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

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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
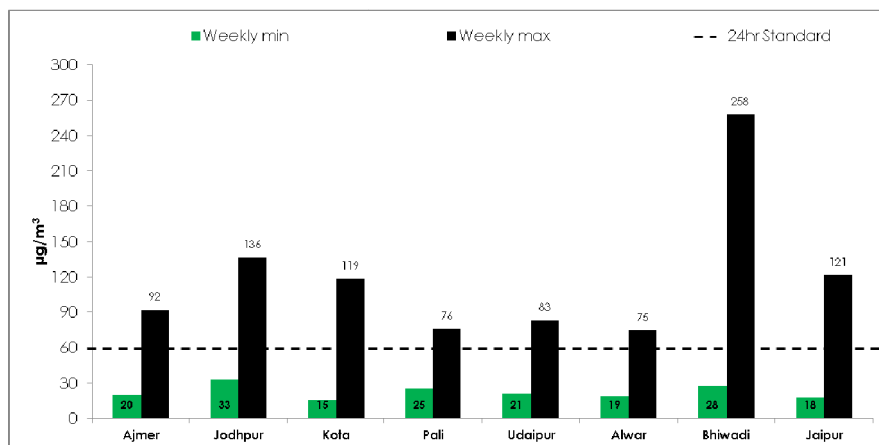
Note: Average PM$_{2.5}$ concentration for a week is based on mean of all CAAQM stations in the city. Dirtiest week for all cities was on the week ending on 15 November 2020 except in Bhiwadi which was a week earlier. Cleanest week for Alwar and Pali was in the early April, 2020. Ajmer and Kota had their 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)
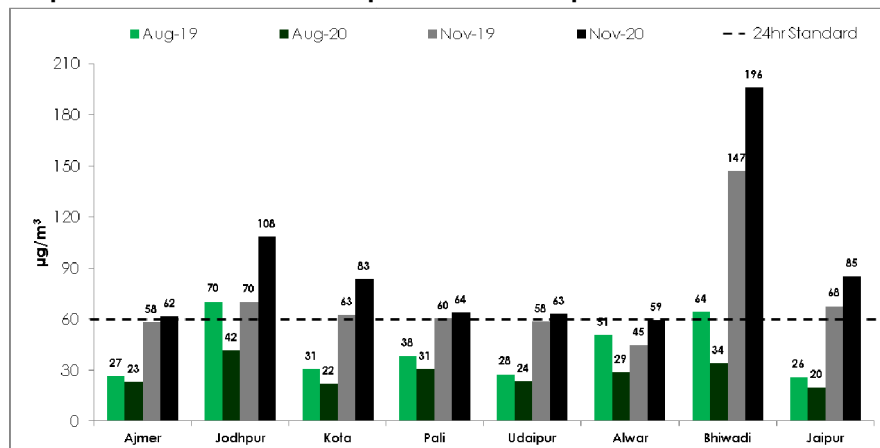
Note: Average PM$_{2.5}$ concentration for a month is based on mean of all CAAQM stations in the city.
Source: CSE analysis of CPCB's real time air quality data

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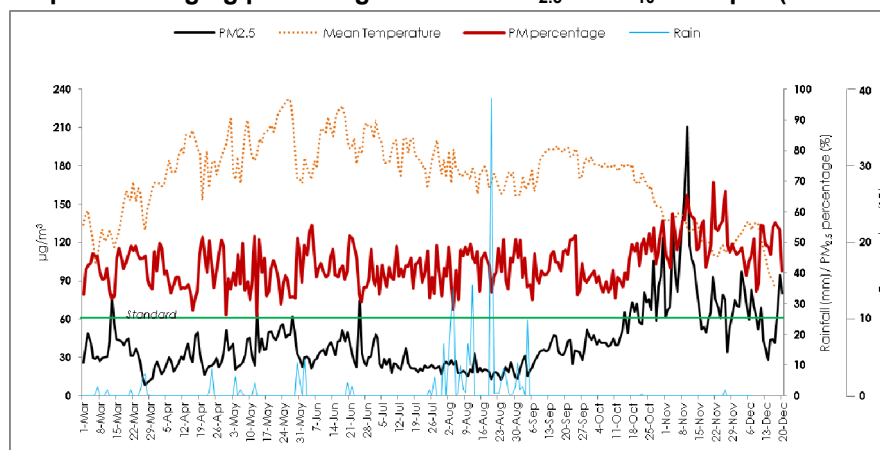
Data: CPCB (PM$_{10}$ and PM$_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

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.
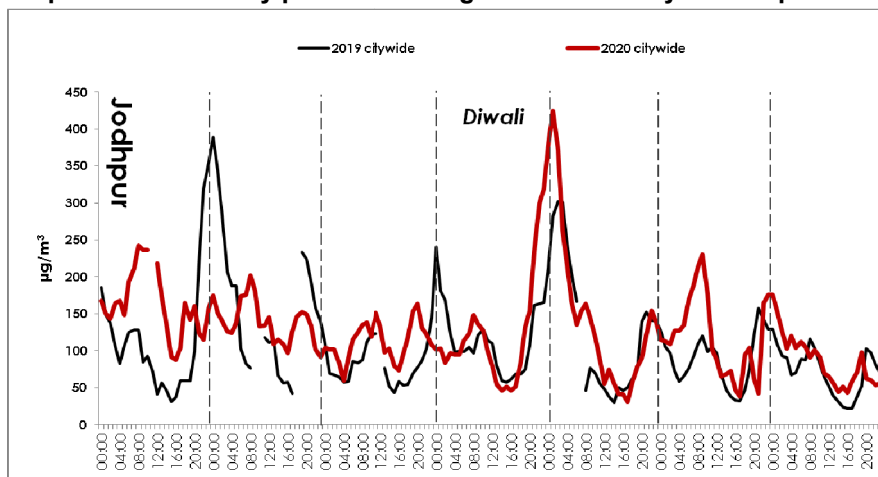
**Graph 4a: How hourly pollution changed on Diwali day in Jaipur**
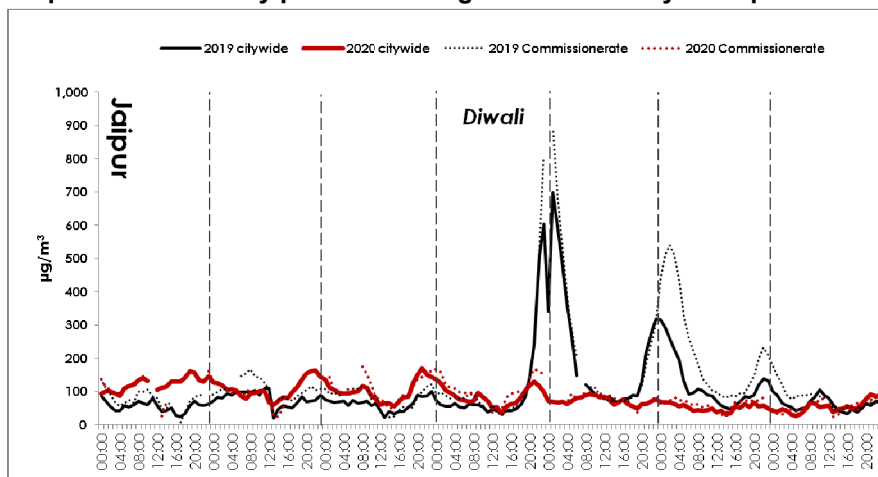
Note: Diwali dates are 27 Oct 2019, and 14 Nov 2020. Citywide is based on average PM2.5 concentration of all CAAQM stations operational in the city on a given day. Dotted lines represent a specific CAAQM station of the city to showcase variation in PM$_{2.5}$ concentrations among city's numerous CAAQM 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
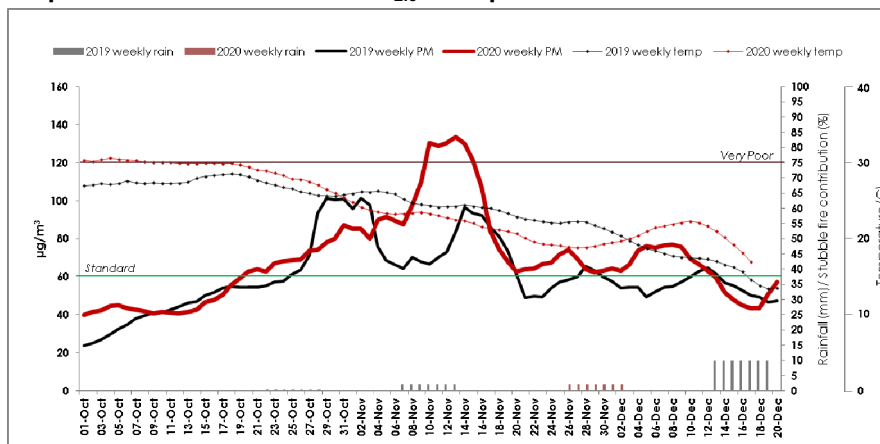
Note: All values are rolling weekly average.
Data: CPCB (PM$_{2.5}$), IMD (Temperature and rainfall)
Source: CSE analysis

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.
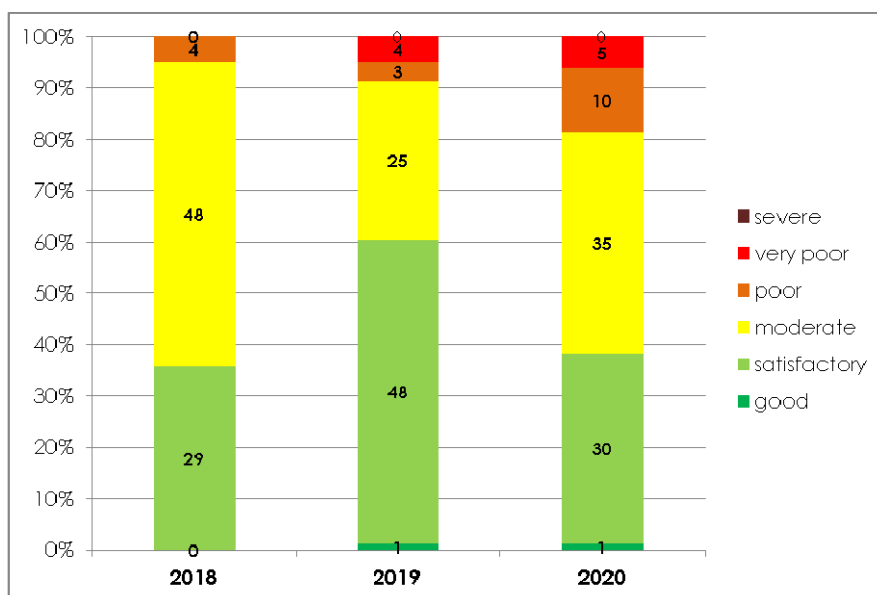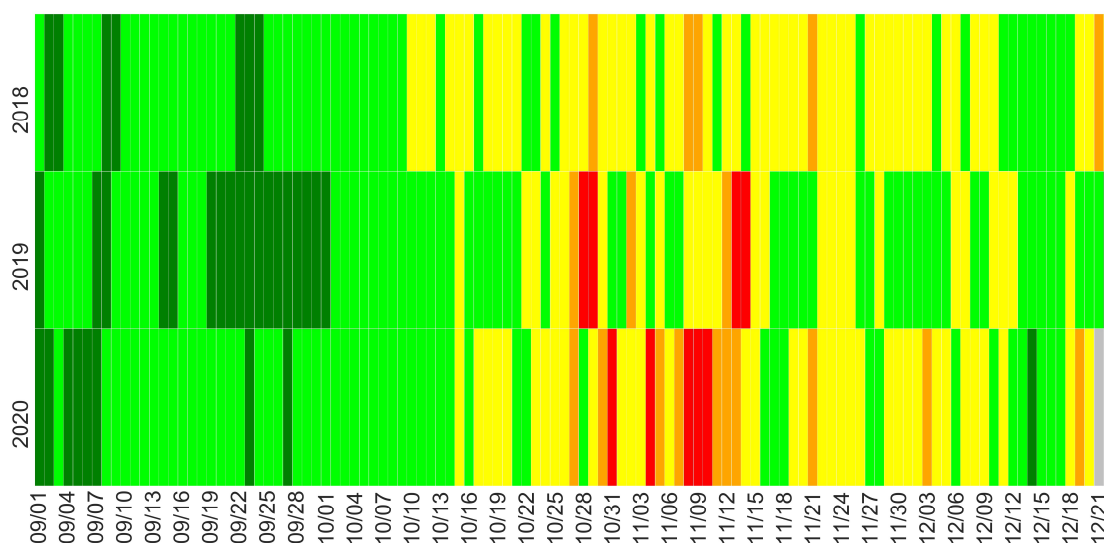

Note: Average PM$_{2.5}$ concentration for a day is based on mean of all 3 CAAQM stations of Jaipur.
Source: CSE analysis of CPCB's realtime air quality data

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
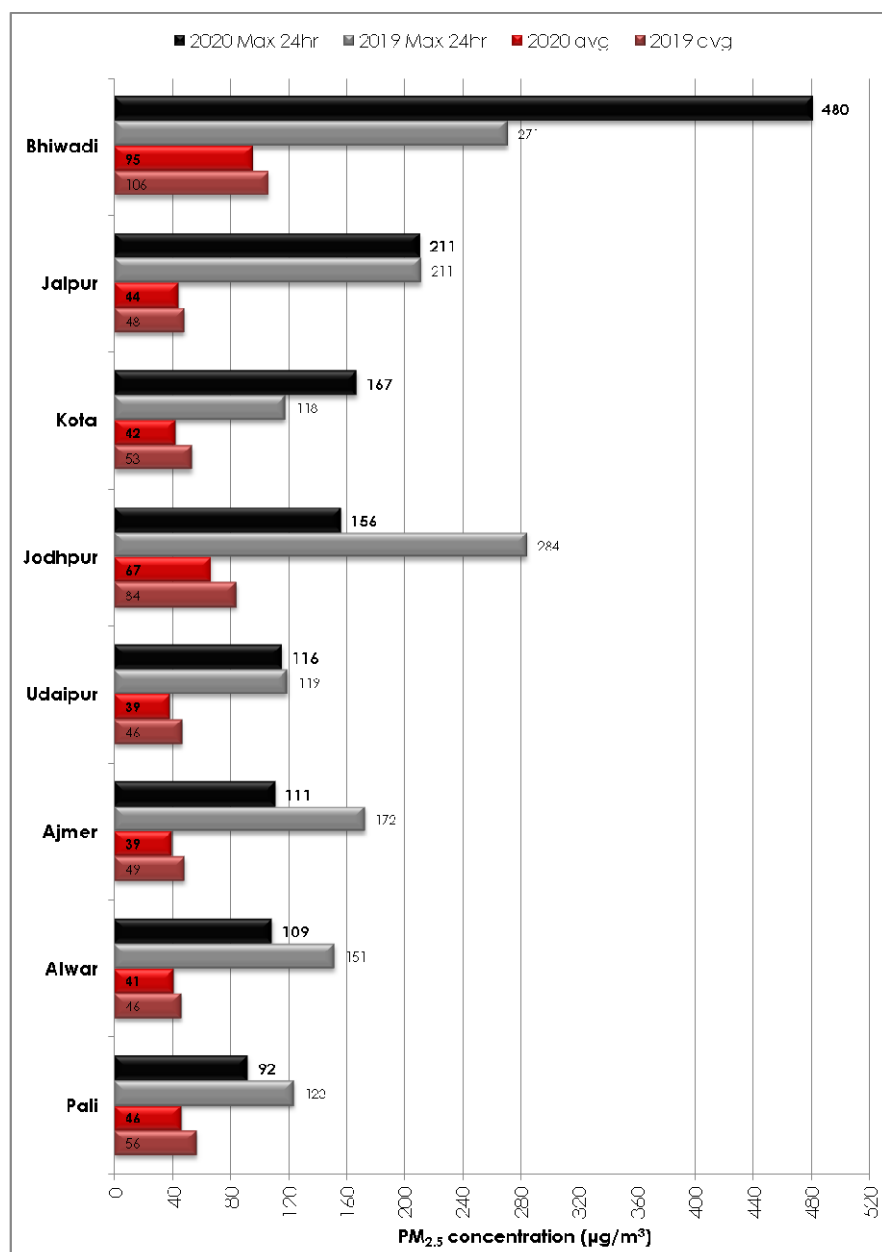

Note: 2020 numbers are based on data up to 8 Dec 2020.
Source: CSE analysis of CPCB's realtime air quality data

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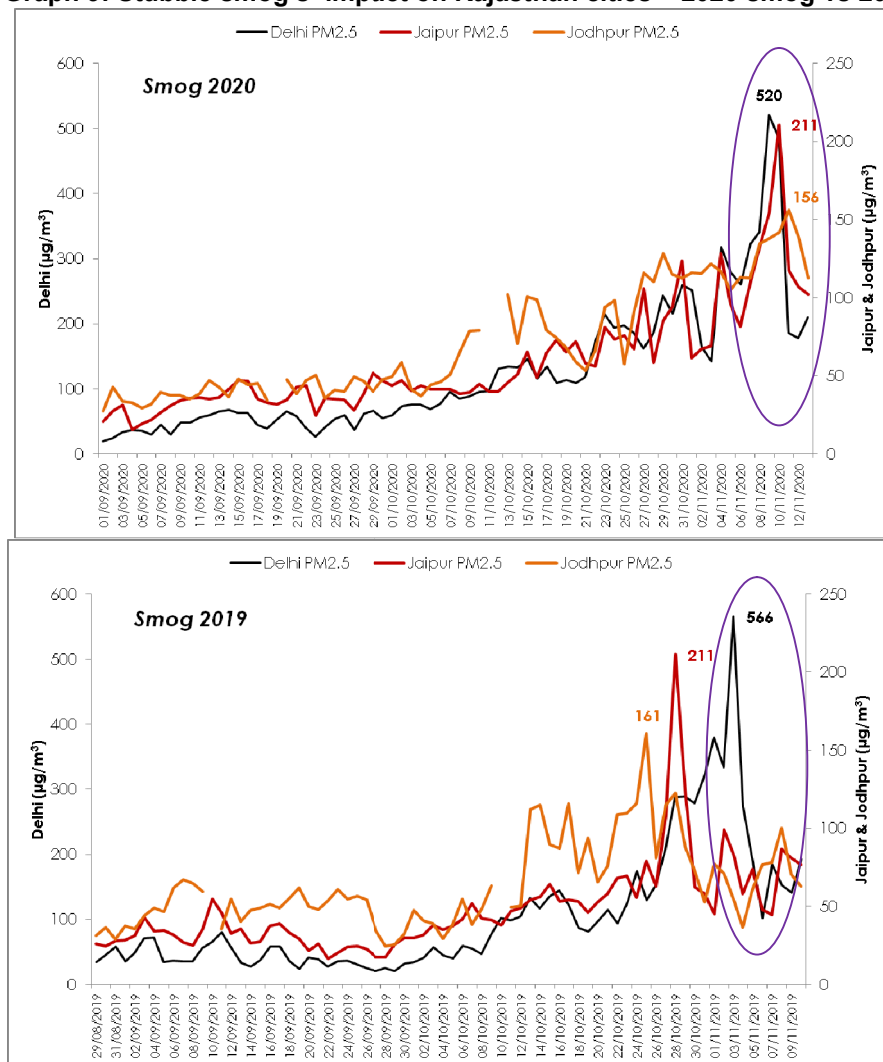
Note: Average PM$_{2.5}$ concentration is based on mean of all CAAQM stations in the city.
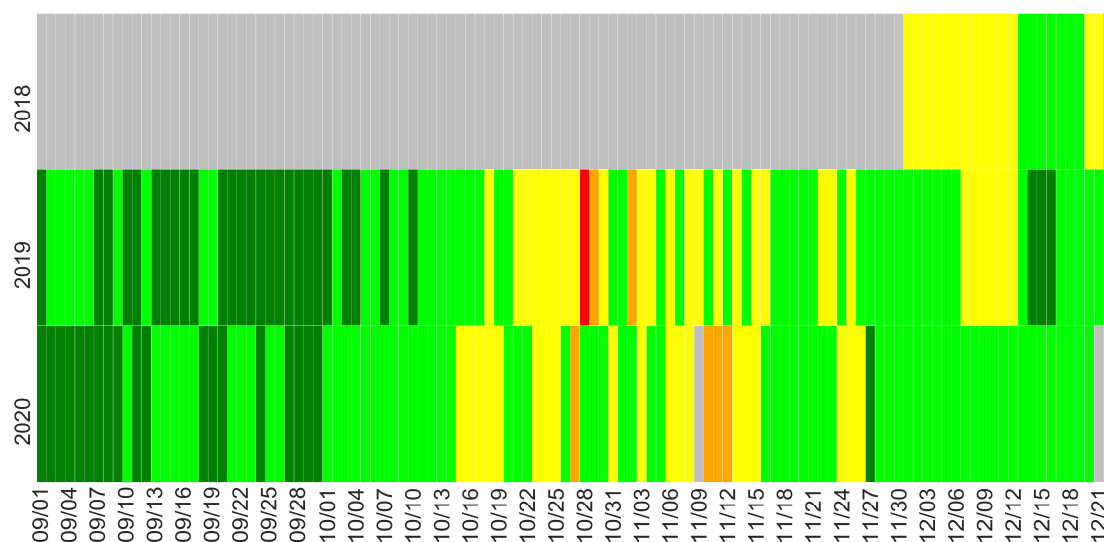Source: CSE analysis of CPCB's real time air quality data

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.
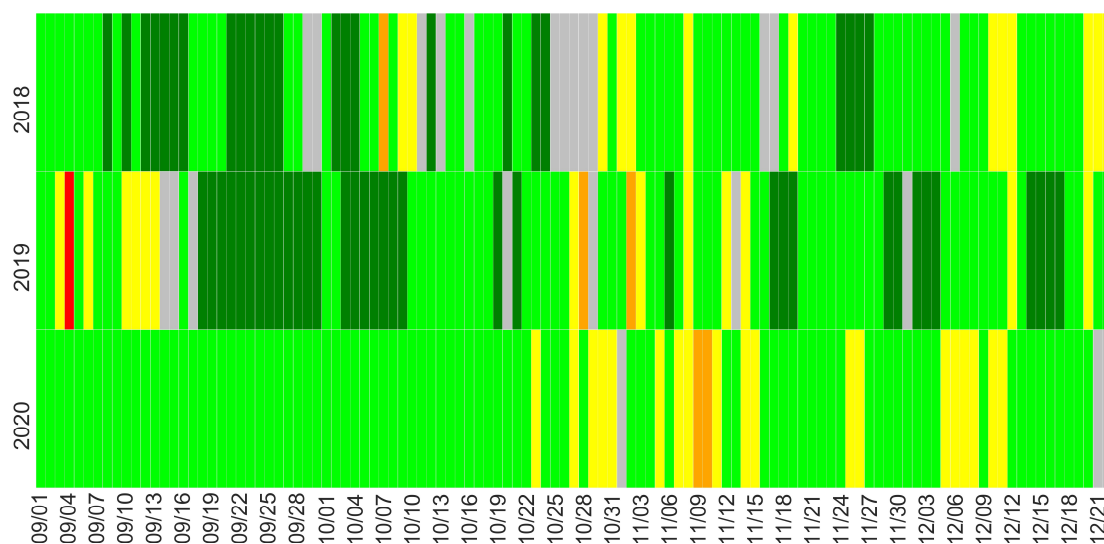
Additional graphs for Rajasthan cities

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.
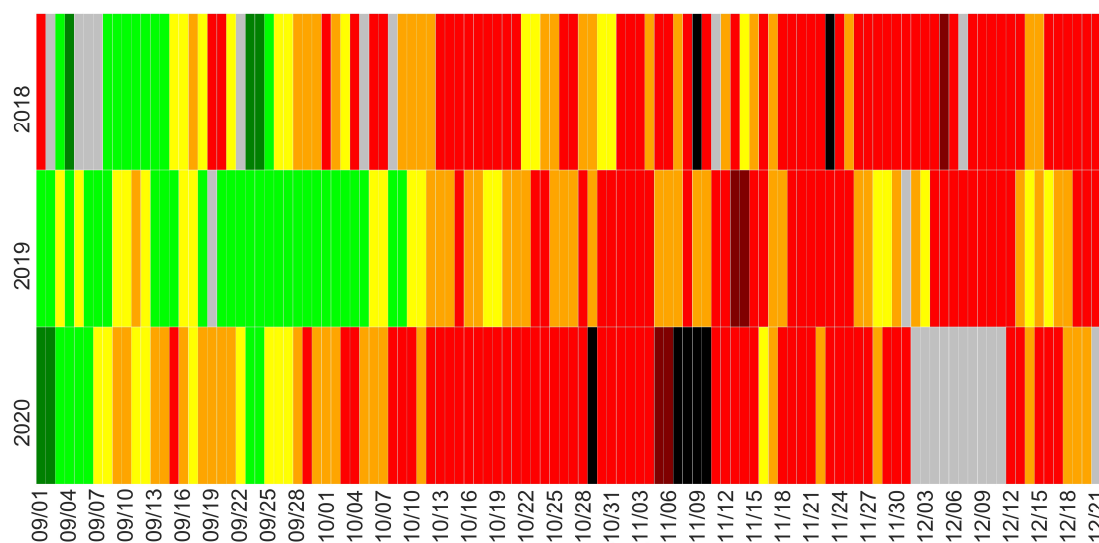Source: CSE analysis of CPCB's realtime air quality data

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.
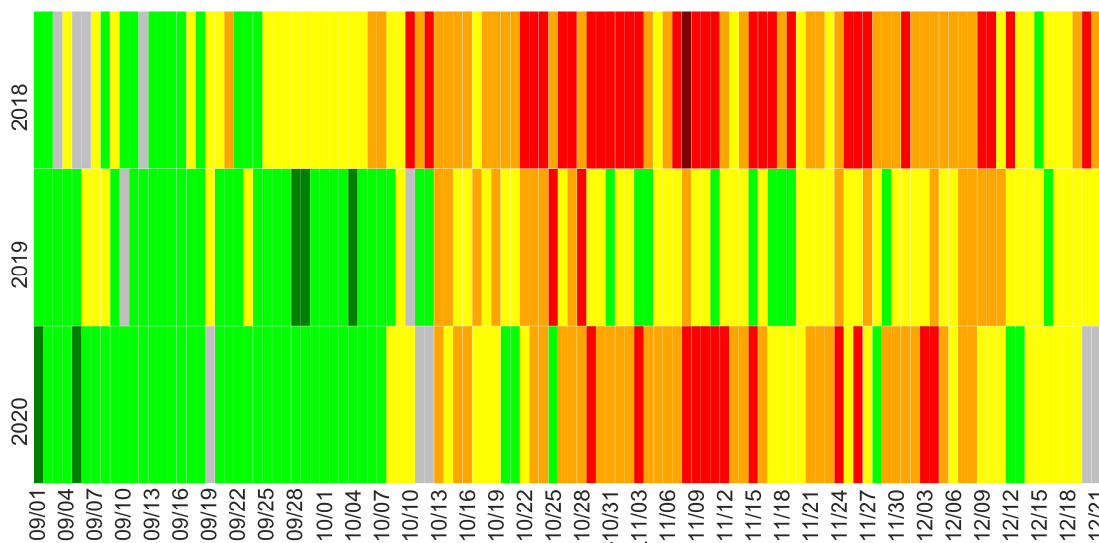Source: CSE analysis of CPCB's realtime air quality data

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.
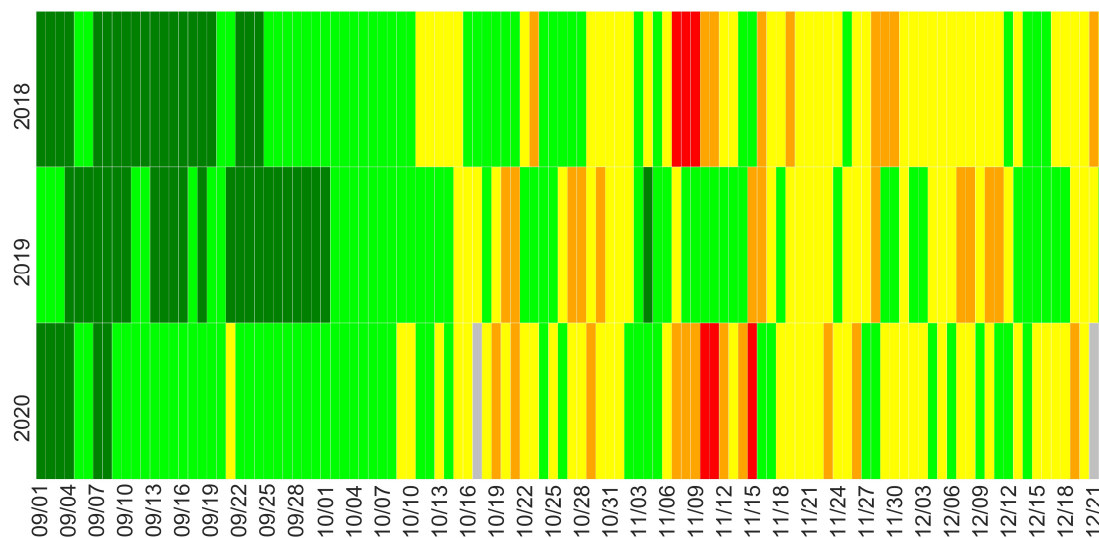Source: CSE analysis of CPCB's realtime air quality data

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.
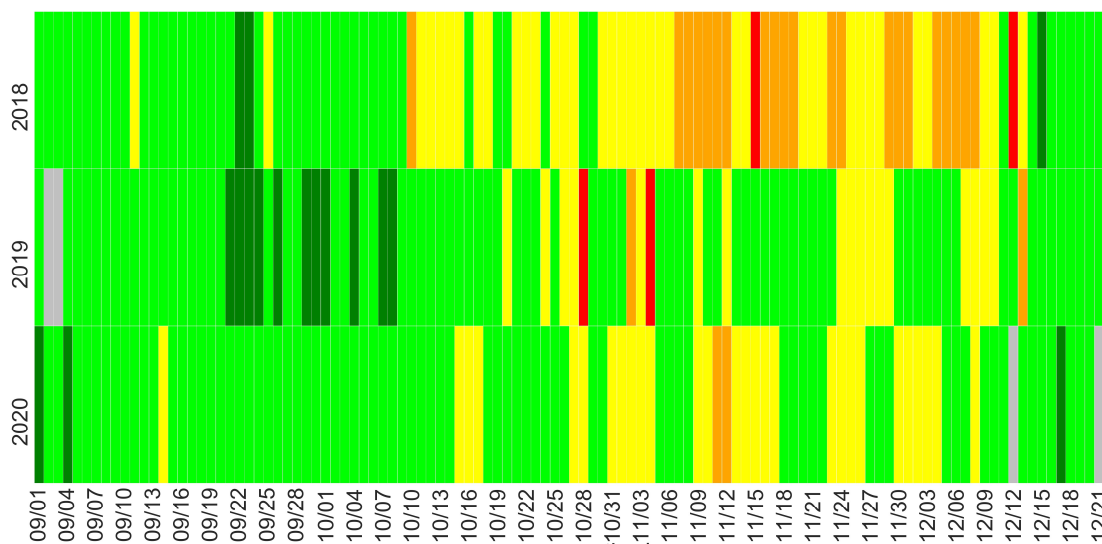Source: CSE analysis of CPCB's realtime air quality data

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.
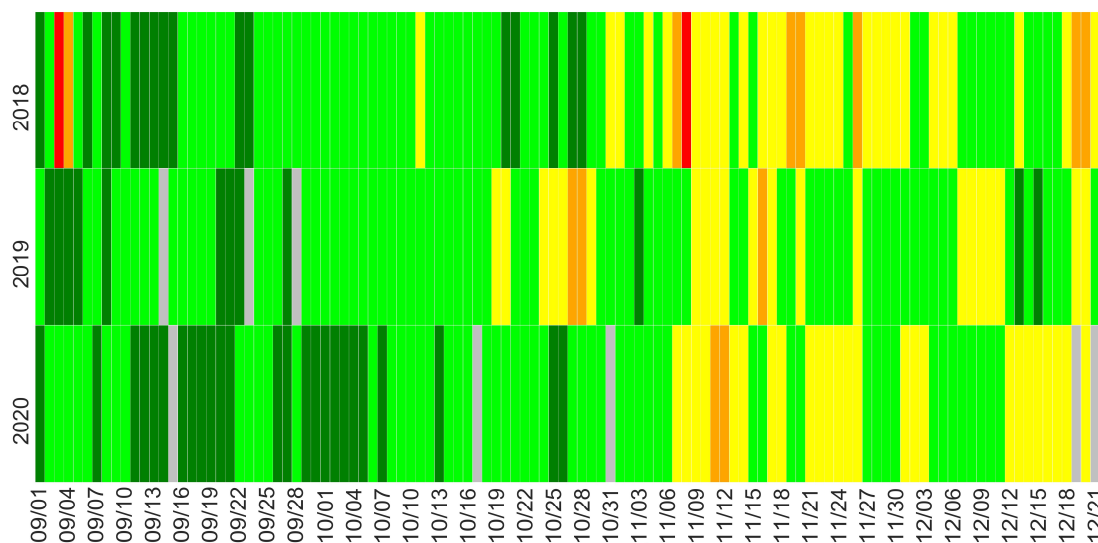Source: CSE analysis of CPCB's realtime air quality data

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

List of CAAQM stations used in the study

SN	State	City	Station name
1		Ajmer	Civil Lines, Ajmer
2		Alwar	Moti Doongri, Alwar
3		Bhiwadi	RIICO Ind. Area III, Bhiwadi
4			Shastri Nagar, Jaipur
5	Rajasthan	Jaipur	Adarsh Nagar, Jaipur
6			Police Commissionerate, Jaipur
7		Jodhpur	Collectorate, Jodhpur
8		Kota	Shrinath Puram, Kota
9		Pali	Indira Colony Vistar, Pali
10		Udaipur	Ashok Nagar, Udaipur