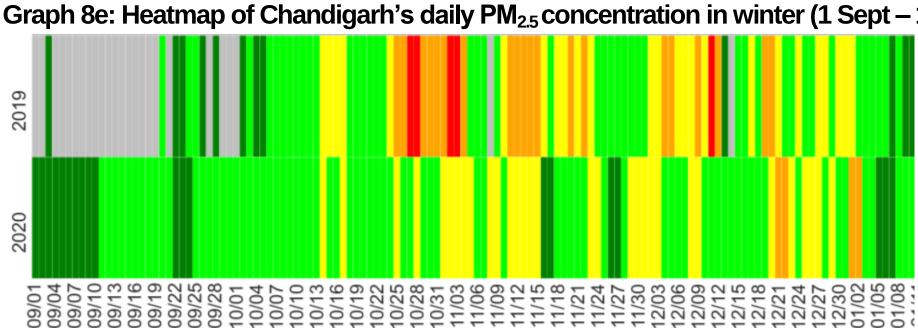
Note: Average $PM_{2.5}$ concentration for a day is based on mean of 3 CAAQM stations of Lucknow. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8d: Heatmap of Patna's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on a single CAAQM station. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

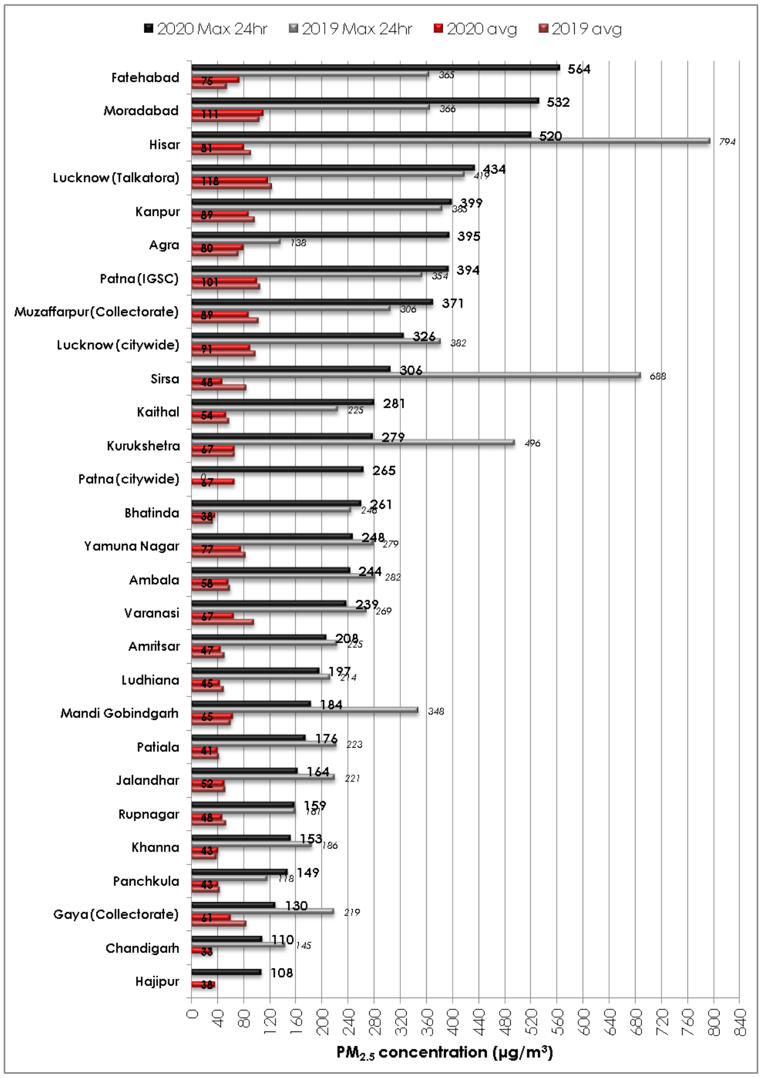
Graph 8e: Heatmap of Chandigarh's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on a single CAAQM station. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Even with comparatively cleaner air during this year, most cities recorded daily spikes similar to those observed in 2019: CSE has compared the annual averages and peak 24hr averages in these cities of IGP between 2019 and 2020. This shows that the smaller towns even with much lower annual average levels of $PM_{2.5}$ have experienced almost same or higher maximum daily levels during winter when the entire region got air locked (See *Graph 9: How annual average and maximum level changed in cities and towns of IGP outside NCR – comparison of 2019 and 2020*). Punjab cities have relatively lower daily peak compared to the rest.

Graph 9: How annual average and maximum level changed in cities and towns of IGP outside NCR – comparison of 2019 and 2020



Note: 2020 numbers are based on data up to 31 Dec 2020.
Source: CSE analysis of CPCB's realtime air quality data

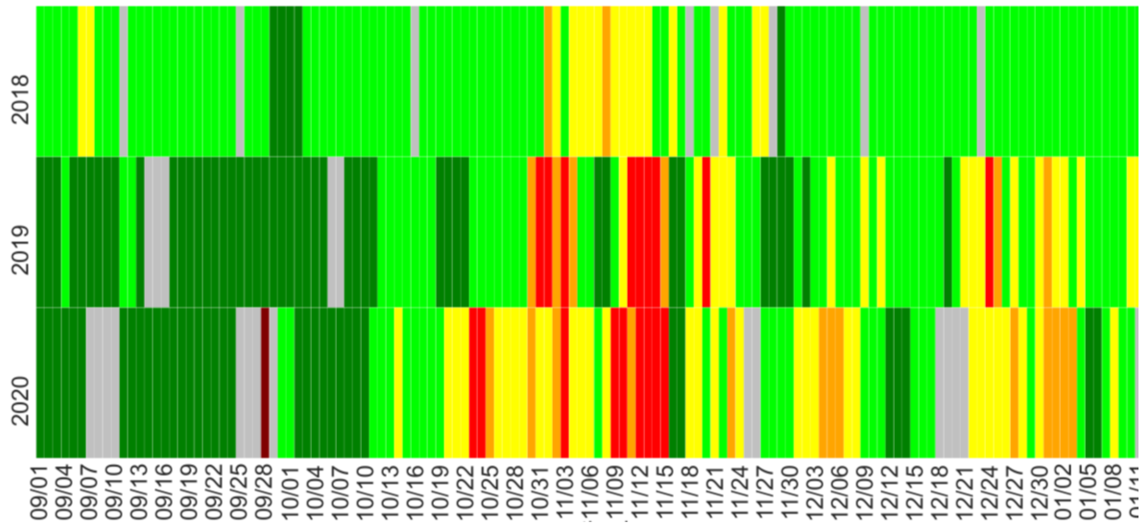
Need deep cuts

To avoid winter pollution peaks all cities of Maharashtra will have to reduce the annual average level of pollution to meet the national ambient air quality standards and even bring it further down to be closure to health based guidelines of the World Health Organisation.

How the pollution level will play out during the rest of the winter remains to be seen. But it is clear that the region has to take forward its wins so far and raise the level of ambition to drive action across all key sectors of pollution and in the entire region. Enforce power plant standards across the state, minimise use of coal and other dirt fuels in the industry while improving emissions control, scale up public transport and vehicle restraint measures and manage waste to have a zero waste and zero landfill strategy.

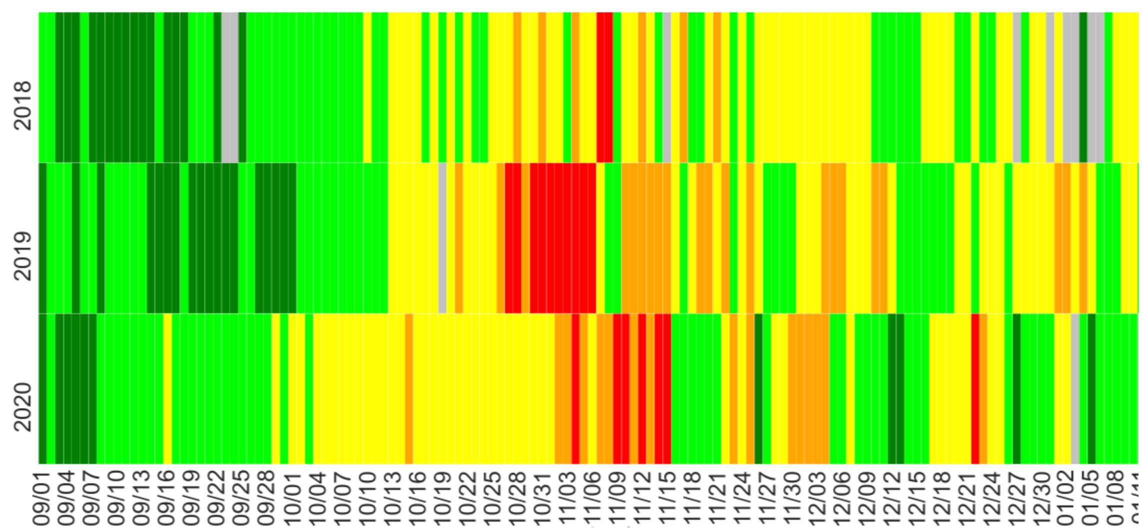
Annexures: Heatmap of other cities

Graph 8f: Heatmap of Bhatinda's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



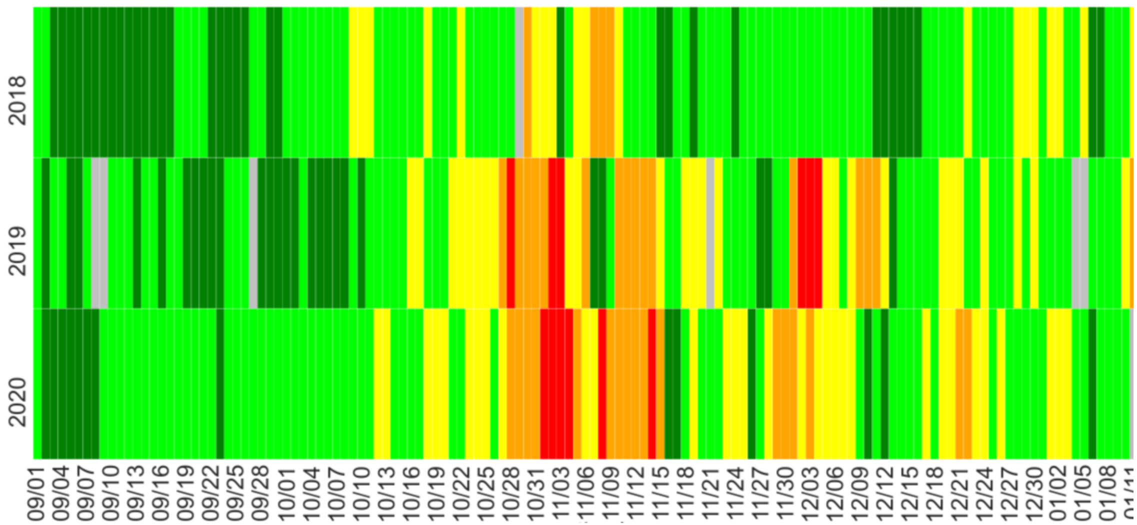
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8g: Heatmap of Jalandhar's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



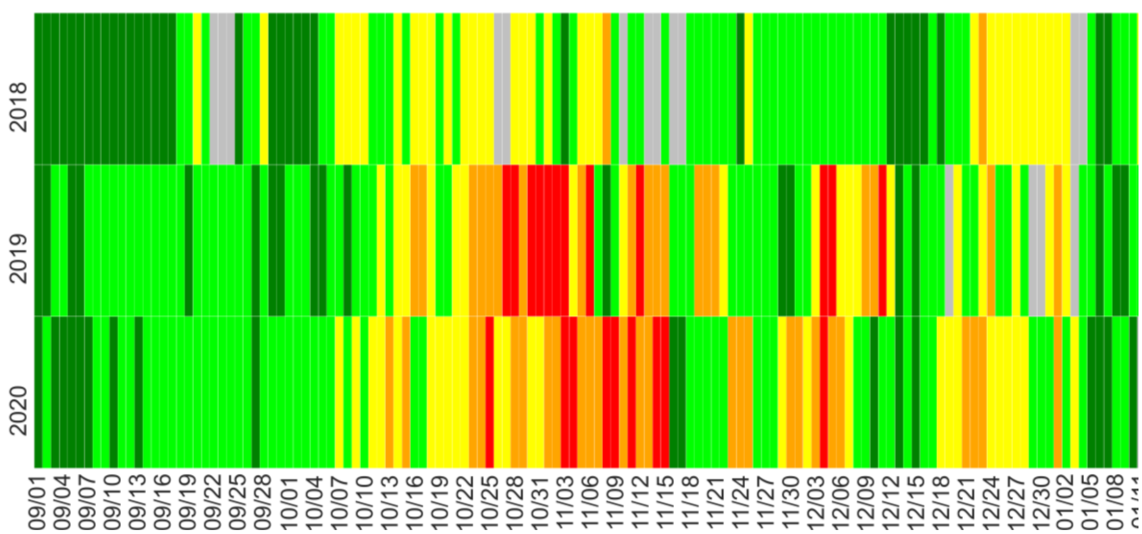
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3 and is based on mean of two CAAQM stations in the city. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8h: Heatmap of Khanna's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



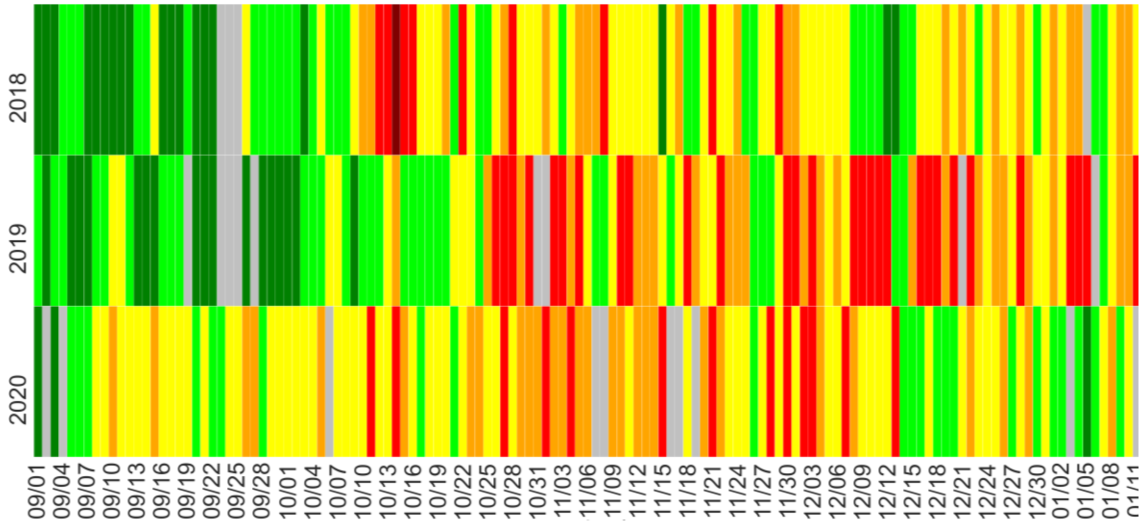
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8i: Heatmap of Ludhiana's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



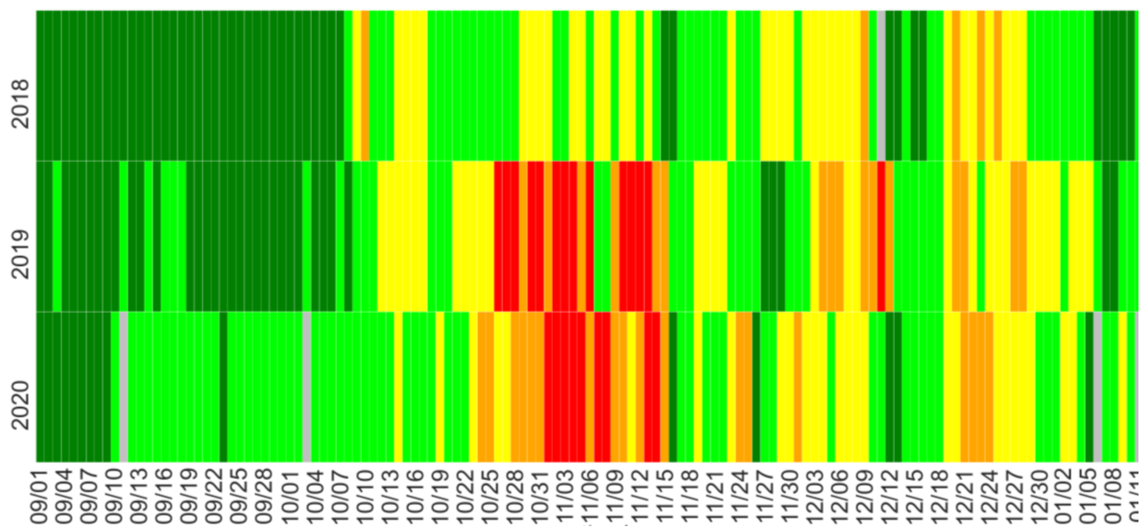
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8j: Heatmap of Mandi Gobindgarh's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



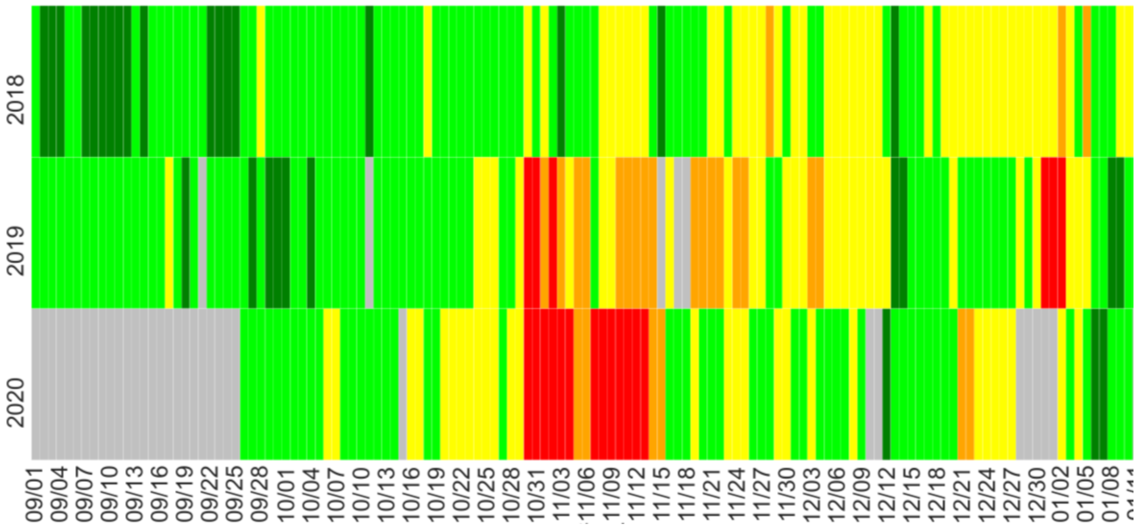
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8k: Heatmap of Patiala's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



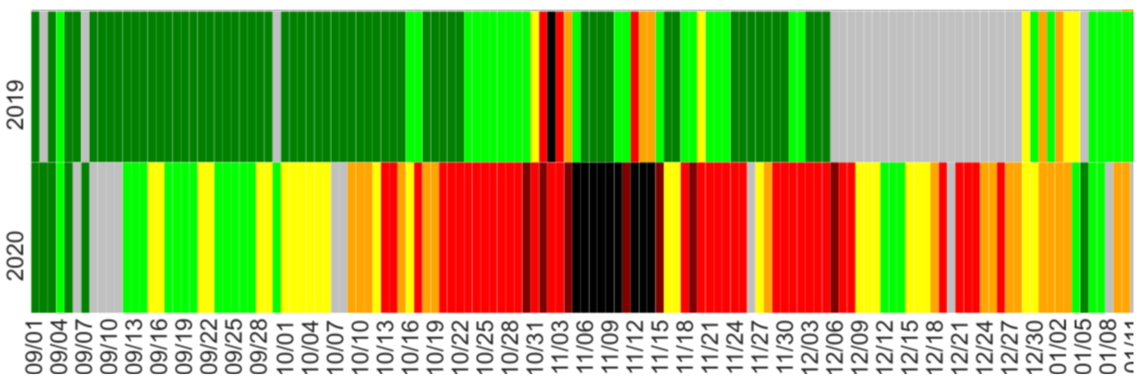
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8l: Heatmap of Rupnagar's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



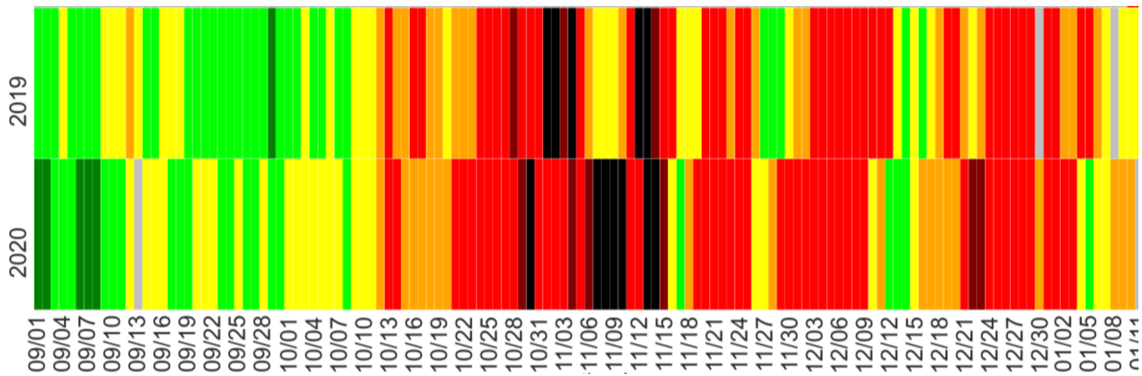
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8m: Heatmap of Fatehabad's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2019 and 2020



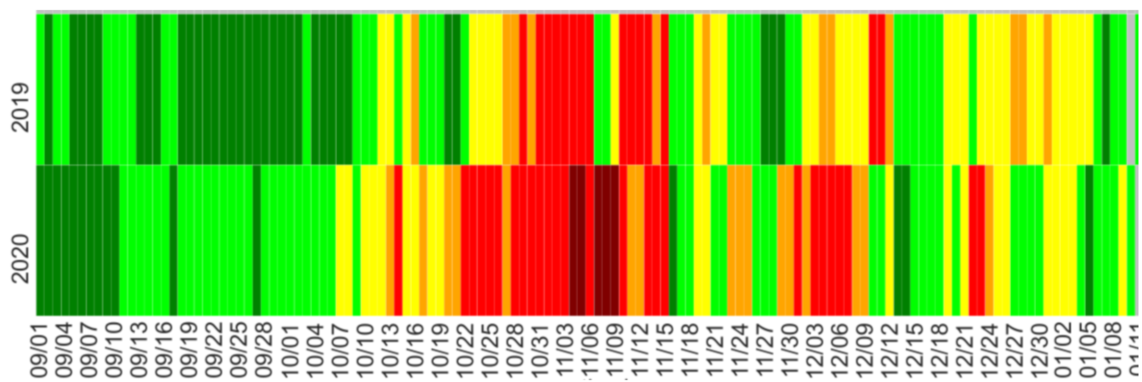
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8n: Heatmap of Hisar's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2019 and 2020



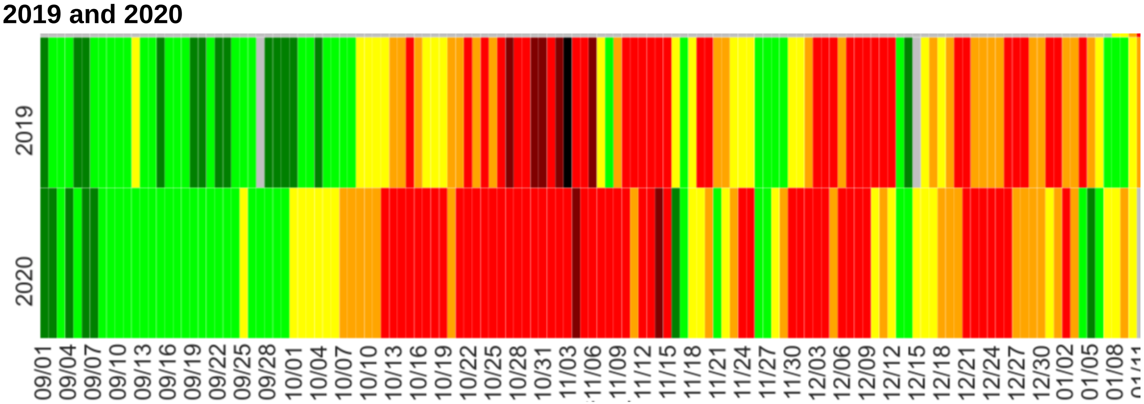
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8o: Heatmap of Kaithal's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2019 and 2020



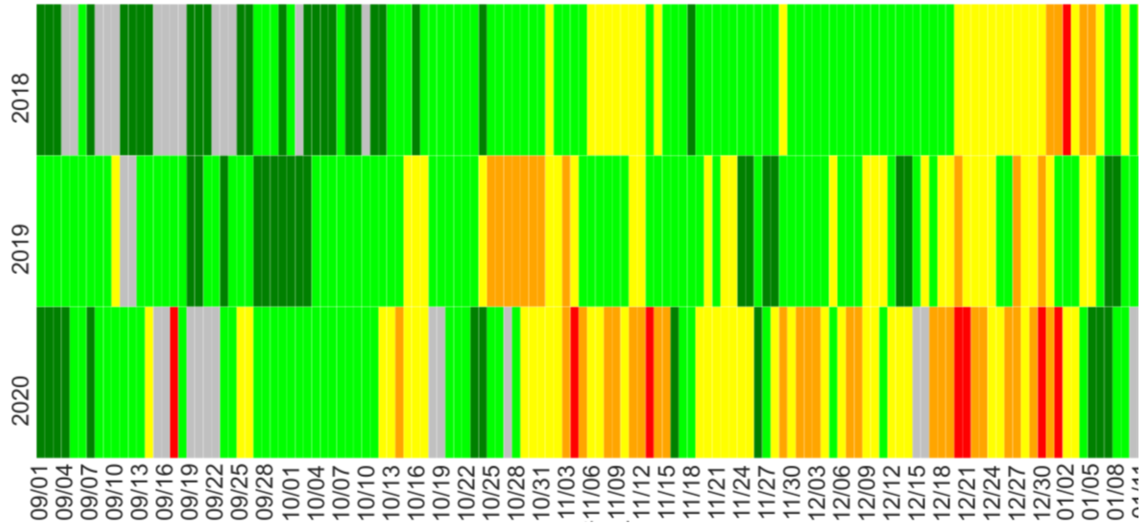
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8p: Heatmap of Kurukshetra's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



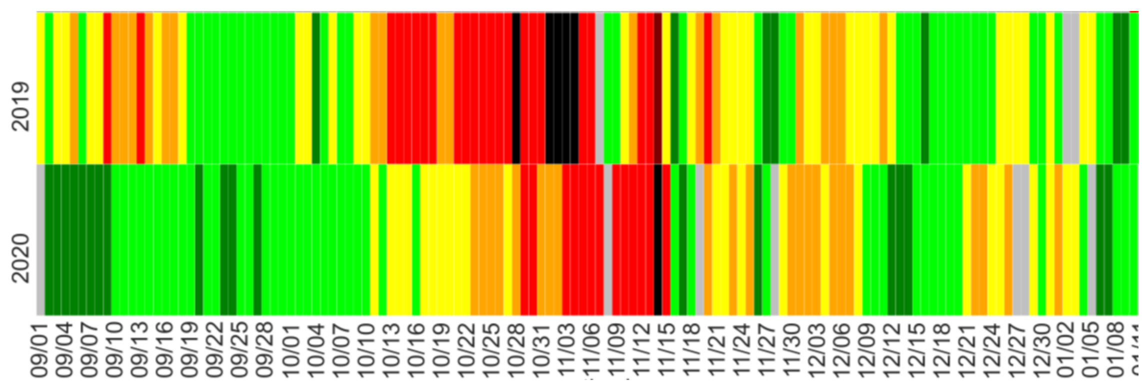
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8q: Heatmap of Panchkula's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



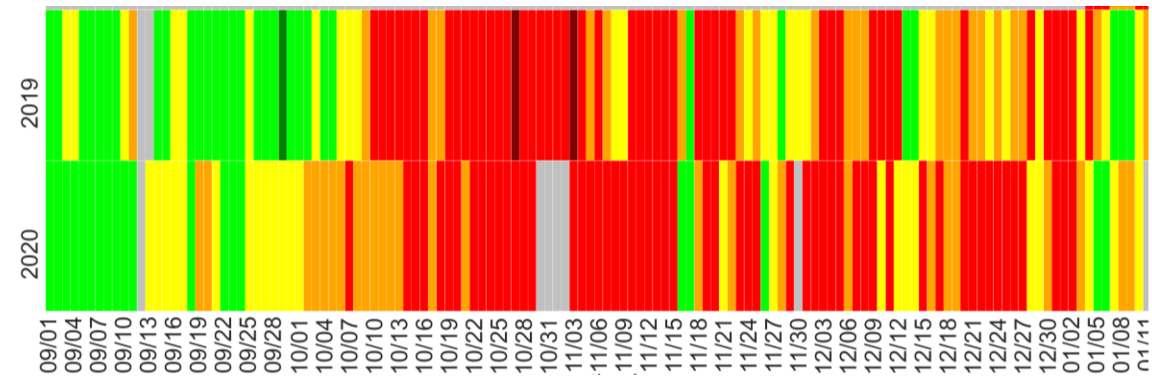
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8r: Heatmap of Sirsa's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



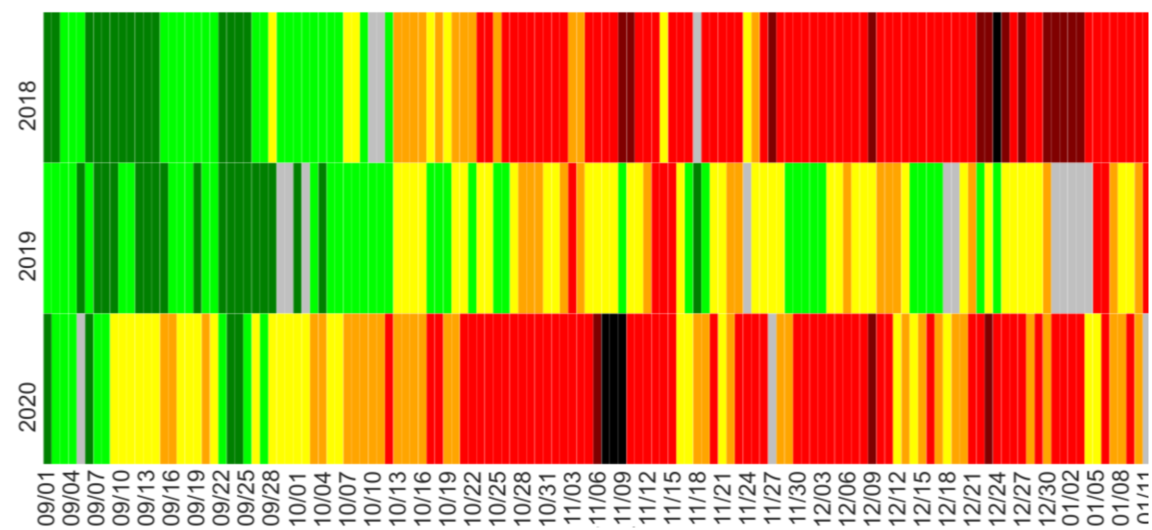
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8s: Heatmap of Yamuna Nagar's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2019 and 2020



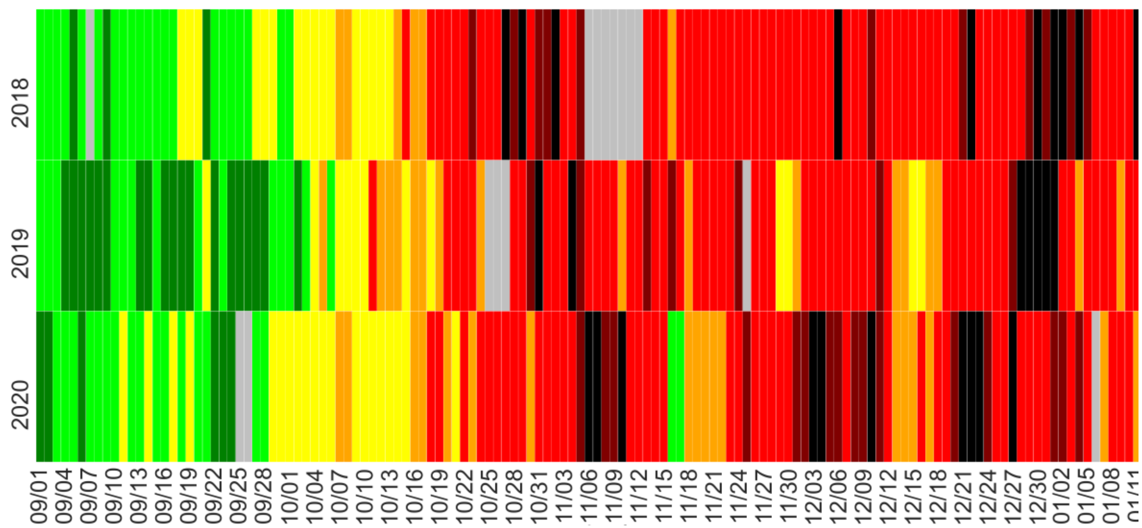
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8t: Heatmap of Agra's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



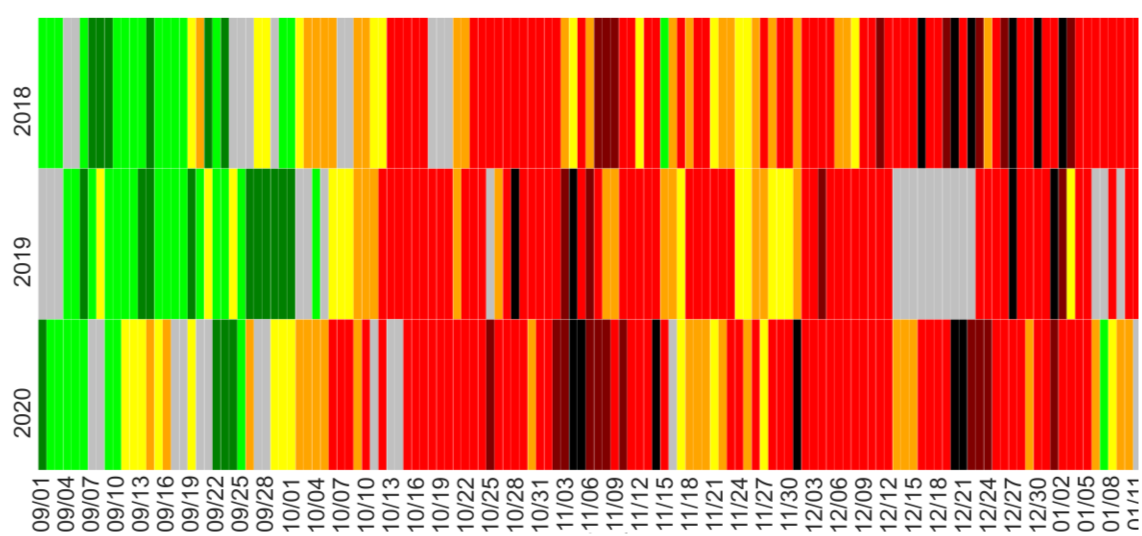
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8u: Heatmap of Kanpur's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



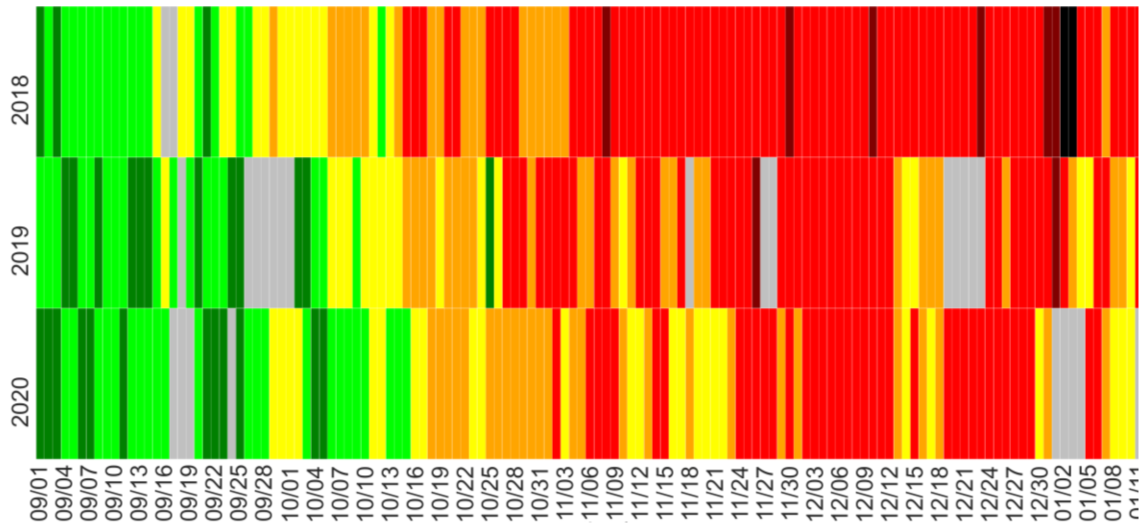
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8v: Heatmap of Moradabad's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



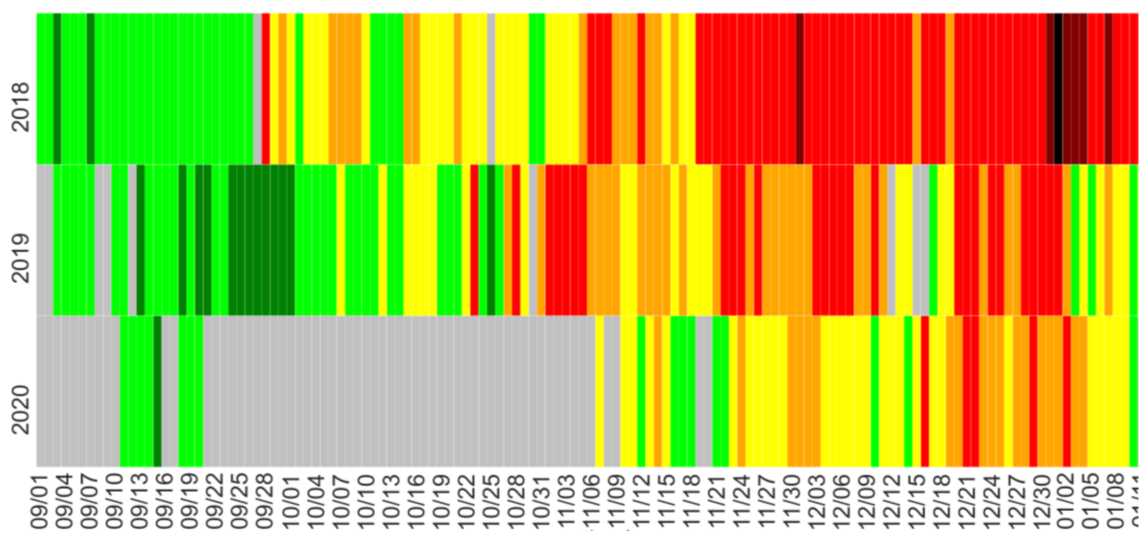
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8w: Heatmap of Varanasi's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



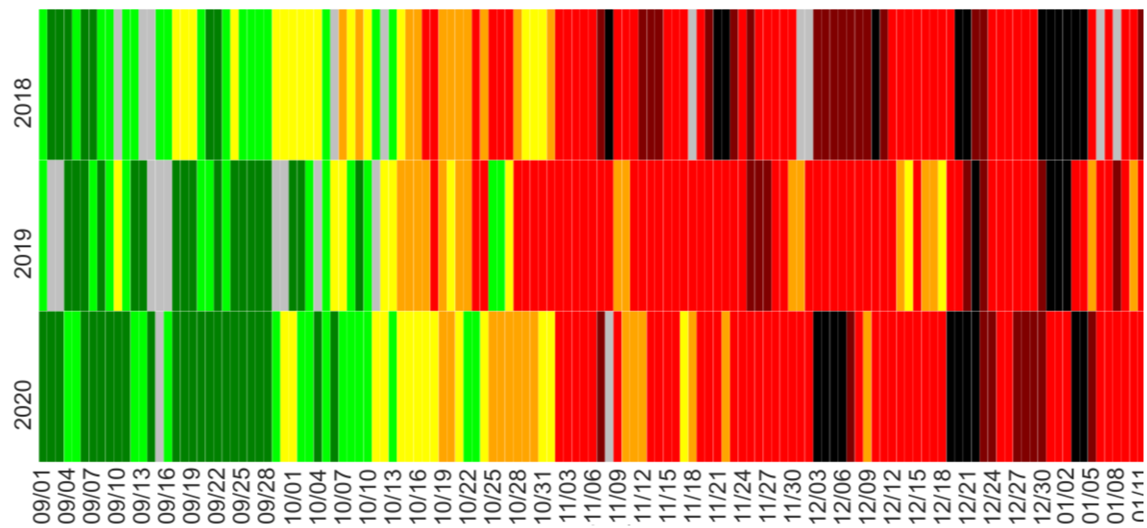
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8x: Heatmap of Gaya's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8y: Heatmap of Muzaffarpur's daily $PM_{2.5}$ concentration in winter (1 Sept – 10 Jan) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

6 ■Decoding winter air pollution in cities of Southern India

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, January, 2021

This analysis is part of the next in the series of air quality tracker initiative the Centre for Science and Environment (CSE) to follow changing patterns of air quality trends in different regions of the country. This seeks to understand the impact of the extraordinary year 2020 that has witnessed one of the biggest disruptions in the recent times. This is also an inflexion point at the onset of the new decade. This addresses basic curiosities around the impact of the lockdown, lowering of the regional influence on local air quality, and deeper seasonal patterns that unmask the underlying high trends despite the lockdown phases. After analyzing the changing trends in the Indo-Gangetic Plain, Delhi and National Capital region, Rajasthan, Maharashtra, and West Bengal, this analysis unravels the pattern in cities of Southern India– vulnerable but poorly monitored region from air quality perspective.

New analysis of winter pollution (until 26 January of this year), shows how clean air gains of the lockdown and monsoon period were lost with the reopening of the economy and with the onset of the winter. Even though the atmospheric conditions during winter in this region is not the same as that of the Indo Gangetic Plain in the northern region, trapping of winter pollution is not insignificant either -- especially in inland cities.

Higher $PM_{2.5}$ levels is a typical and predictable winter trend when continuous emissions from local sources including vehicles, industry, construction, and episodic pollution from biomass burning get trapped due to meteorological changes. But winter is not as harsh in southern cities therefore impact of inversion is expected to be limited, yet pollution build-up has been noted. Even though the average level of $PM_{2.5}$ for the summer and monsoon months in 2020 is considerably lower than the previous year due to the pandemic related to summer lockdown, the $PM_{2.5}$ levels this winter have risen beyond the 2019 in most of the monitored cities. Chennai and Thiruvananthapuram being the only exception. Combination of the reopening of the economy and changing meteorology is responsible for high winter pollution but this regional variation calls out for more nuanced and robust pollution control strategy. The region cannot rely only on natural advantage of warmer winters and sea breeze to avoid bad air. This demands speed and scale of action.

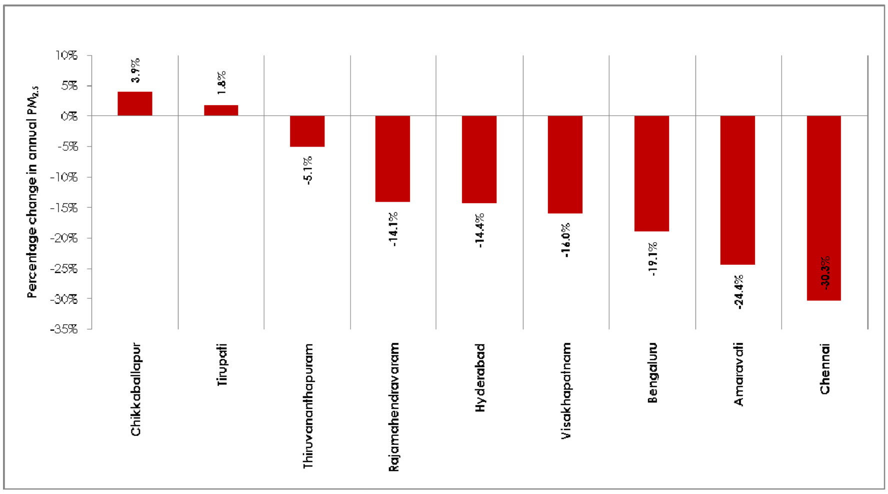
This detailed data analysis points to the fact that the air pollution is a south India problem as well and this requires quicker reforms and action in key sectors of pollution – vehicles, industry, power plants and waste management to control winter pollution and further bend the annual air pollution curve.

Data used in the analysis: The analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. Real-time data from 36 cities was accessed but only 21 cities – Hyderabad, Amaravati, Rajamahendravaram, Tirupati, Visakhapatnam, Bagalkot, Chikkaballapur, Chikkamagaluru, Hubballi, Mysuru, Ramnagara, Vijaypura, Yadgir, Bengaluru, Coimbatore, Chennai, Kannur, Kollam, Kozhikode, Kochi, and Thiruvananthapuram have been selected for this analysis because real time data is available for these cities for whole of 2020. This has analysed data recorded by 10 air quality monitoring stations at Bengaluru, 8 stations in Chennai, 6 stations in Hyderabad, 3 stations in Kochi, 2 stations in Thiruvananthapuram, one station each rest of the cities under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Weather data for Bengaluru, Chennai, Hyderabad, Thiruvananthapuram, and Visakhapatnam has been sourced from the weather stations of Indian Meteorological Department (IMD) located at the airport of each city. This air quality trend analysis does not include investigation of local sources of pollution.

Key highlights

While several bigger cities have witnessed reduction in annual trends in PM2.5, smaller towns and cities have experienced increase: Only 9 out of the 21 cities have data for complete 2019. The 2020 average $PM_{2.5}$ level in many inland cities in the Deccan Plateau has climbed up to breach the average concentration recorded in 2019. Chikkaballapur in southern Karnataka is the worst performer with 3.9 per cent increase from 2019 level. Tirupati registered 1.8 per cent increase. Most improvement is noted in Chennai which closed 2020 with a 30 per cent lower $PM_{2.5}$. Amravati at 24 per cent, Bengaluru at 19 per cent, Visakhapatnam at 16 per cent, Hyderabad and Rajamahendravaram at 14 per cent are other best performers in the pool. Thiruvananthapuram showed improvement of 5 per cent (See *Graph1: Percentage change in $PM_{2.5}$ annual average in south Indian cities*). For context, Delhi's 2020 average is 13 per cent lower than its 2019 level.

Graph1: Percentage change in $PM_{2.5}$ annual average in south Indian cities



Note: Annual average $PM_{2.5}$ concentration is based on mean of monthly averages. For cities with multiple stations average of only those stations are used which were working in both 2019 and 2020 for all 12 months. Data uptill 31 December 2020.
Source: CSE analysis of CPCB's real time air quality data

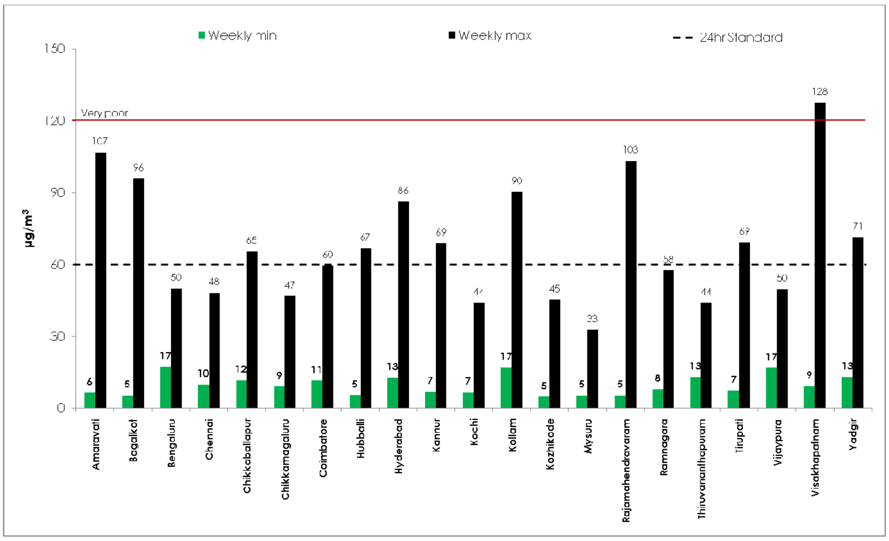
Average level of $PM_{2.5}$ has been lowest during this summer and monsoon due to the lockdown but could not prevent the winter spike: The overall $PM_{2.5}$ average this summer and monsoon has been predictably lower compared to the previous year largely because of the unprecedented economic disruption during the summer lockdown and phased unlocking. But reopening of the economy coinciding with the onset of the winter trapping of pollution made $PM_{2.5}$ levels rose starting October. From the respective cleanest week the weekly average of $PM_{2.5}$ in Hyderabad rose 7 times, in Bengaluru 3 times, Chennai 5 times, Visakhapatnam 14 times, and Thiruvananthapuram 3 times to the dirtiest week. These major cities recorded lesser deterioration than Delhi where weekly air quality worsened 14 times but smaller towns beat the capital. Rajamahendravaram deteriorated 19 times, Bagalkot 18 times, Amravati 17 times, Hubballi 12 times, Kannur and Kozhikode 10 times each (See *Graph 3: Change in weekly $PM_{2.5}$ levels 2020 – Difference between cleanest and most polluted week*).

Andhra Pradesh cities were most polluted in the region with Visakhapatnam, Amravati, and Rajamahendravaram being only cities with weekly average exceeding 100 µg/m^3. Mysuru was cleanest city with its worst weekly average only rising to 33 µg/m^3. Bengaluru, Chennai, Chikkaballapur, Chikkamagaluru, Coimbatore, Hubballi, Hyderabad, Kannur, Kochi, Kollam, Kozhikode, Rajamahendravaram, Ramnagara, Thiruvananthapuram, Tirupati, and Vijaypura are other cities whose worst weekly average was found to be below 24hr standard i.e. 60 µg/m^3.

Dirtiest week for Hyderabad, Amravati, Rajamahendravaram, Chikkaballapur, and Yadgir was week ending on 3 January 2021. For Tirupati, Visakhapatnam, Hubballi, Chennai, Coimbatore, Kannur, Kozhizode, Kochi, and Thiruvananthapuram, the dirtiest week on the week ending on 27 December

2020. Chikkamagaluru and Vijaypura the dirtiest week on the week ending on 8 November 2020. Bengaluru, Bagalkot, Mysuru, Ramnagara, and Kollam the dirtiest week on the week ending on 1 November 2020. Cleanest week for Rajamahendravaram, Tirupati, Visakhapatnam, Bagalkot, Chikkaballapur, Chikkamagaluru, Hubballi, Mysuru, Ramnagara, Vijaypura, Yadgir, Bengaluru, Coimbatore, Chennai, Kannur, Kollam, Kozhikode, Kochi, and Thiruvananthapuram was recorded pre-monsoon in months of April, May, and early June. Rest of the region recorded their cleanest week during monsoon (July, August, and September). The transient change of the lockdown phases could not be sustained without the systemic changes needed to control pollution from vehicles, industry, power plants, and waste.

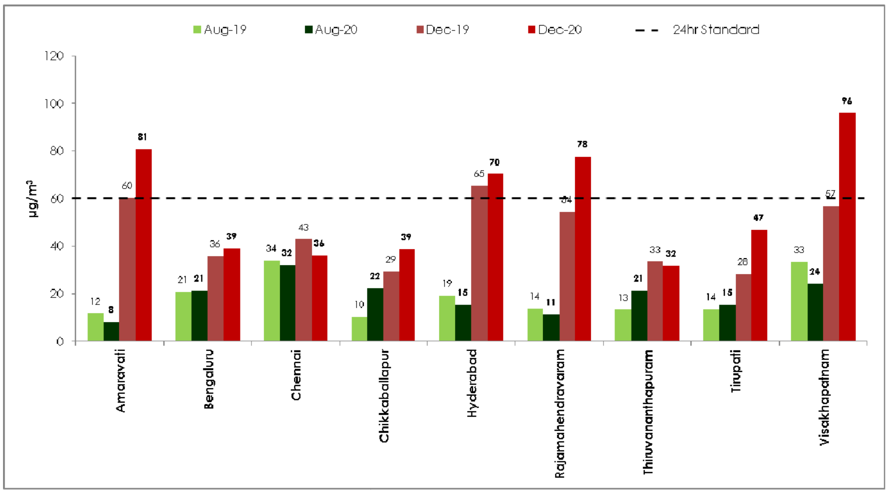
Graph 3: Change in weekly $PM_{2.5}$ levels 2020 – Difference between cleanest and most polluted week



Note: Average $PM_{2.5}$ concentration for a week is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

Average December $PM_{2.5}$ level has been considerably higher in inland cities this year: December this year was dirtier across most inland cities in the peninsula. The $PM_{2.5}$ average this December was worst in Andhra Pradesh with 69 per cent higher in Visakhapatnam, 66 per cent in Tirupati, 43 per cent in Rajamahendravaram and 34 per cent in Amravati compared to December 2019. Karnataka cities recorded dirtier December as well with 33 per cent higher in Chikkaballapur and 8 per cent in Bengaluru. Hyderabad's December was 7.5 per cent dirtier in 2020 compared to 2019. Chennai and Thiruvananthapuram buck the trend recorded registered 16 per cent and 5 per cent cleaner December respectively compared to 2019 (See *Graph 4: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages*).

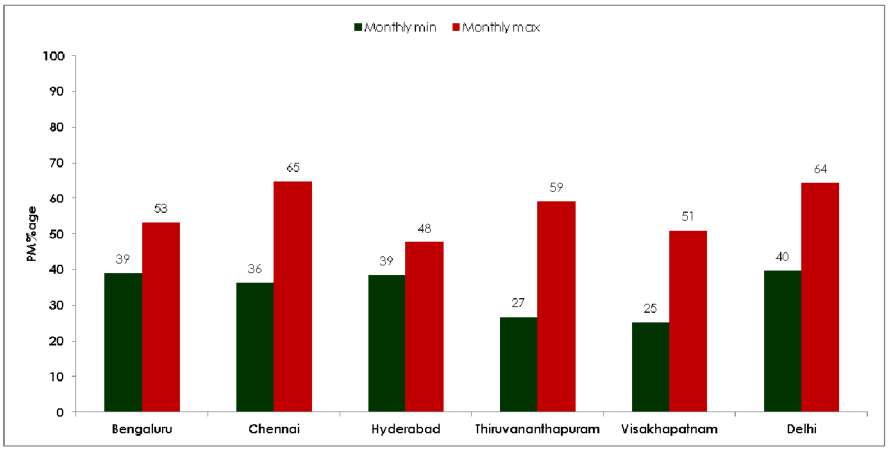
Graph 4: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages)



Note: Average $PM_{2.5}$ concentration for a month is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

Air quality gets more toxic with the onset of winter - share of tinier $PM_{2.5}$ in the PM_{10} increases: The share of tinier and finer particles in the overall coarser PM_{10} concentration determines the toxicity of air. When the overall share of tinier $PM_{2.5}$ in the overall coarser PM_{10} is higher, the air is more toxic as the tiny particles penetrate deep inside the lungs and cut through the blood barrier increasing health risk. Interestingly, during lockdown, when the overall suspended coarser particles had settled down reducing the PM_{10} levels, the $PM_{2.5}$ had also come down. Bengaluru and Hyderabad have relatively high PM2.5 percentage throughout the year but their monthly peaks are lower relative to coastal metro cities (See *Graph 5: Changing share of percentage share of $PM_{2.5}$ in PM_{10} among months*). The share of $PM_{2.5}$ in PM_{10} in Chennai has been identical range as registered in Delhi in 2020 though overall levels are lower.

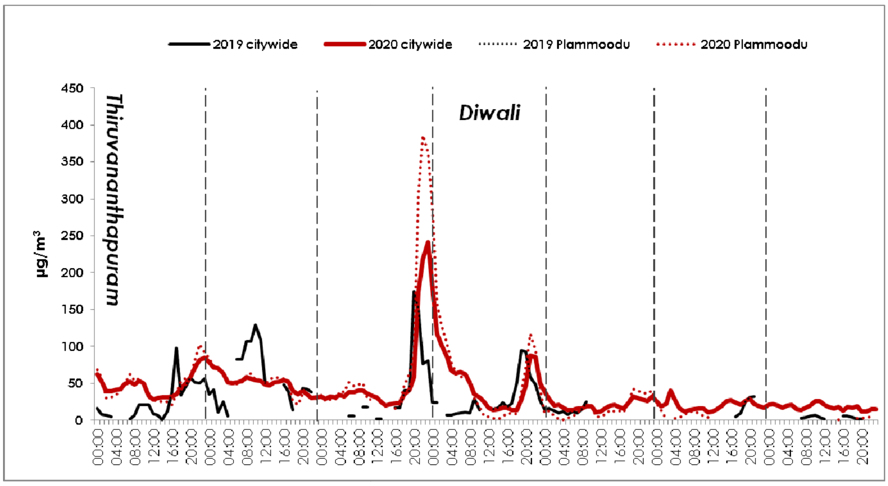
Graph 5: Changing percentage share of $PM_{2.5}$ in PM_{10} among months



Note: Average of only those stations has been used that have valid daily value for both $PM_{2.5}$ and PM_{10}.
Source: CSE analysis of CPCB's real time air quality data

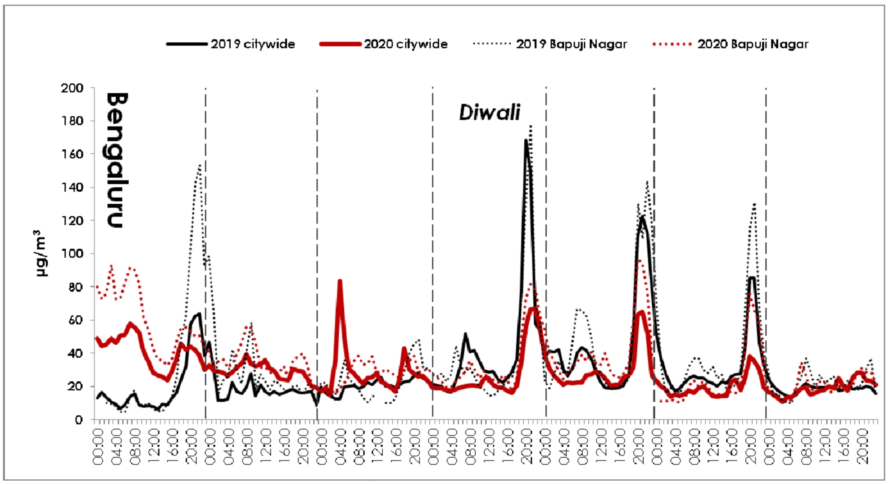
Diwali is an issue in southern cities as well: Thiruvananthapuram had dirtier diwali night in 2020 compared to 2019: In 2020 there was 114 per cent higher rise in hourly $PM_{2.5}$ concentration at Plammoodu station of Thiruvananthapuram between afternoon and night of Diwali that is mostly caused due to firecracker busting. Hourly concentration peaked at 386 µg/m^3 in the evening of November 2020, which is the highest hourly concentration recorded in the capital city of Kerala between start of lockdown in March to end of 2020 (See *Graph 6: How hourly pollution changed on Diwali day in Thiruvananthapuram*).Bengaluru, Chennai, Hyderabad, and Visakhapatnam too registered abnormal spike in hourly pollution on Diwali night but is was considerably lower compared to spike noted in 2019 Diwali.

Graph 6a: How hourly pollution changed on Diwali day in Thiruvananthapuram



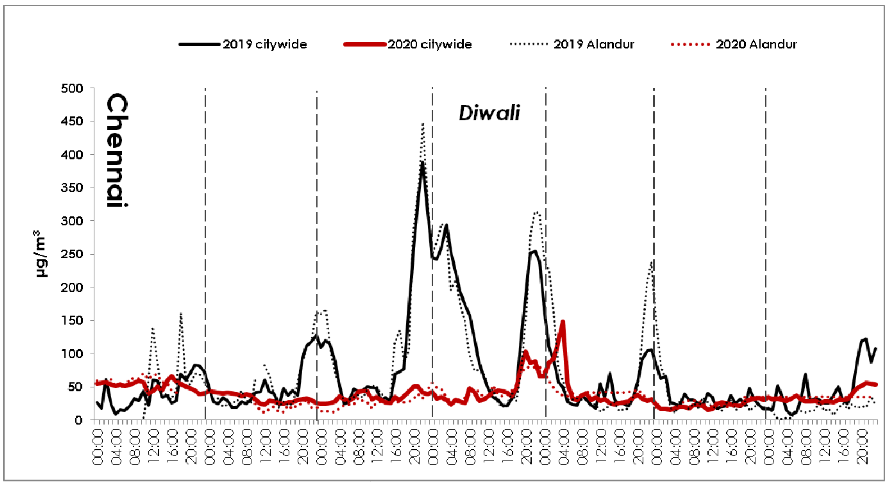
Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Graph 6b: How hourly pollution changed on Diwali day in Bengaaluru



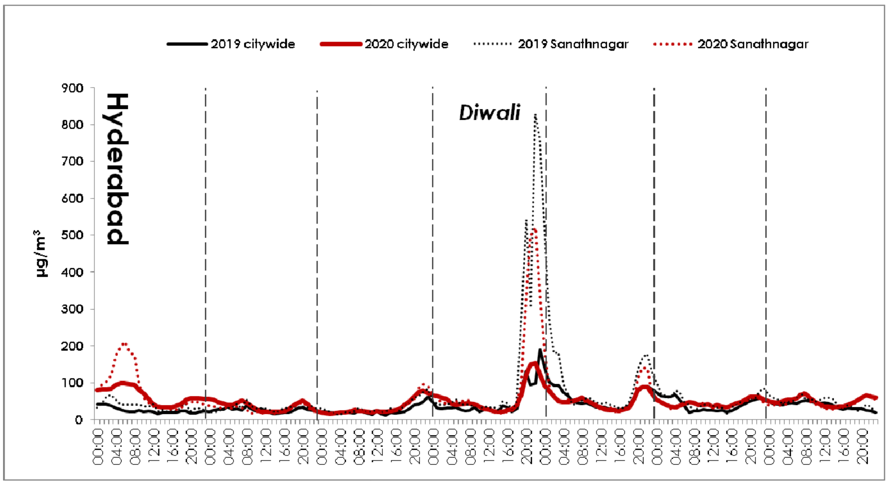
Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Graph 6c: How hourly pollution changed on Diwali day in Chennai



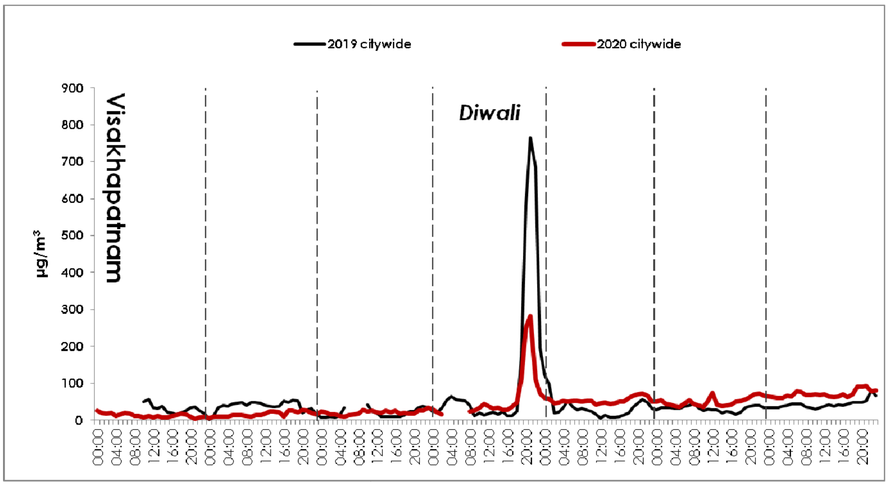
Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

Graph 6d: How hourly pollution changed on Diwali day in Hyderabad



Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in $PM_{2.5}$ concentrations among city's numerous CAAQM stations.
Source: CSE analysis of CPCB's real time air quality data

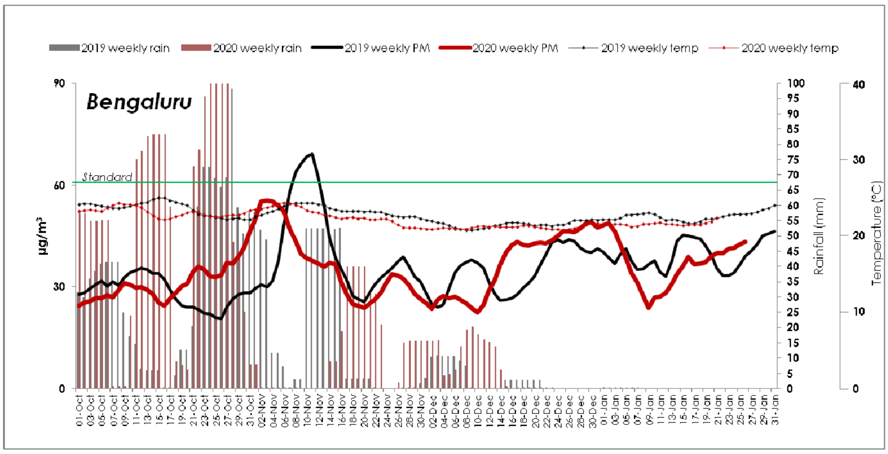
Graph 6e: How hourly pollution changed on Diwali day in Visakhapatnam



Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of single CAAQM station operational in the city.
Source: CSE analysis of CPCB's real time air quality data

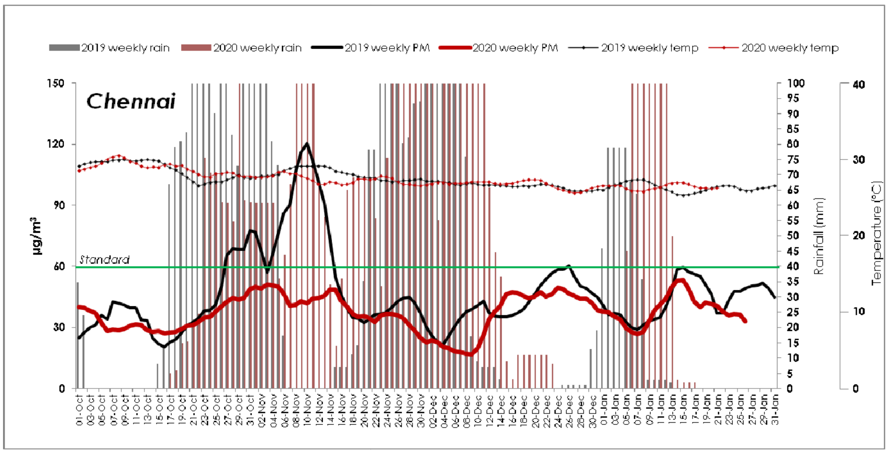
Hyderabad and Visakhapatnam had earlier start of bad air days in 2020 winter: The rolling weekly average rose over the 24hr standard or 60 µg/m^3 in Visakhapatnam on October 23 (9 days earlier), and Hyderabad on October 25 (14 days earlier). This winter overall has been 34 per cent dirtier in Visaakhapatnam, 7 per cent in Hyderabad, and 9 per cent in Thiruvananthapuram. Bengaluru registered no change in the seasonal average while Chennai was 20 per cent cleaner. The rolling weekly average didn't breach the standard in Bengaluru, Chennai and Thiruvananthapuram (See *Graph 7: Rate of increase in PM$_{2.5}$ in a) Bengaluru, b) Chennai, c) Hyderabad, d)* Thiruvananthapuram, *e)* Visakhapatnam*: 2019 vs 2020*).

Graph 6a: Rate of increase in PM$_{2.5}$ in Bengaluru: 2019 vs 2020



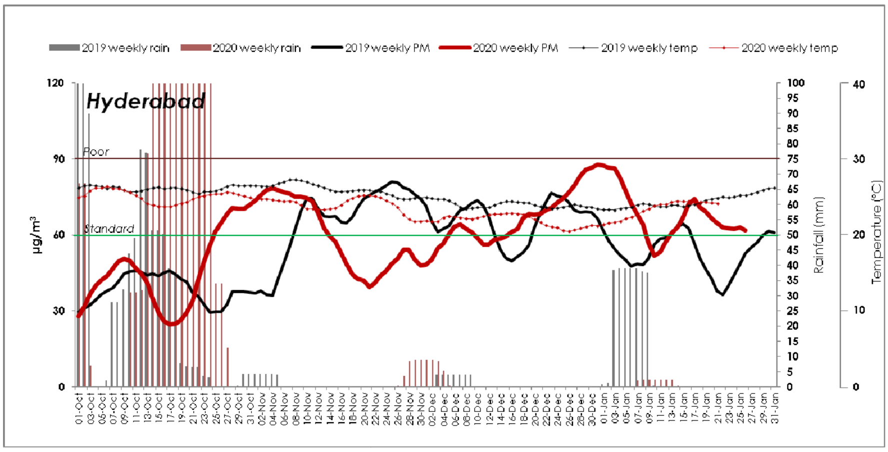
Note: All values are rolling weekly average. Data: CPCB (PM$_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Graph 6b: Rate of increase in $PM_{2.5}$ in Chennai: 2019 vs 2020



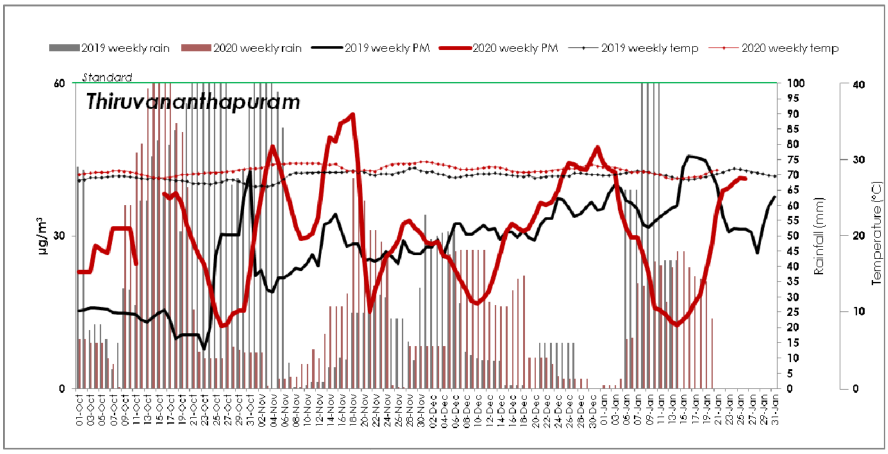
Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Graph 6c: Rate of increase in $PM_{2.5}$ in Hyderabad: 2019 vs 2020



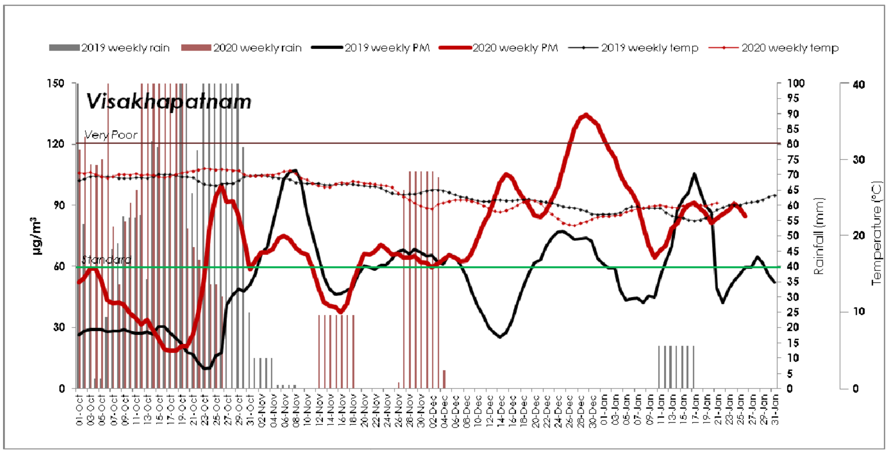
Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

Graph 6d: Rate of increase in $PM_{2.5}$ in Thiruvananthapuram: 2019 vs 2020



Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

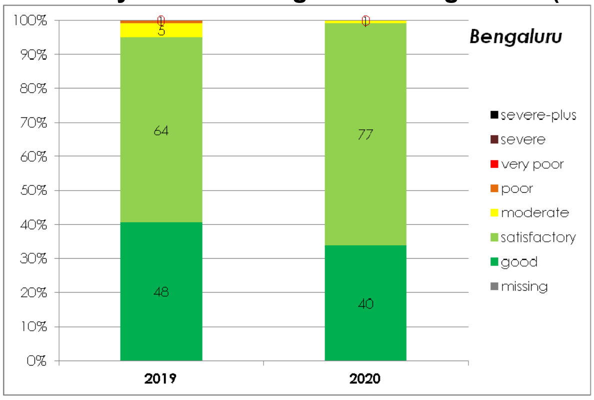
Graph 6e: Rate of increase in $PM_{2.5}$ in Visakhapatnam: 2019 vs 2020



Note: All values are rolling weekly average. Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

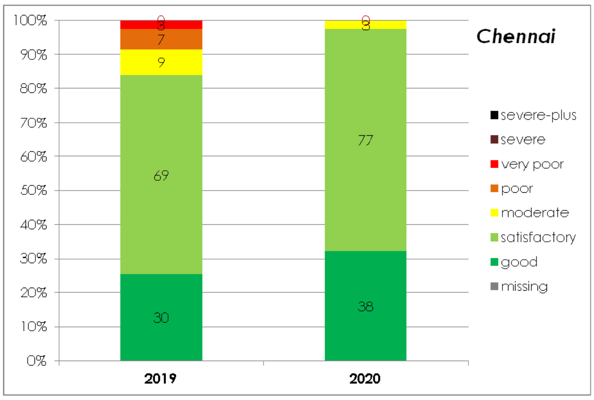
Number of days with $PM_{2.5}$ concentration meeting standard was considerably lower this winter in Hyderabad and Visakhapatnam; Bengaluru, Chennai. Thiruvananthapuram seen lesser bad air days: There have been 31 days of poor or worse air days this winter compared to 10 recorded last year in Visakhapatnam. Hyderabad registered a day will poor air quality compared to zero in winter of 2019. Similarly standard days have been lesser by 11 days in Hyderabad, 23 days in Visakhapatnam (See *Graph 7: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in a) Bengaluru, b) Chennai, c) Hyderabad, d)* Thiruvananthapuram*, e)* Visakhapatnam *during winter (1 Oct –26 Jan) 2019 and 2020*). Thiruvananthapuram met the air quality standard on all the days of this winter. Chennai and Bengaluru saw reduction in number of days with PM level exceeding the standard but Bengaluru also saw decrease in number of days with good air quality.

Graph 7a: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Bengaluru during winter (1 Oct – 26 Jan) 2019 and 2020.



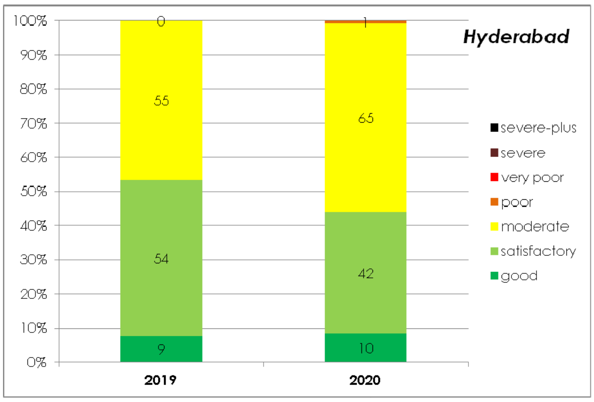
Note: Average $PM_{2.5}$ concentration for a day is based on single CAAQM station.
Source: CSE analysis of CPCB's realtime air quality data

Graph 7b: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Chennai during winter (1 Oct – 26 Jan) 2019 and 2020.



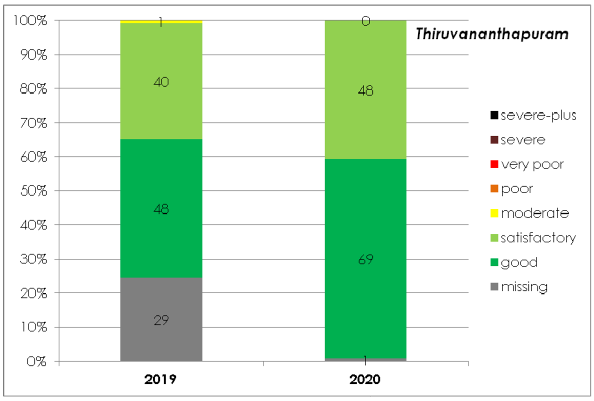
Note: Average $PM_{2.5}$ concentration for a day is based on single CAAQM station.
Source: CSE analysis of CPCB's realtime air quality data

Graph 7c: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Hyderabad during winter (1 Oct – 26 Jan) 2019 and 2020.



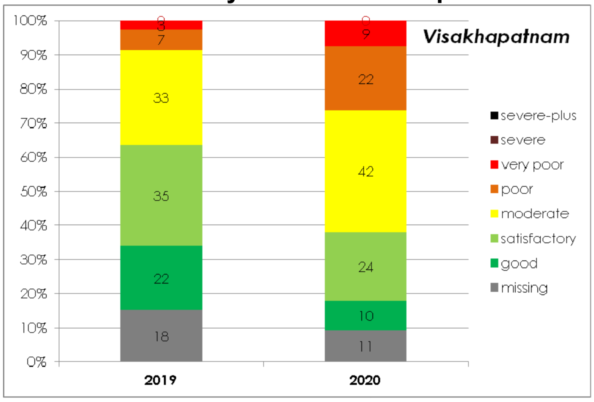
Note: Average $PM_{2.5}$ concentration for a day is based on mean of 3 CAAQM stations of Lucknow.
Source: CSE analysis of CPCB's realtime air quality data

Graph 7d: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Thiruvananthapuram during winter (1 Oct – 26 Jan) 2019 and 2020.



Note: Average $PM_{2.5}$ concentration for a day is based on single CAAQM station at IGSC, Patna.
Source: CSE analysis of CPCB's realtime air quality data

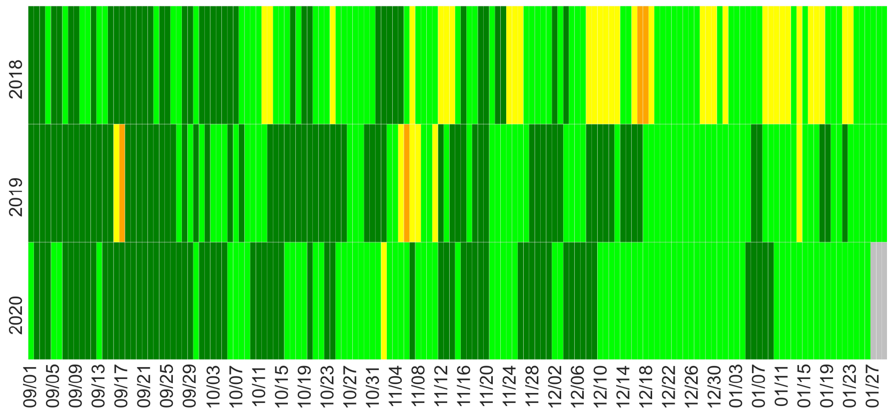
Graph 7e: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Viskhapatnam during winter (1 Oct – 26 Jan) 2019 and 2020.



Note: Average $PM_{2.5}$ concentration for a day is based on single CAAQM station.
Source: CSE analysis of CPCB's realtime air quality data

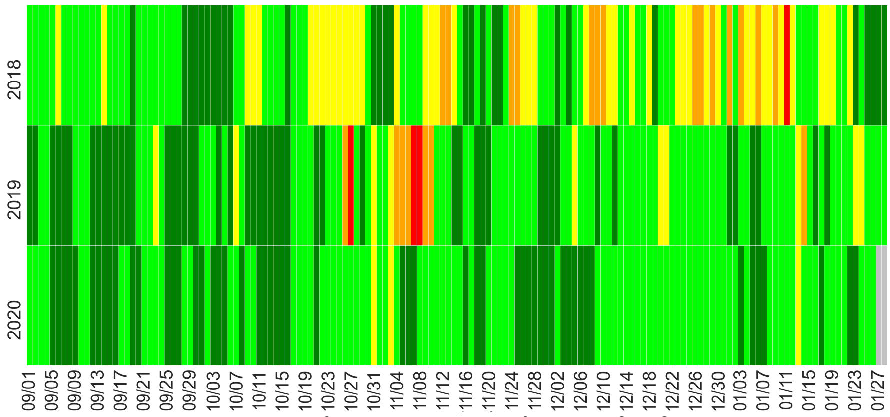
The cyclical ups and down of pollution this winter is less volatile – showing slower rise and fall than pervious winter: This inelastic behavior of $PM_{2.5}$ levels in southern cities is looking more volatile during this winter with frequent quicker rise and drop (*See Graph 8: Heatmap of daily $PM_{2.5}$ concentration in winter a) Bengaluru, b) Chennai, c) Hyderabad, d)* Thiruvananthapuram*, e)* Visakhapatnam *(1 Sept – 26 Jan) of 2018, 2019, and 2020*). This can be the impact of meteorology.

Graph 8a: Heatmap of Bengaluru's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



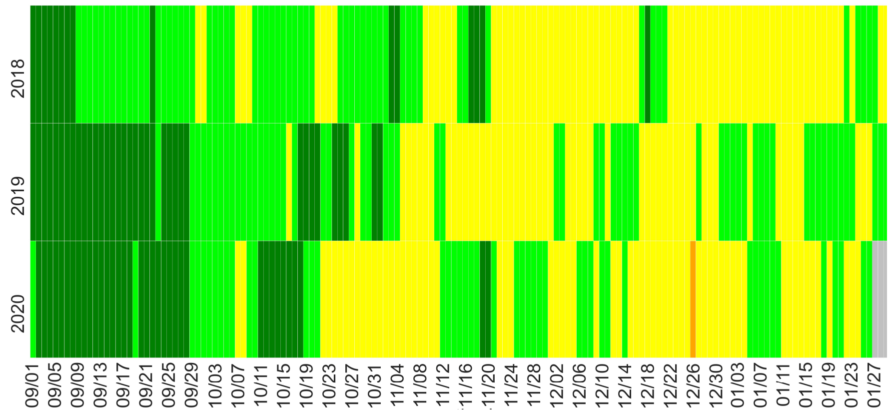
Note: Average $PM_{2.5}$ concentration for a day is based on average of all CAAQM stations in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8b: Heatmap of Chennai's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



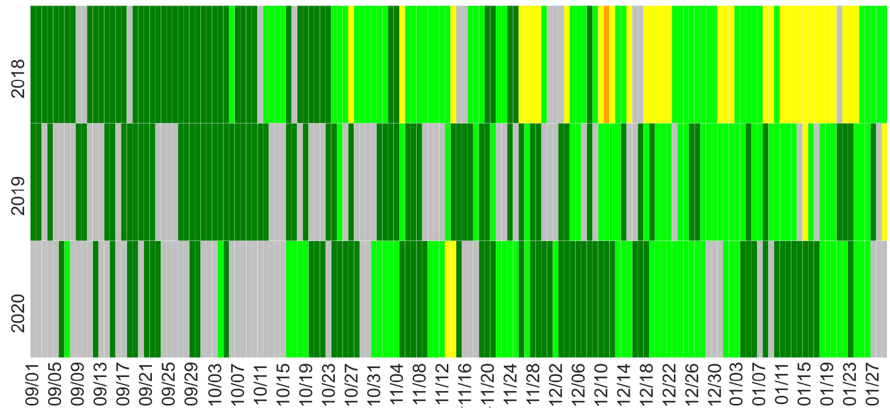
Note: Average $PM_{2.5}$ concentration for a day is based on four older CAAQM stations in the city. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8c: Heatmap of Hyderabad's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



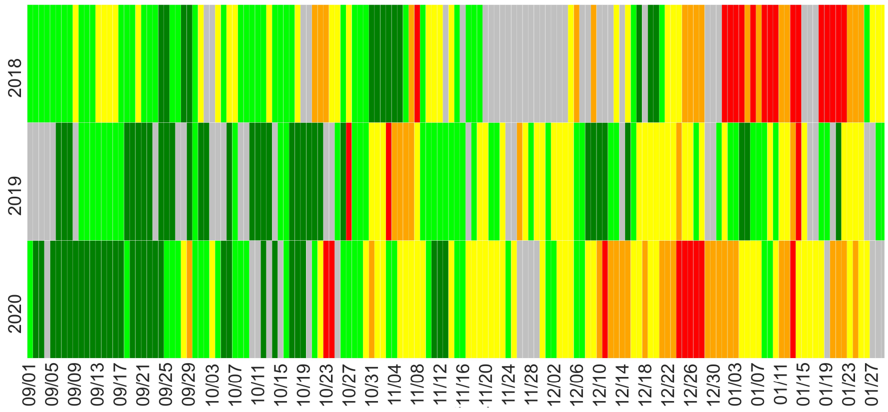
Note: Average $PM_{2.5}$ concentration for a day is based on mean of 3 CAAQM stations of Lucknow. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8d: Heatmap of Thiruvananthapuram's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on a single CAAQM station. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

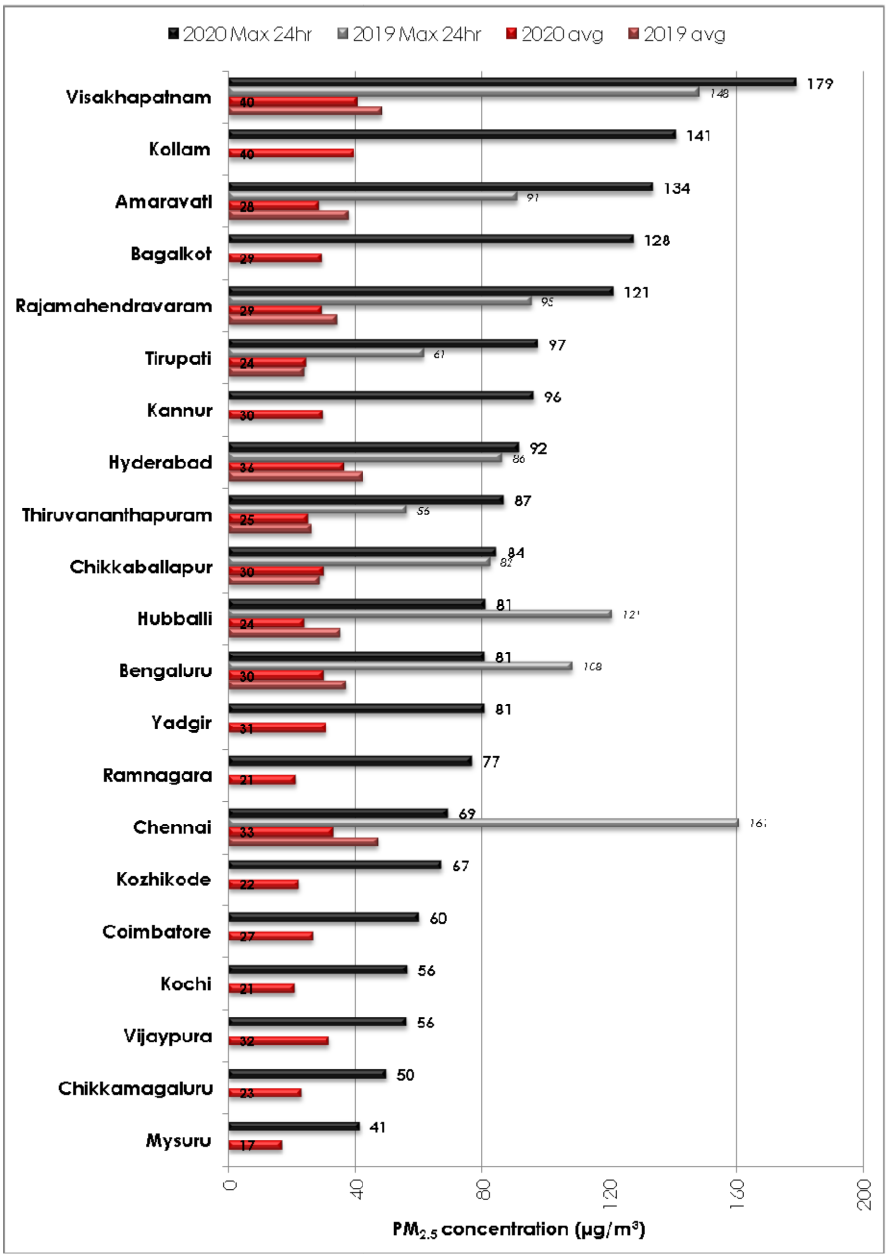
Graph 8e: Heatmap of Visakhapatnam's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is based on a single CAAQM station. Days are colored based on AQI categories.
Source: CSE analysis of CPCB's realtime air quality data

Even with comparatively cleaner air during this year, most cities recorded daily spikes similar to those observed in 2019: CSE has compared the annual averages and peak 24hr averages in these southern cities between 2019 and 2020. This shows that the smaller towns even with much lower annual average levels of $PM_{2.5}$ have experienced almost same or higher maximum daily levels during winter when the entire region got air locked (See *Graph 9: How annual average and maximum level changed in southern cities and towns– comparison of 2019 and 2020*). Andhra Pradesh cities have relatively highest daily peak compared to the rest.

Graph 9: How annual average and maximum level changed in southern cities and towns– comparison of 2019 and 2020



Note: 2020 numbers are based on data up to 31 Dec 2020.
Source: CSE analysis of CPCB's realtime air quality data

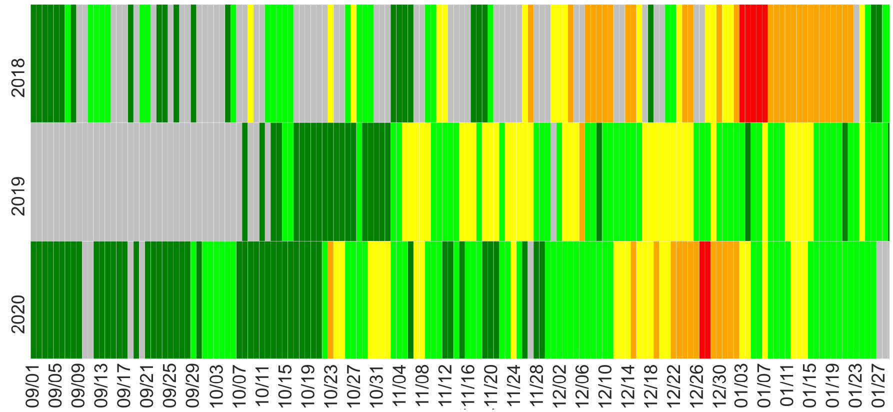
Need deep cuts

This analysis bears out the need for deeper clean air action in the regions of southern India that otherwise is considered less polluted than the northern belt. But the region will have to work harder to meet not only the national ambient air quality standards but also aspire to meet the health based guidelines of the World Health Organisation to reduce public health risk.

It is clear that the region has to take forward its wins so far and raise the level of ambition to drive action across all key sectors of pollution and in the entire region. Enforce power plant standards across the state, minimise use of coal and other dirty fuels in the industry while improving industrial emissions control systems, scale up public transport and vehicle restraint measures and manage waste to have a zero waste and zero landfill strategy.

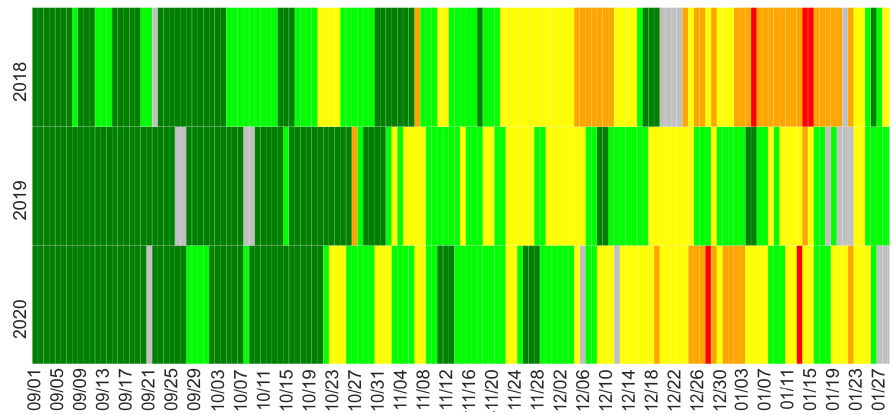
Annexures: Heatmap of other cities

Graph 8f: Heatmap of Amravati's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



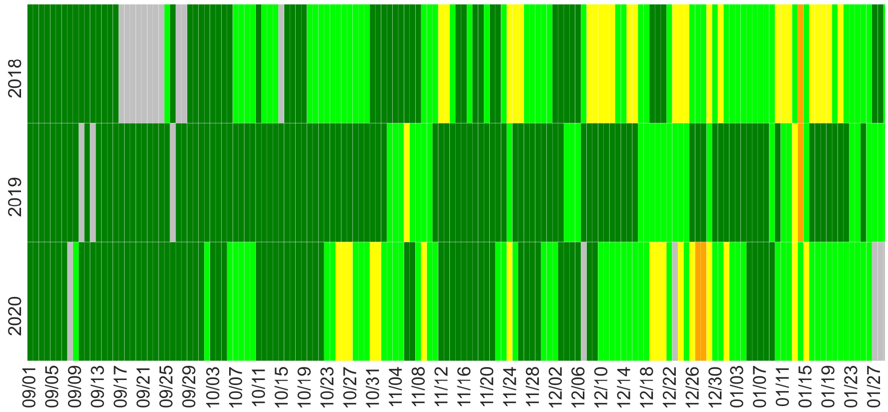
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8g: Heatmap of Rajamaaahendrvaram's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



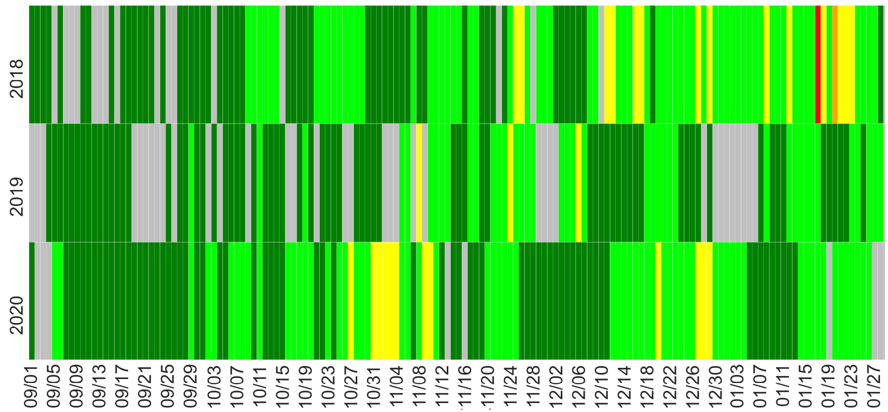
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3 and is based on mean of two CAAQM stations in the city. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8h: Heatmap of Tirupati's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

Graph 8i: Heatmap of Chikkaballapur's daily $PM_{2.5}$ concentration in winter (1 Sept – 26 Jan) of 2018, 2019 and 2020



Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

7 Air pollution and pandemic winter: Spread and scale of crisis

(Andhra Pradesh, Assam, Bihar, Chandigarh, Delhi-NCR, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Nagaland, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, West Bengal)

-- Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, February, 2021

As the winter season is nearing end and summer trends are setting in across most regions of the country, understanding the changes in winter pollution trends across regions becomes necessary to know the challenge and depth of action needed to meet the clean air benchmark. Centre for Science and Environment (CSE) has carried out extensive analysis of real time data from cities of different region to throw light on the difference between 2020-21 winter with the previous winters. This has been a special winter that coincides with the unlocking of the economy post pandemic linked hard lockdown phases.

Winter is a special challenge when inversion, and cool and calm weather traps and spikes daily pollution. While the northern Indo Gangetic Plain is most affected, other regions also experience rise but with lesser intensity. But this year even though the average level of $PM_{2.5}$ during summer and monsoon months was considerably lower than the previous year due to the summer lockdown, the winter $PM_{2.5}$ concentration has risen compared to 2019 winter in many cities across regions. This bouncing back of pollution post-lockdown unmasks the high impacts of local and regional pollution. This demands quicker regional reforms to curb pollution from vehicles, industry, power plants and waste burning to curb the winter pollution and also sustain annual improvement at a regional scale with speed.

This analysis has considered 99 cities where data availability for two consecutive winters meets the minimum criteria of 75 per cent of data completeness requirement. This analysis has helped to understand the regional differences in regional profile of winter pollution. Even though there is considerable regional variation, peak pollution episodes increased and synchronized within the regions during winter. At the same time, uneven rise across monitoring locations and contiguous cities bring out the impact of local pollution.

This analysis is part of the air pollution tracker initiative of CSE. This round up analysis of winter pollution is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. The data is captured from 249 official stations under the Continuous Ambient Air Quality Monitoring System (CAAQMS) spread across 115 cities in 22 states and union territories. CAAQMS has many more cities in its network than included in the analysis.

Data used in the analysis: The analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. The data is captured from 249 official stations under the Continuous Ambient Air Quality Monitoring System (CAAQMS) spread across 115 cities in 22 states and union territories. Apart from Delhi and Chandigarh, there are 8 cities in Punjab, 24 cities in Haryana, 13 cities in Uttar Pradesh, 4 cities in Bihar, 4 cities in West Bengal, 8 cities in Rajasthan, 15 cities in Madhya Pradesh, 4 cities in Gujarat, 4 cities in Andhra Pradesh, 7 cities in Karnataka, two in Odisha, 6 cities in Kerala, 7 cities in Maharashtra, 1 city each in Tamil Nadu, Telangana, Assam, Meghalaya, Mizoram, Nagaland, and Tripura. These cities were selected as the have real-time monitoring and have at least 92 valid 24hr $PM_{2.5}$ averages during 1 Oct 2020 – 31 Jan 2021 (75 per cent of the days in winter). CAAQMS has many more cities in its network than included in the analysis; they were left out as they failed to meet the 75 per cent data completeness requirement.

Delhi (40), Mumbai (21), Bengaluru (10), Chennai (8), Pune (8), Kolkata (7), Hyderabad (6), Patna (6), Lucknow (5), Ghaziabad (4), Noida (4), Gurugram (4), Faridabad (4), Navi Mumbai (4) Meerut (3), Jaipur (3), Howrah (3), Kochi (3), Thiruvananthapuram (2), Ahmedabad (2), Guwahati (2), Greater Noida (2), Kanpur (2), Gaya (2), Muzzafarpur (2), Chandrapur (2) and Gwalior (2) have more than one real-time station, therefore citywide average is used for analysis and it is defined as average of all city stations that meet minimum 75 per cent data completeness criteria.

Key highlights

North India

Real time data is available for 49 cities spread across Punjab, Haryana, Chandigarh, Delhi-NCR, and UP. This also includes union Alwar district of Rajasthan as is part of NCR. Geographically this region represents the North Central Plains.

Cities with stable trend: 15 cities in the region show stable trend i.e. less than 8 per cent change from last winter. These include almost all major cities in the region. These are Faridabad, Varanasi, Jalandhar, Khanna, Noida, Ambala, Patiala, Amritsar, Rupnagar, Ghaziabad, Narnaul, Delhi, Moradabad, Greater Noida, and Kanpur. ((See Graph 1: Trend in winter pollution among cities of North India).

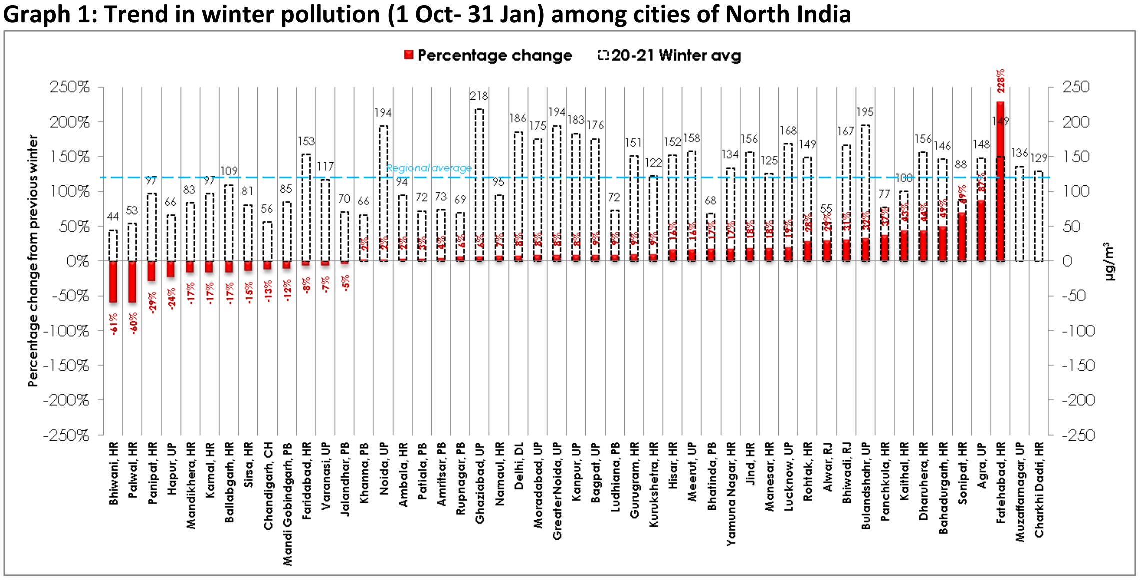
Cities with increasing trend: 26 cities in the region show increasing trend, i.e. more than 8 per cent increase from last winter. Fatehabad in Haryana saw a staggering jump of 228 per cent in the seasonal average. It was followed by Agra that registered 87 per cent increase from last winter. Other cities that show significant increase were Bagpat, Ludhiana, Gurugram, Kurukshetra, Hisar, Meerut, Bhatinda, Yamuna Nagar, Jind, Manesar, Lucknow, Rohtak, Alwar, Bhiwadi, Bulandshahr, Panchkula, Kaithal, Dharuhera, Bahadurgarh, and Sonipat.

Cities with declining trend: 12 cities in the region show declining trend, i.e. more than 8 per cent decrease from last winter. Bhiwani and Palwal in Haryana saw a drop of over 60 per cent in their seasonal average. Other cities with declining trend are Panipat, Hapur, Mandikhera, Karnal, Ballabgarh, Sirsa, Chandigarh, and Mandi Gobindgarh.

Most polluted city cluster: Most polluted cluster is the Delhi-NCR region with Ghaziabad Bulandshahr, Greater Noida, Noida, and Delhi leading the pack. Kanpur and Lucknow occupied sixth and ninth position on the chart.

Least polluted cities: Bhiwani and Palwal in Haryana and Alwar in Rajasthan recorded the lowest seasonal average during 2020-21 winter. Interestingly, Chandigarh is the only major city among the five least polluted. No city had seasonal average below the annual standard of 40 µg/m^3.

Graph 1: Trend in winter pollution (1 Oct- 31 Jan) among cities of North India



Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Cities that don't meet minimum data requirement for previous winter are included in the graph but have not been assigned a percentage change value.
Source: CSE analysis of CPCB's real time air quality data

Table 1: Peer comparison of winter pollution in cities of North India						
Regional Rank	City	Winter $PM_{2.5}$ average ($\mu g/m^3$)		Winter $PM_{2.5}$ peak ($\mu g/m^3$)		$PM_{2.5}$ %age
		2020-21	%age change from 2019-20	2020-21	%age change from 2019-20	
1	Ghaziabad, UP	218	6%	529	-20%	61%
2	Bulandshahr, UP	195	32%	501	18%	61%
3	Greater Noida, UP	194	8%	452	-19%	56%
4	Noida, UP	194	2%	506	-14%	61%
5	Delhi, DL	186	8%	520	-8%	60%
6	Kanpur, UP	183	8%	399	0%	NA
7	Bagpat, UP	176	9%	428	-45%	56%
8	Moradabad, UP	175	8%	532	46%	65%
9	Lucknow, UP	168	19%	326	-15%	55%
10	Bhiwadi, RJ	167	31%	480	77%	53%
11	Meerut, UP	158	16%	334	-41%	52%
12	Jind, HR	156	18%	519	-21%	70%
13	Dharuhera, HR	156	44%	500	63%	47%
14	Faridabad, HR	153	-8%	396	-14%	44%
15	Hisar, HR	152	16%	520	-35%	67%
16	Gurugram, HR	151	9%	481	8%	66%
17	Fatehabad, HR	149	228%	564	54%	66%
18	Rohtak, HR	149	28%	530	19%	NA
19	Agra, UP	148	87%	395	106%	NA
20	Bahadurgarh, HR	146	49%	468	52%	69%
21	Muzaffarnagar, UP	136	NA	305	NA	48%
22	Yamuna Nagar, HR	134	17%	248	-11%	60%
23	Charkhi Dadri, HR	129	NA	322	NA	49%
24	Manesar, HR	125	18%	418	20%	57%
25	Kurukshetra, HR	122	9%	279	-44%	61%
26	Varanasi, UP	117	-7%	239	-15%	46%
27	Ballabgarh, HR	109	-17%	278	-8%	47%
28	Kaithal, HR	100	43%	281	25%	50%
29	Karnal, HR	97	-17%	305	-43%	61%
30	Panipat, HR	97	-29%	246	-63%	31%
31	Narnaul, HR	95	7%	196	-10%	43%
32	Ambala, HR	94	2%	244	-14%	44%
33	Sonipat, HR	88	69%	308	101%	35%
34	Mandigobindgarh, PB	85	-12%	184	-18%	47%
35	Mandikhera, HR	83	-17%	280	10%	60%
36	Sirsa, HR	81	-15%	306	-56%	45%
37	Panchkula, HR	77	37%	149	27%	NA
38	Amritsar, PB	73	4%	208	-7%	54%
39	Ludhiana, PB	72	9%	197	-8%	49%
40	Patiala, PB	72	3%	176	-21%	45%
41	Jalandhar, PB	70	-5%	164	-26%	45%
42	Rupnagar, PB	69	6%	159	22%	NA
43	Bhatinda, PB	68	17%	186	-25%	48%
44	Khanna, PB	66	2%	153	-18%	47%
45	Hapur, UP	66	-24%	187	-71%	29%
46	Chandigarh, CH	56	-13%	110	-24%	47%
47	Alwar, RJ	55	29%	109	7%	53%
48	Palwal, HR	53	-60%	129	-66%	31%
49	Bhiwani, HR	44	-61%	192	-54%	23%

Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Seasonal peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that meet the data completeness requirement. Cities that don't meet minimum data requirement for previous winter are included in the table with 'NA' in filled in for percentage change.
Source: CSE analysis of CPCB's real time air quality data

East India

Realtime data is available for 10 cities spread across Bihar, West Bengal and Odisha. Geographically this region represents the Eastern Plains and Eastern Highlands.

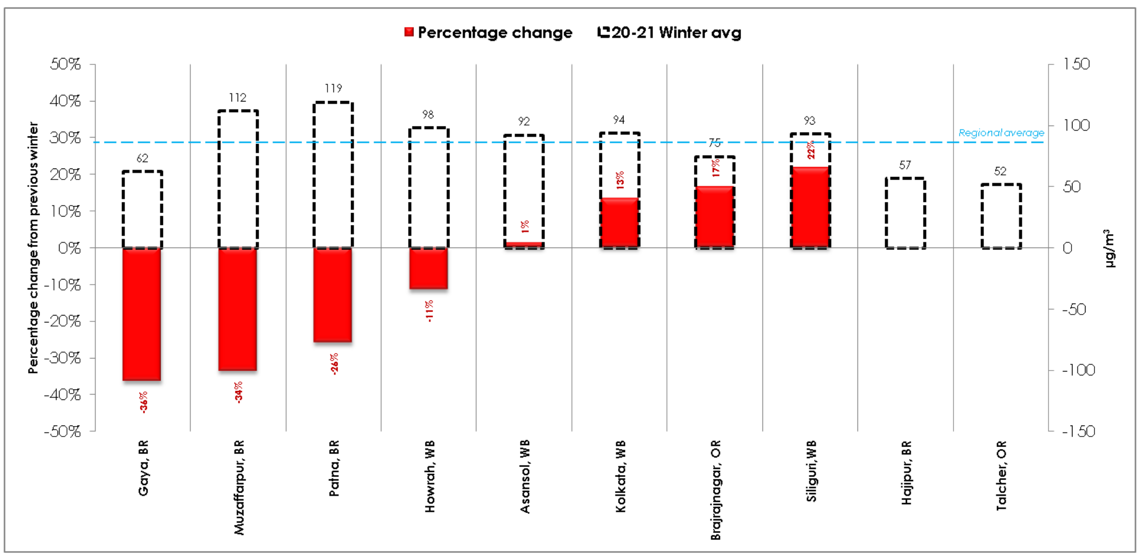
Cities with stable trend: Asansol was the only city in the region show stable trend, i.e. less than 8 per cent change from last winter (See *Graph 2: Trend in winter pollution among cities of East India*).

Cities with increasing trend: Siliguri, Bajrangnagar, and Kolkata show increasing trend, i.e. more than 8 per cent increase from last winter.

Cities with declining trend: Gaya, Muzzafarpur, Patna, and Howrah show declining trend, i.e. more than 8 per cent decrease from last winter. All Bihar cities have shown decline.

Most polluted cities: Most polluted city in the region was Patna with seasonal average of 119 µg/m^3. Howrah and Kolkata occupied third and fourth position on the chart. (See *Table 2: Peer comparison of winter pollution in cities of East India*). **Least polluted cities:** Talcher in Odisha and Hajipur in Bihar recorded the lowest seasonal average in the season. No city had seasonal average below the annual standard of 40 µg/m^3.

Graph 2: Trend in winter pollution (1 Oct- 31 Jan) among cities of East India



Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Cities that don't meet minimum data requirement for previous winter are included in the graph but have not been assigned a percentage change value.
Source: CSE analysis of CPCB's real time air quality data

Table 2: Peer comparison of winter pollution in cities of East India

Regional Rank	City	Winter $PM_{2.5}$ average (µg/m^3)		Winter $PM_{2.5}$ peak (µg/m^3)		PM2.5
		2020-21	%age change from 2019-20	2020-21	%age change from 2019-20	%age
1	**Patna, BR**	119	-26%	265	-25%	51%
2	**Muzaffarpur, BR**	112	-34%	231	-44%	30%
3	**Howrah, WB**	98	-11%	214	6%	53%
4	**Kolkata, WB**	94	13%	199	13%	55%
5	**Siliguri,WB**	93	22%	216	25%	NA
6	**Asansol, WB**	92	1%	190	-10%	54%
7	**Brajrajnagar, OR**	75	17%	130	-3%	54%
8	**Gaya, BR**	62	-36%	144	-39%	66%
9	**Hajipur, BR**	57	NA	108	NA	34%
10	**Talcher, OR**	52	NA	91	NA	41%

Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Seasonal peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that meet the data completeness requirement. Cities that don't meet minimum data requirement for previous winter are included in the table with 'NA' in filled in for percentage change.
Source: CSE analysis of CPCB's real time air quality data

Central and West India

Real time data is available for 32 cities spread across Rajasthan (except Alwar district), Madhya Pradesh, Gujarat and Maharashtra. Geographically this region represents the Arid west, Central Highlands, Northern Deccan plateau and Konkan Coast.

Cities with stable trend: 16 cities in the region show stable trend, i.e. less than 8 per cent change from last winter. These include almost all major cities in the region. These are Chandrapur, Pune, Bhopal, Singrauli, Nashik, Maihar, Ajmer, Satna, Ahmedabad, Dewas, Aurangabad, Indore, Katni, Mumbai, Jabalpur, Ratlam, and Pali. (See *Graph 3: Trend in winter pollution among cities of Central and West India*).

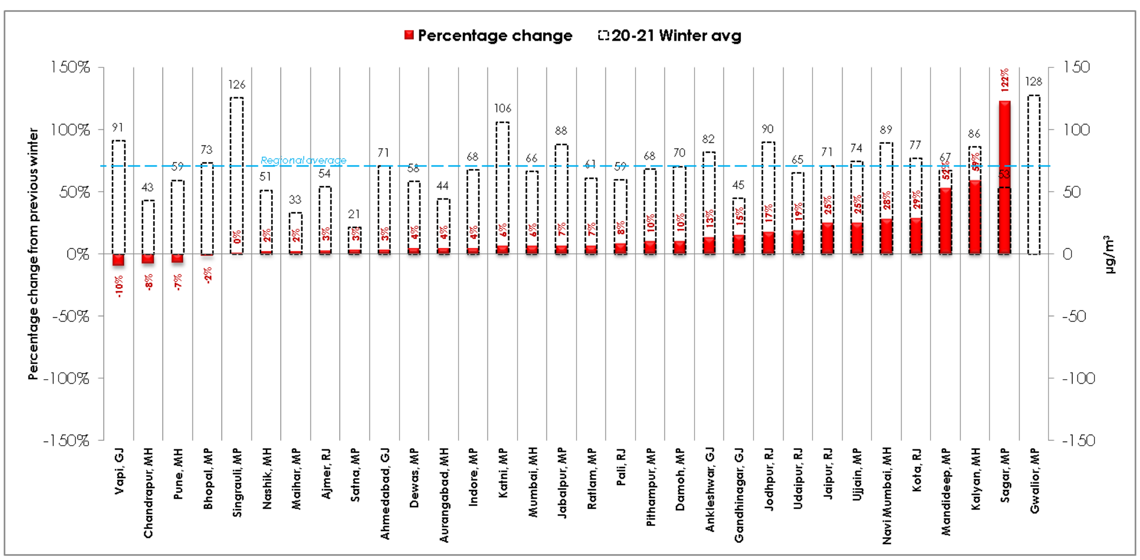
Cities with increasing trend: 13 cities in the region show increasing trend, i.e. more than 8 per cent increase from last winter. Sagar in Madhya Pradesh saw a staggering jump of 112 per cent in the seasonal average. It was followed by Kalyan in Maharashtra that registered 59 per cent increase from last winter. Other cities that show significant increase were Pithampur, Damoh, Ankleshwar, Gandhinagar, Jodhpur, Udaipur, Jaipur, Ujjain, Navi Mumbai, Kota, and Mandideep.

Cities with declining trend: Only Vapi in Gujarat showed declining trend, i.e. more than 8 per cent decrease from last winter. It made it to the list only by a whisker as its seasonal improved by 10 per cent.

Most polluted cities: Most polluted city in the region was Gwalior with seasonal average of 128 µg/m^3. Next two spot were occupied by its fellow Bundelkhandi cities of Singrauli and Katni. Bundelkhand abuts the southern border of NCR. Vapi in Gujarat, Jodhpur in Rajasthan, and Navi Mumbai occupy next three spots on the most polluted chart. (See *Table 3: Peer comparison of winter pollution in cities of Central and West India*).

Least polluted cities: Satna and Maihar in Bundelkhand region of MP recorded the lowest seasonal average in the season. This coexistence of the most and the least polluted cities in close proximity noted in Bundelkhand is similar phenomena as noted in NCR. Chandrapur, Aurangabad, and Gandhinagar round up the list of five least polluted.

Graph 3: Trend in winter pollution (1 Oct- 31 Jan) among cities of Central and West India



Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Cities that don't meet minimum data requirement for previous winter are included in the graph but have not been assigned a percentage change value.
Source: CSE analysis of CPCB's real time air quality data

Table 3: Peer comparison of winter pollution in cities of Central and West India						
Regional Rank	City	Winter $PM_{2.5}$ average (µg/m³)		Winter $PM_{2.5}$ peak (µg/m³)		$PM_{2.5}$ %age
		2020-21	%age change from 2019-20	2020-21	%age change from 2019-20	
1	Gwalior, MP	128	NA	292	NA	64%
2	Singrauli, MP	126	0%	286	-4%	49%
3	Katni, MP	106	6%	188	-4%	49%
4	Vapi, GJ	91	-10%	178	-10%	56%
5	Jodhpur, RJ	90	17%	156	-3%	48%
6	Navi Mumbai, MH	89	28%	171	13%	50%
7	Jabalpur, MP	88	7%	201	17%	48%
8	Kalyan, MH	86	59%	172	65%	53%
9	Ankleshwar, GJ	82	13%	153	21%	45%
10	Kota, RJ	77	29%	167	42%	59%
11	Ujjain, MP	74	25%	145	11%	50%
12	Bhopal, MP	73	-2%	171	22%	46%
13	Jaipur, RJ	71	25%	211	0%	49%
14	Ahmedabad, GJ	71	3%	133	-24%	40%
15	Damoh, MP	70	10%	140	9%	56%
16	Pithampur, MP	68	10%	152	31%	56%
17	Indore, MP	68	4%	135	15%	48%
18	Mandideep, MP	67	52%	126	48%	43%
19	Mumbai, MH	66	6%	139	2%	53%
20	Udaipur, RJ	65	19%	131	10%	51%
21	Ratlam, MP	61	7%	133	19%	39%
22	Pali, RJ	59	8%	121	-2%	47%
23	Pune, MH	59	-7%	103	-3%	62%
24	Dewas, MP	58	4%	140	30%	50%
25	Ajmer, RJ	54	3%	111	-36%	50%
26	Sagar, MP	53	122%	135	293%	44%
27	Nashik, MH	51	2%	101	17%	67%
28	Gandhinagar, GJ	45	15%	75	-7%	45%
29	Aurangabad, MH	44	4%	82	14%	51%
30	Chandrapur, MH	43	-8%	70	-31%	36%
31	Maihar, MP	33	2%	93	-3%	53%
32	Satna, MP	21	3%	37	-47%	25%

Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Seasonal peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that meet the data completeness requirement. Cities that don't meet minimum data requirement for previous winter are included in the table with 'NA' in filled in for percentage change.
Source: CSE analysis of CPCB's real time air quality data

South India

The region includes 19 cities spread across Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Telangana. Geographically this region represents the southern Deccan plateau, Western Ghats, Malabar and Coramandal coasts.

Cities with stable trend: Bengaluru, Thiruvananthapuram, and Hyderabad in the region show stable trend, i.e. less than 8 per cent change from last winter (See *Graph 4: Trend in winter pollution among cities of South India*).

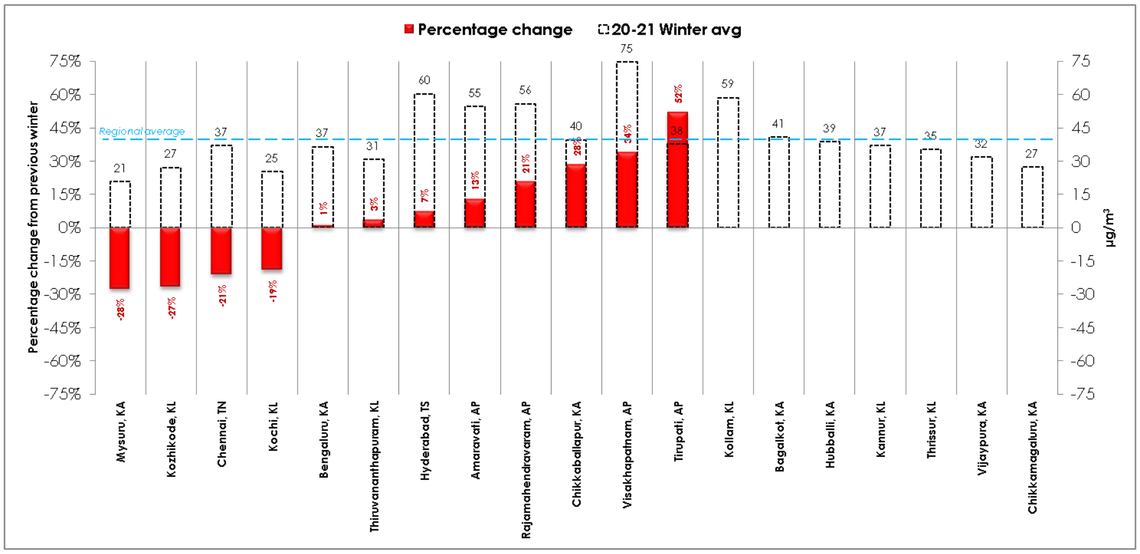
Cities with increasing trend: 5 cities in the region show increasing trend, i.e. more than 8 per cent increase from last winter. Tirupati in Andhra Pradesh saw a jump of 52 per cent in the seasonal average. It was followed by Visakhapatnam that registered 34 per cent increase from last winter. Other cities that show significant increase were Rajamahendravaram, Amaravati, and Chikkaballapur.

Cities with declining trend: Mysuru, Kozhikode, Chennai, and Kochi showed declining trend, i.e. more than 8 per cent decrease from last winter. The improvement in these southern cities was is 19-28 per cent.

Most polluted cities: Most polluted city in the region was Visakhapatnam with seasonal average of 75 µg/m³. Next two spot were occupied by Hyderabad and Kollam in Kerala. (See *Table 4: Peer comparison of winter pollution in cities of South India*).

Least polluted cities: Mysuru recorded the lowest seasonal average in the region. Kochi and Kozhikode of Kerala round up the list of three least polluted. Karnataka has the least polluted cities of the region followed by Kerala.

Graph 4: Trend in winter pollution (1 Oct- 31 Jan) among cities of South India



Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Cities that don't meet minimum data requirement for previous winter are included in the graph but have not been assigned a percentage change value.
Source: CSE analysis of CPCB's real time air quality data

Table 4: Peer comparison of winter pollution in cities of South India

Regional Rank	City	Winter $PM_{2.5}$ average (µg/m³)		Winter $PM_{2.5}$ peak (µg/m³)		$PM_{2.5}$ %age
		2020-21	%age change from 2019-20	2020-21	%age change from 2019-20	
1	**Visakhapatnam, AP**	75	34%	179	2%	48%
2	**Hyderabad, TS**	60	7%	92	6%	48%
3	**Kollam, KL**	59	NA	141	NA	67%
4	**Rajamahendravaram, AP**	56	21%	133	18%	53%
5	**Amaravati, AP**	55	13%	134	47%	61%
6	**Bagalkot, KA**	41	NA	128	NA	58%
7	**Chikkaballapur, KA**	40	28%	84	2%	59%
8	**Hubballi, KA**	39	NA	81	NA	41%
9	**Tirupati, AP**	38	52%	97	7%	66%
10	**Chennai, TN**	37	-21%	98	-44%	55%
11	**Kannur, KL**	37	NA	96	NA	62%
12	**Bengaluru, KA**	37	1%	81	-11%	48%
13	**Thrissur, KL**	35	NA	75	NA	52%
14	**Vijaypura, KA**	32	NA	56	NA	56%
15	**Thiruvananthapuram, KL**	31	3%	63	0%	51%
16	**Chikkamagaluru, KA**	27	NA	52	NA	55%
17	**Kozhikode, KL**	27	-27%	67	51%	40%
18	**Kochi, KL**	25	-19%	61	40%	47%
19	**Mysuru, KA**	21	-28%	41	-36%	42%

Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Seasonal peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that meet the data completeness requirement. Cities that don't meet minimum data requirement for previous winter are included in the table with 'NA' in filled in for percentage change.
Source: CSE analysis of CPCB's real time air quality data

Northeast

Monitoring is very limited in this region. Data is available for only Guwahati in Assam and Kohima in Nagaland. Real-time monitoring has recently started in Shillong, Agartala, and Aizwal. But for the purpose of this analysis they do not meet the minimum data requirement. Geographically this region represents the Eastern Himalayas and Brahmaputra plains.

Guwahati has recorded worst levels in the region with seasonal winter average of 103 µg/m^3. This large and populated city in the plains has a valley effect and is markedly different from other cities in the region which are located in the hills and are much smaller. City's winter average rose by 7 per cent (About 450 km away Siliguri in West Bengal saw 22 per cent increase in seasonal pollution average).

Kohima in Nagaland was the only other city which met the data completeness requirement in the region. With a seasonal average of 38 µg/m^3 it is one of the cleanest city not just in the region but also among all other cities in the analysis. But the air quality in the city can drop to "poor" AQI category on multiple days which is a reason for concern (See *Table 5: Peer comparison of winter pollution in cities of Northeast India*).

Agartala, Shillong, and Aizwal also have real-time monitors that became operational only near the end of 2020. Data availability is more than 50 per cent but less than 75 per cent of the study duration. Therefore, their provisional seasonal averages have been computed but not used for comparative analysis. Agartala's winter average of 84 µg/m^3 which is more than double than the levels noted in other hill-towns of the region, in fact it is higher than all cities of south India. In Agartala $PM_{2.5}$ 73 per cent of PM_{10}. This indicates highly toxic air. Influence of inert crustal dust is much less. Shillong and Aizwal also have high share of $PM_{2.5}$ but significantly lower concentration.

Table 5: Peer comparison of winter pollution in cities of Northeast India

Regional Rank	City	Winter $PM_{2.5}$ average (µg/m^3)		Winter $PM_{2.5}$ peak (µg/m^3)		$PM_{2.5}$ %age
		2020-21	%age change from 2019-20	2020-21	%age change from 2019-20	
1	**Guwahati, AS**	103	7%	273	-24%	58%
2	**Kohima, NL**	38	NA	109	NA	45%
-	**Agartala, TR***	84	NA	184	NA	73%
-	**Aizwal, MZ***	32	NA	95	NA	72%
-	**Shillong, ML***	19	NA	50	NA	79%

Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Seasonal peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that meet the data completeness requirement. Cities that don't meet minimum data requirement for previous winter are included in the table with 'NA' in filled in for percentage change.
* Provisional values based on less than 75 per cent data.
Source: CSE analysis of CPCB's real time air quality data

All India

Winter pollution across all regions: a mixed trend

The North and East regions have registered a collective decline in the intensity of peak smog episode. East was the only region which saw a decline in collective average as well, even when the mega city of the region, Kolkata, saw substantial rise in the winter average. Central and West region saw maximum worsening of air quality at collective level compared to previous winter (See Graph 5: Trend in winter pollution among regions of India). Pollution is on rise in South India as well even though it is currently a lot cleaner than other regions.

This analysis of $PM_{2.5}$ data show that while some cities have witnessed arresting or stabilization of trend with small variation, others have experienced either increase or decrease. North Indian cities are on average the most polluted in the country, over three times the average of South Indian cities. (See *Graph 6: Winter pollution averages (1 Oct-31 Jan) among regions of India*).

Overall winter $PM_{2.5}$ levels have worsened significantly in 43 cities out of 99 cities that have valid daily $PM_{2.5}$ concentration data for over 75 per cent of days for this and previous winter seasons (1-Oct to 31 Jan). This pool of cities mostly consist of Tier-1 or even smaller cities. Most prominent among them are Gurugram, Lucknow, Jaipur, Visakhapatnam, Agra, Navi Mumbai, and Jodhpur. Kolkata is the only mega city in this unfortunate group.

Out of the 99 cities considered, 19 cities have experienced substantial improvement in their winter air quality compared to the previous winter. Chennai is the only mega city included in this pool.

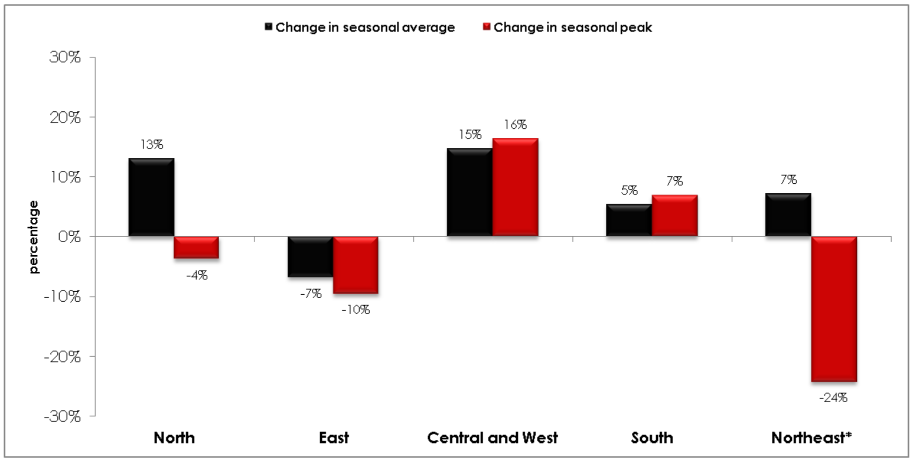
37 cities out of 99 cities, which include most of the mega cities, have not experienced significant change in their seasonal average compared to previous winter.

There is also wide variation in peak pollution level experienced during winter. It is noteworthy that in about 37 cities that are otherwise showing stable or declining seasonal average their peak levels have risen significantly during winter. These include Aurangabad, Indore, Nashik, Jabalpur, Rupnagar, Bhopal, Dewas, Kochi, and Kozhikode. On the other hand, in North India, other cities including Delhi have experienced the reverse, i.e. increase in seasonal average but decline in seasonal peak. (See *Graph 7: Winter peak pollution (1 Oct- 31 Jan) among regions of India*).

When put in an order the top 23 polluted cities are from North India. While Mysuru is the least polluted, followed by Satna in MP and Kochi in Kerala, Ghaziabad is the most polluted city in the country. There are only 4 cities (Satna, Mysuru, Vijaypura, and Chikkamagaluru) that have seasonal peak below the 24hr standard (60 µg/m^3) during the winter season. These four and 12 other cities have seasonal average below the annual standard (40 µg/m^3) (See *Table 6: All India peer comparison of winter pollution*).

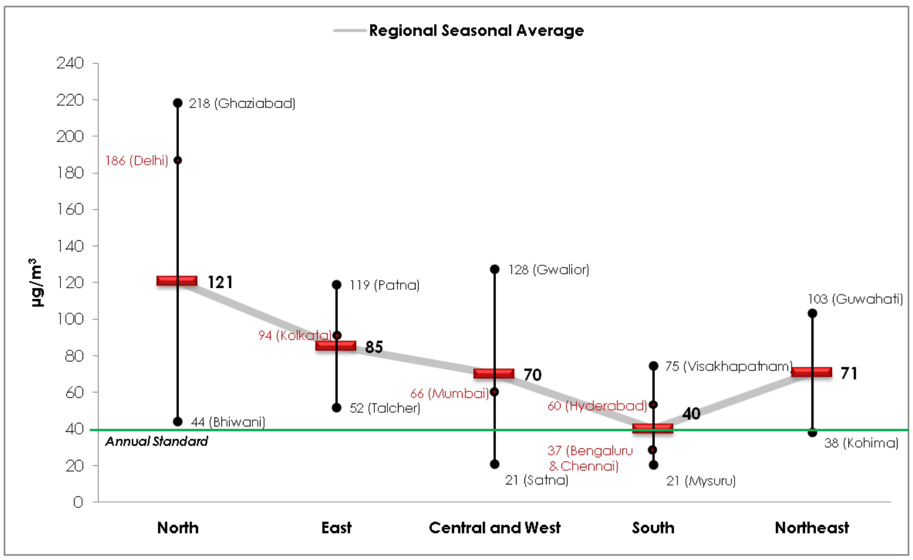
It is important to note that mega cities are not the most polluted in any of the regions. It is the smaller and upcoming cities that are the pollution hotspots. This is even more evident in the seasonal peak data. This report findings make it is amply clear that this winter pollution challenge is not limited to mega cities or one specific region; it is an omnipresent problem and requires urgent and deliberate action everywhere. This requires quicker reforms and action in key sectors of pollution – vehicles, industry, power plants and waste management to control winter pollution and bend the annual air pollution curve. Most polluted cities this winter were located in Delhi-NCR and UP. In fact, eight of top ten were UP cities with Ghaziabad and Bulandshahr taking the top spots. Delhi at number five and Bhiwadi, Rajasthan at number 10 were the only exception.

Graph 5: Trend in winter pollution among regions of India



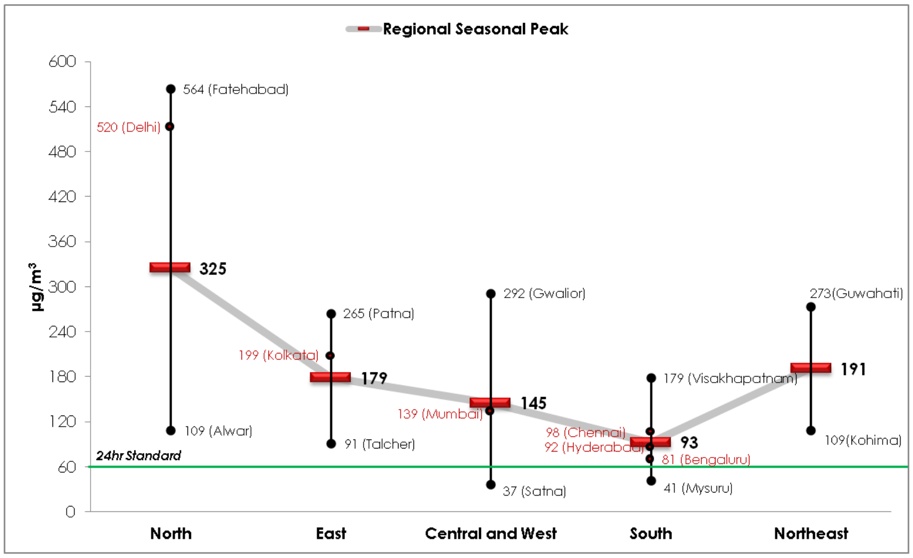
Note: Regional Average $PM_{2.5}$ concentration is based on mean of seasonal value determined for each cities in the region. Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Regional $PM_{2.5}$ peak is based on mean of seasonal peak value determined for each cities in the region. Seasonal peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. * Northeast had only one city (Guwahati) which had data for both winters.
Source: CSE analysis of CPCB's real time air quality data

Graph 6: Winter pollution averages (1 Oct- 31 Jan) among regions of India



Note: Regional Average $PM_{2.5}$ concentration is based on mean of seasonal value determined for each cities in the region. Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter.
Source: CSE analysis of CPCB's real time air quality data

Graph 7: Winter peak pollution (1 Oct- 31 Jan) among regions of India



Note: Regional $PM_{2.5}$ peak is based on mean of seasonal peak value determined for each cities in the region. Seasonal peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter.
Source: CSE analysis of CPCB's real time air quality data

Table 6: All India peer comparison of winter pollution

National RANK	City	Winter $PM_{2.5}$ average (µg/m³)		Winter $PM_{2.5}$ peak (µg/m³)		$PM_{2.5}$ %age
		2020-21	%age change from 2019-20	2020-21	%age change from 2019-20	
1	**Ghaziabad, UP**	218	6%	529	-20%	61%
2	**Bulandshahr, UP**	195	32%	501	18%	61%
3	**Greater Noida, UP**	194	8%	452	-19%	56%
4	**Noida, UP**	194	2%	506	-14%	61%
5	**Delhi, DL**	186	8%	520	-8%	60%
6	**Kanpur, UP**	183	8%	399	0%	NA
7	**Bagpat, UP**	176	9%	428	-45%	56%
8	**Moradabad, UP**	175	8%	532	46%	65%
9	**Lucknow, UP**	168	19%	326	-15%	55%
10	**Bhiwadi, RJ**	167	31%	480	77%	53%
11	**Meerut, UP**	158	16%	334	-41%	52%
12	**Jind, HR**	156	18%	519	-21%	70%
13	**Dharuhera, HR**	156	44%	500	63%	47%
14	**Faridabad, HR**	153	-8%	396	-14%	44%
15	**Hisar, HR**	152	16%	520	-35%	67%
16	**Gurugram, HR**	151	9%	481	8%	66%
17	**Fatehabad, HR**	149	228%	564	54%	66%
18	**Rohtak, HR**	149	28%	530	19%	NA
19	**Agra, UP**	148	87%	395	106%	NA
20	**Bahadurgarh, HR**	146	49%	468	52%	69%
21	**Muzaffarnagar, UP**	136	NA	305	NA	48%
22	**Yamuna Nagar, HR**	134	17%	248	-11%	60%
23	**Charkhi Dadri, HR**	129	NA	322	NA	49%
24	**Gwalior, MP**	128	NA	292	NA	64%
25	**Singrauli, MP**	126	0%	286	-4%	49%
26	**Manesar, HR**	125	18%	418	20%	57%
27	**Kurukshetra, HR**	122	9%	279	-44%	61%

28	**Patna, BR**	119	-26%	265	-25%	51%
29	**Varanasi, UP**	117	-7%	239	-15%	46%
30	**Muzaffarpur, BR**	112	-34%	231	-44%	30%
31	**Ballabgarh, HR**	109	-17%	278	-8%	47%
32	**Katni, MP**	106	6%	188	-4%	49%
33	**Guwahati, AS**	103	7%	273	-24%	58%
34	**Kaithal, HR**	100	43%	281	25%	50%
35	**Howrah, WB**	98	-11%	214	6%	53%
36	**Karnal, HR**	97	-17%	305	-43%	61%
37	**Panipat, HR**	97	-29%	246	-63%	31%
38	**Narnaul, HR**	95	7%	196	-10%	43%
39	**Ambala, HR**	94	2%	244	-14%	44%
40	**Kolkata, WB**	94	13%	199	13%	55%
41	**Siliguri,WB**	93	22%	216	25%	NA
42	**Asansol, WB**	92	1%	190	-10%	54%
43	**Vapi, GJ**	91	-10%	178	-10%	56%
44	**Jodhpur, RJ**	90	17%	156	-3%	48%
45	**Navi Mumbai, MH**	89	28%	171	13%	50%
46	**Jabalpur, MP**	88	7%	201	17%	48%
47	**Sonipat, HR**	88	69%	308	101%	35%
48	**Kalyan, MH**	86	59%	172	65%	53%
49	**Mandi Gobindgarh, PB**	85	-12%	184	-18%	47%
50	**Mandikhera, HR**	83	-17%	280	10%	60%
51	**Ankleshwar, GJ**	82	13%	153	21%	45%
52	**Sirsa, HR**	81	-15%	306	-56%	45%
53	**Panchkula, HR**	77	37%	149	27%	NA
54	**Kota, RJ**	77	29%	167	42%	59%
55	**Visakhapatnam, AP**	75	34%	179	2%	48%
56	**Brajrajnagar, OR**	75	17%	130	-3%	54%
57	**Ujjain, MP**	74	25%	145	11%	50%
58	**Amritsar, PB**	73	4%	208	-7%	54%
59	**Bhopal, MP**	73	-2%	171	22%	46%
60	**Ludhiana, PB**	72	9%	197	-8%	49%
61	**Patiala, PB**	72	3%	176	-21%	45%
62	**Jaipur, RJ**	71	25%	211	0%	49%
63	**Ahmedabad, GJ**	71	3%	133	-24%	40%
64	**Jalandhar, PB**	70	-5%	164	-26%	45%
65	**Damoh, MP**	70	10%	140	9%	56%
66	**Rupnagar, PB**	69	6%	159	22%	NA
67	**Bhatinda, PB**	68	17%	186	-25%	48%
68	**Pithampur, MP**	68	10%	152	31%	56%
69	**Indore, MP**	68	4%	135	15%	48%
70	**Mandideep, MP**	67	52%	126	48%	43%
71	**Khanna, PB**	66	2%	153	-18%	47%
72	**Mumbai, MH**	66	6%	139	2%	53%
73	**Hapur, UP**	66	-24%	187	-71%	29%
74	**Udaipur, RJ**	65	19%	131	10%	51%
75	**Gaya, BR**	62	-36%	144	-39%	66%
76	**Ratlam, MP**	61	7%	133	19%	39%
77	**Hyderabad, TS**	60	7%	92	6%	48%
78	**Pali, RJ**	59	8%	121	-2%	47%
79	**Pune, MH**	59	-7%	103	-3%	62%
80	**Kollam, KL**	59	NA	141	NA	67%
81	**Dewas, MP**	58	4%	140	30%	50%
82	**Hajipur, BR**	57	NA	108	NA	34%
83	**Chandigarh, CH**	56	-13%	110	-24%	47%
84	**Rajamahendravaram, AP**	56	21%	133	18%	53%

85	**Alwar, RJ**	55	29%	109	7%	53%
86	**Amaravati, AP**	55	13%	134	47%	61%
87	**Ajmer, RJ**	54	3%	111	-36%	50%
88	**Sagar, MP**	53	122%	135	293%	44%
89	**Palwal, HR**	53	-60%	129	-66%	31%
90	**Talcher, OR**	52	NA	91	NA	41%
91	**Nashik, MH**	51	2%	101	17%	67%
92	**Gandhinagar, GJ**	45	15%	75	-7%	45%
93	**Bhiwani, HR**	44	-61%	192	-54%	23%
94	**Aurangabad, MH**	44	4%	82	14%	51%
95	**Chandrapur, MH**	43	-8%	70	-31%	36%
96	**Bagalkot, KA**	41	NA	128	NA	58%
97	**Chikkaballapur, KA**	40	28%	84	2%	59%
98	**Hubballi, KA**	39	NA	81	NA	41%
99	**Kohima, NL**	38	NA	109	NA	45%
100	**Tirupati, AP**	38	52%	97	7%	66%
101	**Chennai, TN**	37	-21%	98	-44%	55%
102	**Kannur, KL**	37	NA	96	NA	62%
103	**Bengaluru, KA**	37	1%	81	-11%	48%
104	**Thrissur, KL**	35	NA	75	NA	52%
105	**Maihar, MP**	33	2%	93	-3%	53%
106	**Vijaypura, KA**	32	NA	56	NA	56%
107	**Thiruvananthapuram, KL**	31	3%	63	0%	51%
108	**Chikkamagaluru, KA**	27	NA	52	NA	55%
109	**Kozhikode, KL**	27	-27%	67	51%	40%
110	**Kochi, KL**	25	-19%	61	40%	47%
111	**Satna, MP**	21	3%	37	-47%	25%
112	**Mysuru, KA**	21	-28%	41	-36%	42%
-	**Agartala, TR***	84	NA	184	NA	73%
-	**Aizwal, MZ***	32	NA	95	NA	72%
-	**Shillong, ML***	19	NA	50	NA	79%

Note: Seasonal average of a city is based on mean of daily $PM_{2.5}$ values recorded at CAAQM stations in the city that have minimum 75 per cent data for this winter and previous winter. Seasonal peak of a city is based on mean of the highest daily $PM_{2.5}$ value recorded at CAAQM stations in the city that meet the data completeness requirement. Cities that don't meet minimum data requirement for previous winter are included in the table with 'NA' in filled in for percentage change.
* Provisional values based on less than 75 per cent data
Source: CSE analysis of CPCB's real time air quality data

8. Winter pollution in Delhi-NCR: October-February, 2020-21

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, February, 2021

The worst of winter in Delhi and National Capital Region (NCR) is over. For the purpose of implementation of the Graded Response Action Plan (GRAP) winter in this region is officially defined as from October 15 to February 1. There is a special interest in understanding the winter pollution trend given the extraordinary situation due to the pandemic this year. Winter is the most difficult season in this region due to the atmospheric conditions of inversion, calm wind, and cold conditions. Trapped winter air traps local and regional pollution and creates deadly winter smog.

Winter after winter Delhi battles serious challenge of prolonged smoggy days. However, in the time horizon of 2015-2020, several multi-sector action has been initiated as part of the comprehensive clean air action plan as well as graded response action plan. Year-on-year basis annual average of $PM_{2.5}$ levels are declining in Delhi. Is this also moderating the impact on the pollution build up and severe peaks during winter when pollution is trapped across the region? Therefore, this analysis of winter pollution trend since 2018 helps to build the pattern of change.

Winter season is always a special challenge when inversion, and cool and calm weather traps and spikes daily pollution. But this is also the bar to understand the effectiveness of round the year action in reducing long term pollution in the region. Despite the declining trend (year-on-year basis) due action taken over the last few years on clean fuels and technology for industry and transport, power plants, trucks, old vehicles among others, the winter $PM_{2.5}$ concentration has bounced back unmasking the impacts of local and regional pollution. This demands quicker and more ambitious regional reforms to curb pollution from all sources with scale and speed.

This analysis has helped to understand the regional pattern across Delhi-NCR as well as the local variation pollution build up. Even though there is considerable regional variation, peak pollution episodes have increased and synchronized within the region. But there is also an uneven pattern in rise in concentration of PM2.5 across the monitoring locations - even if they are contiguous. This also brings out the impact of local pollution.

The analysis is based on publically available data from various government agencies. Most granular data (15-minute averages) has been sourced from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management - All India (https://app.cpcbccr.com/). This has analysed data recorded by 81 air quality monitoring stations or cent per cent of the current NCR network under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Farm stubble fire data has been sourced from System of Air Quality and Weather Forecasting and Research (SAFAR). Weather data has been sourced from the Palam weather station of Indian Meteorological Department (IMD).There is variation in the number of air quality monitoring stations -- Delhi (40), Ghaziabad (4), Noida (4), Gurugram (4), Faridabad (4), Meerut (3) and Greater Noida (2). Therefore, citywide average is used for comparative analysis and it is defined as average of all city stations that meet minimum 75 per cent data availability criteria. $PM_{2.5}$ concentration has been classified according to the principles of the National Air Quality Index.

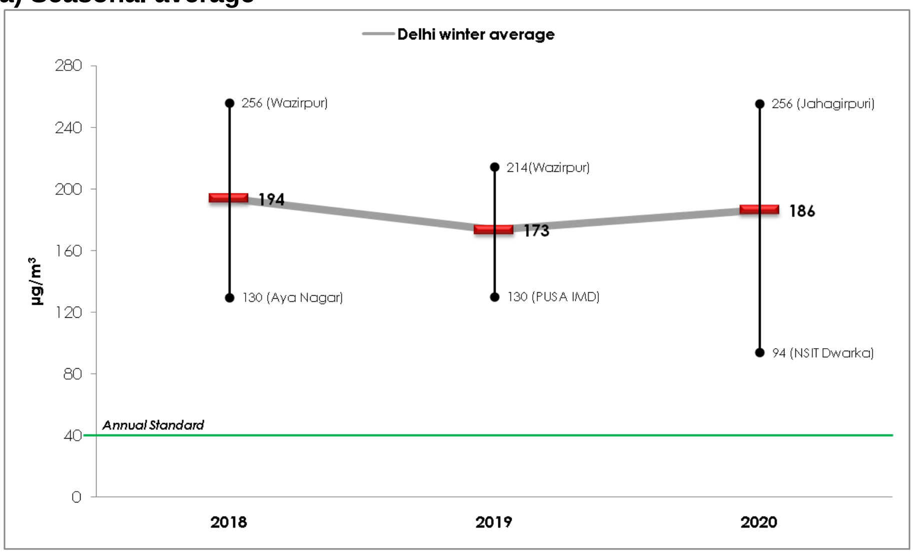
Key highlights

Delhi

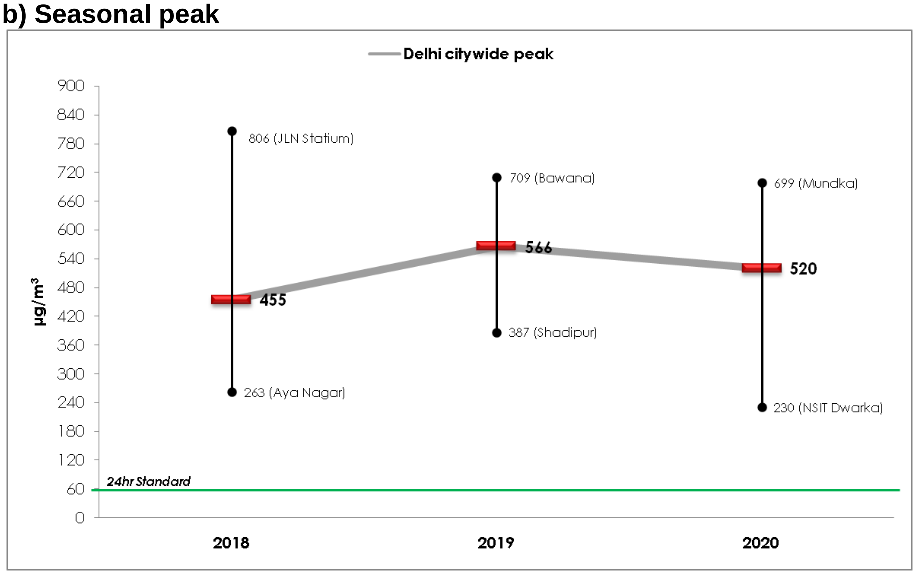
Severe intensity of 2020-21 winter smog is comparatively lower but seasonal average is marginally higher: There is an interesting trend this winter. The number of days with severe and very poor levels of PM2.5 concentration (as per the concentration classification of the national air quality index - AQI) has been comparatively lower this winter. But the number of days with concentration level in poor category has increased. At the same time, the overall the city-wide average for the season has been comparatively higher this year. The citywide average for winter months in Delhi stood at 186 µg/m^3 was 7 per cent higher than the seasonal average of 2019-20 winter.

Graph 1: Trend on winter pollution in Delhi

a) Seasonal average



b) Seasonal peak



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 35 CAAQM stations in the city that have adequate data for all three winters. Five stations excluded for this are Alipur, Burrari Crossing, East Arjun Nagar, Chandni Chowk, and Lodhi Road-IITM.

Source: CSE analysis of CPCB's real time air quality data

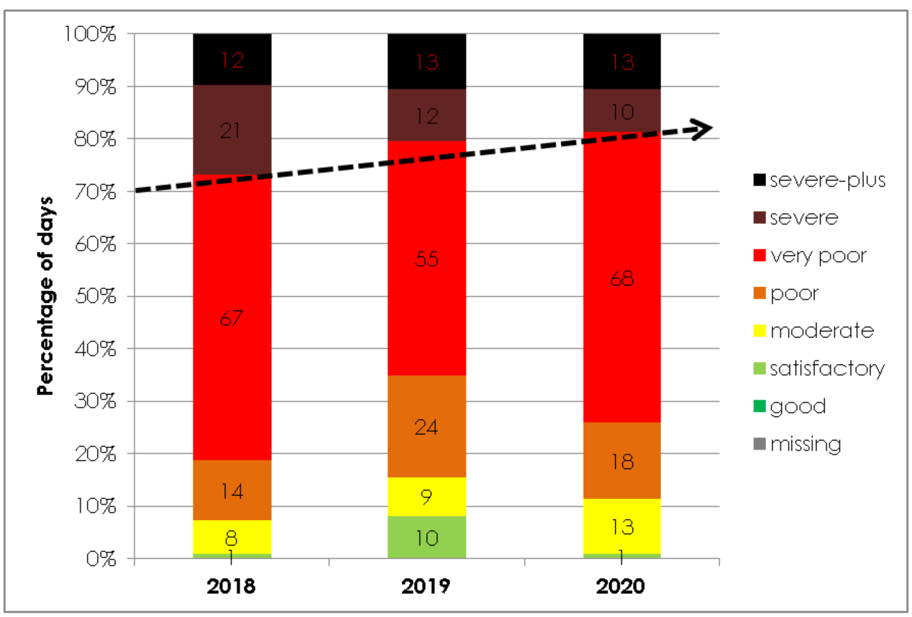
But, the seasonal peak has been about 8 per cent lower compared to last winter (See Graph 1: Trend on winter pollution in Delhi a) seasonal average b) seasonal peak). Meteorologically – mainly from the perspective of rainfall and temperature, this winter has been somewhat similar to 2018-19 winter and seasonal average this winter has been 4 per cent lower than 2018-19 winter. But 2019-20 winter has seen more rains.

Overall, higher seasonal average but lower peak can be attributed to meteorology and peaks due to change in farm stubble burning pattern. But considerable variation has been noted among individual stations in the city. This also indicates dominance of local pollution sources.

Number of days with severe concentration of PM2.5 declined and smog episodes were of shorter duration: This winter 23 days had citywide average of $PM_{2.5}$ concentration in "severe' or worse AQI category, this is down from 25 such days in pervious winter and 33 days in 2018-19 winter (See Graph 2: Decline in number of "severe" and worse air days in Delhi). Technically, a smog episode is defined for the purpose of implementing emergency action under the Graded Response Action Plan when the levels of $PM_{2.5}$ remain in "severe" category for three consecutive days. From this perspective, this winter there were two continuous smog episodes. The first episode was of longer duration as it started on 3rd Nov and lasted 7 days. The second started on 22nd Dec and lasted for 3 days (See Graph 3: Map of smog episode in Delhi). Thus the continuous smog episodes are fewer and shorter compared to previous winters. 2019-20 winter had three smog episodes of 8 days, 6 days and 5 days durations. 2018-19 winter had four smog episodes of 10 days, couple of 6 days and a 3 days durations.

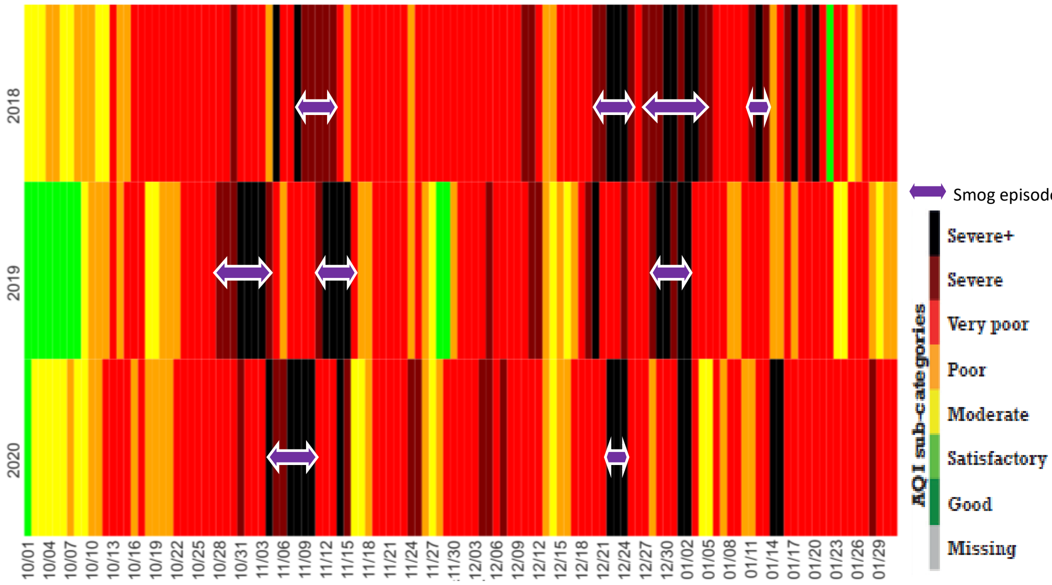
Relatively faster dissipation of smog episodes without any major rainfall or pollution control-emergency action this year points towards downward trend in the annual average concentration. This period also coincide with the gradual unlocking of economy and travel in the air shed (perhaps residual impact of lockdown). But still persistent high level suggest impact of local pollution.

Graph 2: Decline in number of "severe" and worse air days in Delhi



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 35 CAAQM stations in the city that have adequate data for all three winters. Four stations excluded for this are Alipur, Burrari Crossing, East Arjun Nagar, Chandni Chowk, and Lodhi Road-IITM.
Source: CSE analysis of CPCB's real time air quality data

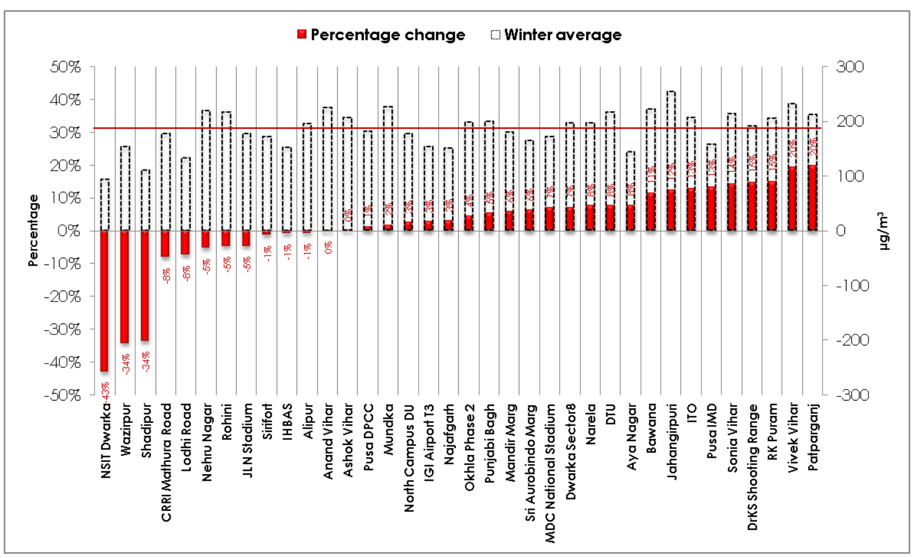
Graph 3: Map of smog episode in Delhi



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 35 CAAQM stations in the city that have adequate data for all 3 winters. 5 stations excluded for this are Alipur, Burrari Crossing, East Arjun Nagar, Chandni Chowk, and Lodhi Road-IITM.
Source: CSE analysis of CPCB's real time air quality data

The difference between different monitoring locations in the city more varied indicating dominance of local pollution sources this winter: 12 stations saw improvement in their seasonal average over last year. Improvement was noted at NSIT Dwarka, Wazirpur, and Shadipur. Increase was noted at Patparganj, Vivek Vihar, and RK Puram which are residential areas. Stations in North and East Delhi continued to exhibit highest $PM_{2.5}$ levels, while west Delhi was relatively cleaner (See Graph 4: $PM_{2.5}$ variation among stations of Delhi). Bewildering aspect of the trend is that there is no clear clustering of stations that show improvement or deterioration. In fact, many neighboring stations have shown diverging trend. For instance station at Shadipur shows 34 per cent improvement while next door at PUSA IMD station registered 13 per cent worsening from previous winter. This heterogeneous spatial distribution further indicates impact of local sources and micro climate.

Graph 4: $PM_{2.5}$ variation among stations of Delhi

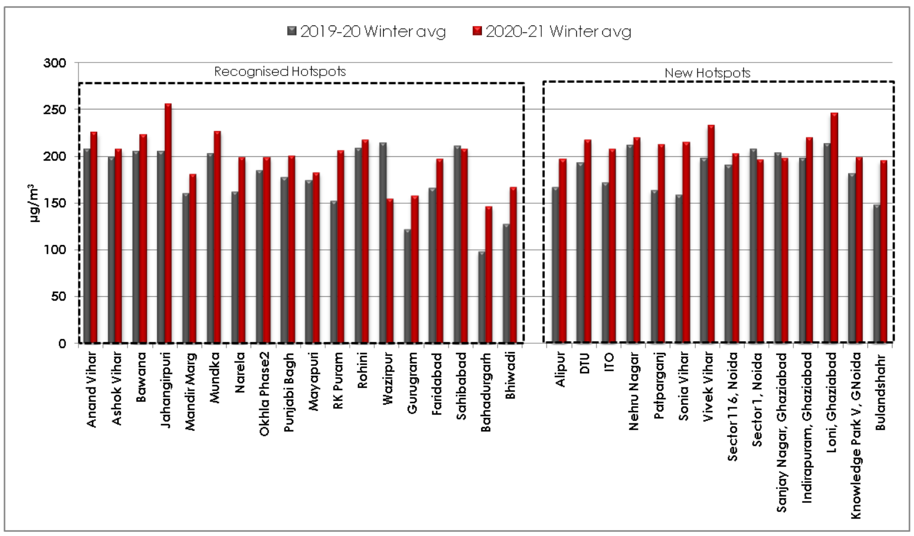


Note: Five stations excluded for this are Alipur, Burrari Crossing, East Arjun Nagar, Chandni Chowk, and Lodhi Road-IITM for inadequate data.
Source: CSE analysis of CPCB's real time air quality data

16 of 18 recognized hotspot registered worsening of air: Except Wazirpur and Sahibabad, all the locations on Delhi-NCR pollution hotspot list saw spike in the seasonal PM2.5 level compared to last winter. Jahangirpuri with a seasonal average of 256 µg/m^3 was the dirtiest among the recognized hotspots. Bahadurgarh that recorded almost 50 per cent jump in PM2.5 level was cleaner than other hotspots. But heavier deterioration was noted in many other locations that are not yet designated as hotspots. Originally, hotspots were defined as those with annual average levels higher than the mean value of the city – that is any case is much worse than the national ambient air quality standards.

However, during the winter months, at least 14 more locations registered higher seasonal average than the mean of recognized hotspots, i.e. 197 µg/m^3 (See Graph 5: Winter pollution at hotspots). These were Alipur, DTU, ITO, Nehru Nagar, Patparganj, Sonia Vihar and Vivek Vihar in Delhi, Sector 1 and 116 in Noida, Loni, Sanjay Vihar and Indirapuram in Ghaziabad, Knowledge Park V in Greater Noida and Bulandshahr. This again points towards impact of local pollution.

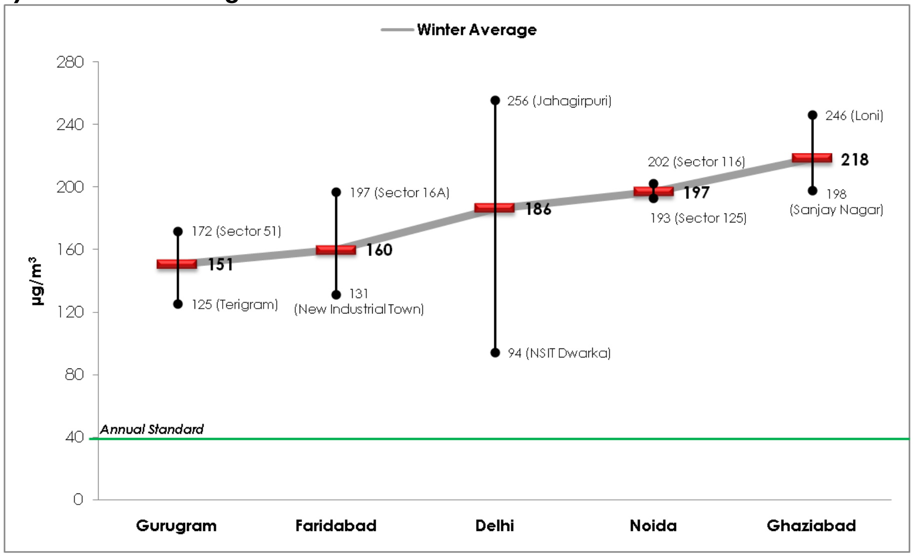
Graph 5: Winter pollution at hotspots



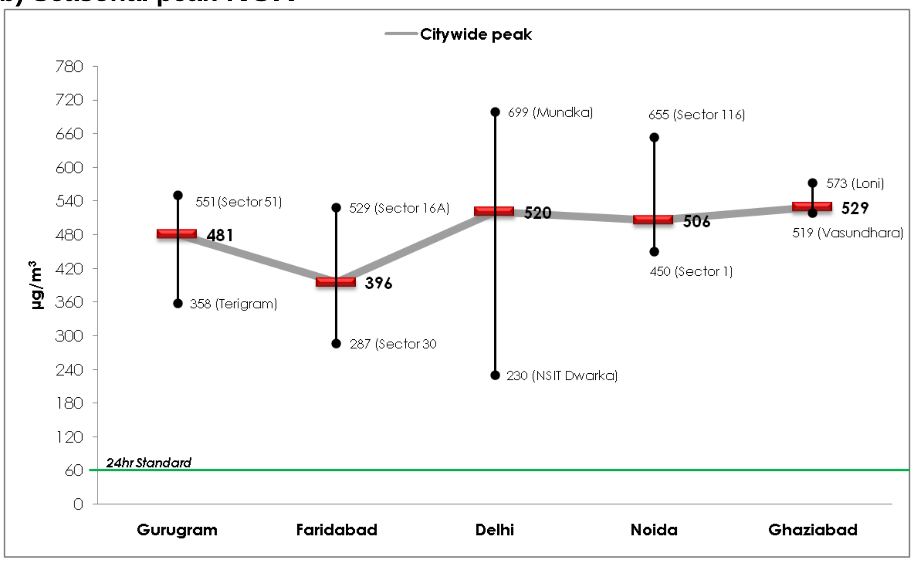
Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at the CAAQM stations given it has adequate data for the winter. . Mayapuri and Sahibabad don't have a CAAQM station, therefore nearest station to them (Pusa DPCC and Vasundhara respectively) is used to represent their air quality. Gurugram and Faridabad are represented by their oldest station- Vikas Sadan and Sector 16A respectively.
Source: CSE analysis of CPCB's real time air quality data

Ghaziabad was the most polluted among the four major neighbouring towns of Delhi, and all of them registered increase in their seasonal average compared to last winter. Haryana cities are relatively less polluted than the cities of Uttar Pradesh (See Graph 6: Winter pollution in main NCR cities a) seasonal average b) seasonal peak). North Delhi was dirtiest place in the region with Jahangirpuri recording the worst seasonal average and Mundkaa with the worst seasonal peak. In the larger NCR, there is wide variation in trend among neighbouring towns.

Graph 6: Winter pollution in main NCR cities
a) Seasonal average NCR



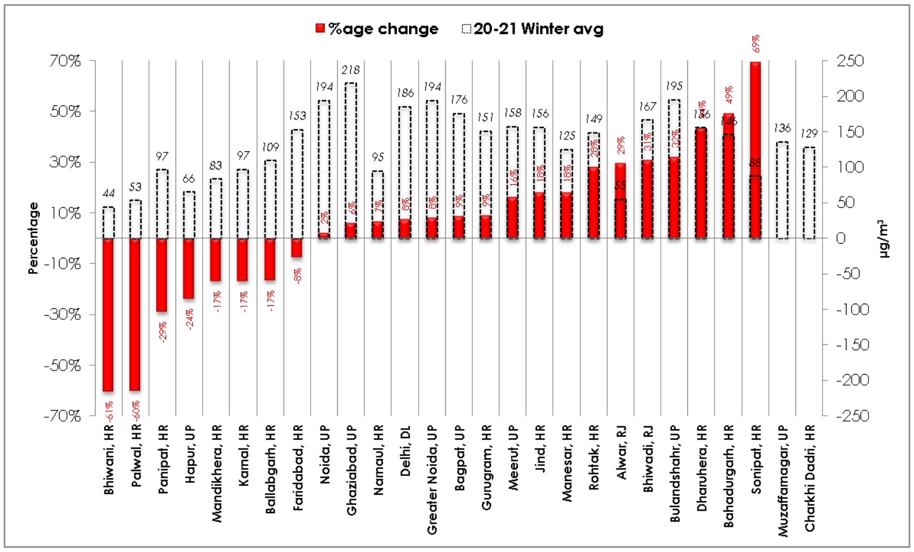
b) Seasonal peak NCR



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data for the winter.
Source: CSE analysis of CPCB's real time air quality data

25 out of 27 NCR towns have adequate data for previous winter that makes comparison possible. Eight towns show improvement in sesonal average from last year with Bhiwani and Palwal in Haryana showing the most improvement (exceeding 60 per cent). But Sonipat (69 per cent) and Bahadurgarh (49 per cent) lead the pack of towns with maximum detoriation in seasonal average. It is noteworthy that Hapur and Bulandshahr are neighbours but Hapur saw 24 per cent improvement while Bulandshahr deteriorated by 32 per cent. In fact, the seasonal average of Bulandshahr is three times that of Hapur. There are many such pair of cities and towns in NCR and larger North India this year. This heterogeneous spatial distribution further strengthens the observation that local pollution and micro climate has been driving factor this winter. It must be noted that these pairs are mostly of smaller towns that have some higher seasonal fluctuations compared to bigger cities of the region (See Graph 7: Winter pollution level aand trend in NCR cities).

Graph 7: Winter pollution level aand trend in NCR cities



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in the city that have adequate data for the winter.

Source: CSE analysis of CPCB's real time air quality data

End note

The winter of 2020-21 coincided with the gradual unlocking of the economy after the hard lockdown phases during summer. There were still some residual effect as all establishments had not fully opened. While the entire region was affected by the winter inversion and trapping of the pollution at a regional scale, the data indicates an interesting trend towards very wide variation across monitorong locations and towns and cities of Delhi-NCR. There is no clear clustering of cities. This indicates impact of local pollution while micro climates may have als played a role. This winter, other than the initial implementation of the basic GRAP measures in October in terms of reinforcing enforcement of pollution control measures, the additional measures for severely polluted days were not implemented.

At the same, lesser number of smog episodes and lesser number of days in severe categories is also a reflection of the overall decline in year-on-year average levels due to the implementation of some of the critical sectoral measures over the last five years. This includes closure of coal based power plants in Delhi, expansion of CNG programm for public transport and commercial vehicles and use of natural gas in industry, banning of dirty fuels like petcoke and furnace oil (and coal in Delhi), controls on truck entry into Delhi, banning of old vehicles among others. The arresting of the trend is the cummulative impact of all these measures. This however has not been uniformly implemented across the entire NCR.

This is clearly an inflexion point for Delhi-NCR. Urgent nexts steps are needed for scale and speed of action across all sectors and across the entire NCR. The region needs massive clean fuel and technology transition in industry setcor; time bound implementation of power plant standards, massive mobility transition across Delhi and NCR; and paradigm shift in waste management with strong compliance and accountability.

9 ■ Pandemic and air pollution in Delhi-NCR: Insights on World Environment Day

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, June 4, 2021

On this World Environment Day, Centre for Science and Environment releases the latest results of air quality analysis that shows how air quality trend has changed through the successive seasons during the pandemic times in Delhi and National Capital Region (NCR). This assessment period is from September 2018 to May 2021 that captures three successive winter seasons, pre and pandemic era and also different stages of lockdown in Delhi and the National Capital Region.

The key highlight this time is that the spring time – January to March, when pollution level begins to subside after winter, $PM_{2.5}$ this year has recorded highest seasonal levels compared to the corresponding period in preceding years including the normal year of 2019.

This indicates that despite the partial restrictions the pollution level have increased. While the reason needs investigation, it is important to underscore that there would be a rebound effect with full opening of the economy and intensification of traffic. Pandemic management during the second wave may have slowed down action but this has to speed up to prevent the rebound effect or retaliatory emissions to ensure longer term air quality gains. This is particularly important given the new science on the linkage between air quality and its effect on vulnerability to the pandemic.

This analysis is based on the real time data available from the current working air quality monitoring stations in Delhi and NCR. However, even though Delhi's monitoring network grew to 40 AQM stations by the end of 2020 (24 of Delhi Pollution Control Committee or DPCC, 8 of IMD, 6 of Central Pollution Control Board -CPCB and 2 of IITM), the number of active stations have reduced to 32 as all the IMD stations have gone offline. IMD's station at Burari Crossing has been offline since 13 Dec, 2020 while Ayanagar, CRRI Mathura Road, IGI Airport, Lodi Road, North Campus DU, and PUSA stations went offline on March 10, 2021. In fact, their two other stations (Gwal Pahari, Gurugram and Noida Sector 62) have also gone offline.

As far as data availability is concerned there is a wide variation between monitoring locations. While over 90 per cent of hourly data is available for all DPCC and CPCB stations for the time period between 1 January to 31 May, 2021, data availability for two IITM stations is 75-86 per cent. HSPCB stations in Gurugram shows over 90 per cent data availability, but the stations in Faridabad has only 70-89 per cent data available. UPSPCB stations in Nodia, Ghaziabad and Greater Nodia have over 85 per cent data available except the stations at Noida Sector 125 and Greater Noida Knowledge Park-III which have just 65 per cent data.

Overall, monitoring network strength in Delhi and big five NCR cities has come down from 58 stations to 48 stations now. This along with lower availability of data at many stations is a matter of concern as this makes the investments in monitoring network sub-optimal.

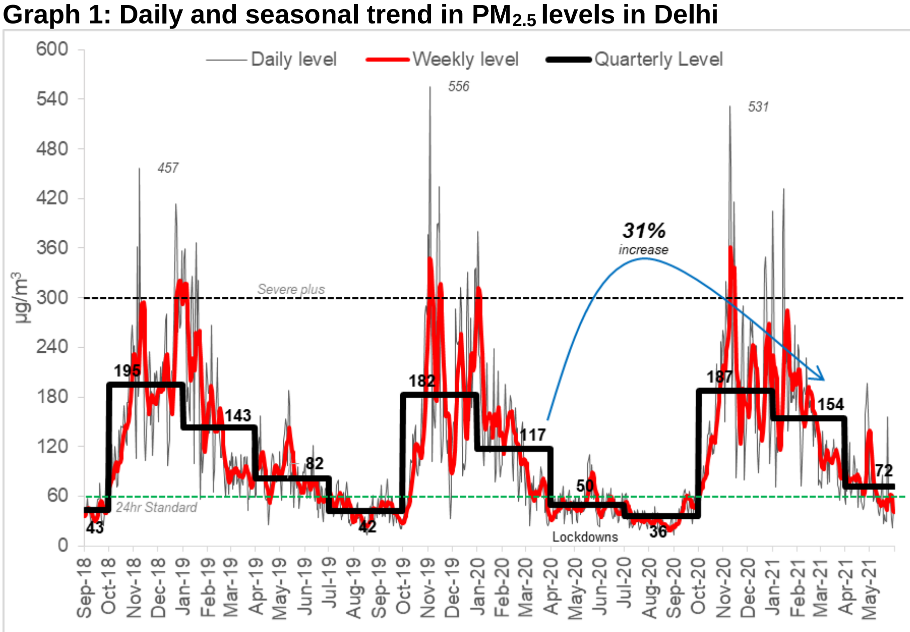
Key highlights

The broad sweep trend in $PM_{2.5}$ levels from September 2018 to May 2021: The overall annual trend is arrested and is downward. But there is a variation in seasonal pattern. Normally, $PM_{2.5}$ level have a seasonal cycle with winter being the most polluted and monsoon being the cleanest. Spring (January to March) acts as transitional period between the two extremes – winter and summer. Significant drop in $PM_{2.5}$ levels happens as the weather warms up and wind picks up speed during spring. There was a 26 per cent drop between winter of 2018 and spring of 2019. In 2020 this drop increased to 36 per cent due to pollution control measures in place and also imposition of partial lockdowns in March 2020. But this downward trend in spring pollution did not continue this year, with seasonal drop limited to 18 per cent. In fact, spring this year has been 31 per cent dirtier than 2020 and 8 per cent dirtier than 2019 (See *Graph 1: Daily and seasonal trend in $PM_{2.5}$ levels in Delhi*).

Lockdown with a difference: Lockdowns were effective in bringing down $PM_{2.5}$ levels this year as well. But given the shorter duration and lesser stringency of lockdowns this year $PM_{2.5}$ levels are not as low as summer of 2020. The monthly average level of $PM_{2.5}$ in April and May, 2021 – the hard lockdown phase, was higher than the corresponding levels in April-May, 2020, – also a hard lockdown phase.

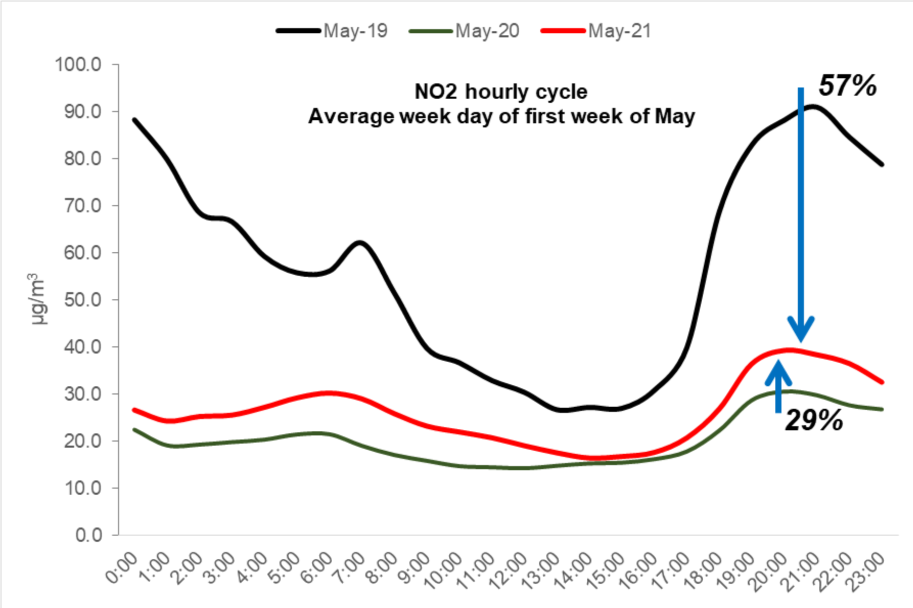
Meteorology would be part responsible for this elevated level but this could also be a reflection of weakening of pollution control measures and efforts in the city and region during the pandemic phase. Traffic intensity was also comparatively higher. Evening peak of hourly cycle of NO_2 was 29 per cent higher in 2021 hard-lockdown than observed in 2020 hard lockdown (See *Graph 2: Hourly NO_2 cycle in Delhi*). But it was still 57 per cent lower than regular evening peak noted in May of 2019.

Graph 1: Daily and seasonal trend in $PM_{2.5}$ levels in Delhi



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 26 CAAQM stations in the city that have adequate data for all three years.
Source: CSE analysis of CPCB's real time air quality data

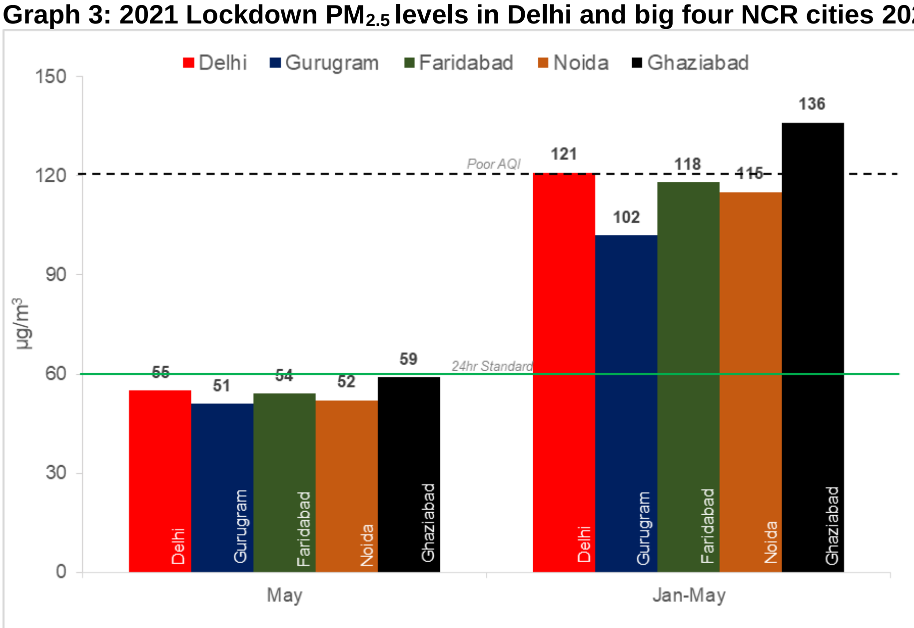
Graph 2: Hourly NO_2 cycle in Delhi



Note: Average NO_2 concentration is based on mean of hourly values recorded at all CAAQM stations in Delhi that have adequate data for all three years.
Source: CSE analysis of CPCB's real time air quality data

The month of May which was completely under lockdown saw Delhi and big four cities record identical $PM_{2.5}$ levels (See *Graph 3: 2021 Lockdown $PM_{2.5}$ levels in Delhi and big four NCR cities*). Ghaziabad with monthly average of 59 µg/m³ was the most polluted during the lockdown while Gurugram with 51 µg/m³ was the cleanest. Average for the year so far (January to May) shows similar spatial trend among the cities.

Graph 3: 2021 Lockdown $PM_{2.5}$ levels in Delhi and big four NCR cities 2021

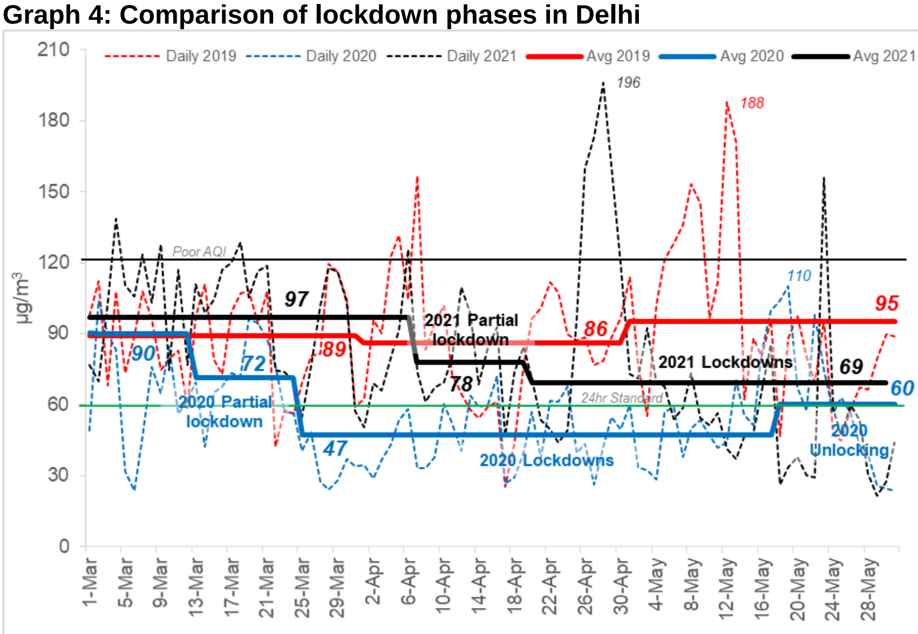


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at CAAQM stations in each city that have adequate data for this years.
Source: CSE analysis of CPCB's real time air quality data

Varying pattern of hard lock down phase and semi-lockdown phase of 2020 and 2021: This year restriction in form of night-curfews and weekend lockdowns started on April 6 with complete lockdown being imposed on April 19. Imposition of partial-lockdown lowered $PM_{2.5}$ levels by 20 per cent, the complete lockdown brought the average down by further 12 per cent (See *Graph 4: Comparison of lockdown phases in Delhi*).
In 2020, partial lockdown started 12 March, 2020 with hard lockdown kicking in on March 25, which was lifted in phase-wise manner from May 18 onwards. Then the partial lockdown also brought $PM_{2.5}$ levels down by 20 per cent but the hard lockdown reduced it by another 35 per cent. Lifting of restriction from May 18 led to 28 per cent rise in $PM_{2.5}$ levels.

When compared to summer of 2019 which had no lockdowns, lockdown summers have been 25-40 per cent cleaner.

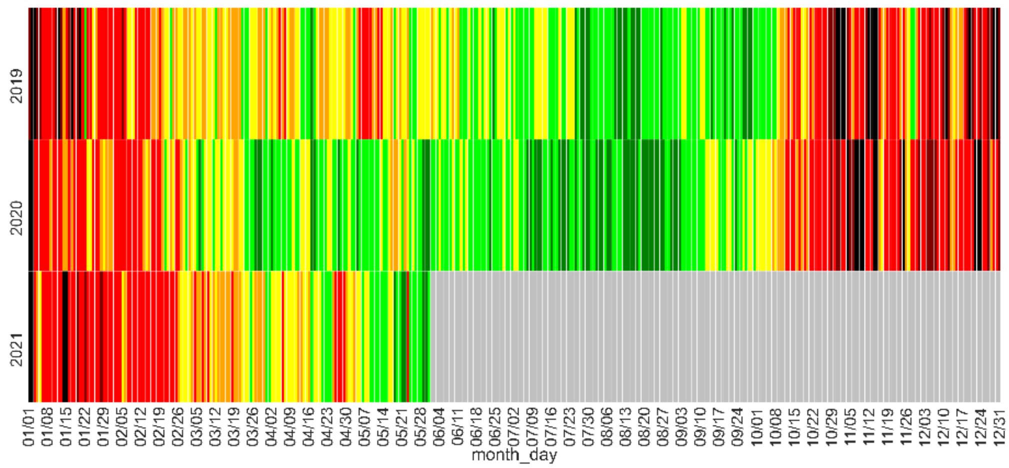
Graph 4: Comparison of lockdown phases in Delhi



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 26 CAAQM stations in the city that have adequate data for all three years.
Source: CSE analysis of CPCB's real time air quality data

Heat map of daily air quality pattern during 2019 to 2021 show the changing pattern of smog episodes and cleaner days in Delhi and NCR: Daily $PM_{2.5}$ levels have been further classified according to the air quality index categories. The number of days in the very poor AQI $PM_{2.5}$ sub-category dramatically increased in Feb-March of 2021 (See *Graph 5: Heatmap of Delhi's daily $PM_{2.5}$ AQI sub-category*). There were 27 days of "very poor" days this Feb-March compared to 17 in 2020 and 12 in 2019. Days meeting the standard also plummeted this spring with just two days recorded. 2020 had 16 and 2019 had 6 days when the standard was met. This red shift breaks the three year trend of accelerated dissipation of bad winter air.

Graph 5: Heatmap of Delhi's daily $PM_{2.5}$ AQI sub-category

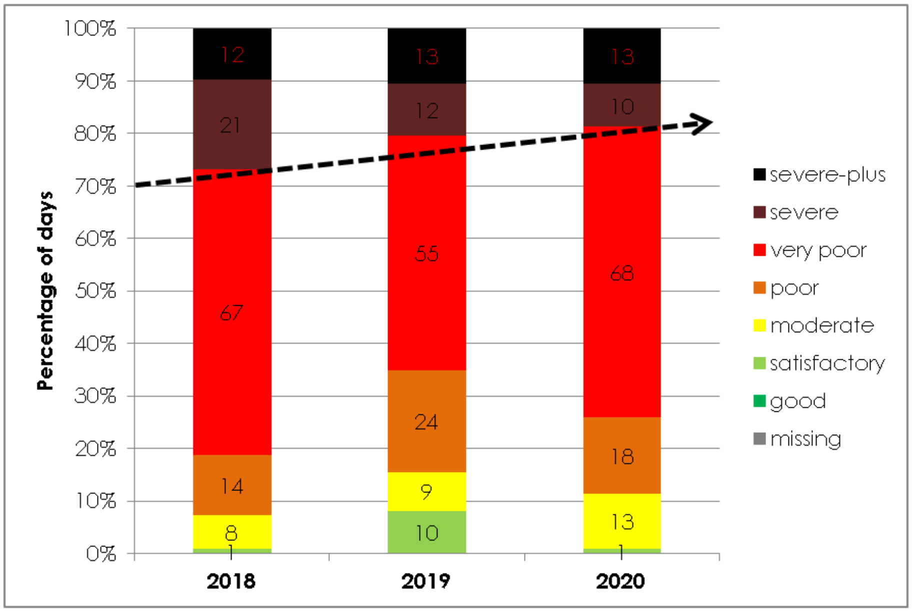


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 26 CAAQM stations in the city that have adequate data for all three years. Cell colors are based on AQI color scheme based on their 24-hourly averge.
Source: CSE analysis of CPCB's real time air quality data

Number of days with severe concentration of $PM_{2.5}$ declined while duration of smog episodes were shorter during 2020-21 winter: This winter 23 days had citywide average of $PM_{2.5}$ concentration in "severe' or worse AQI sub-category, this is down from 25 such days in pervious winter and 33 days in 2018-19 winter (See *Graph 6: Decline in number of "severe" and worse air days in Delhi*). Technically, a smog episode is defined for the purpose of implementing emergency action under the Graded Response Action Plan when the levels of $PM_{2.5}$ remain in "severe" category for three consecutive days. From this perspective, this winter there were two continuous smog episodes. The first episode was of longer duration as it started on 3rd November and lasted 7 days. The second started on 22nd Dec and lasted for 3 days (See *Graph 7: Map of smog episode in Delhi*). Thus the continuous smog episodes are fewer and shorter compared to previous winters. 2019-20 winter had three smog episodes of 8 days, 6 days and 5 days durations. 2018-19 winter had four smog episodes of 10 days, couple of 6 days and a 3 days durations.

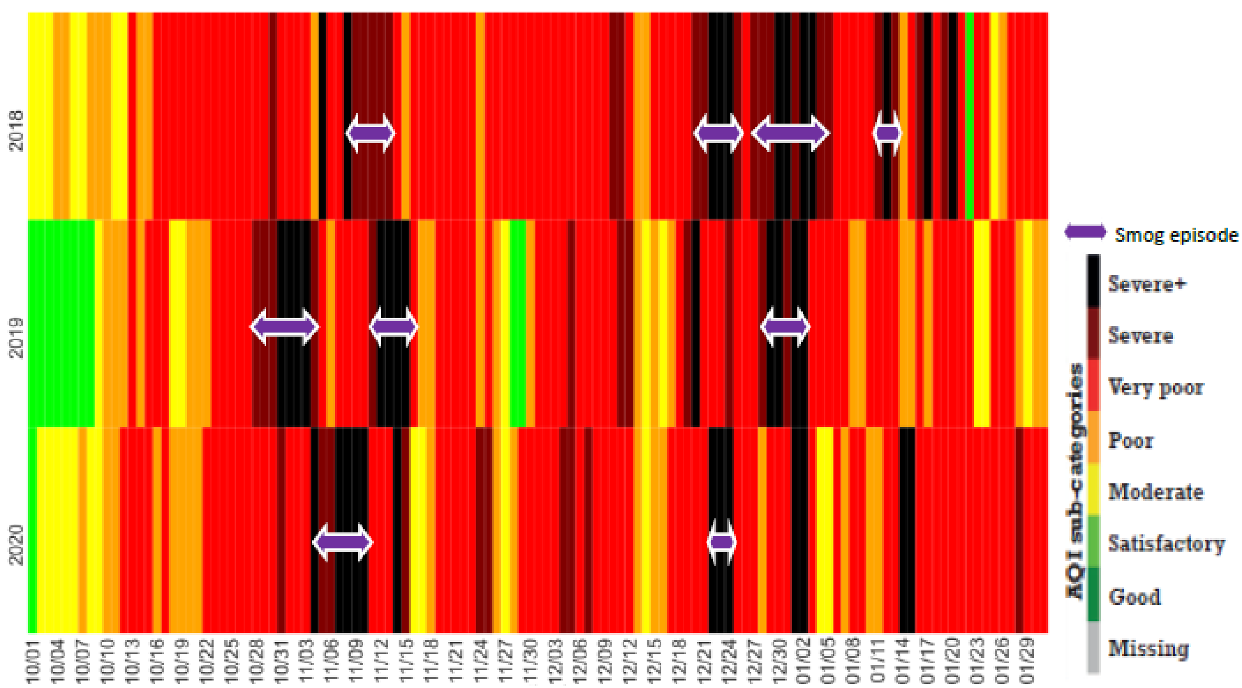
Relatively faster dissipation of smog episodes without any major rainfall or pollution control-emergency action this year points towards downward trend in the annual average concentration. This period also coincide with the gradual unlocking of economy and travel in the air shed (perhaps residual impact of lockdown). But still persistent high level suggest impact of local pollution.

Graph 6: Decline in number of "severe" and worse air days in Delhi (1 Oct– 31 Jan)



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 35 CAAQM stations in the city that have adequate data for all three winters.
Source: CSE analysis of CPCB's real time air quality data

Graph 7: Map of smog episode in Delhi

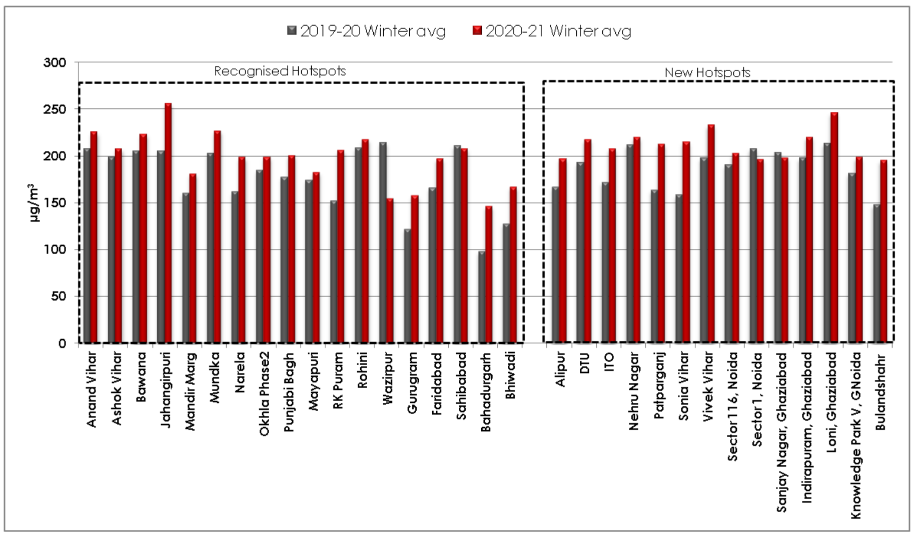


Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at 35 CAAQM stations in the city that have adequate data for all three winters.
Source: CSE analysis of CPCB's real time air quality data

Shifting position of city hotspots in relation to the city average over the three winters - 16 of 18 recognized hotspot registered worsening of air: There is a broad classification of hotspots. Originally, hotspots were defined as those with annual average levels higher than the mean value of the city – that is any case is much worse than the national ambient air quality standards. According to the original list, except Wazirpur and Sahibabad, all the locations on Delhi-NCR pollution hotspot list saw spike in the seasonal $PM_{2.5}$ level compared to last winter. Jahangirpuri with a seasonal average of 256 µg/m^3 was the dirtiest among the recognized hotspots. Bahadurgarh that recorded almost 50 per cent jump in $PM_{2.5}$ level was cleaner than other hotspots. But heavier deterioration was noted in many other locations that are not yet designated as hotspots.

However, during the winter months, at least 14 more locations registered higher seasonal average than the mean of recognized hotspots, i.e. 197 µg/m^3 (See *Graph 8: Winter pollution at hotspots*). These were Alipur, DTU, ITO, Nehru Nagar, Patparganj, Sonia Vihar and Vivek Vihar in Delhi, Sector 1 and 116 in Noida, Loni, Sanjay Vihar and Indirapuram in Ghaziabad, Knowledge Park V in Greater Noida and Bulandshahr. This again points towards impact of local pollution.

Graph 8: Winter pollution at hotspots



Note: Average $PM_{2.5}$ concentration is based on mean of daily values recorded at the CAAQM stations given it has adequate data for the winter. . Mayapuri and Sahibabad don't have a CAAQM station, therefore nearest station to them (Pusa DPCC and Vasundhara respectively) is used to represent their air quality. Gurugram and Faridabad are represented by their oldest station- Vikas Sadan and Sector 16A respectively.
Source: CSE analysis of CPCB's real time air quality data

Behavior of pollution hotspots during lockdowns: If we look at places that reported relatively higher $PM_{2.5}$ levels during the lockdown this year, the hotspots (old and new) occupy the top of the list without exception (See *Table 1: Location wise data for month of May, 2020*). Further, 21 out of 43 stations that have data for both this lockdown and 2020 lockdown show improvement in $PM_{2.5}$ levels. Among stations that saw improvement Panjabi Bagh (-42 per cent) was the best followed by Rohini (-21 per cent) and Dilshad Garden (-20 per cent). Almost all sites with improvement are primarily residential in nature.

Most significant increase is noted at RK Puram (51 per cent) followed by Patparganj (45 per cent), Sadipur (36 per cent), and Mandir Marg (30 per cent). The increase in Mandir Marg and Sadipur can be due to ongoing construction work at Central Vista as these stations are downwind of the construction.

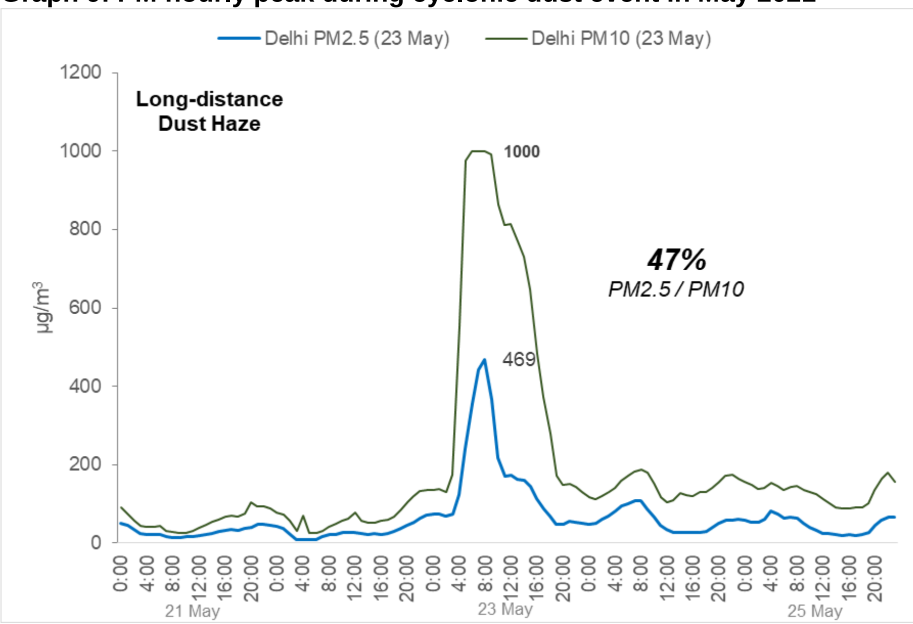
Table 1: Location wise data for month of May, 2020			
	May-21	May-20	Change*
Sector 11, FD	77.7		
Loni, GHZ	77.2	69.4	11%
Bawana, DL	74.1	80.0	-7%
NSIT Dwarka, DL	72.0	71.3	1%
Anand Vihar, DL	71.4	71.1	0%
Sector 30, FD	70.0	63.4	10%
Patparganj, DL	68.4	47.0	45%
DTU, DL	68.3	65.4	4%
Sector 51, GGN	65.0	57.1	14%
Narela, DL	63.9	72.5	-12%
New Industrial Town, FD	63.2		
Sonia Vihar, DL	62.5	54.7	14%
Vivek Vihar, DL	62.4	53.3	17%
Alipur, DL	61.3	66.0	-7%
Vasundhara, GHZ	61.3	56.9	8%
Mandir Marg, DL	61.1	47.1	30%
Jahangirpuri, DL	60.8	65.2	-7%
RK Puram, DL	59.6	39.5	51%
Mundka, DL	59.2	64.2	-8%
Rohini, DL	56.4	71.2	-21%
Wazirpur, DL	56.3	59.1	-5%
Punjabi Bagh, DL	56.3	96.4	-42%
Lodhi Road (IITM), DL	56.1		
Sanjay Nagar, GHZ	54.8	63.1	-13%
Noida Sector 116	54.0	48.0	13%
Sector 16A, FD	53.6	42.3	27%
Ashok Vihar, DL	52.8	55.4	-5%
Noida Sector 125	52.1	46.8	11%
Najafgarh, DL	51.4	59.3	-13%
Shadipur, DL	51.4	37.9	36%
Vikas Sadan, GGN	51.3	50.1	2%
Knowledge Park V, GND	50.7	45.5	12%
Dwarka Sector 8, DL	50.6	51.4	-1%
TeriGram, GGN	50.5	56.4	-10%
Nehru Nagar, DL	48.2	50.0	-4%
Indirapuram, GHZ	46.1	51.1	-10%
Okhla Phase 2, DL	45.6	47.2	-3%
IHBAS Dilshad Garden, DL	45.5	57.2	-20%
Knowledge Park III, GND	45.3	44.0	3%
JLN Stadium, DL	45.2	43.2	5%
Sirifort, DL	44.7	47.0	-5%
Dr KS Shooting Range, DL	44.5	34.6	29%
Pusa (DPCC), DL	44.4	49.7	-11%
Sri Aurobindo Marg, DL	44.2	43.2	2%
MDC National Stadium,DL	42.3	44.2	-4%
Noida Sector 1	41.7	51.6	-19%
Chandni Chowk, DL	38.1		
Aya Nagar, DL		76.2	
ITO, DL		72.6	
Lodhi Road (IMD), DL		55.3	
CRRI Mathura Road, DL		54.4	
IGI Airport T3, DL		54.2	
Gwal Pahari, GGN		52.0	
North Campus, DL		50.8	
Noida Sector 62		50.4	
Pusa (IMD), DL			
Burari Crossing, DL			
East Arjun Nagar, DL			

Note: * negative value means reduction in PM2.5 this year. Blank cells means no data or not enough data available to compute monthly average. Values in µg/m^3
Source: CSE analysis of CPCB's real time air quality data

Highlights of key pollution episodes

Dust event in May 2021: In the morning of 23rd May, Delhi woke up to strange yellow haze with city's AQ monitors blinking red with $PM_{2.5}$ levels in severe level. This haze appeared straight after the wettest week with strong winds in May in Delhi that was affected by the cyclone Tauktae. PM_{10} levels that is affected more by coarse dust shot up 10-folds within 4 hours, while $PM_{2.5}$ rose about 5-folds. At its peak PM_{10} was beyond 1,000 µg/m³ while $PM_{2.5}$ was 469 µg/m³, i.e. 47 percentage (See *Graph 9: PM hourly peak during cyclonic dust event in May 2021*). Winter pollution at hotspots). The haze disappeared almost as quickly as it had appeared. This was a rare meteorological phenomena in which cyclonic systems carried dust along.

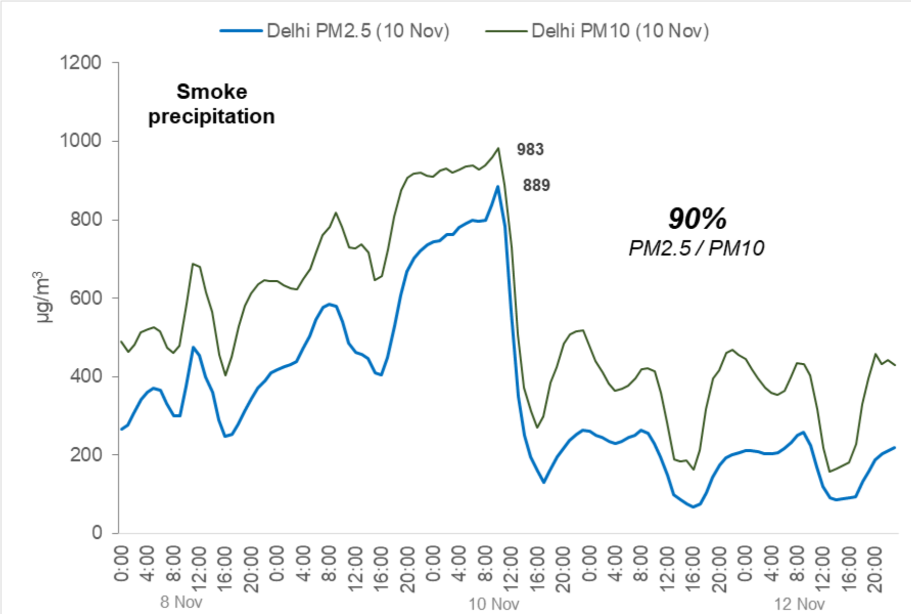
Graph 9: PM hourly peak during cyclonic dust event in May 2021



Note: $PM_{2.5}$ concentration is based on mean of hourly values recorded at all CAAQM stations in the city that have adequate data for the event.
Source: CSE analysis of CPCB's real time air quality data

Winter smog: During the dust event in May 2021, though the PM levels for those few hours were as high as that noted during infamous Delhi smog but it was chemically and physically different. During the winter smog episode that peaked on November 10, 2020 the $PM_{2.5}$ was almost 90 per cent of the PM10 in the air. And this peak had built-up over two days (See *Graph 10: PM hourly peak during smog event in November 2020*). This early November smog is also a result of winds transporting PM and smoke from stubble burning in northern plains. SAFAR noted that over 20 per cent of $PM_{2.5}$ in Delhi came from the stubble fire smoke during this period.

Graph 10: PM hourly peak during smog event in November 2020

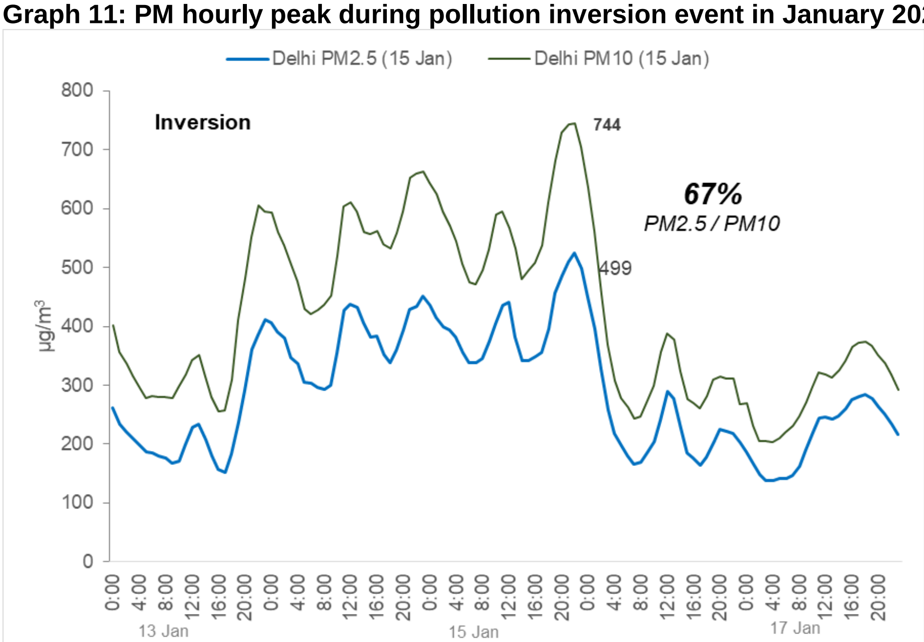


Note: $PM_{2.5}$ concentration is based on mean of hourly values recorded at all CAAQM stations in the city that have adequate data for the event.
Source: CSE analysis of CPCB's real time air quality data

Another high PM event happened in Delhi in January when cold weather and calm wind trapped local pollution spiking PM concentration. Peak of this seasonal phenomena happened on January 15, 2021 when PM_{10} rose to 744 µg/m^3 and $PM_{2.5}$ hit 499 µg/m^3. $PM_{2.5}$ was 67 per cent of the overall PM concentration (See *Graph 11: PM hourly peak during pollution inversion event in January 2021*). This had a diurnal cycle with peak almost always occurring late night, loosely linked to traffic rush hours.

Yet another PM event is associated with Diwali. It builds-up rapidly and is very toxic.

Graph 11: PM hourly peak during pollution inversion event in January 2021



Note: $PM_{2.5}$ concentration is based on mean of hourly values recorded at all CAAQM stations in the city that have adequate data for the event.
Source: CSE analysis of CPCB's real time air quality data

10. Ground-level ozone in Delhi-NCR: Unmasking the hidden and growing health risk

Anumita Roychowdhury and Avikal Somvanshi

Centre for Science and Environment, New Delhi, July, 2021

Centre for Science and Environment (CSE) has alerted from time to time about the growing problem of ground level ozone in Indian cities. While policy and public attention is nearly fully drawn towards very high level of particulate pollution, the challenge of this emerging toxic gas has not attracted adequate policy attention for mitigation and prevention. Inadequate monitoring, limited data and inappropriate methods of trend analysis have weakened the understanding of this growing toxic risk.

Yet the insidious link between ozone and premature deaths representing growing health risk is beginning to get documented in health literature. The most recent 2020 State of Global Air report states that age-standardized rates of death attributable to ozone is among the highest in India and the seasonal 8-hour daily maximum concentrations have recorded one of the highest increases in India between 2010 and 2017– about 17 per cent. This requires deeper understanding of what is going on in different cities and regions to inform mitigation.

City and region specific analysis remains a challenge as ozone monitoring is still very limited in India. Therefore, some of the regions like Delhi-NCR that has relatively better network of monitoring, particularly Delhi with 40 monitoring stations, is an opportunity to understand the ozone behavior. This is an emerging concern in India and requires deeper assessment and insight.

Why ozone needs special attention? Complex chemistry of ozone makes it a difficult pollutant to track and mitigate. Ground level ambient ozone is not directly emitted from any source. It is produced from complex interaction between nitrogen oxides (NOx) and volatile organic compounds (VOCs) that are emitted from vehicles, power plants, factories, and other combustion sources and undergo cyclic reactions in the presence of sunlight to generate ground level ozone. VOCs can also be emitted from natural sources, such as plants. Ozone is also a heat trapping greenhouse gas. Ozone not only builds up in cities but also drifts long distances to form a regional pollutant that makes both local and regional action necessary. Mitigation demands stringent control of gases from all combustion sources. It is therefore necessary that while designing mitigation of particulate matter the action strategy is also calibrated for reduction of ozone precursors.

This highly reactive gas has serious health consequences. Those with respiratory conditions, asthma, chronic obstructive pulmonary disease, and particularly children with premature lungs and older adults are at serious risk. This can inflame and damage airways, make lungs susceptible to infection, aggravate asthma, emphysema, and chronic bronchitis and increase the frequency of asthma attacks leading to increased hospitalisation. This demands exposure management wherever ozone build up is happening. This is the reason why the standard for ground level ozone have been set for hourly and eight-hourly duration unlike 24-hourly and annual standard set for other pollutants.

The investigation: In view of this rising toxic threat and the past data on rising ozone levels, CSE has therefore, embarked on this new assessment of the ozone trends in different regions to understand the varying nature of this problem. The first in this series is the assessment of ozone behaviour over the past three years (2018-2021) in Delhi and the National Capital Region (NCR) which is the hotbed of pollution action.

As part of this air quality tracker initiative, the Urban Data Analytics of Centre for Science and Environment (CSE) seeks to understand the nature of ozone pollution in the region over the last three years and how it has been impacted by the extraordinary pandemic year of 2020 that has witnessed one of the biggest disruptions in the recent times. This is an inflexion point but also an indicator of what may change and yet not changed despite the disruption. This helps to address some of the basic curiosities related to how ozone pollution has persisted even with stopping of activities, and deeper seasonal patterns that unmask the high local pollution that may have been triggered due to the forced change during the lockdown phases. Also if ozone trend analysis is appropriate to capture the growing risk.

Method and data: This assessment has traced trends during different seasons – summer (March-June), winter (October-February) and monsoon (July-September), between 2018 to 2021 July (upto July 18th). The analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. The data has been captured from 81 official stations under the Continuous Ambient Air Quality Monitoring System (CAAQMS) spread across Delhi-NCR. Delhi (40), Gurugram (4), Faridabad (4), Noida (4), Ghaziabad (4), Meerut (3), and Greater Noida (2) that have more than one real-time station. More than 55 million data points have been sourced and analysed from the CPCB portal for this analysis.

Given the volatile and highly localized nature of ozone pollution build-up and its variability across space, and consistent with the global good practice, this analysis has considered station level trends in terms of number of days exceeding the 8-hour standard over time. As ozone formation depends on complex atmospheric chemistry and on photochemical reaction its level varies across time and space horizon. Meteorological parameters such as sunny and warm weather, stagnant wind patterns etc have bearing on its formation.

This has considered global good practice and taken on board the USEPA approach of computing eight-hour averages for a day and then checking for the maximum value among them to capture the daily ozone pollution level. USEPA assesses city-wide or regional AQI based on highest value recorded among all city stations. Thus, trends have been calculated in terms of number of days when the daily level has exceeded the 8-hr standard (referred as exceedance days hereafter). Being a highly reactive gas ozone does not have a 24-hourly or annual standard. A simple city-wide spatial averaging has not been considered for the trend analysis though it has been assessed. It is also not an adequate indicator to understand the health risk from local build up and spatial variation.

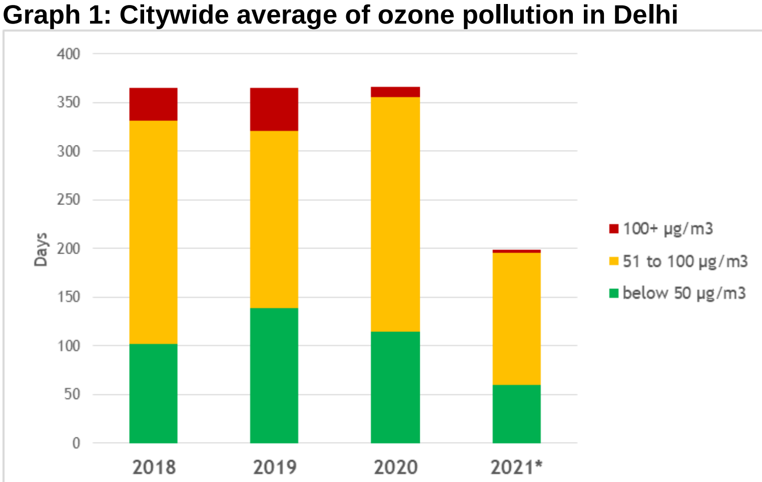
While analysing the data it has also been noted that the ozone data available on CPCB portal never exceeds 200µg/m^3, while data for the corresponding time on Delhi Pollution Control Committee may show higher levels. Therefore, due to this capping of data it is not possible to understand the nature of peaking in the city. This needs to be addressed as there are two sets of standard for ozone – 8-hourly standard of 100 µg/m^3 and one hourly standard at 180 µg/m^3. Capping can make assessment of one-hourly standard challenging. This study has assessed trends only based on 8 hourly standard.

Key highlights of the analysis

Citywide averages hide risk from ozone pollution. Need focus on the pollution build-up across the city to communicate and reduce health risk

The current regulatory practice of computing average of all stations to derive the city-wide average for ozone hugely underestimates the risk. This is also not consistent with the global good practice. The city-wide average shows little exceedance of standards (See *Graph 1: Citywide average of ozone in Delhi*). Even from that yardstick the good air days – that is 50 per cent below the daily 8-hr concentration standard ('good' category under Air Quality Index - AQI) – has started to decline in the city. There were 115 good days in 2020 which is 24 days less than 2019; but higher than 2018 when 'good' ozone days were just 102. As ozone is an emerging problem it is important to adopt appropriate method of trend analysis and risk assessment.

Graph 1: Citywide average of ozone pollution in Delhi

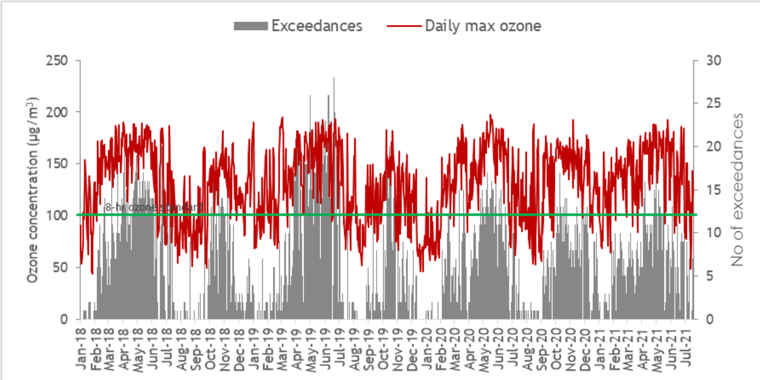


Note: Citywide average was calculated as mean of all stations in the city.
Source: CSE analysis of CPCB real-time data

Globally regulators focus on capturing the worst levels recorded in a day in the city to communicate risk and plan mitigation. USEPA for instance has moved away from spatial averaging even for reporting AQI. According to 40 CFR Appendix G to Part 58 - Uniform Air Quality Index (AQI) and Daily Reporting, the AQI for a region with multiple monitoring stations has to be calculated based on "the highest concentration among all of the monitors within each reporting area". By this method, Delhi city's AQI has to be based on most polluted or the worst station of the day and not the average of all stations (See *Graph 2: Ozone pollution in Delhi if calculated using USEPA method*). This is needed to capture the health risk from ozone.

Citywide average is not a good measure of ozone pollution and severely undermines the AQI's objective of providing health advisory to people sensitive to ozone pollution. Unlike $PM_{2.5}$, ozone build-up is a hyper-local phenomenon (there is recorded evidence of over 100 µg/m^3 difference in ozone level between neighbouring stations) and health impact of it is almost immediate (reason why it has only 1-hourly and 8-hourly standard). Given the fact that on most days more than half of the stations don't exceed the standards, the citywide average systematically water-downs the health risk posed to public living around ozone hotspots and denies them benefit of prevention and action under the AQI system.

Graph 2: Ozone pollution in Delhi if calculated using USEPA method



Note: Daily max ozone for Delhi is calculated as the highest daily value recorded among city stations. The daily value is based on the maximum 8-hr average recorded in a day at a station from a rolling 8-hr average.
Source: CSE analysis of CPCB real-time data using USEPA method

At this moment it is not possible to compute the peak pollution in the city as the data that is available from CPCB portal is capped at 200 µg/m^3 for daily AQI reporting purpose. Ozone data available on CPCB portal never exceeds 200 µg/m^3. But there are timestamps for corresponding time and date for which Delhi Pollution Control Committee has reported values higher than 200 µg/m^3. For instance, during last week of April, 2021, DPCC has reported hourly concentrations exceeding 200 µg/m^3 at Dr Karni Singh Shooting Range AQM station for four continuous days i.e. 26-29 April 2021 that varied between 209 µg/m^3 to 255.2 µg/m^3. Considering the real time data on peak levels is particularly important in the case of ozone pollution as this has immediate trigger effect on vulnerable population, real time data reporting has to be more robust and transparent.

Frequency, distribution and intensity of exceedance of ozone standard

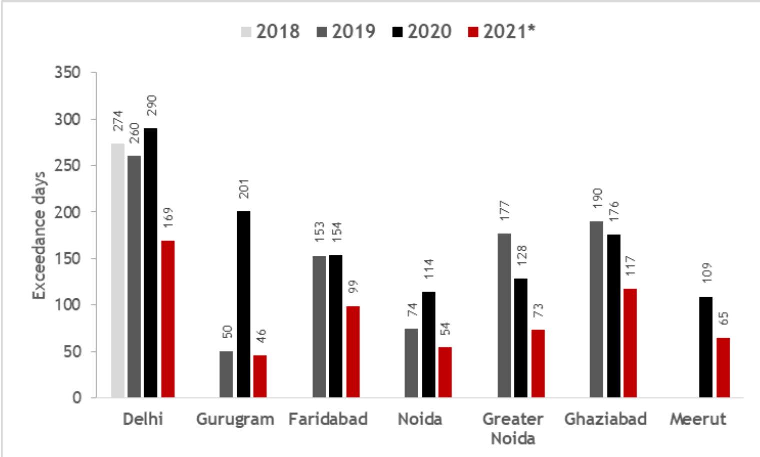
It is the frequency of exceedance in any part of the city and intensity of the pollution that matters more from health and mitigation perspective. Therefore, this analysis has tracked the individual stations and number of days in each station that have exceeded the standard over the years. This has captured three prominent trends – i) exceedance at least in one stations per day over the years; ii) exceedance in multiple stations changing over time - 0 station, 1-5, 6-10, 11-15, 16-20 and 20+ (Note that only Delhi has 40 stations; other cities in NCR have only 1- 4 stations); and; iii) extreme events when all or more than 16 or 20 stations have reported exceedance together on the same day.

- **Exceedance at least in one station per day over the years**: 8-hourly standard for ground-level ozone exceeded at least in one station in Delhi on 290 days in 2020 (this also includes days with multiple stations exceeding standard). It is up by 30 days compared to 2019 and 26 days more than 2018 (See *Graph 3: Annual trend in Ozone pollution in Delhi and major NCR cities*). This year has already recorded 169 days of exceedance during the first six month (Jan-June), increase of 21 days for same period last year.

  Among major cities of NCR, Gurugram saw maximum jump in number of exceedance days between 2019 and 2020. Its tally of 201 days in 2020 was an increase by over 300 per cent from previous year. Nodia also registered a jump but at a relatively moderate 54 per cent. Faridabad recorded no change between 2019 and 2020. Ghaziabad and Greater Noida saw decline in number of exceedance days. Ghaziabad registered 7 per cent lesser exceedance days in 2020 compared to 2019. The drop was of 28 per cent for Greater Noida. Meerut does not have adequate data for 2019 to carry out comparative trend but with 109 days of exceedance in 2020, it was the least polluted major city in NCR.

  Data for 2021 so far shows that exceedance numbers for Ghaizabad, Greater Noida, and Meerut have already crossed last year level in the first six months this year. Faridabad is showing no change this year as well. Noida and Gurugram show drop in their numbers.

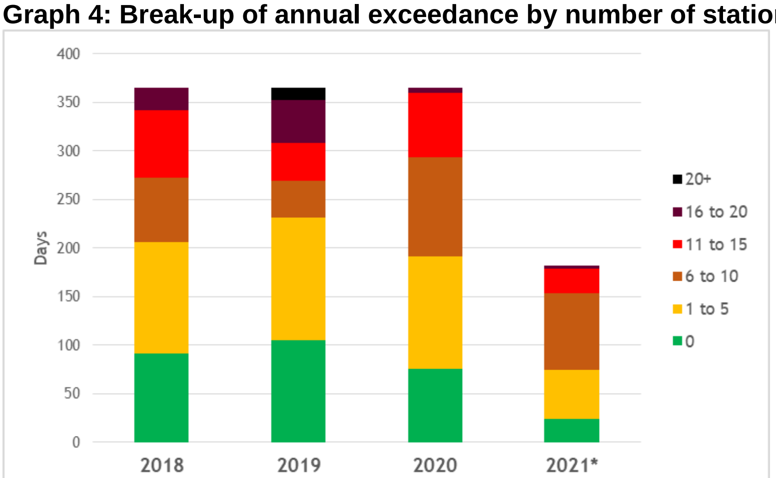
Graph 3: Annual trend in exceedance in at least one station in Delhi and major NCR cities



Note: City level exceedance is based at least one station in the city exceeding the 8-hr ozone standard on a particular day.
Source: CSE analysis of CPCB real-time data

- **Days with multiple stations exceeding the standard are on the rise:** This is a worrying trend. Not only some part of the city is breaching the standard daily, but now multiple locations have also started to breach indicating wider distribution of the risk. Break-up of annual data by number of stations reveals that there are more days when multiple stations exceed the standard. 2020 had 30 per cent more days when six or more stations exceeded the standard compared to 2019. This year already in its first half has registered 108 days when six or more stations exceeded the standard, higher than previous years (See *Graph 4: Break-up of annual exceedance by number of stations for Delhi*).

Graph 4: Break-up of annual exceedance by number of stations for Delhi



Note: Break-up of city level exceedance is based on number of stations in the city exceeding the 8-hr ozone standard on a day.
Source: CSE analysis of CPCB real-time data

- **Extreme events declining:** Despite the overall increase and more distributed instances of exceedance in the cities, extreme events (more than 20 stations exceeding the standard on a single day) have declined. Most instances of extreme event was recorded during the summer of 2019. This roughly coincided with one of the hottest and longest heat wave in North India since the weather reporting started in the region. Both 2020 and 2021 summers have been lighter on heat waves in comparison. Interestingly, even in 2019 the maximum ozone levels were not recorded on the hottest days, in fact the peak of 28 stations exceeding the standard fell on 20th June, 2019, a good week after the heat wave ended. Therefore, it is safe to say that ambient heat is not the primary driver of ozone build-up as generally perceived.

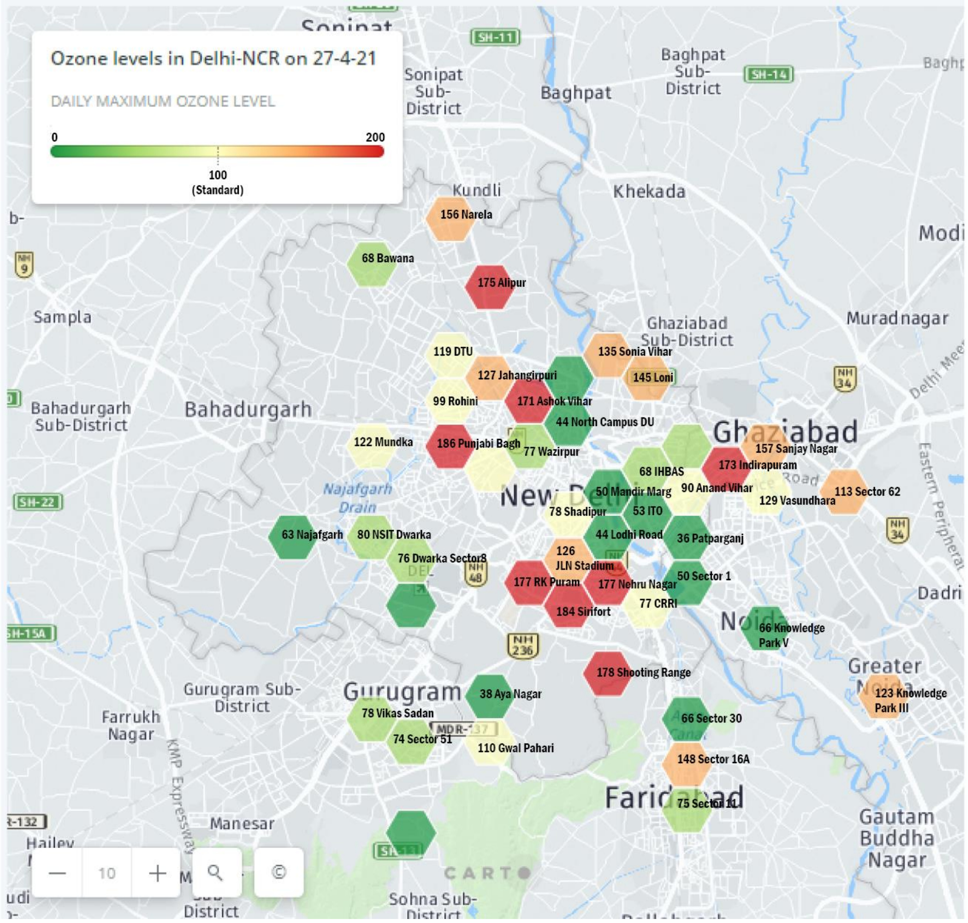
The summer of 2020 and 2021 have been unique due to pandemic lockdowns that drastically reduced non-ozone pollution and also ozone precursors in the city that form ozone. Taking this into account and considering that there were no major heat waves since 2019 in the city, the significant increase in number of days with exceedance at six or more stations in 2020 and 2021 is a major concern. It shows that ozone build-up in the city is happening at higher frequency with a wider geographical spread even with considerably lower supply of anthropogenic and environmental ingredients perceived to be necessary for ozone generation.

Daily levels vary widely cross the city

The ozone level can vary dramatically within the city on any given day. This needs to be tracked on a daily basis.

Illustratively, on 27 April, 2021 Delhi saw high variation between locations – the difference could be as high as 150 µg/m3 (See *Map 1: Spatial variation in ozone pollution a given day*). On this day while the areas adjoining Yamuna, Lyuten's Delhi and west Delhi showed low ozone levels, the levels in south, central, and north Delhi recorded substantially higher levels. South-east Delhi had the highest levels that day. While some locations regularly appear as high ozone pollution zone in the city with high levels and prolonged duration, several other locations experience sporadic instances of exceedance.

Map 1: Spatial variation in ozone pollution a given day (27 April 2021)



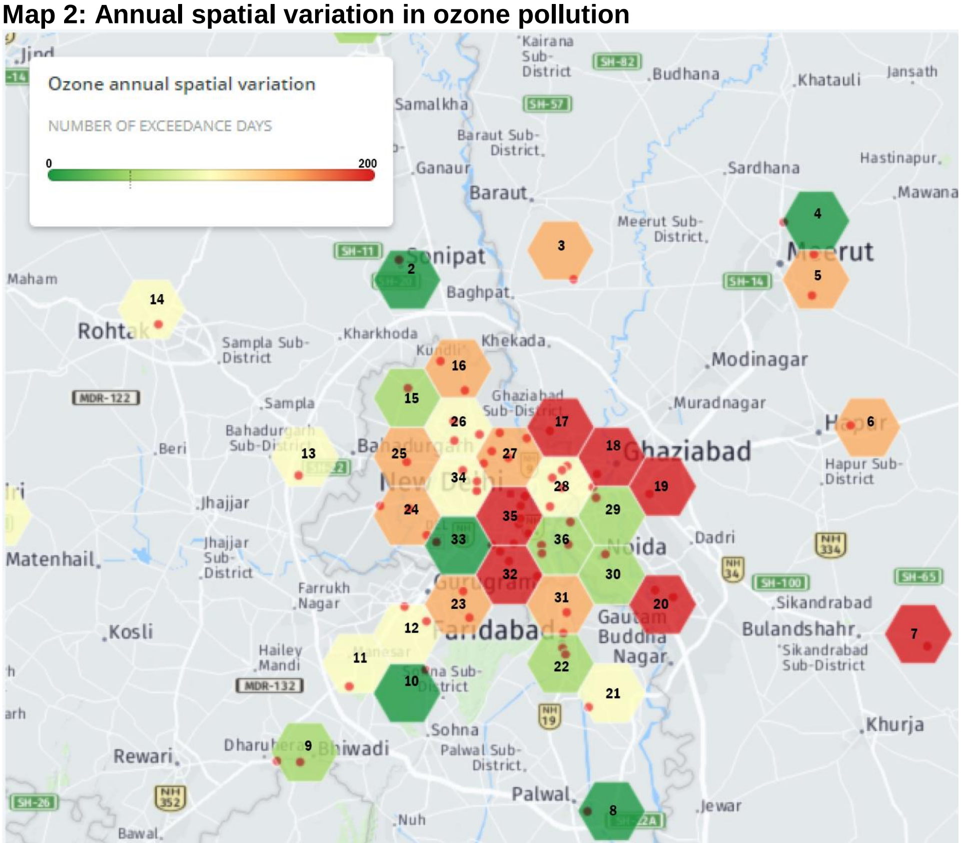
Source: CSE analysis of CPCB real-time data

Cluster of ozone hotspots in South Delhi and Lutyen Delhi

If looked at from the perspective of the number of days exceeding the standard in a year, south, central and north Delhi along with Ghaziabad have recorded higher number of exceedance days. Comparatively the number of days in East Delhi, Nodia, and West Delhi have recorded lesser number of days. (See *Map 2: Annual spatial variation in ozone pollution*).

In South Delhi Dr KS Shooting Range (233 days), Sirifort (150 days), Nehru Nagar (174 days), and Sri Aurobindo Marg (126 days) have more than 120 exceedance days during 2020. They make up four of the top 5 most polluted spots within Delhi. In Lyuten's Delhi JNL Stadium (116 days) and National Stadium (82 days) have relatively high numbers of exceedance days as well. Both have recorded over 80 days of exceedance in 2020. North, East and West Delhi also have few stations recording high exceedance (Sonia Vihar in east Delhi had 142 days of exceedance) but these are not closely clustered as seen in South Delhi-Luyten Delhi region.

Map 2: Annual spatial variation in ozone pollution



List of stations under each cluster number.									
2	Sonipat, HR	15	Bawana, DL	23	TeriGram, Gurugram, HR	28	IHBAS Dilshad Garden, DL	34	Pusa IMD, DL
3	Bagpat, UP	16	Narela, DL	24	Najafgarh, DL	28	ITO, DL	34	Shadipur, DL
4	Pallavpuram, Meerut, UP	16	Alipur, DL	24	Dwarka Sector 8, DL	28	Chandni Chowk IITM, DL	34	Mandir Marg, DL
5	Jaibhimnagar, Meerut, UP	17	Loni, , Ghaziabad, UP	24	NSIT Dwarka, DL	29	Patparganj, DL	35	Sirifort, DL
5	Ganganagar, Meerut, UP	18	Indirapuram, Ghaziabad, UP	25	Mundka, DL	29	Vivek Vihar, DL	35	Nehru Nagar, DL
6	Hapur, UP	18	Vasundhara, Ghaziabad, UP	26	DTU, DL	29	Sector 62, Noida, UP	35	JLN Stadium, DL
7	Bulandshahr , UP	19	Sanjay Nagar, , Ghaziabad, UP	26	Jahangirpuri, DL	30	Sector116, Noida, UP	35	National Stadium, DL
8	Palwal, HR	20	Knowledge Park III, Greater Noida, U	26	Rohini, DL	31	Sector 16A, Faridabad, HR	35	Lodhi Road IMD, DL
9	Dharuhera, HR	20	Knowledge Park V, Greater Noida, U	27	Sonia Vihar, DL	31	New Industrial Town, Faridabad, HR	35	Lodhi Road IITM, DL
9	Bhiwadi, RJ	21	Ballabgarh, HR	27	Ashok Vihar, DL	32	Dr KS Shooting Range, DL	36	Okhla Phase 2, DL
10	Mandikhera, HR	22	Sector 30, , Faridabad, HR	27	Wazirpur, DL	32	Sri Aurobindo Marg, DL	36	CRRI Mathura Road, DL
11	Manesar, HR	22	Sector 11, , Faridabad, HR	27	North Campus DU, DL	32	RK Puram, DL	36	Sector 1, Noida, UP
12	Sector 51, Gurugram, HR	23	Aya Nagar, DL	27	Burari Crossing, DL	33	IGI Airport T3, DL	36	Sector 125, Noida, UP
13	Bahadurgarh, HR	23	Gwal Pahari, Gurugram, HR	28	East Arjun Nagar, DL	34	Punjabi Bagh, DL		
14	Rohtak, HR	23	Vikas Sadan, Gurugram, HR	28	Anand Vihar, DL	34	Pusa DPCC, DL		

Note: Clustered are determined by spatial distance. A cluster can have single or multiple stations within it based on density of stations in the area. Color of cluster represents relative severity of ozone exceedance in that cluster compared to other clusters. Yellow represents median severity. Light green is marginally less than median, dark green is significantly less than the median. Similarly, orange is marginarly higher than the median and red is significantly higher than the median.

Source: CSE analysis of CPCB real-time data

Ground-level ozone is a year-round problem

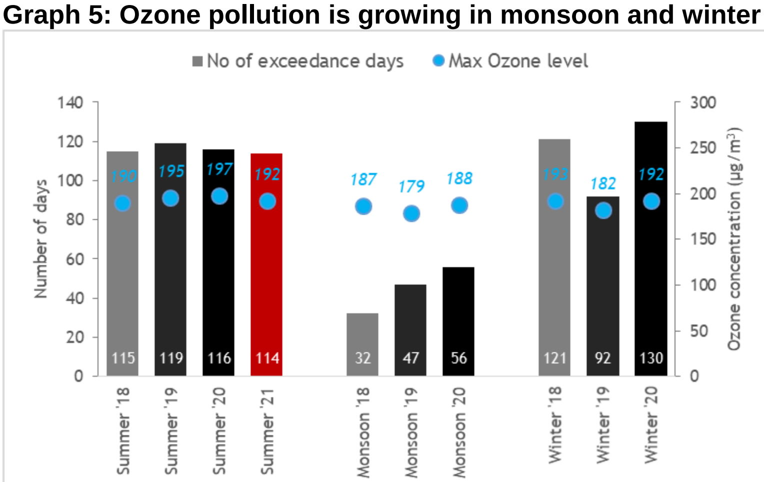
This analysis has also bust the myth that ozone is only a summer problem and is not a concern during colder months. It has come as a surprise how the number of days exceeding the standards across stations are well distributed across the months and seasons. Days breaching the 8-hr standard is happening throughout the year despite varying weather conditions. As the formation of ozone is highly dependent on the local atmospheric chemistry the levels vary widely across the city. It may be more helpful to understand the seasonal pattern of exceedance across monitoring locations. It has been found that there can be days when even with fewer stations exceeding the standards, the city average can be higher than days when more stations across the city exceed the standards. It is necessary to understand this daily spatial spread as the local health impacts can be higher.

This analysis has captured nature and level of exceedance in different parts of the city while also noting the city average level. Moreover, there is another limitation with regard to computing city average and peak levels. As mentioned earlier, currently, in the CPCB portal ozone levels above 200 µg/m^3 is not recorded. This capping does not allow estimation of peak levels and real world maximum averages for cities. When levels breach the standard in any monitoring location the levels reach nearly the same maximum 8-hr ozone levels. This is certainly a side-effect of capping of maximum value reported by CPCB. Thus, the capping stunts the reported peak level as 8-hr average cannot breach 200 µg/m^3.

Ozone is a problem of all seasons – even winter and monsoon

The stunning aspect of the ozone phenomenon is that this problem of ozone that is normally treated as a sunny summer problem, is evidently a concern even during the winter. This has not been adequately tracked and studied to inform policy. This analysis has found unsafe ozone levels during winter and especially during smog episode making the smog more toxic. (See *Graph 5: Ozone pollution is growing in monsoon and winter*).

Graph 5: Ozone pollution is growing in monsoon and winter



Source: CSE analysis of CPCB real-time data

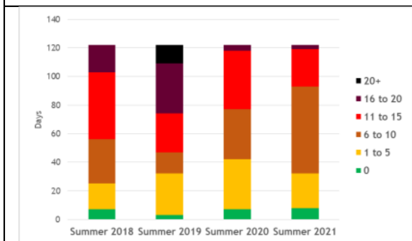
Most of the shift in annual number are due to uncharacteristic increase in ozone during monsoon and winter. Winter of 2020-21 shows a dramatic 84 per cent increase in number of days with six or more stations exceeding the standard. In fact, there is a 32 per cent increase in number of days when more than 10 stations exceeded the standard during 2020-21 winter compared to previous two winters (See *Graph 6: Seasonal break-up of annual exceedance by number of stations: a) Summer, b) Monsoon, c) Winter*).
In comparison, summer data looks quite stable over years. 2021 summer has had 90 days with six or more stations exceeding the standard, which is identical to 2019 summer and 10 days more than 2020 summer. This is despite the fact 2021 summer was one of the mildest in recent years with no severe heat waves reported.

This shift in seasonal pattern is worrying given the fact that monsoon and the foggy-smoggy winters of Delhi that are characterized by low sunshine are not expected to be conducive for ozone formation. This means the strategy for combating ozone in the city would have to be reworked and start looking beyond summer action plan.

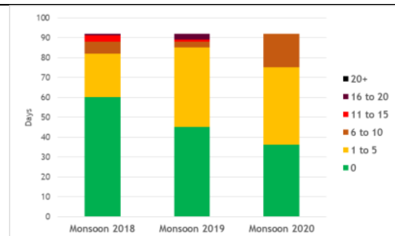
Monsoon data is another shocker. 2020 monsoon saw 140 per cent more days with six or more stations exceeding the standard compared to 2019 monsoon. If looked from the perspective from days when no exceedance was recorded in the city, 2020 monsoon had only 36 such days, while the number for 2019 monsoon was 45 days and for 2018 monsoon 60 days.

Graph 6: Seasonal break-up of annual exceedance by number of stations:

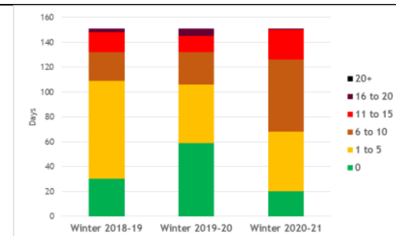
Summer



Monsoon



Winter



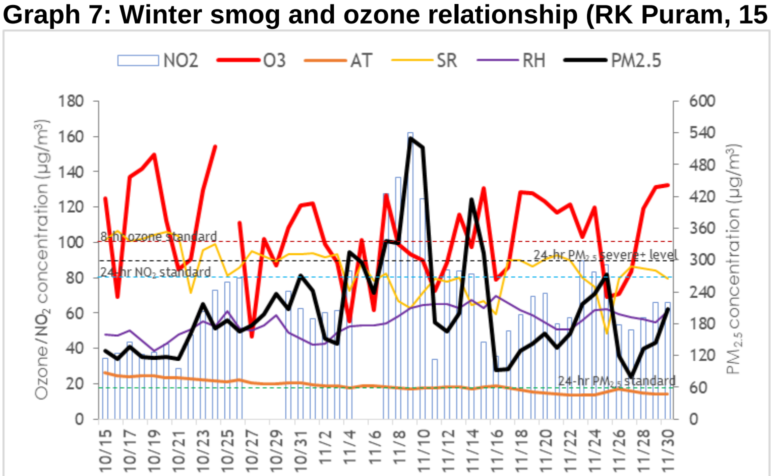
Note: Break-up of city level exceedance is based on number of stations in the city exceeding the 8-hr ozone standard on a particular day. Summer is considered from March to June, monsoon from July to September, and winter from October to February.
Source: CSE analysis of CPCB real-time data

Ozone during winter smog episodes

How ozone behaves during the winter smog episode is still the least understood phenomenon. To understand this, data on Ozone, $PM_{2.5}$ and NO_2 levels in RK Puram were analysed for the smog season of 2020. It is a matter of concern that ozone has remained high throughout the winter smog season. There is minor drop noted on the peak smog day when the solar radiation was considerably lower, but as soon as the wind improved and removed $PM_{2.5}$, ozone levels spiked up. During these few days, even high level of NO_2 in the air did not seem to have considerable impact on reducing ozone levels (See *Graph 7: Winter Smog and ozone relationship*).

This shows how dangerously elevated levels of ozone and NO_2 remain masked by the big build-up of $PM_{2.5}$ levels and fails to draw public and policy attention. This neglect can increase health risk. Elevated level of ozone and NO_2 makes the smog more toxic. Further, ozone builds up again after thinning of the smog episode means that the toxic treat persists during winter.

Graph 7: Winter smog and ozone relationship (RK Puram, 15 Oct – 30 Nov 2020)



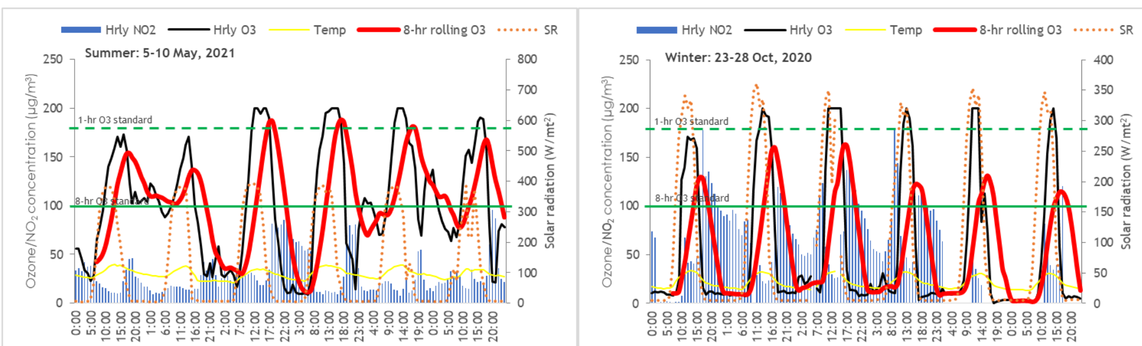
Source: CSE analysis of CPCB real-time data

Meteorology aids in ozone formation both during summer and winter

It is now well understood that sunshine plays a critical role in triggering photochemical reaction between gases to form ozone and it is typically expected that ozone is a bigger problem in summer. But the problem seems to be quite uniformly spread across seasons. To understand this phenomenon, ozone data from two stations RK Puram and Sirifort were correlated with solar radiation, temperature, and NO_2 to understand spatial differences and difference between summer and winter. It was noted that hourly peak ozone level in the day perfectly corresponds with the peak solar radiation but it is not proportional. Quantum of ozone generated at 600-700 W/mt^2 of solar radiation during summer was identical to ozone generated at 100-300 W/mt^2 of solar radiation during winter. However, temperature does not seem to have as much impact on increasing the concentration. But night time ozone seems to have some relationship with higher night-time temperature. This needs to be further investigated. Similarly, NO_2 and ozone that has a very strong negative relationship during summer somewhat weakens during winter. Winter ozone has a much defined diurnal cycle compared to summer. This can also be further investigated.

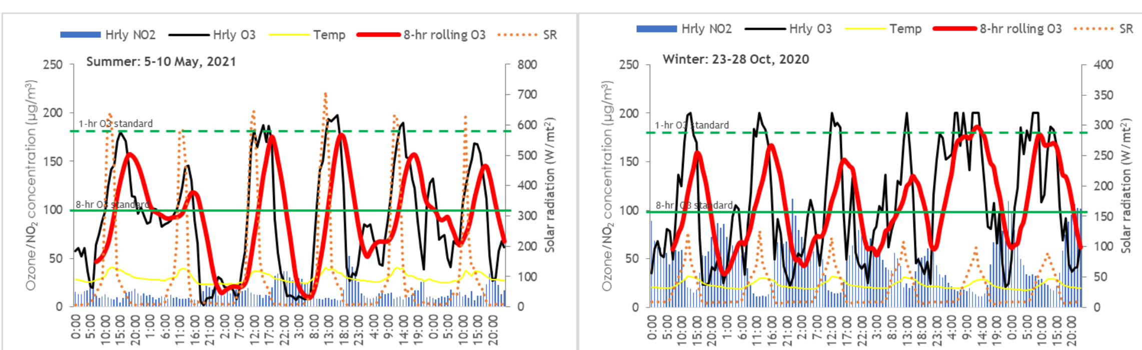
In RK Puram, the rolling 8hr average remained above the standard for significant 31 hours between 5th and 6th of May, 2021 (See *Graph 8: Trend in hourly ozone pollution at RK Puram*). Drop in ozone level during evening rush hours was noted but levels rapidly build-up post 10-11 PM indicating presence of low level inversion in the neighbourhood. Similar summer trend was noted at Sirifort (See *Graph 9: Trend in hourly ozone pollution at Sirifort*).

Graph 8: Trend in hourly ozone pollution at RK Puram
i) Summer (5-10 May 2021) **ii) Winter (23-29 Oct 2020)**



Source: CSE analysis of CPCB real-time data

Graph 9: Trend in hourly ozone pollution at Sirifort
i) Summer (5-10 May 2021) **ii) Winter (23-29 Oct 2020)**



Source: CSE analysis of CPCB real-time data

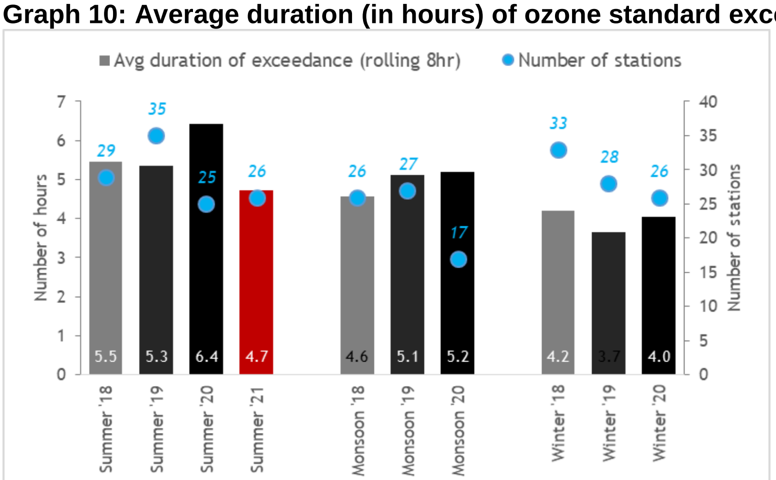
Pandemic effect – ozone problem persisted and duration of ozone exceedance also increased

Ozone behaved very differently from other pollutants during the lockdown phases. While particulate and NOx levels dropped quite significantly and predictably, ozone levels recorded high levels in several locations. During the pandemic year of 2020, days recording exceedance was also noted during monsoon months.

Also the duration of high elevated levels for number of hours increased during the lockdown phases. For instance, the stations noting exceedance of the 8-hr ozone standard during the summer of 2019 recorded continuous elevation for about 5.3 hours during the day. But this duration jumped by 20 per cent during the 2020 summer lockdown due to the pandemic. This increase in duration of elevated levels was also noted during monsoon and winter that followed in 2020 (See *Graph 10: Average duration (in hours) of ozone standard exceedance in a day*).

This needs to be studied further in terms of how the ratio between NOx and VOC level behaved during these phases to understand the deeper pattern that contributed to ozone formation. It is also quite possible that with lower day time and night time NOx during this period (largely owing to reduced traffic) ozone had less chance of further reacting to get mopped up. This might have slowed down the breaking process of ozone leading to longer duration and elevation of heightened levels.

Graph 10: Average duration (in hours) of ozone standard exceedance in a day



Source: CSE analysis of CPCB real-time data

It is also notable that even though the regular ozone hotspots in the city registered prolonged duration of elevated levels, several locations that otherwise recorded sporadic instances of exceedance before the pandemic, did not experience any exceedance during the pandemic. For example, DU North Campus, Aya Nagar, and Patparganj which had registered a 6-10 days of exceedance in summer of 2019 have not registered a single day with exceedance during the summer of 2020 and 2021.

But there are also places that were not noted as ozone hotspots before the pandemic but registered significant number of days with exceedances during the pandemic. Ananda Vihar is most striking among such places. It had less than 5 days of exceedances during previous two summers (2018 and 2019) but during the pandemic summer it registered 49 days of exceedances. It highlights the volatile nature of ozone formation and build-up which is aided by calm environmental conditions which was made available by lockdowns.

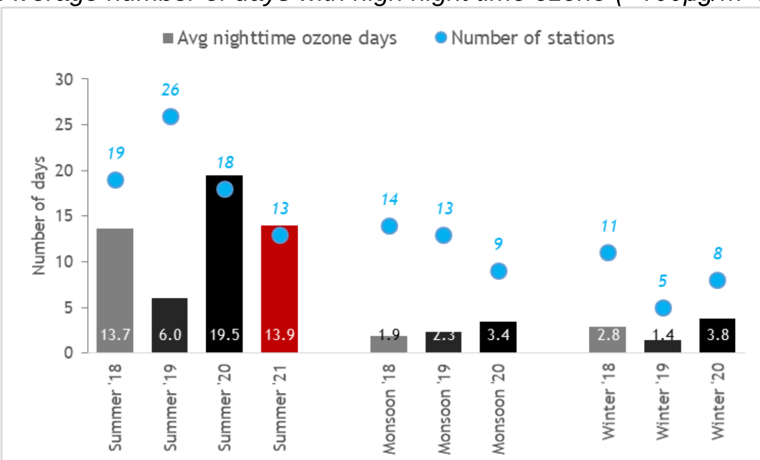
Night time ozone higher during pandemic lockdown and night curfews

Ozone generally disintegrates in the atmosphere after sunset as in the absence of sunlight NOx in the air attacks and neutralizes it. But as evident from the data, elevated ozone level has been noticed during night time. International scientific literature has also noted this phenomenon in other countries stating that this is connected with persisting low level inversions, under which the photochemically generated ozone is trapped during the day. With the gradual setting in of inversion towards the evening and reduced traffic, ozone levels rise, remaining above standard even after midnight. This uncommon phenomena seems to have become common-place in Delhi during the pandemic when number of day with high night time levels have breached 100µg/m^3 after 10PM (See *Graph 11: Night time ozone in Delhi*).

Hourly ozone level were found to be in excess of 100 µg/m^3 beyond 10PM at 18 Delhi stations during the Pandemic summer of 2020. These stations on an average registered this unusually high levels on 19-20 nights during the summer. Dr Karni Singh Shooting Range with 54 nights was the most affected with nighttime ozone, followed by Sirifort (44 nights) and Nehru Nagar (34 nights). Numbers are relatively lower this summer.

Graph 11: Night time ozone pollution in Delhi

Average number of days with high night time ozone (>100µg/m^3 after 10PM) in Delhi



Source: CSE analysis of CPCB real-time data

Ozone pollution in major NCR cities

Ozone is also an emerging problem in the NCR. After Delhi, Faridabad is next on the list with the station at Sector 16A recording 152 days of exceedance during 2020. There is considerable spatial variation among Faridabad stations. Station at New Industrial Town recorded just three instances of exceedance in 2020, two of which happened during winter. Stations at Gurugram and Ghaziabad also have very high number of days exceeding the standard. There are more exceedances recorded during summer than winter among Ghaziabad stations.

All stations in Ghaziabad have very high exceedances while Gurugram is more like neighbouring Faridabad with considerable spatial variation among its stations. Vikas Sadan with 139 days of exceedance was the most polluted part of the city while Terigram recorded just 35 days of exceedances (mostly during winter). Noida has shown the least number of days with exceedance among the big four cities in NCR, with three of its four of its stations recording less than 20 days of exceedance in 2020. Neighbouring Greater Noida has considerably higher number of exceedances, with majority happening during winters. (See *Annexure 1: Number of days that exceeded the 8-hourly ozone standard in different locations of Delhi and NCR*).

Top twenty locations in Delhi and NCR with higher number of days with exceedance shows ozone is also a small town problem

When cities and towns in Delhi and NCR are ranked in terms of number of days exceeding the standards, even smaller towns of NCR including Bulandshahr in Uttar Pradesh and Bhiwani in Haryana are next on the list of ozone afflicted towns and cities. Dr Karni Singh Shooting Range, Bulandshahr, and Nehru Nagar were the most polluted spots in Delhi-NCR in 2020. Bulandshahr at second spot is shockingly as smaller cities are usually not seen as ozone hotspots. Bhiwani, HR is another small town that makes the list at 11th spot, and its 2021 data so far is indicating it might move up the list this year. Stations from Gurugram, Ghaziabad and Faridabad also feature among the top 10 (See *Table 1: Top 20 locations with highest ozone pollution in NCR*).

However, the small towns have only one monitoring station which is not adequate to capture the spatial variation and its location may also not be optimum for capturing ozone pollution as it is highly localized. Inadequate data reaffirms the fact that there is no room for complacency.

Table 1: Top 20 locations with highest ozone pollution in NCR

Rank	Station name	2020 exceedance days	2021 exceedance days so far
1	Dr KS Shooting Range, DL	233	135
2	Bulandshahr, UP	214	119
3	Nehru Nagar, DL	174	120
4	Sector 16A, Faridabad, HR	152	94
5	Sirifort, DL	150	119
6	Sonia Vihar, DL	142	57
7	Vikas Sadan, Gurugram, HR	139	19
8	Indirapuram, Ghaziabad, UP	129	83
9	Sri Aurobindo Marg, DL	126	134
10	DTU, DL	122	17
11	Bhiwani, HR	120	93
12	JLN Stadium, DL	116	33
13	Sector 51, Gurugram, HR	110	9
14	Jai Bhim Nagar, Meerut, UP	106	44
15	Knowledge Park III, Greater Noida, UP	104	38
16	Sector 1, Noida, UP	103	9
17	Dwarka Sector 8, DL	102	4
18	Bawana, DL	100	2
19	Knowledge Park V, Greater Noida, UP	89	50
20	RK Puram, DL	87	90
Note: Ranks are based on number of exceedance days recorded in 2020. Data for 2021 is up till 18 July, and is meant to provide information about current year but has not been used for ranking calculation. Many locations lower in this list have recorded exceptionally high rate of exceedances in 2021 compared to 2020 and are thus highlighted in yellow.			

Source: CSE analysis of CPCB real-time data

Daily trend and Air Quality Index bulletin must capture the intensity and spread of ozone pollution across locations

The analysis has shown that the current method of spatial averaging of ozone for city-wide averages for computing city-wide trend and AQI may not effectively capture the most polluted part of the day and therefore the magnitude of the danger. Nature of ozone pollution is such that at any given day only a fraction of city's monitoring stations would exceed the standard. By averaging all stations for daily AQI bulletin severity of the localized impact of zone pollution gets masked.

Further, the CPCB AQI bulletin considers only an 8 AM-4 PM concentration average of ozone to compute and compare with the eight-hour standard. But this analysis shows that this approach is not correct as it may fail to include the hours with higher elevation. Ozone concentration generally peaks in the late afternoon in Delhi and the usual peak hour is either 4-5 PM or 5-6 PM during summer. Therefore, exclusively using 8 AM-4 PM averages leaves out the most polluted hours from the calculations. For instance, on July 16, 2021, the eight-hour average for RK Puram for 8 AM-4 PM stood at 96 µg/m^3, just below the standard. But the eight-hour average for 10 AM-7 PM rose to 103 µg/m^3, above the standard. In fact, data shows that even the 4 PM-midnight average can exceed the standard, something CPCB's AQI bulletin currently fails to inform.

This approach has to change. For instance, the USEPA uses maximum 8-hr value recorded in a day to report daily AQI. The AQI is also station based. They do not do spatial averaging. Additionally, they also do real time AQI release under their AirNow program which is updated every hour for ozone.[1] Moreover, USEPA's AQI related health warnings are different ozone and particulate matter. If ozone is the lead pollutant of the day the warning will be more explicit as ozone is sensitive for more vulnerable groups.

[1] USEPA 2018, Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI).

Need urgent response

Address health risk from ozone in national clean air programme and in comprehensive clean air action plan for Delhi NCR: This analysis has exposed that ground level ozone is emerging as a serious health risk in the region. This highly reactive gas has serious health consequences for those suffering from respiratory conditions and asthma. This needs refined action to reduce the risk.

Refine the comprehensive clean air action plan to include ozone mitigation strategies: The comprehensive clean air action plan as well as graded response action plan that are being currently implemented in Delhi and NCR need to be recalibrated to reduce the key precursor gases – particularly NOx and VOCs that come entirely from the combustion sources. Their changing ratio and local atmospheric conditions need to be assessed to control and prevent ozone risk. Specific action is needed to control gases from combustion sources. If action plan focuses only on controlling particulate pollution, ozone can grow as a bigger threat that will be difficult to undo. Over emphasis on dust control to reduce particulate matter and other particulate related action may increase the ozone problem. This demands integrated reduction strategy for both the pollutants.

Take strong action on high emitters of NOx and VOCs – vehicles and industry: The recent source inventory studies in Delhi have shown that the transport sector is the highest contributor of NOx and VOCs in Delhi followed by industry and other sources. The SAFAR emission inventory of 2018 shows that transport is responsible for 62.5 per cent of NOx load and industry 24 per cent. In the case of VOCs transport is responsible for as much as 90.4 per cent followed by industry at 9 per cent. Similarly, the ARAI-TERI inventory that has considered more pollution sources indicate that transport is responsible for 81.4 per cent of NOx load followed by power plant at 7.2 per cent. For VOCs transport is responsible for 80.1 per cent followed by solvents at 13.4 per cent. Other contributors are waste burning. This demands immediate refinement of measures to target vehicles, transport and industrial sources in Delhi. Over emphasis on dust control for particulate pollution can detract attention from the more toxic sources.

While scaling up public transport and vehicle electrification, also restrain vehicle numbers with parking policy and pricing, congestion pricing and road design to promote walking cycling and use of public transport. Industrial sector will require massive scaling up of clean fuels and control of dirty fuels especially small scale units and strong controls on stack emissions. Also strengthen municipal systems for decentralised systems for waste segregation, material recovery and reuse and move towards zero landfill target.

Include ozone in winter smog mitigation plan: It is deeply worrying that the ozone levels have been found to be exceeding the mark of 100 µg/m^3 during both summer and winter and is highly sensitive to solar radiation. In fact, not only the number of days exceeding the standard in different locations during winter is high, it also spikes after the dimming effect of particulate matter is reduced after dissipation of the smog episodes. Both NOx and VOCs will have to be effectively reduced to tame ozone. Also, the other benefit of reducing gases includes reduction of particulate concentration as these gases also form secondary particulate and contribute towards increase in particulate concentration. The IIT Kanpur source apportionment study has shown that secondary particulate can be as high as 25 per cent of the particulate concentration during the winter in Delhi.

Refine the approach to ozone trend analysis and AQI reporting to provide ozone appropriate advisory on days when ozone is the lead pollutant: As ozone is a very harmful gas it is important to calibrate AQI to report the most polluted 8 hr average of the day, ideally making it an hourly alert. Also the current practice of only city averaging needs to change to include alerts based on the worst affected area as is the global good practice. Moreover, any capping of data needs to be avoided for real time reporting to enable assessment of peak levels and health risk in the city. Capping can hamper assessment of both hourly trend and 8 hourly trend, as ozone standards are set for one hour (180 µg/m^3) average and 8 hour average (100 µg/m^3). Such short term standards are needed to reduce the health risk from this extremely reactive and harmful gas.

Annexure 1: Number of days that exceeded the 8-hourly ozone standard in different locations of Delhi and NCR (2020 and 2021)

Station name	2020 exceedance days	Seasonal exceedance days*			
		2021 summer	2020-21 winter	2020 monsoon	2020 summer
Delhi					
Dr KS Shooting Range, DL	**233**	103	87	43	105
Sirifort, DL	**150**	84	96	16	70
Nehru Nagar, DL	**174**	94	69	26	87
Sri Aurobindo Marg, DL	**126**	100	54	0	72
RK Puram, DL	**87**	83	56	14	20
Punjabi Bagh, DL	**19**	88	44	0	0
Sonia Vihar, DL	**142**	52	59	16	46
Ashok Vihar, DL	**43**	67	40	0	8
Najafgarh, DL	**74**	13	82	0	6
Narela, DL	**87**	49	39	0	43
Alipur, DL	**58**	45	32	0	27
JLN Stadium, DL	**116**	25	33	15	61
National Stadium, DL	**82**	3	34	26	26
Mundka, DL	**78**	23	28	0	39
Dwarka Sector 8, DL	**102**	2	36	10	56
DTU, DL	**122**	17	15	15	85
Jahangirpuri, DL	**27**	22	25	0	2
Okhla Phase 2, DL	**18**	27	9	7	1
East Arjun Nagar, DL	**19**	1	38	0	0
Bawana, DL	**100**	2	16	4	70
Anand Vihar, DL	**64**	6	2	13	49
Pusa DPCC, DL	**35**	11	0	4	29
IGI Airport T3, DL	**5**	0	3	2	0
Pusa IMD, DL	**4**	0	3	1	0
Shadipur, DL	**22**	3	0	0	22
Rohini, DL	**0**	3	0	0	0
Wazirpur, DL	**3**	0	3	0	2
CRRI Mathura Road, DL	**1**	1	0	1	0
NSIT Dwarka, DL	**34**	1	1	0	33
Lodhi Road IMD, DL	**2**	0	0	2	0
Mandir Marg, DL	**2**	0	1	0	0
IHBAS Dilshad Garden, DL	**0**	0	0	0	0
ITO, DL	**13**	0	0	0	13
North Campus DU, DL	**0**	0	0	0	0
Aya Nagar, DL	**0**	0	0	0	0
Burari Crossing, DL	**0**	0	0	0	0
Chandni Chowk IITM, DL	**0**	0	0	0	0
Lodhi Road IITM, DL	**0**	0	0	0	0
Patparganj, DL	**0**	0	0	0	0
Vivek Vihar, DL	**1**	0	0	0	1
Haryana					
Faridabad					
Sector 16A, Faridabad, HR	**152**	82	32	24	77
New Industrial Town, Faridabad, HR	**3**	32	0	0	3
Sector 30, , Faridabad, HR	**5**	12	4	0	1
Sector 11, , Faridabad, HR	**6**	1	2	0	4
Gurugram					
Gwal Pahari, Gurugram, HR	**79**	31	63	12	6
Vikas Sadan, Gurugram, HR	**139**	19	26	10	84
Sector 51, Gurugram, HR	**110**	9	8	9	93
TeriGram, Gurugram, HR	**35**	0	4	0	31
Other Haryana cities					
Bhiwani, HR	**120**	77	82	14	23
Charkhi Dadri, HR	**69**	0	32	10	27
Bahadurgarh, HR	**29**	19	21	0	8
Manesar, HR	**32**	6	30	0	2
Ballabgarh, HR	**37**	1	0	31	6
Rohtak, HR	**14**	18	14	0	0

	Panipat, HR	**46**	0	28	0	17
	Jind, HR	**50**	9	0	7	40
	Karnal, HR	**5**	13	0	0	5
	Dharuhera, HR	**13**	1	6	0	6
	Mandikhera, HR	**32**	0	0	0	25
	Narnaul, HR	**0**	0	0	0	0
	Palwal, HR	**0**	0	0	0	0
	Sonipat, HR	**0**	0	0	0	0
Uttar Pradesh						
Ghaziabad						
	Indirapuram, Ghaziabad, UP	**129**	66	55	32	57
	Vasundhara, Ghaziabad, UP	**82**	64	22	28	26
	Sanjay Nagar, , Ghaziabad, UP	**43**	67	23	7	13
	Loni, , Ghaziabad, UP	**68**	60	27	2	49
Greater Noida						
	Knowledge Park III, Greater Noida, UP	**104**	30	62	7	37
	Knowledge Park V, Greater Noida, UP	**89**	42	41	5	41
Meerut						
	Jaibhimnagar, Meerut, UP	**106**	36	63	9	26
	Ganganagar, Meerut, UP	**5**	18	10	0	0
	Pallavpuram, Meerut, UP	**0**	5	0	0	0
Noida						
	Sector 62, Noida, UP	**19**	24	2	0	16
	Sector116, Noida, UP	**6**	18	7	1	1
	Sector 1, Noida, UP	**103**	2	4	13	68
	Sector 125, Noida, UP	**1**	0	1	0	0
Other UP cities						
	Bulandshahr , UP	**214**	92	80	16	93
	Bagpat, UP	**76**	4	55	14	9
	Hapur, UP	**18**	44	18	0	0
	Muzaffarnagar, UP	**0**	0	0	0	0
Rajasthan						
	Bhiwadi, RJ	**7**	4	4	0	2
	Alwar, RJ	**12**	0	6	0	3

Note: Stations are arranged based geography and on any kind of ranking in this table.
* Seasonal data provided in the table will not add up to 2020 figure as 2020-21 winter includes data of Jan-Feb of 2021. Summer is considered from March to June, monsoon from July to September, and winter from October to February.
Source: CSE analysis of CPCB real-time data

Annexure: List of CAAQM stations used in the study					
State		City		Station Name	
1	Andhra Pradesh	1	Amaravati	1	Secretariat, Amaravati - APPCB
		2	Rajamahendravaram	2	Anand Kala Kshetram, Rajamahendravaram - APPCB
		3	Tirupati	3	Tirumala, Tirupati - APPCB
		4	Visakhapatnam	4	GVM Corporation, Visakhapatnam - APPCB
2	Assam	5	Guwahati	5	Railway Colony, Guwahati - APCB
				6	Pan Bazaar, Guwahati - APCB
3	Bihar	6	Gaya	7	Collectorate, Gaya - BSPCB
				8	SFTI Kusdihra, Gaya - BSPCB
		7	Hajipur	9	Industrial Area, Hajipur - BSPCB
		8	Muzaffarpur	10	Muzaffarpur Collectorate, Muzaffarpur - BSPCB
				11	Buddha Colony, Muzaffarpur - BSPCB
		9	Patna	12	IGSC Planetarium Complex, Patna - BSPCB
				13	Muradpur, Patna - BSPCB
				14	Samanpura, Patna - BSPCB
				15	Rajbansi Nagar, Patna - BSPCB
				16	DRM Office Danapur, Patna - BSPCB
				17	Govt. High School Shikarpur, Patna - BSPCB
4	Chandigarh	10	Chandigarh	18	Sector-25, Chandigarh - CPCC
5	Delhi	11	Delhi	19	Alipur, Delhi - DPCC
				20	Shadipur, Delhi - CPCB
				21	IHBAS, Dilshad Garden, Delhi - CPCB
				22	NSIT Dwarka, Delhi - CPCB
				23	DTU, Delhi - CPCB
				24	ITO, Delhi - CPCB
				25	Sirifort, Delhi - CPCB
				26	Mandir Marg, Delhi - DPCC
				27	Anand Vihar, Delhi - DPCC
				28	R K Puram, Delhi - DPCC
				29	Punjabi Bagh, Delhi - DPCC
				30	Aya Nagar, Delhi - IMD
				31	Lodhi Road, Delhi - IMD
				32	North Campus, DU, Delhi - IMD
				33	Burari Crossing, Delhi - IMD
				34	CRRI Mathura Road, Delhi - IMD
				35	Pusa, Delhi - IMD
				36	IGI Airport (T3), Delhi - IMD
				37	East Arjun Nagar, Delhi - CPCB
				38	Ashok Vihar, Delhi - DPCC
				39	Jawaharlal Nehru Stadium, Delhi - DPCC
				40	Nehru Nagar, Delhi - DPCC
				41	Dwarka-Sector 8, Delhi - DPCC
				42	Dr. Karni Singh Shooting Range, Delhi - DPCC
				43	Patparganj, Delhi - DPCC
				44	Sonia Vihar, Delhi - DPCC
				45	Jahangirpuri, Delhi - DPCC
				46	Rohini, Delhi - DPCC
				47	Najafgarh, Delhi - DPCC
				48	Vivek Vihar, Delhi - DPCC
				49	Major Dhyan Chand National Stadium, Delhi - DPCC
				50	Narela, Delhi - DPCC
				51	Okhla Phase-2, Delhi - DPCC
				52	Wazirpur, Delhi - DPCC
				53	Bawana, Delhi - DPCC
				54	Sri Aurobindo Marg, Delhi - DPCC
				55	Pusa, Delhi - DPCC
				56	Mundka, Delhi - DPCC
				57	Lodhi Road, Delhi - IITM
				58	Chandni Chowk, Delhi - IITM
6	Gujarat	12	Ahmedabad	59	Maninagar, Ahmedabad - GPCB
				60	Phase-4 GIDC, Vatva - GPCB

		13	Ankleshwar	61	GIDC, Ankleshwar - GPCB
		14	GandhiNagar	62	Sector-10, Gandhinagar - GPCB
		15	Vapi	63	Phase-1 GIDC, Vapi - GPCB
7	Haryana	16	Ambala	64	Patti Mehar, Ambala - HSPCB
		17	Bahadurgarh	65	Arya Nagar, Bahadurgarh - HSPCB
		18	Ballabgarh	66	Nathu Colony, Ballabgarh - HSPCB
		19	Bhiwani	67	H.B. Colony, Bhiwani - HSPCB
		20	Charkhi Dadri	68	Mini Secretariat, Charkhi Dadri - HSPCB
		21	Dharuhera	69	Municipal Corporation Office, Dharuhera - HSPCB
		22	Faridabad	70	Sector- 16A, Faridabad - HSPCB
				71	New Industrial Town, Faridabad - HSPCB
				72	Sector 11, Faridabad - HSPCB
				73	Sector 30, Faridabad - HSPCB
		23	Fatehabad	74	Huda Sector, Fatehabad - HSPCB
		24	Gurgaon	75	Vikas Sadan, Gurugram - HSPCB
				76	NISE Gwal Pahari, Gurugram - IMD
				77	Sector-51, Gurugram - HSPCB
				78	Teri Gram, Gurugram - HSPCB
		25	Hisar	79	Urban Estate-II, Hisar - HSPCB
		26	Jind	80	Police Lines, Jind - HSPCB
		27	Kaithal	81	Rishi Nagar, Kaithal - HSPCB
		28	Karnal	82	Sector-12, Karnal - HSPCB
		29	Kurukshetra	83	Sector-7, Kurukshetra - HSPCB
		30	Mandikhera	84	General Hospital, Mandikhera - HSPCB
		31	Manesar	85	Sector-2 IMT, Manesar - HSPCB
		32	Narnaul	86	Shastri Nagar, Narnaul - HSPCB
		33	Palwal	87	Shyam Nagar, Palwal - HSPCB
		34	Panchkula	88	Sector-6, Panchkula - HSPCB
		35	Panipat	89	Sector-18, Panipat - HSPCB
		36	Rohtak	90	MD University, Rohtak - HSPCB
		37	Sirsa	91	F-Block, Sirsa - HSPCB
		38	Sonipat	92	Murthal, Sonipat - HSPCB
		39	Yamunanagar	93	Gobind Pura, Yamuna Nagar - HSPCB
8	Karnataka	40	Bagalkot	94	Vidayagiri, Bagalkot - KSPCB
		41	Bangalore	95	Sanegurava Halli, Bengaluru - KSPCB
				96	City Railway Station, Bengaluru - KSPCB
				97	BWSSB Kadabesanahalli, Bengaluru - CPCB
				98	Peenya, Bengaluru - CPCB
				99	BTM Layout, Bengaluru - CPCB
				100	Bapuji Nagar, Bengaluru - KSPCB
				101	Silk Board, Bengaluru - KSPCB
				102	Hebbal, Bengaluru - KSPCB
				103	Hombegowda Nagar, Bengaluru - KSPCB
				104	Jayanagar 5th Block, Bengaluru - KSPCB
		42	Chikkaballarpur	105	Chikkaballapur Rural, Chikkaballapur - KSPCB
		43	Chikkamagaluru	106	Kalyana Nagara, Chikkamagaluru - KSPCB
		44	Hubballi	107	Deshpande Nagar, Hubballi - KSPCB
		45	Mysuru	108	Hebbal 1st Stage, Mysuru - KSPCB
		46	Vijayapura	109	Ibrahimpur, Vijayapura - KSPCB
9	Kerala	47	Kochi	110	Udyogamandal, Eloor - Kerala PCB
				111	Kacheripady, Ernakulam - Kerala PCB
				112	Vyttila, Kochi - Kerala PCB
		48	Kannur	113	Thavakkara, Kannur - Kerala PCB
		49	Kollam	114	Polayathode, Kollam - Kerala PCB
		50	Kozhikode	115	Palayam, Kozhikode - Kerala PCB
		51	Thiruvananthapuram	116	Plammoodu, Thiruvananthapuram - Kerala PCB
				117	Kariavattom, Thiruvananthapuram - Kerala PCB
		52	Thrissur	118	Corporation Ground, Thrissur- Kerala PCB
10	Madhya Pradesh	53	Bhopal	119	T T Nagar, Bhopal - MPPCB
		54	Damoh	120	Shrivastav Colony, Damoh - MPPCB
		55	Dewas	121	Bhopal Chauraha, Dewas - MPPCB
		56	Gwalior	122	City Center, Gwalior - MPPCB
				123	Phool Bagh, Gwalior - Mondelez Ind. Food
		57	Indore	124	Chhoti Gwaltoli, Indore - MPPCB

		58	Jabalpur	125	Marhatal, Jabalpur - MPPCB
		59	Katni	126	Gole Bazar, Katni - MPPCB
		60	Maihar	127	Sahilara, Maihar - KJS Cements
		61	Mandideep	128	Sector-D Industrial Area, Mandideep - MPPCB
		62	Pithampur	129	Sector-2 Industrial Area, Pithampur - MPPCB
		63	Ratlam	130	Shasthri Nagar, Ratlam - IPCA Lab
		64	Sagar	131	Deen Dayal Nagar, Sagar - MPPCB
		65	Satna	132	Bandhavgar Colony, Satna - Birla Cement
		66	Singrauli	133	Vindhyachal STPS, Singrauli - MPPCB
		67	Ujjain	134	Mahakaleshwar Temple, Ujjain - MPPCB
11	Maharashtra	68	Aurangabad	135	More Chowk Waluj, Aurangabad - MPCB
		69	Chandrapur	136	Chandrapur, Chandrapur - MPCB
				137	MIDC Khutala, Chandrapur - MPCB
		70	Kalyan	138	Khadakpada, Kalyan - MPCB
		71	Mumbai	139	Bandra, Mumbai - MPCB
				140	Chhatrapati Shivaji Intl. Airport (T2), Mumbai - MPCB
				141	Powai, Mumbai - MPCB
				142	Vasai West, Mumbai - MPCB
				143	Vile Parle West, Mumbai - MPCB
				144	Kurla, Mumbai - MPCB
				145	Worli, Mumbai - MPCB
				146	Borivali East, Mumbai - MPCB
				147	Sion, Mumbai - MPCB
				148	Colaba, Mumbai - MPCB
				149	Mazgaon, Mumbai - IITM
				150	Bandra Kurla Complex, Mumbai - IITM
				151	Borivali East, Mumbai - IITM
				152	Deonar, Mumbai - IITM
				153	Malad West, Mumbai - IITM
				154	Navy Nagar-Colaba, Mumbai - IITM
				155	Chakala-Andheri East, Mumbai - IITM
				156	Khindipada-Bhandup West, Mumbai - IITM
				157	Kandivali East, Mumbai - MPCB
				158	Mulund West, Mumbai - MPCB
				159	Siddharth Nagar-Worli, Mumbai - IITM
		72	Nashik	160	Gangapur Road, Nashik - MPCB
		73	Navi Mumbai	161	Airoli, Navi Mumbai - MPCB
				162	Nerul, Navi Mumbai - MPCB
				163	Mahape, Navi Mumbai - MPCB
				164	Sector-19A Nerul, Navi Mumbai - IITM
		74	Pune	165	Karve Road, Pune - MPCB
				166	Bhosari, Pune - IITM
				167	Mhada Colony, Pune - IITM
				168	Revenue Colony-Shivajinagar, Pune - IITM
				169	Transport Nagar-Nigdi, Pune - IITM
				170	Alandi, Pune - IITM
				171	Hadapsar, Pune - IITM
				172	MIT-Kothrud, Pune - IITM
12	Meghalaya	75	Shillong	173	Lumpyngngad, Shillong - Meghalaya PCB
13	Mizoram	76	Aizawl	174	Sikulpuikawn, Aizawl - Mizoram PCB
14	Nagaland	77	Kohima	175	PWD Juction, Kohima - NPCB
15	Odisha	78	Brajrajnagar	176	GM Office, Brajrajnagar - OSPCB
		79	Talcher	177	Talcher Coalfields,Talcher - OSPCB
16	Punjab	80	Amritsar	178	Golden Temple, Amritsar - PPCB
		81	Bathinda	179	Hardev Nagar, Bathinda - PPCB
		82	Jalandhar	180	Civil Line, Jalandhar - PPCB
		83	Khanna	181	Kalal Majra, Khanna - PPCB
		84	Ludhiana	182	Punjab Agricultural University, Ludhiana - PPCB
		85	Mandigobindgarh	183	RIMT University, Mandi Gobindgarh - PPCB
		86	Patiala	184	Model Town, Patiala - PPCB
		87	Rupnagar	185	Ratanpura, Rupnagar - Ambuja Cements
17	Rajasthan	88	Ajmer	186	Civil Lines, Ajmer - RSPCB
		89	Alwar	187	Moti Doongri, Alwar - RSPCB
		90	Bhiwadi	188	RIICO Ind. Area III, Bhiwadi - RSPCB

		91	Jaipur	189	Shastri Nagar, Jaipur - RSPCB
				190	Adarsh Nagar, Jaipur - RSPCB
				191	Police Commissionerate, Jaipur - RSPCB
		92	Jodhpur	192	Collectorate, Jodhpur - RSPCB
		93	Kota	193	Shrinath Puram, Kota - RSPCB
		94	Pali	194	Indira Colony Vistar, Pali - RSPCB
		95	Udaipur	195	Ashok Nagar, Udaipur - RSPCB
18	Tamil Nadu	96	Chennai	196	Manali, Chennai - CPCB
				197	Velachery Res. Area, Chennai - CPCB
				198	Alandur Bus Depot, Chennai - CPCB
				199	Manali Village, Chennai - TNPCB
				200	Kodungaiyur, Chennai - TNPCB
				201	Royapuram, Chennai - TNPCB
				202	Arumbakkam, Chennai - TNPCB
				203	Perungudi, Chennai - TNPCB
19	Telangana	97	Hyderabad	204	Central University, Hyderabad - TSPCB
				205	ICRISAT Patancheru, Hyderabad - TSPCB
				206	Bollaram Industrial Area, Hyderabad - TSPCB
				207	IDA Pashamylaram, Hyderabad - TSPCB
				208	Zoo Park, Hyderabad - TSPCB
				209	Sanathnagar, Hyderabad - TSPCB
20	Tripura	98	Agartala	210	Kunjaban, Agartala - Tripura SPCB
21	Uttar Pradesh	99	Agra	211	Sanjay Palace, Agra - UPPCB
		100	Baghpat	212	New Collectorate, Baghpat - UPPCB
		101	Bulandshahr	213	Yamunapuram, Bulandshahr - UPPCB
		102	Ghaziabad	214	Vasundhara, Ghaziabad - UPPCB
				215	Indirapuram, Ghaziabad - UPPCB
				216	Loni, Ghaziabad - UPPCB
				217	Sanjay Nagar, Ghaziabad - UPPCB
		103	Greater Noida	218	Knowledge Park - III, Greater Noida - UPPCB
				219	Knowledge Park - V, Greater Noida - UPPCB
		104	Hapur	220	Anand Vihar, Hapur - UPPCB
		105	Kanpur	221	Nehru Nagar, Kanpur - UPPCB
				222	IITK, Kanpur - IITK
		106	Lucknow	223	Talkatora District Industries Center, Lucknow - CPCB
				224	Central School, Lucknow - CPCB
				225	Lalbagh, Lucknow - CPCB
				226	Nishant Ganj, Lucknow - UPPCB
				227	Gomti Nagar, Lucknow - UPPCB
		107	Meerut	228	Jai Bhim Nagar, Meerut - UPPCB
				229	Ganga Nagar, Meerut - UPPCB
				230	Pallavpuram Phase 2, Meerut - UPPCB
		108	Muradabad	231	Lajpat Nagar, Moradabad - UPPCB
		109	Muzaffarnagar	232	New Mandi, Muzaffarnagar - UPPCB
		110	Noida	233	Sector - 62, Noida - IMD
				234	Sector - 125, Noida - UPPCB
				235	Sector-1, Noida - UPPCB
				236	Sector-116, Noida - UPPCB
		111	Varanasi	237	Ardhali Bazar, Varanasi - UPPCB
22	West Bengal	112	Asansol	238	Asansol Court Area, Asansol - WBPCB
		113	Howrah	239	Ghusuri, Howrah - WBPCB
				240	Padmapukur, Howrah - WBPCB
				241	Belur Math, Howrah - WBPCB
		114	Kolkata	242	Rabindra Bharati University, Kolkata - WBPCB
				243	Victoria, Kolkata - WBPCB
				244	Fort William, Kolkata - WBPCB
				245	Jadavpur, Kolkata - WBPCB
				246	Rabindra Sarobar, Kolkata - WBPCB
				247	Ballygunge, Kolkata - WBPCB
				248	Bidhannagar, Kolkata - WBPCB
		115	Siliguri	249	Ward-32 Bapupara, Siliguri - WBPCB

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