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

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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.

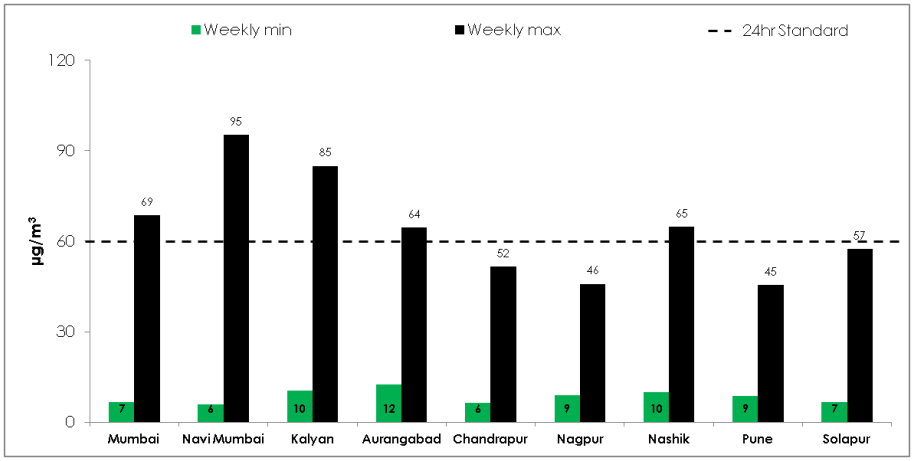
Data used in the analysis: The analysis is based on publicly available granular real time data (15-minute averages) from the Central Pollution Control Board's (CPCB) official online portal Central Control Room for Air Quality Management. Ten cities – Mumbai, Navi Mumbai, Thane, Kalyan, Pune, Nagpur, 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.

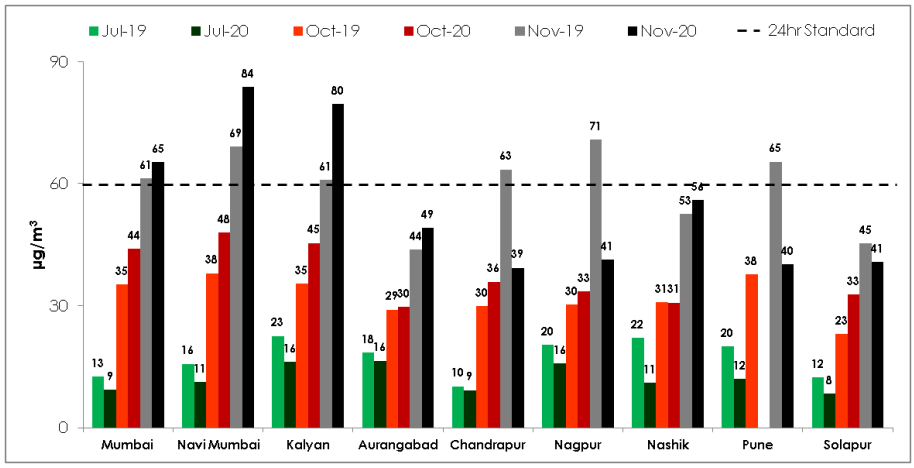
Graph 1: Change in weekly $PM_{2.5}$ levels 2020 – Difference between cleanest and most polluted week



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.

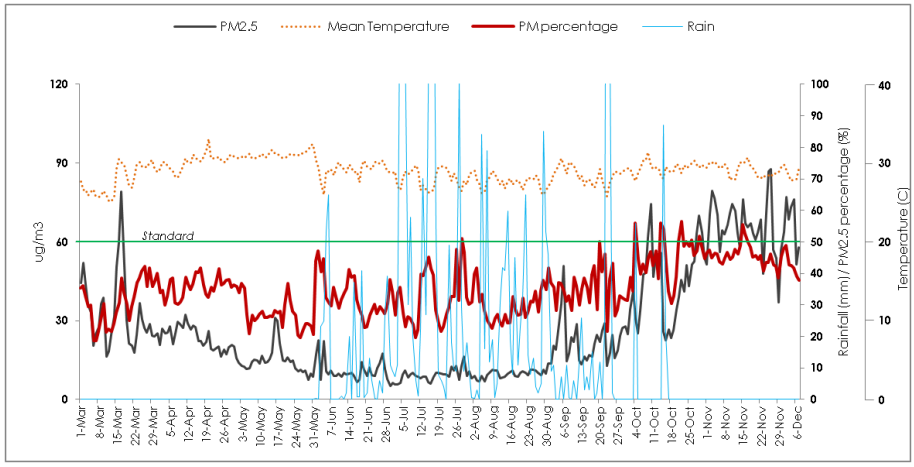
Graph 2: Difference in winter pollution build-up: 2020 winter vs 2019 winter (monthly averages)



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.

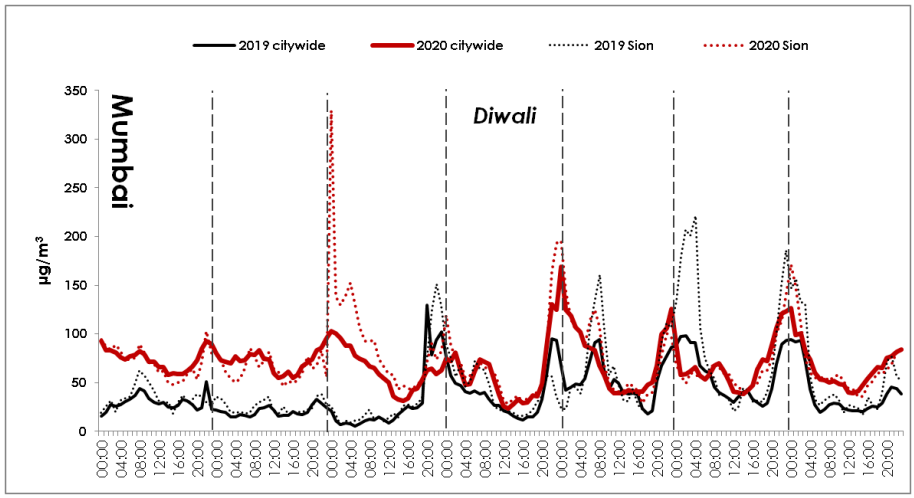
Graph 3: Changing percentage share of $PM_{2.5}$ in PM_{10} in Mumbai (1 Mar – 8 Dec, 2020)



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.

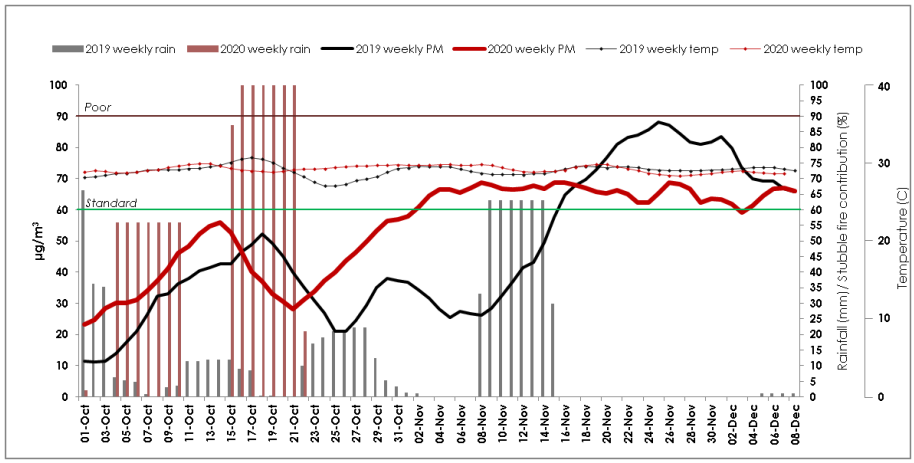
Graph 4: How hourly pollution changed on Diwali day in Mumbai



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

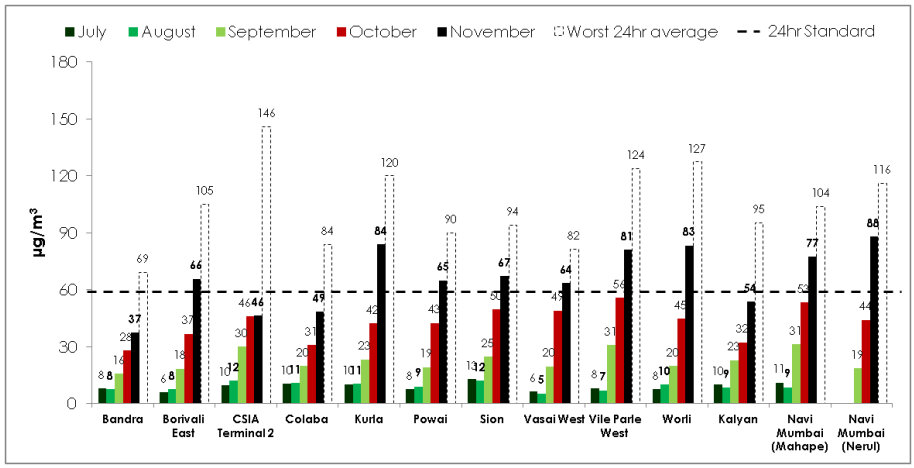


Note: All values are rolling weekly average.
Data: CPCB ($PM_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

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)*).

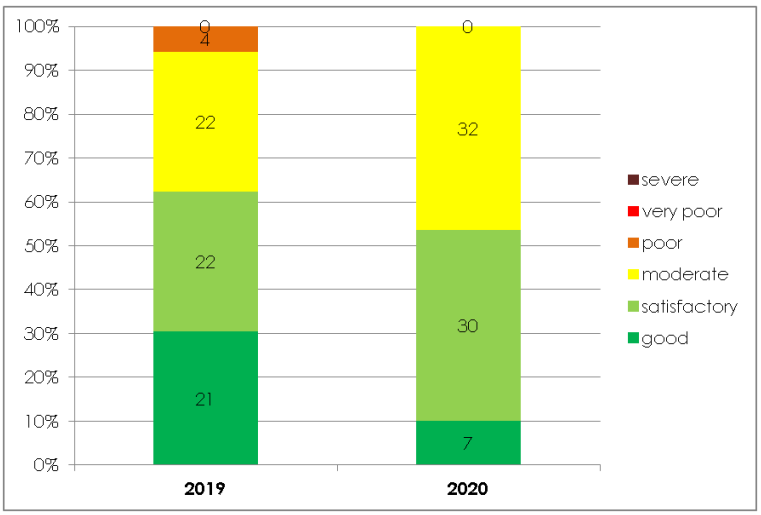
Graph 6: Variation in local pollution build-up in different locations of Mumbai during 2020 winter (monthly averages)



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*).

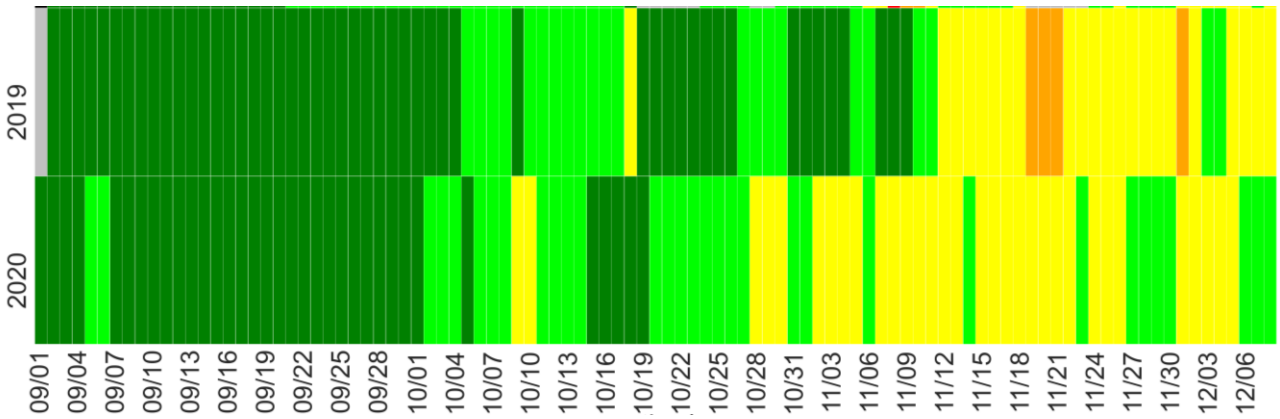
Graph 7: Distribution of days based on $PM_{2.5}$ concentration and classified according to National Air Quality Index in Mumbai during winter (1 Oct – 8 Dec) 2019 and 2020.



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

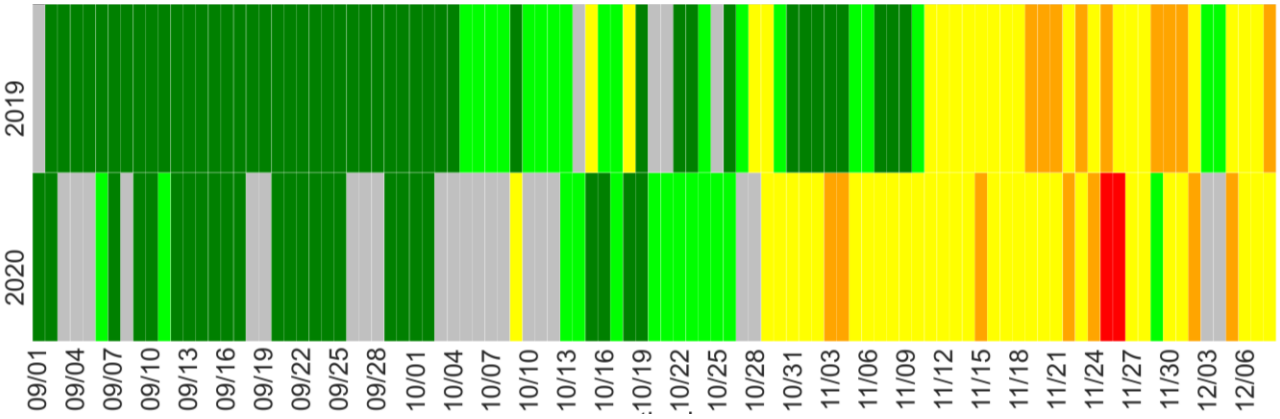
Mumbai: The cyclical ups and down of pollution this winter is less volatile – showing slower rise and fall than pervious winter: This inelastic behavior of $PM_{2.5}$ levels in Mumbai is in contrast to the trend seen in Delhi-NCR and Kolkata-Howrah where the trend has been more volatile during winter 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

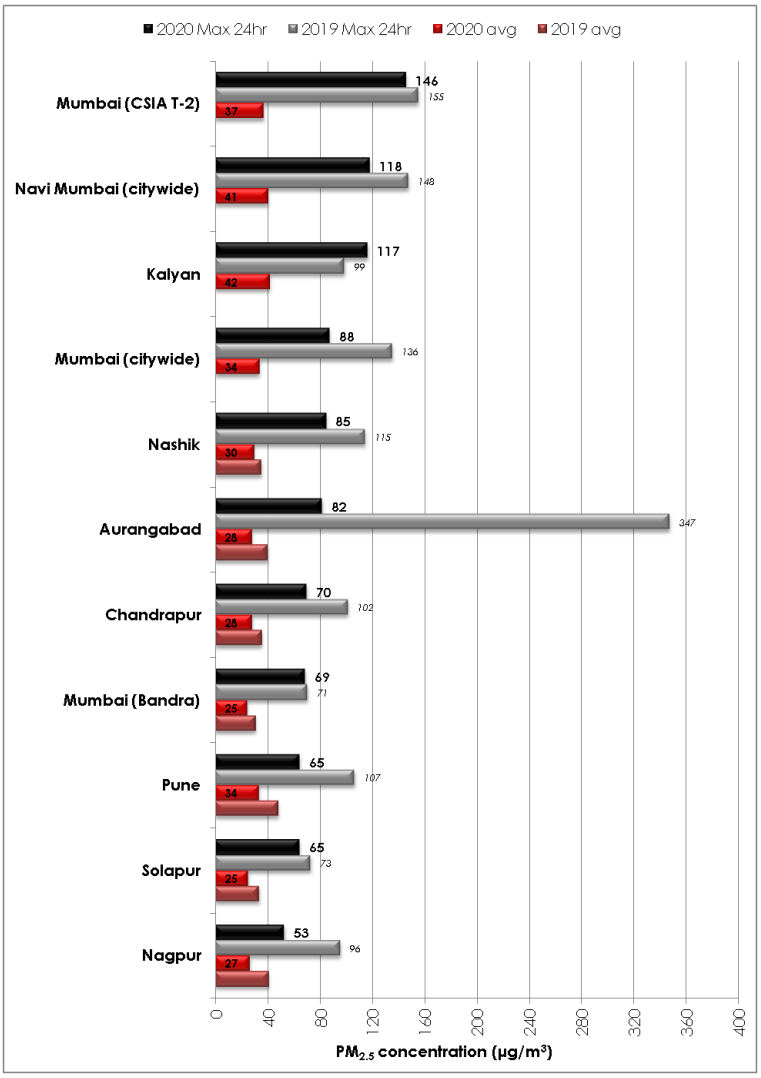
Graph 8b: Heatmap of Worli's daily $PM_{2.5}$ concentration in winter (1 Sept – 8 Dec) of 2019 and 2020



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.

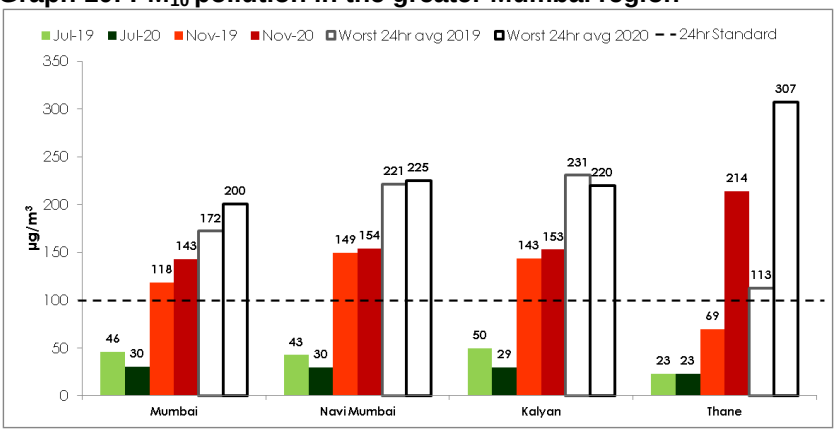
Graph 9: How annual average and maximum level changed in cities and towns of Maharashtra – comparison of 2019 and 2020



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

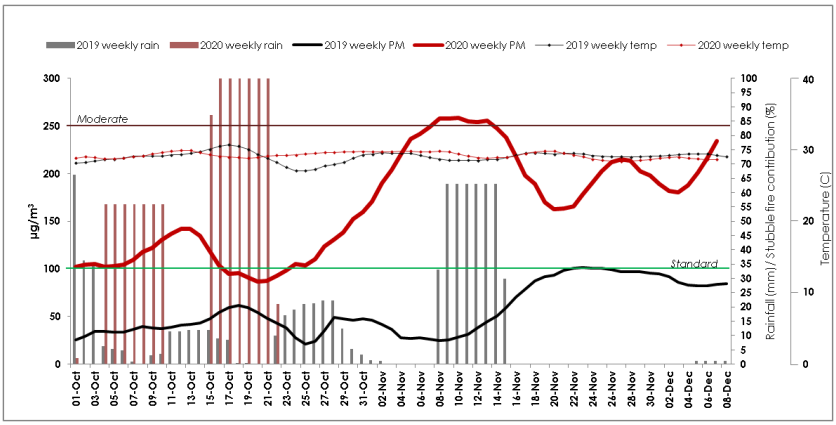
Thane's air dirtiest in the region: CSE has also compared PM_{10} levels during winter months (until December 8) in cities of greater Mumbai region and found Thane (which does not have a working $PM_{2.5}$ monitor) to have the highest levels of PM_{10} (See *Graph 10: PM_{10} pollution in the greater 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

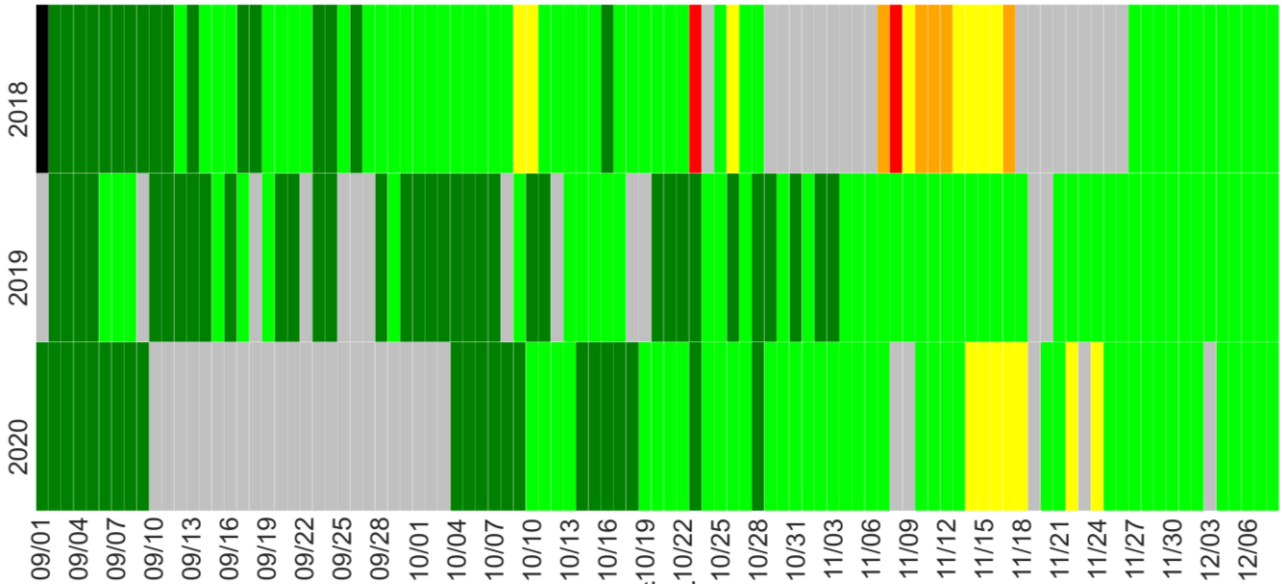
Need deep cuts

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.

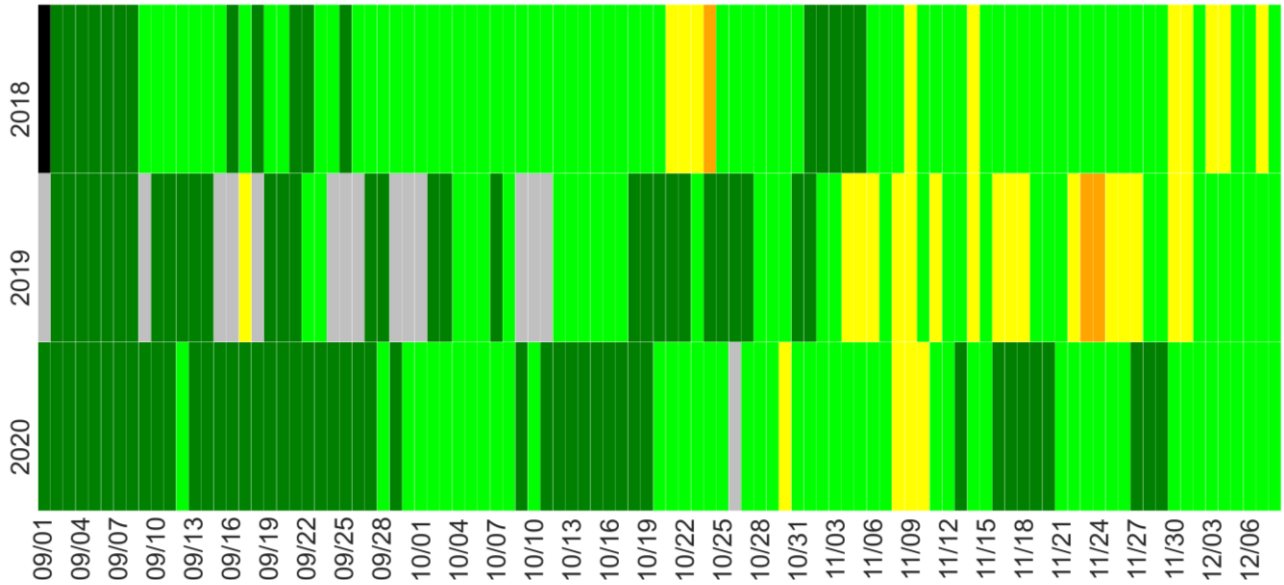
Additional graphs for Maharashtra cities

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



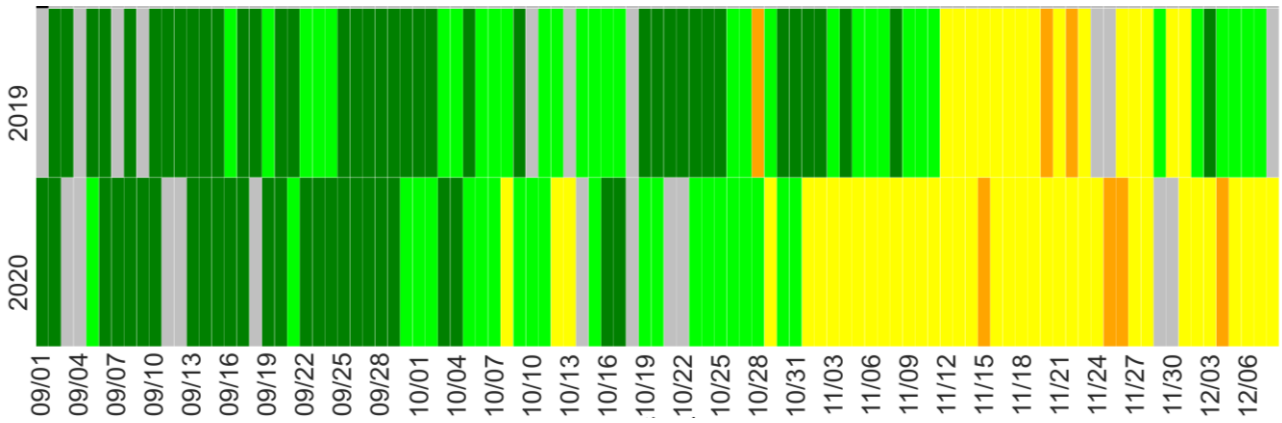
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

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



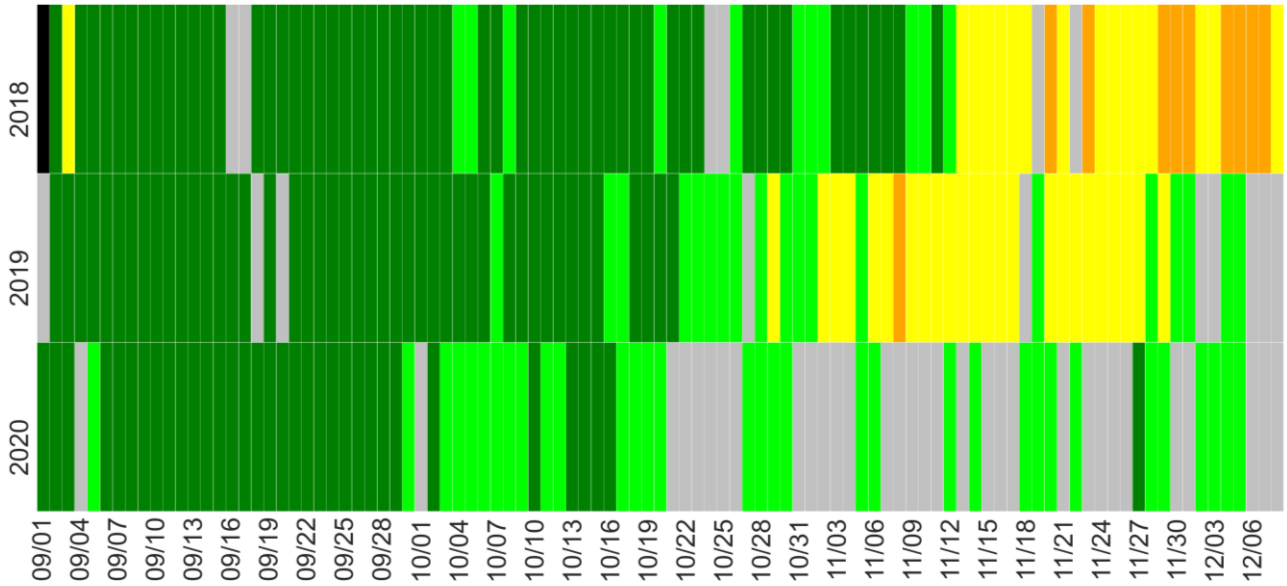
Note: Average $PM_{2.5}$ concentration for a day is in µg/m^3 and is based on mean of two CAAQM stations in the city. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

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



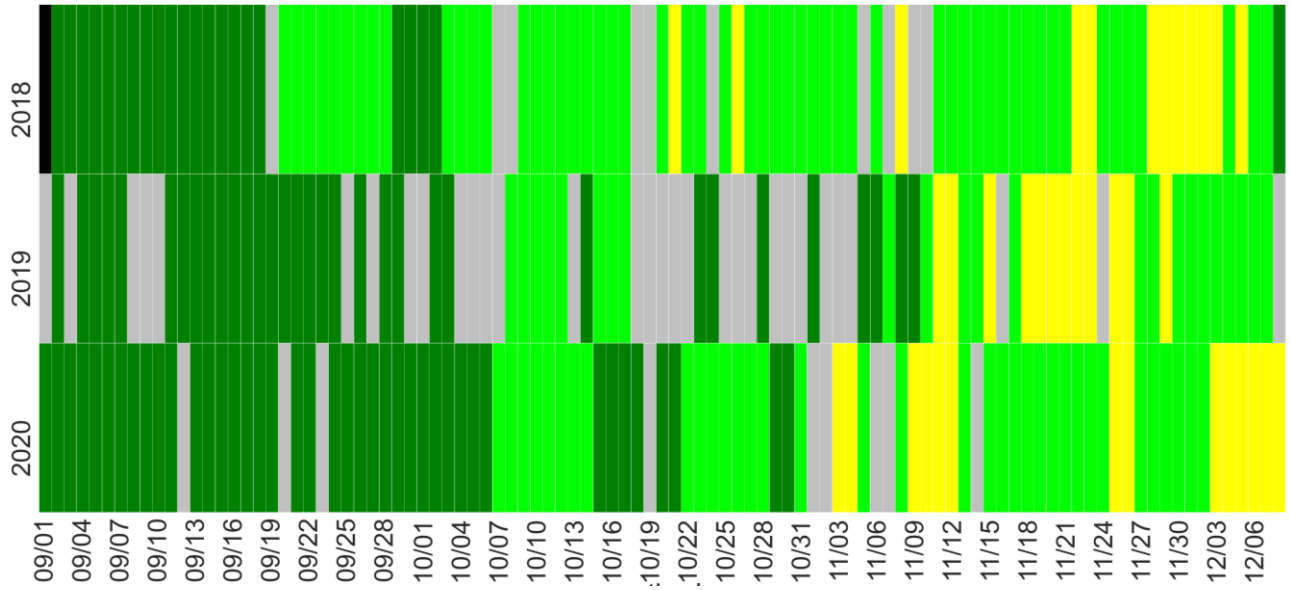
Note: Average $PM_{2.5}$ concentration for a day is in $\mu g/m^3$. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

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



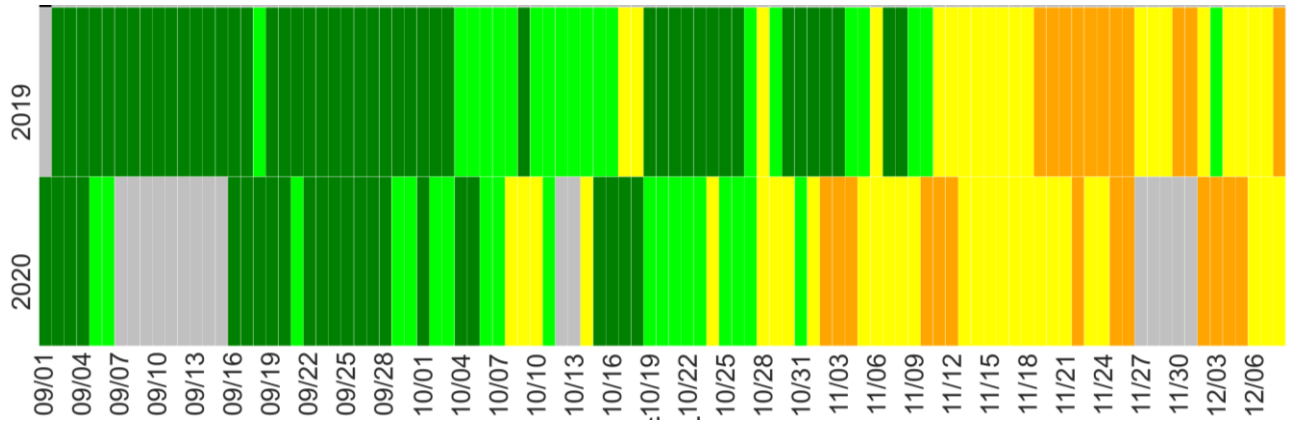
Note: Average $PM_{2.5}$ concentration for a day is in $\mu g/m^3$. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

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



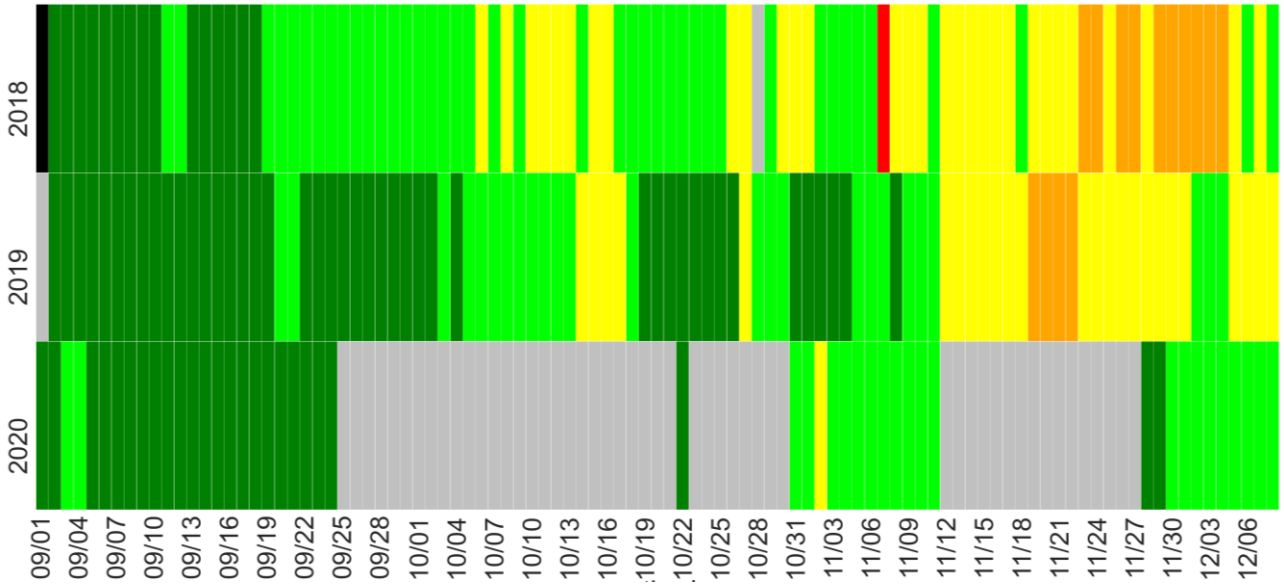
Note: Average $PM_{2.5}$ concentration for a day is in $\mu g/m^3$. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

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



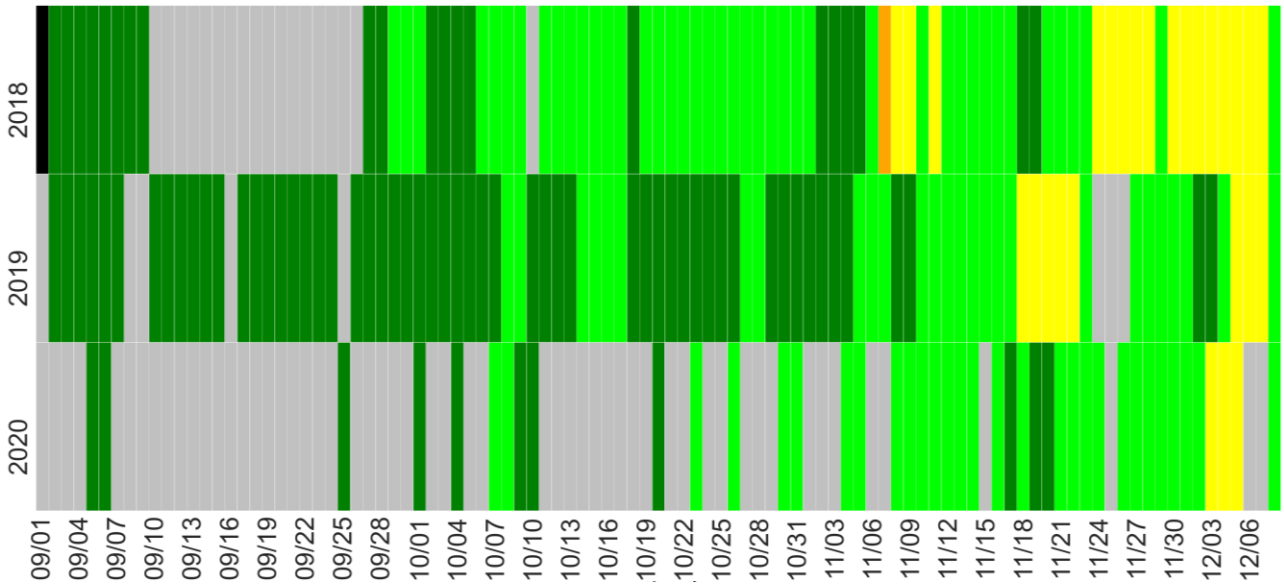
Note: Average $PM_{2.5}$ concentration for a day is in $\mu g/m^3$ and based on mean of the two CAAQM stations in the city. Days are colored based on AQI categories, grey cells represent no valid data for that day.
Source: CSE analysis of CPCB's realtime air quality data

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 $\mu g/m^3$. 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 $\mu g/m^3$. 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

List of CAAQM stations used in the study

State	City	Station Name	
Maharashtra	Aurangabad	1	More Chowk Waluj, Aurangabad - MPCB
	Chandrapur	1	Chandrapur, Chandrapur - MPCB
		2	MIDC Khutala, Chandrapur - MPCB
	Kalyan	1	Khadakpada, Kalyan - MPCB
	Mumbai	1	Bandra, Mumbai - MPCB
		2	Chhatrapati Shivaji Intl. Airport (T2), Mumbai - MPCB
		3	Powai, Mumbai - MPCB
		4	Vasai West, Mumbai - MPCB
		5	Vile Parle West, Mumbai - MPCB
		6	Kurla, Mumbai - MPCB
		7	Worli, Mumbai - MPCB
		8	Borivali East, Mumbai - MPCB
		9	Sion, Mumbai - MPCB
		10	Colaba, Mumbai - MPCB
	Nagpur	1	Opp GPO Civil Lines, Nagpur - MPCB
	Nashik	1	Gangapur Road, Nashik - MPCB
	Navi Mumbai	1	Nerul, Navi Mumbai - MPCB
		2	Mahape, Navi Mumbai - MPCB
	Pune	1	Karve Road, Pune - MPCB
	Solapur	1	Solapur, Solapur - MPCB
	Thane	1	Pimpleshwar Mandir, Thane - MPCB