Growing Air Pollution Risks in Rajasthan: A multi-pollutant analysis

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Cities of Rajasthan are experiencing rising particulate pollution as well as facing the threat of multi-pollutant crisis with several gaseous pollutants including nitrogen dioxide (NO2) and ozone, beginning to rise. This increases public health risk in the state.

This is evident from the new analysis carried out by the Urban Lab at the Centre for Science and Environment (CSE). This analysis was assessed the longer term trends as well as seasonal variation in particulate and gaseous pollutants.

Air quality is worsening not only in non-attainment cities but also in smaller cities and towns of Rajasthan despite the clean air action underway. Time bound improvement in air quality requires state-wide action to improve systems and infrastructure in all the key sectors of pollution including industry, vehicles and transport, clean energy, management of waste streams, construction and greening. Allocate resources equitably for the priority measures in key sectors with a strong compliance framework to meet the clean air targets.

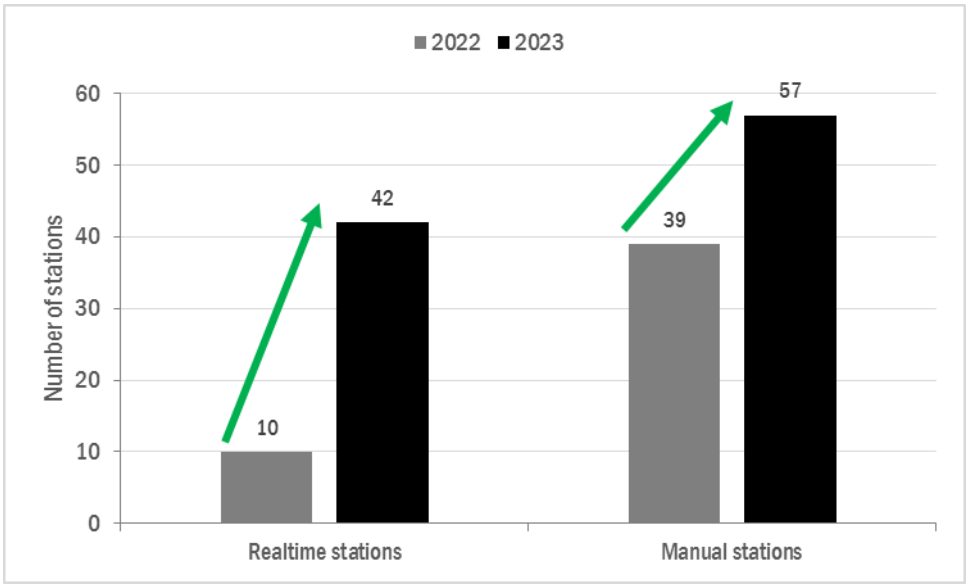
Further expansion and strengthening of air quality monitoring will help to assess the growing risk better. The continuing elevated pollution levels among city stations highlight the systemic pollution that persists in the region due to inadequate infrastructure and systems for pollution control across all sectors. This can only be addressed through stringent and uniform action, round-the-year, to meet clean air standards.

Data used in the analysis: This analysis of the real-time data from monitoring stations in Rajasthan for the period January 1, 2019- May 31, 2023. This is an assessment of annual and seasonal trends in PM2.5, PM10, NO2, ground-level ozone and CO concentration for the period January 1, 2019- May 31, 2023. This analysis is based on the real time data available from the current working air quality monitoring stations in Rajasthan. A huge volume of data points have been cleaned and data gaps have been addressed based on USEPA method for this analysis. This analysis covers 42 continuous ambient air quality monitoring stations (CAAQMS) spread across cities of Rajasthan. Jaipur (5), Jodhpur (5) and Kota (3) have more than one real-time station, therefore citywide average is used for comparative analysis and it is defined as average of all city stations.

Key findings

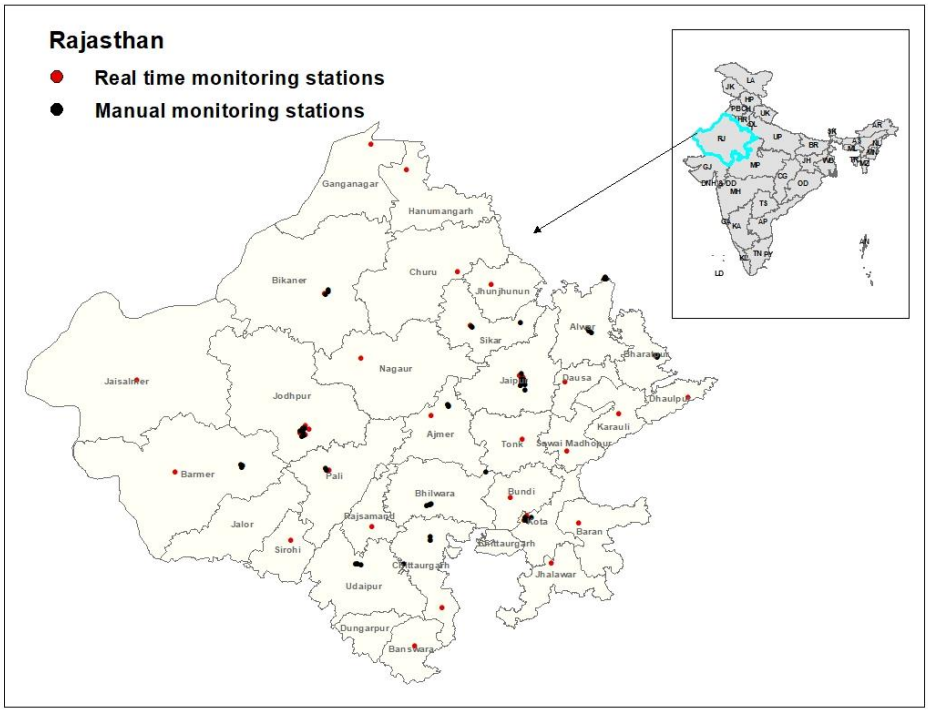
Substantial expansion of the air quality monitoring infrastructure in the state has improved assessment of air quality trends in the state: Substantial efforts have been made to expand the air quality monitoring network in cities of Rajasthan. There were 10 realtime and 39 manual stations operating in the state in 2022. In the first half of 2023 32 new realtime and 18 new manual stations have become operational bringing the total to 99 stations (see *Graph 1: Growth in air quality monitoring infrastructure in Rajasthan*). These stations are spread across 33 cities. Most of the stations, 30 manual and 15 realtime, are located in the five nonattainment cities i.e. Alwar, Jaipur, Jodhpur, Kota and Udaipur (see *Map 1: Air quality monitoring network in Rajasthan*). Overall Rajasthan has added 50 new monitoring stations.

Graph 1: Growth in air quality monitoring infrastructure in Rajasthan



Source: CSE analysis

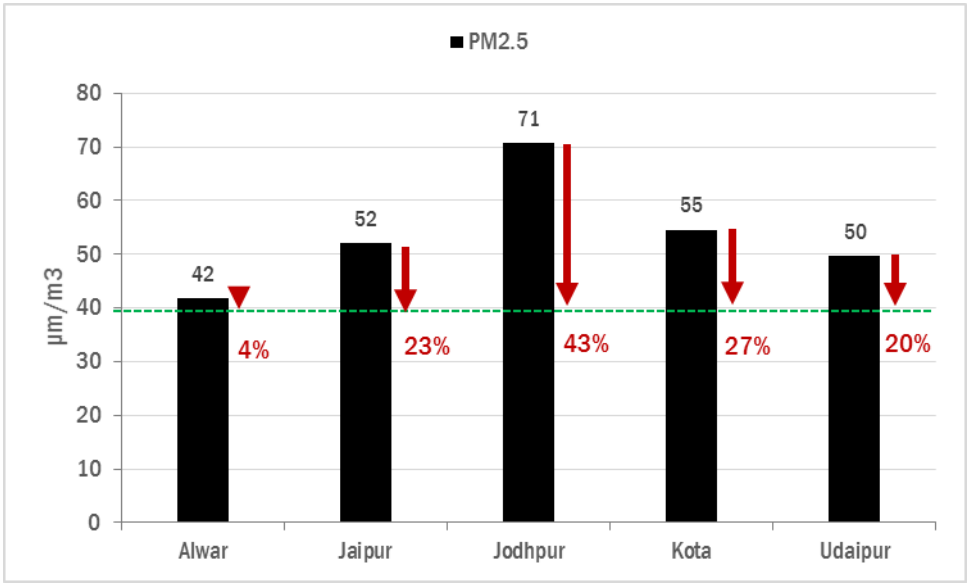
Map 1: Air quality monitoring network in Rajasthan



Source: CSE analysis

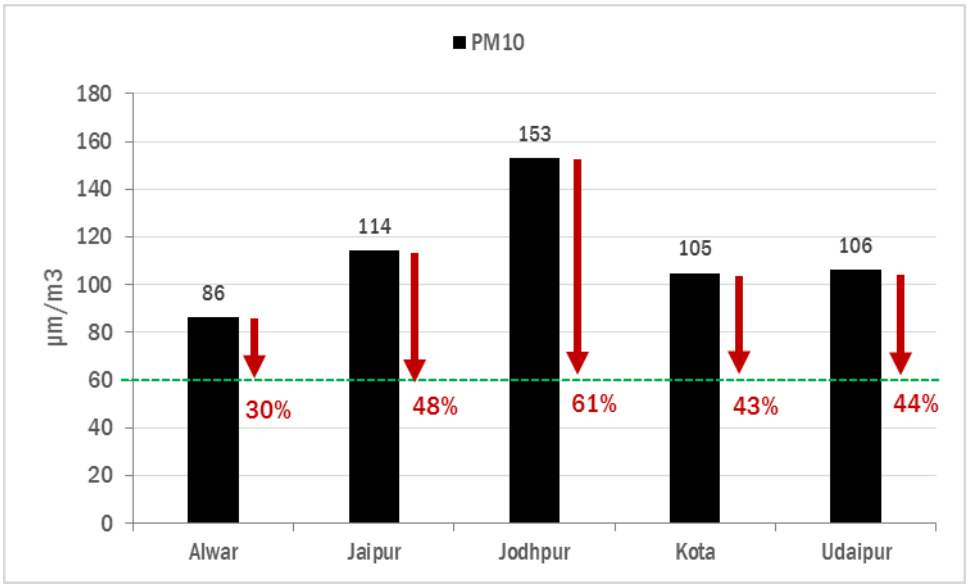
Considerable reduction is needed among all five nonattainment cities of Rajasthan to meet the standard for particulate pollution: Both PM10 and PM2.5 are the challenge in the state. Jodhpur is the most polluted among the five nonattainment cities with 3-yr average for PM2.5 of 71 µg/m^3 and for PM10 of 153 µg/m^3. Kota is second most polluted with 3-yr average for PM2.5 of 55 µg/m^3 and for PM10 of 105 µg/m^3. Jaipur is close third with 3-yr average for PM2.5 of 52 µg/m^3 and for PM10 of 114 µg/m^3. Udaipur and Alwar also exceed the standard and their 3-yr average for PM2.5 stands at 50 µg/m^3 and 42 µg/m^3. PM2.5 reduction target vary between 4 per cent and 43 per cent for these nonattainment cities (see *Graph 2: PM2.5 level among the nonattainment cities of Rajasthan, 3-yr average – 2020-22*). Reduction targets for PM10 are much higher, ranging between 30 per cent and 61 per cent (see *Graph 3: PM10 level among the nonattainment cities of Rajasthan, 3-yr average – 2020-22*).

Graph 2: PM2.5 level among the nonattainment cities of Rajasthan, 3-yr average – 2020-22



Note: 3-year average is based on mean of annual average recorded at the monitoring stations that have been operational since 2020. Jaipur value is based on the mean of three monitoring stations. Annual value for PM2.5 is based on 24-hr average.
Source: CSE analysis of CPCB realtime data.

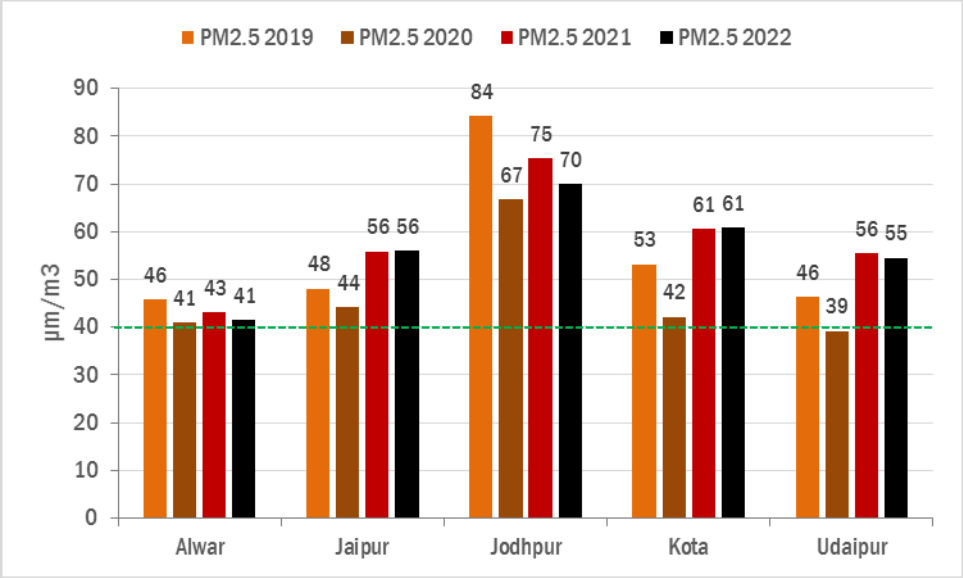
Graph 3: PM10 level among the nonattainment cities of Rajasthan, 3-yr average – 2020-22



Note: 3-year average is based on mean of annual average recorded at the monitoring stations that have been operational since 2020. Jaipur value is based on the mean of three monitoring stations. Annual value for PM10 is based on 24-hr average.
Source: CSE analysis of CPCB realtime data.

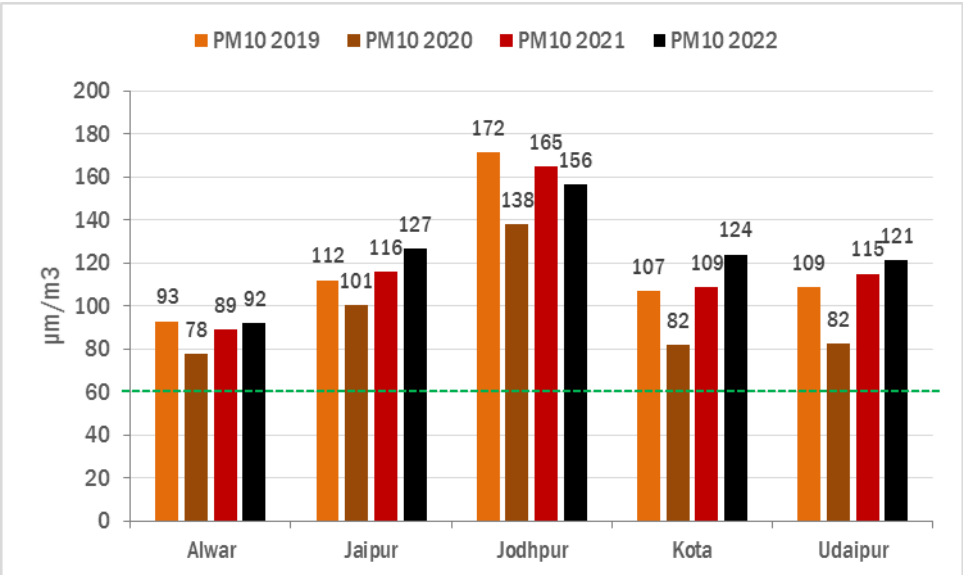
Particulate pollution is on rise in Jaipur, Kota and Udaipur, - the 2022 average levels have crossed the pre-pandemic levels: Both PM2.5 and PM10 levels are worsening in Jaipur, Kota and Udaipur. PM2.5 level in 2022 has been 14-18 per cent higher than the level recorded in 2019 among these three cities (see *Graph 4: Annual trend in PM2.5 level among the nonattainment cities of Rajasthan – 2019-22*). Similarly, PM10 level in 2022 has been 11-16 per cent higher than 2019 PM10 levels (see *Graph 5: Annual trend in PM10 level among the nonattainment cities of Rajasthan – 2019-22*). Alwar shows a stable trend with both PM2.5 and PM10 registering minimal change over the last four years. Jodhpur shows an improving trend with both PM2.5 and PM10 down 17 per cent and 9 per cent respectively from 2019 level.

Graph 4: Annual trend in PM2.5 level among the nonattainment cities of Rajasthan – 2019-22



Note: Based on data recorded at the monitoring stations that have been operational since 2019. Jaipur value is based on the mean of three monitoring stations. Annual value for PM2.5 is based on 24-hr average.
Source: CSE analysis of CPCB realtime data.

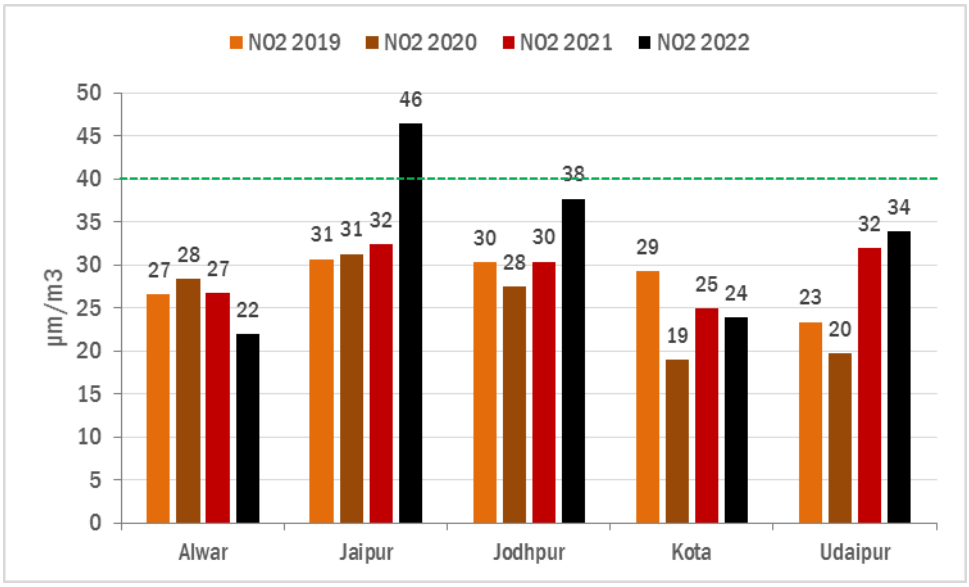
Graph 5: Annual trend in PM10 level among the nonattainment cities of Rajasthan – 2019-22



Note: Based on data recorded at the monitoring stations that have been operational since 2019. Jaipur value is based on the mean of three monitoring stations. Annual value for PM10 is based on 24-hr average.
Source: CSE analysis of CPCB realtime data.

NO2 pollution is on rise in Jaipur, Jodhpur and Udaipur, 2022 level have crossed the pre-pandemic level: Even though the NO2 levels are lower than the national ambient air quality standards in cities of Rajasthan, the cities are witnessing a rising trend. NO2 levels are worsening in Jaipur, Jodhpur and Udaipur. NO2 level has been 24-51 per cent higher than the level recorded in 2019 among these three cities (see *Graph 6: Annual trend in NO2 level among the nonattainment cities of Rajasthan – 2019-22*). It has been exceptionally challenging in Jaipur in 2022 when the NO2 level breeched the annual standard for NO2. Alwar and Kota show a stable trend. This pollutant requires early and preventive action as growing motorization can skew the curve.

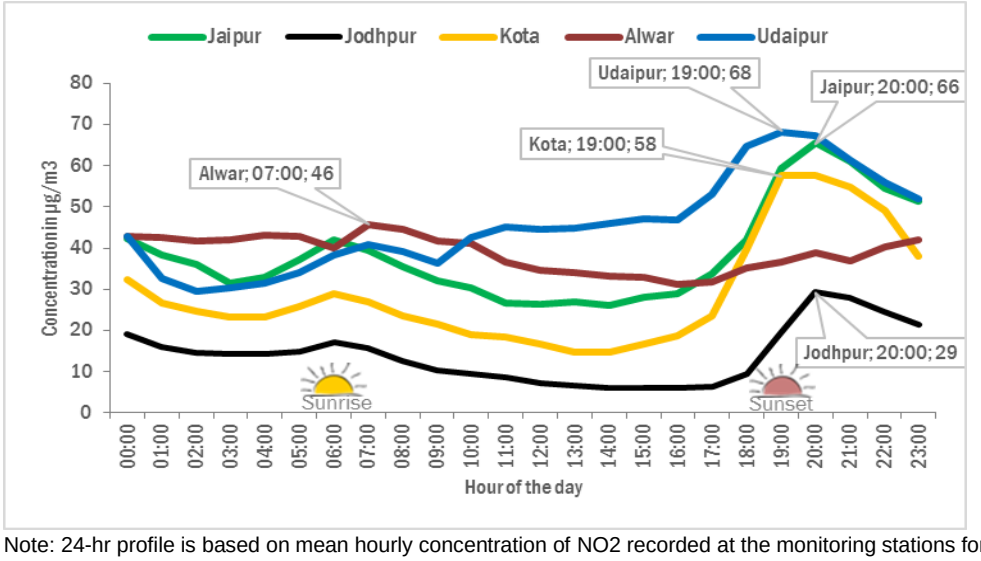
Graph 6: Annual trend in NO2 level among the nonattainment cities of Rajasthan – 2019-22



Note: Based on data recorded at the monitoring stations that have been operational since 2019. Jaipur value is based on the mean of three monitoring stations. Annual value for NO2 is based on 24-hr average.
Source: CSE analysis of CPCB realtime data.

NO2 pollution is closely linked with traffic flow: Diurnal tides of NO2 concentration in all the nonattainment cities follow the traffic flow pattern with peak concentrations aligning with traffic rush hours. There are two peaks in the NO2 concentrations during a typical day (see *Graph 7: Hourly NO2 cycle among nonattainment cities of Rajasthan – typical day May 2023*). First one happening between 7am-9am and second one between 7pm-9pm. The evening peak is higher in Jaipur, Jodhpur, Kota and Udaipur while morning peak is higher in Alwar. This indicates the impact of motorization.

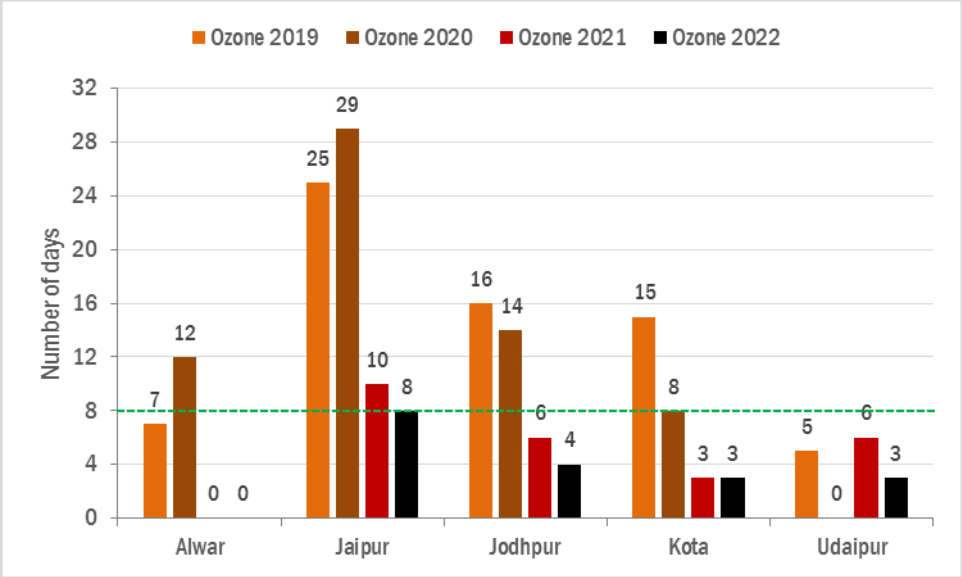
Graph 7: Hourly NO2 cycle among nonattainment cities of Rajasthan – typical day May 2023



Note: 24-hr profile is based on mean hourly concentration of NO2 recorded at the monitoring stations for month of May in 2023. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

Ground-level ozone is emerging as a challenge in nonattainment cities, needs more robust monitoring to assess the risk: Ground level ozone that is highly toxic and can harm even during short duration exposure requires a denser monitoring to assess its build up in local situations across the landscape. As of 2022, only one monitoring station each existed in Alwar, Jodhpur, Kota and Udaipur and three in Jaipur. On a several days in a year the ground-level ozone has started to exceed the 8 hour average standard for ozone in all the non-attainment cities with Jaipur being most affected (see *Graph 8: Annual trend in ground-level ozone exceedances among the nonattainment cities of Rajasthan – 2019-22*). It may be noted that ozone is not directly emitted by any source. A range of gases including NO2, volatile organic compounds, carbon monoxide and other gases that are emitted from vehicles and industries react with each other in the air under the influence of sunlight to form ozone. This is a highly reactive gas and extremely harmful for those suffering from asthma and respiratory conditions. To control all other gases will have to be controlled.

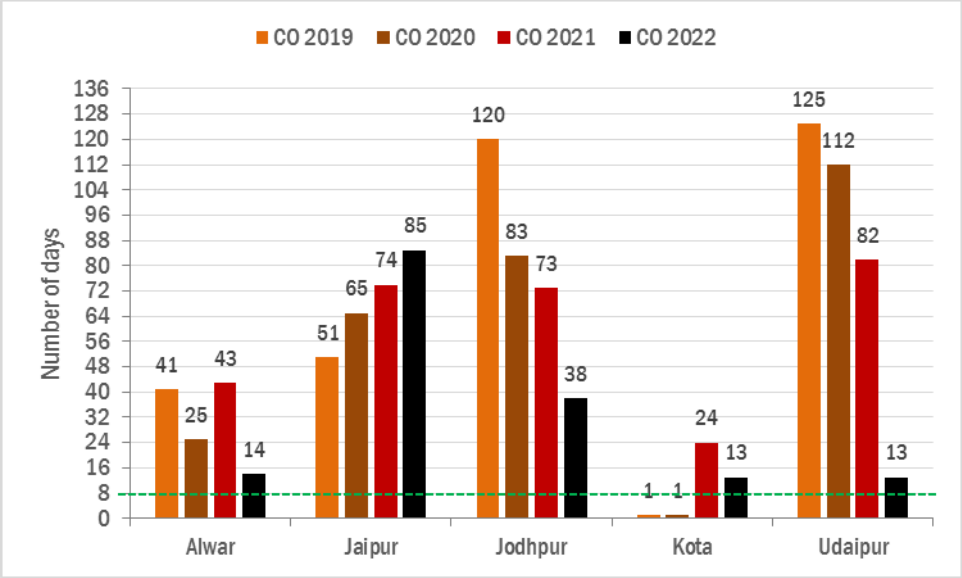
Graph 8: Annual trend in ground-level ozone exceedances among the nonattainment cities of Rajasthan – 2019-22



Note: Based on exceedances recorded at the monitoring stations that have been operational since 2019. Exceedance is computed as daily maximum 8-hr average crossing the ground-level ozone 8-hr standard, i.e. 100 µg/m^3.
Source: CSE analysis of CPCB realtime data.

Carbon monoxide pollution is also a concern in the non-attainment cities: Carbon monoxide (CO) is a very toxic gas and is emitted almost entirely by vehicles especially petrol vehicles. There was only one monitoring station in Alwar, Jodhpur, Kota and Udaipur and three in Jaipur till 2022. Instances of exceedance in CO has been more frequent with Jaipur being the worst affected (see *Graph 9: Annual trend in CO exceedances among the nonattainment cities of Rajasthan – 2019-22*).

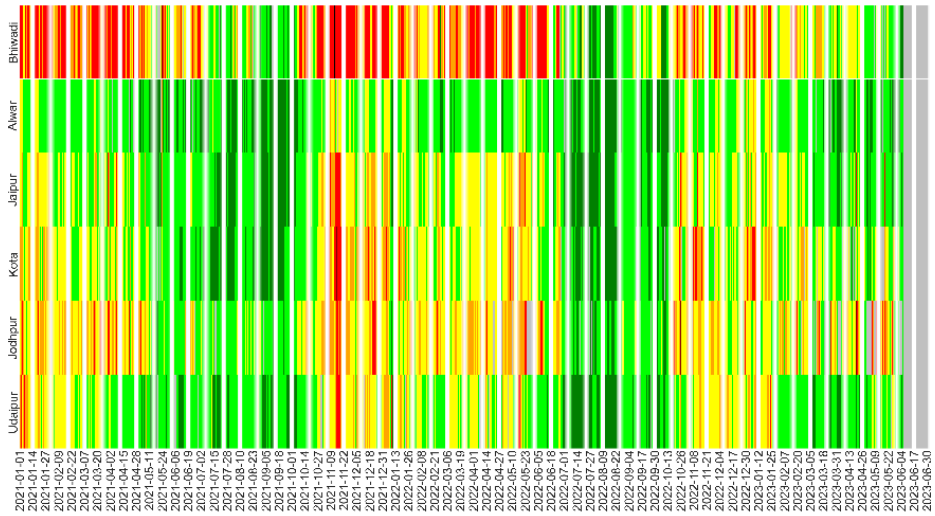
Graph 9: Annual trend in CO exceedances among nonattainment cities of Rajasthan – 2019-22



Note: Based on exceedances recorded at the monitoring stations that have been operational since 2019. Exceedance is computed as daily maximum 8-hr average crossing the carbon monoxide 8-hr standard, i.e. 2 mg/m^3.
Source: CSE analysis of CPCB realtime data.

Pollution during winter season is a challenge in all nonattainment cities; summer is also not clean in Jaipur, Jodhpur and Kota: Poor air quality days start in a synchronised pattern across the nonattainment cities of Rajasthan during the month of November. The intensity of pollution is higher in Jaipur and Kota. The air quality in Alwar and Udaipur improves from poor to moderate categories in spring but in Jaipur, Jodhpur and Kota it continues to remain bad through the summer. Monsoon is the only period when air quality turns good among the nonattainment cities (See *Graph 10: PM2.5 calendar for the nonattainment cities of Rajasthan – 2021-23*).

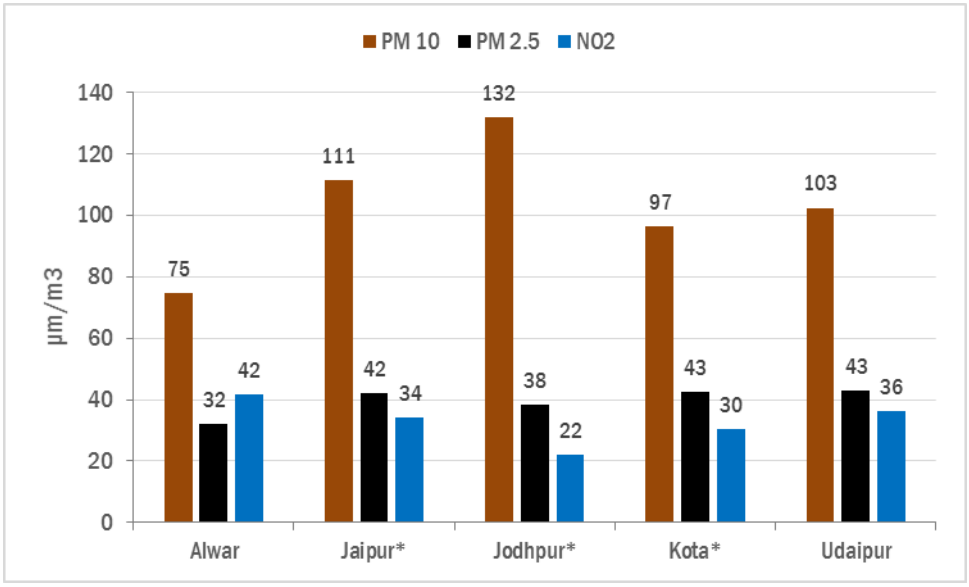
Graph 10: PM2.5 calendar for the nonattainment cities of Rajasthan – 2021-23



Note: PM2.5 level is based on average of city stations that have been operational since 2019. Cell colour is based on the official colour-scheme of AQI sub-categories.
Source: CSE analysis

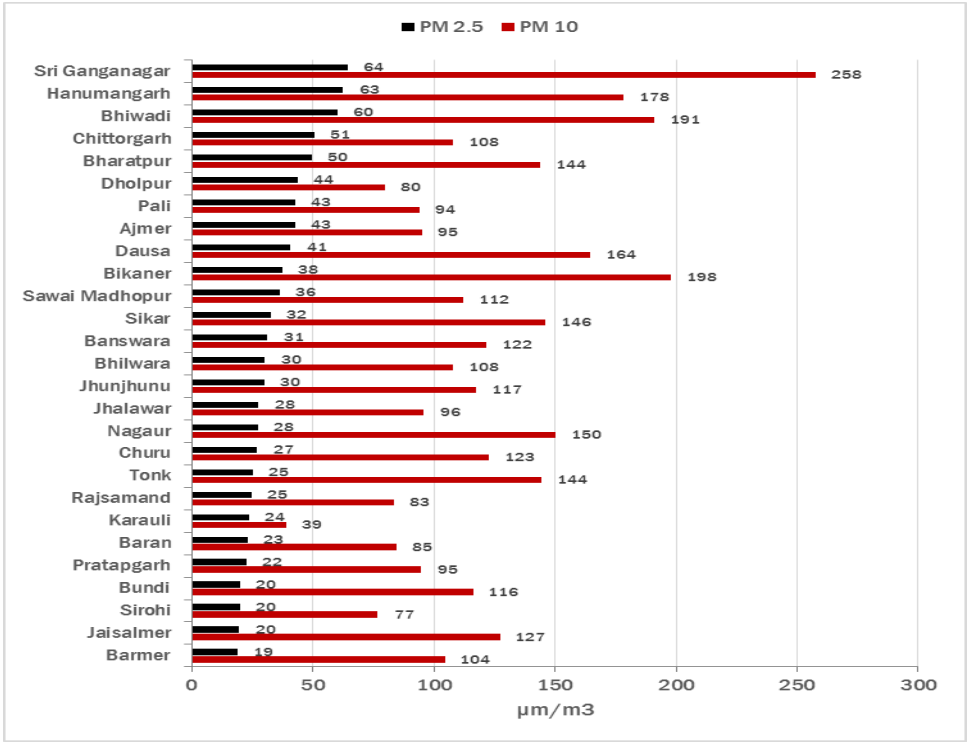
Smaller cities and towns are showing high PM and NO2 pollution as well: 24 smaller cities and towns of Rajasthan have started to monitor their air quality for the first time earlier in the year. Analysis of their data from the summer reveals that several of them can have seasonal levels even higher than the than nonattainment cities. During this summer season (March-May), Jodhpur had worst PM10 level, Kota had worst PM2.5 level and Alwar had worst NO2 level among nonattainment cities (See *Graph 11: 2023 summer pollution level among nonattainment cities of Rajasthan – PM10, PM2.5 and NO2*). During the same period Sri Ganganagar recorded PM2.5 level of 64 µg/m^3 and PM10 level of 258 µg/m^3, which is almost twice of the worst performing nonattainment cities. Hanumangarh, Bhiwadi, Chittorgarh, Bharatpur and Dholpur also had high PM2.5 level than all the nonattainment cities (see *Graph 12: 2023 summer pollution level among small cities and towns of Rajasthan – PM10 and PM2.5*). NO2 levels were also high in several small cities with Sri Ganganagar, Bhiwadi and Dausa being the worst performers (see *Graph 13: 2023 summer pollution level among small cities and towns of Rajasthan – NO2*). These cities and towns will require a careful assessment of annual trends in the future.

Graph 11: 2023 summer pollution level among nonattainment cities of Rajasthan – PM10, PM2.5 and NO2



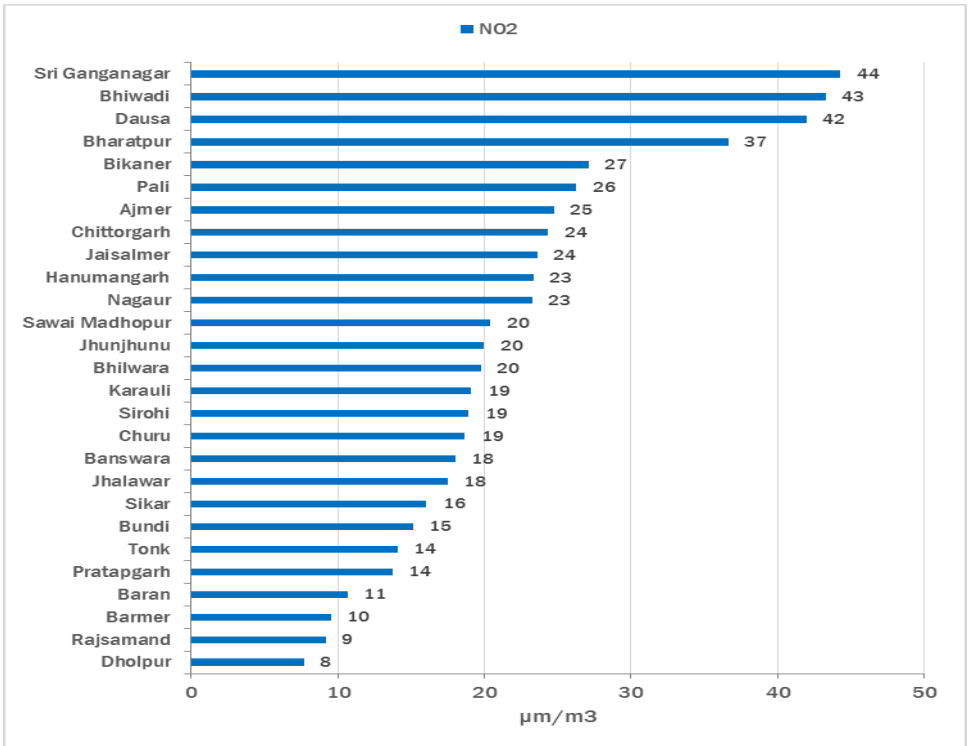
Note: Based on mean of seasonal average recorded at the monitoring stations operational since March 2023. Daily value for PM2.5, PM10 and NO2 is based on 24-hr average. Summer is defined as March to May. Data till 31 May 2023.
* Based on mean of multiple monitoring stations in the city.
Source: CSE analysis of CPCB realtime data.

Graph 12: 2023 summer pollution level among small cities and towns of Rajasthan – PM10 and PM2.5



Note: Based on mean of seasonal average recorded at the monitoring stations operational since March 2023. Daily value for PM2.5 and PM10 is based on 24-hr average. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

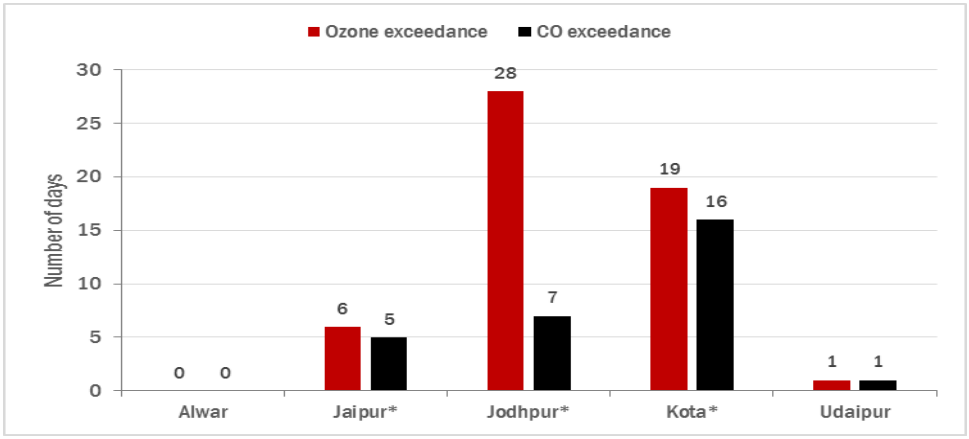
Graph 13: 2023 summer pollution level among small cities and towns of Rajasthan – NO2



Note: Based on mean of seasonal average recorded at the monitoring stations operational since March 2023. Daily value for NO2 is based on 24-hr average. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

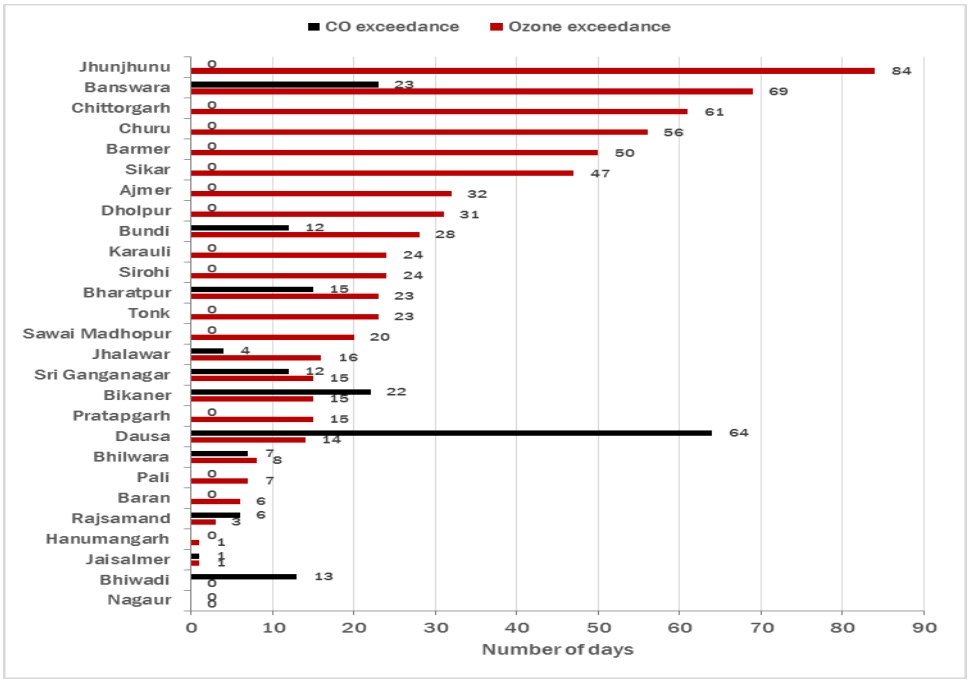
Summer of 2023 has witnessed ground-level ozone and CO exceedances in non-attainment and smaller towns - smaller towns are more affected: This summer season (March-May, 2023) Jodhpur has been most affected by gaseous pollutants among nonattainment cities with 28 exceedance days for ground level ozone and 7 exceedance days for CO. Kota has been the second worst with 19 exceedance days for ground-level ozone and 16 exceedance days for CO (See *Graph 14: 2023 summer pollution level among nonattainment cities of Rajasthan – ground-level ozone and CO*). Smaller cities and towns have fared much worse than the nonattainment cities. Jhunjhunu registered 84 exceedance days for ground level ozone; worst in the state. Banswara, Chittorgarh, Churu and Barmer registered more than 50 exceedance days for ground-level ozone (see *Graph 15: 2023 summer pollution level among small cities and towns of Rajasthan – ground-level ozone and CO*). Dausa has been worst affected by CO pollution with 64 exceedance days.

Graph 14: 2023 summer pollution level among nonattainment cities of Rajasthan – ground-level ozone and CO



Note: Based on exceedances recorded at the monitoring stations that have been operational since March 2023. Exceedance is computed as daily maximum 8-hr average crossing the 8-hr standard for ground-level ozone and carbon monoxide respectively. Summer is defined as March to May. Data till 31 May 2023.*Based on multiple monitoring stations in the city.
Source: CSE analysis of CPCB realtime data.

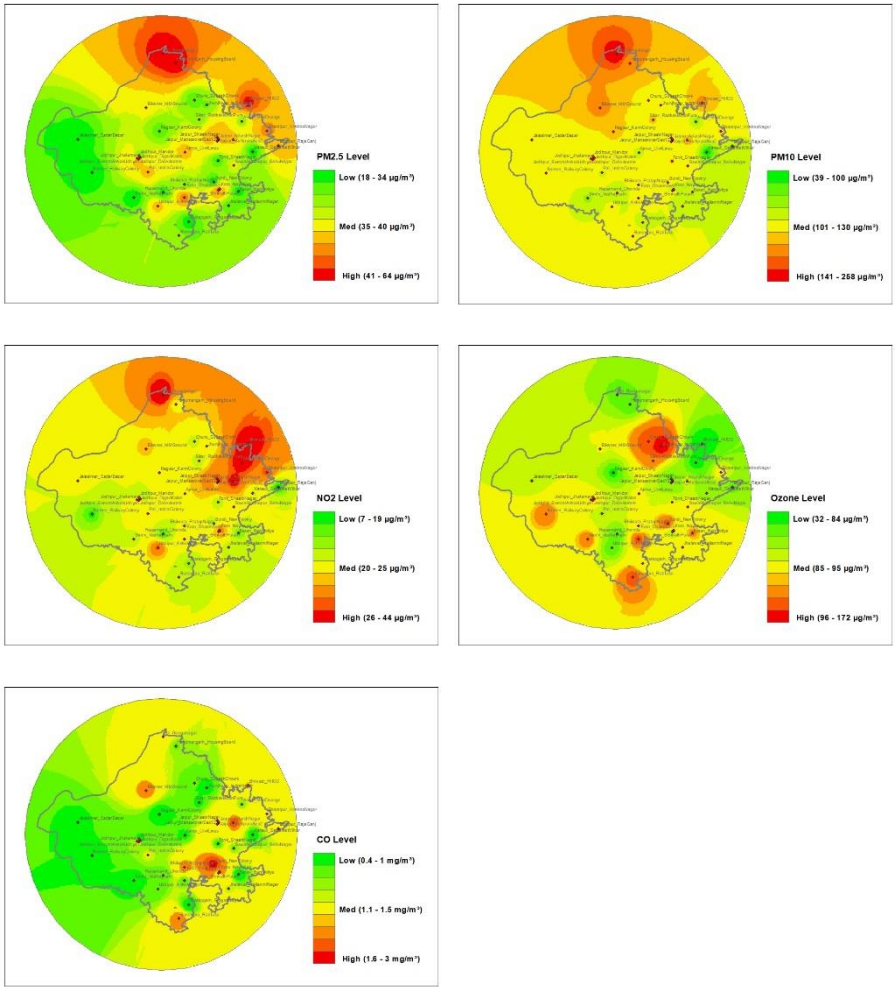
Graph 15: 2023 summer pollution level among small cities and towns of Rajasthan – ground-level ozone and CO



Note: Based on exceedances recorded at the monitoring stations that have been operational since March 2023. Exceedance is computed as daily maximum 8-hr average crossing the 8-hr standard for ground-level ozone and carbon monoxide respectively. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

Multi-pollutant crisis in Rajasthan: Spatial analysis of various pollutant concentrations across the landscape in the state shows that distribution of ground-level ozone is inverse of the NO2, CO and PM (see *Map 2: Spatial relationship among key pollutants during 2023 summer in Rajasthan – PM2.5, PM10, NO2, ground-level ozone and CO*). Northern parts of the start are most affected by PM and NO2 pollution while southern and western parts are hotspot for ground-level ozone.

Map 2: Spatial relationship among key pollutants during 2023 summer in Rajasthan – PM2.5, PM10, NO2, ground-level ozone and CO

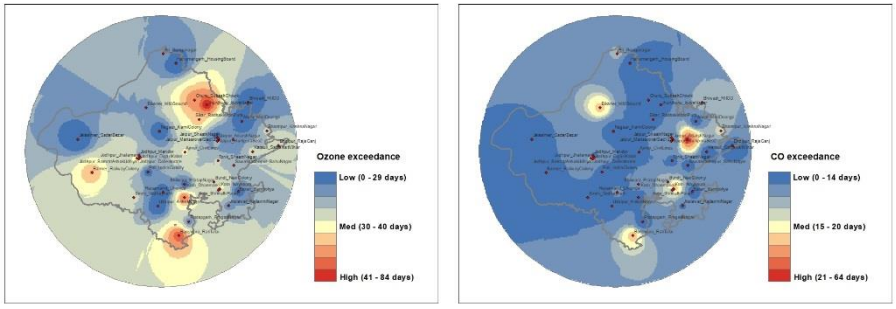


Note: Seasonal average computed as mean of daily values. Daily 24-hr average is used for PM2.5, PM10 and NO2. Daily maximum 8-hr average is used for ground-level ozone and CO. Summer is defined as March to May. Data till 31 May 2023.

Source: CSE analysis of CPCB realtime data.

Ground-level ozone and CO exceedance hotspots are mutually exclusive: Given the unique chemisty of ground-level ozone and CO it is nearly imposible for the concentration of both gases to buildup at same location at same time. This is evident in the spatial distribution of the hotspots of the two gases. This also shows that no part of the state is free of gasous pollution, if not ground-level ozone then CO levels are high (see *Map 3: Heatmap of ground-level ozone and CO exceedance summer hotspots in Rajasthan*).

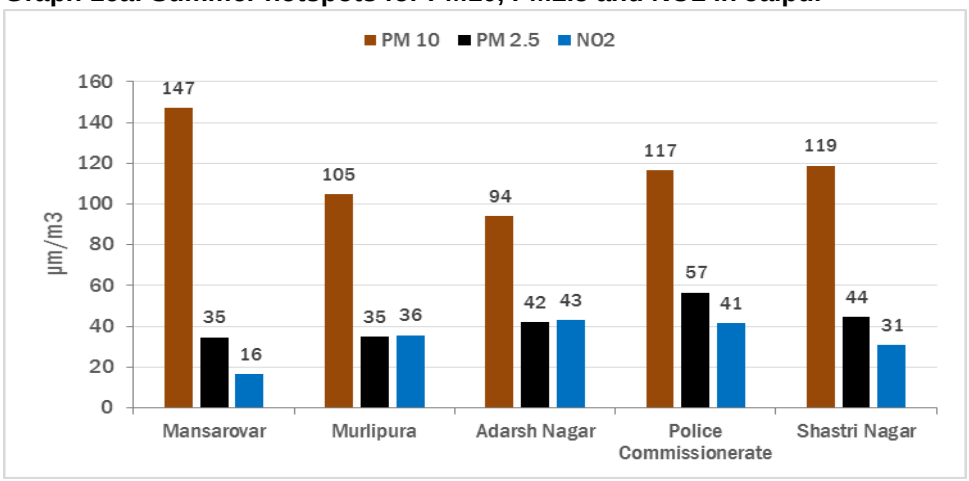
Map 3: Heatmap of ground-level ozone and CO exceedance summer hotspots in Rajasthan



Note: Based on exceedances recorded at the monitoring stations operational since March 2023. Exceedance is computed as daily maximum 8-hr average crossing the 8-hr standard for ground-level ozone and CO respectively. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

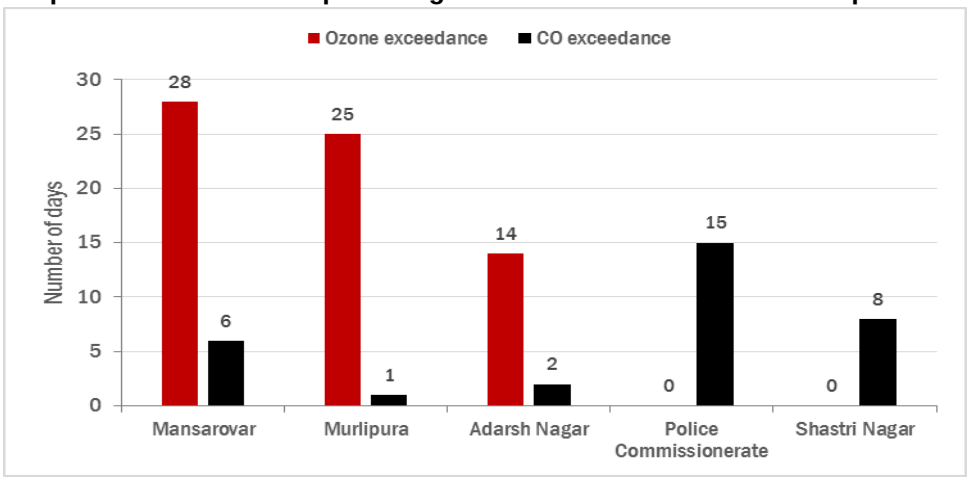
Pollution hotspots within Jaipur: Mansarovar is hotspot for PM10 and ground-level ozone pollution in the city. PM2.5 pollution is worst in Police Commissionerate while NO2 hotspot is Adarsh Nagar. Police Commissionerate also reported most CO exceedances this summer (See *Graph 16a: Summer hotspots for PM10, PM2.5 and NO2 in Jaipur* & *Graph 16b: Summer hotspots for ground-level ozone and CO in Jaipur*).

Graph 16a: Summer hotspots for PM10, PM2.5 and NO2 in Jaipur



Note: Based on mean of seasonal average recorded at the monitoring stations operational since March 2023. Daily value for PM2.5, PM10 and NO2 is based on 24-hr average. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

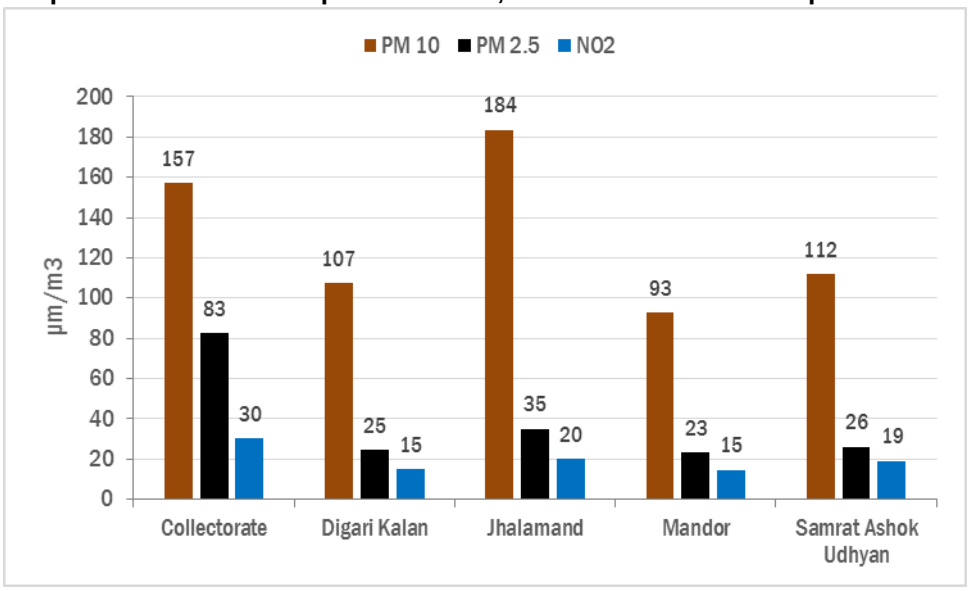
Graph 16b: Summer hotspots for ground-level ozone and CO in Jaipur



Note: Based on exceedances recorded at the monitoring stations that have been operational since March 2023. Exceedance is computed as daily maximum 8-hr average crossing the 8-hr standard for ground-level ozone and carbon monoxide respectively. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

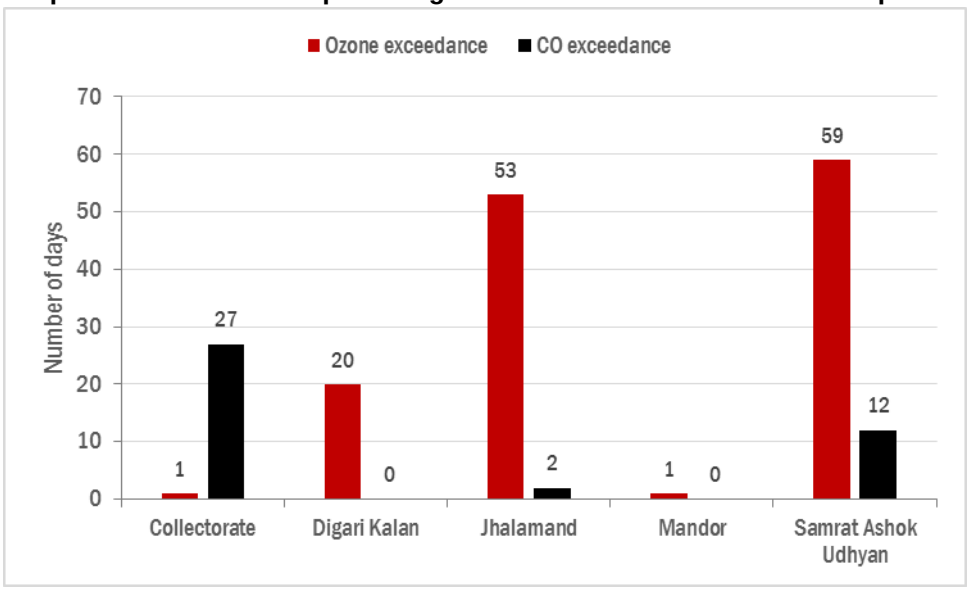
Pollution hotspots within Jodhpur: Jhalamand is hotspot for PM10 in Jodhpur. Collectorate is hotspot for PM2.5, NO2 and CO pollution. Samrat Ashok Udhyan reported most ground-level ozone exceedances this summer (See *Graph 17a: Summer hotspots for PM10, PM2.5 and NO2 in Jodhpur* & *Graph 17b: Summer hotspots for ground-level ozone and CO in Jodhpur*).

Graph 17a: Summer hotspots for PM10, PM2.5 and NO2 in Jodhpur



Note: Based on mean of seasonal average recorded at the monitoring stations operational since March 2023. Daily value for PM2.5, PM10 and NO2 is based on 24-hr average. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

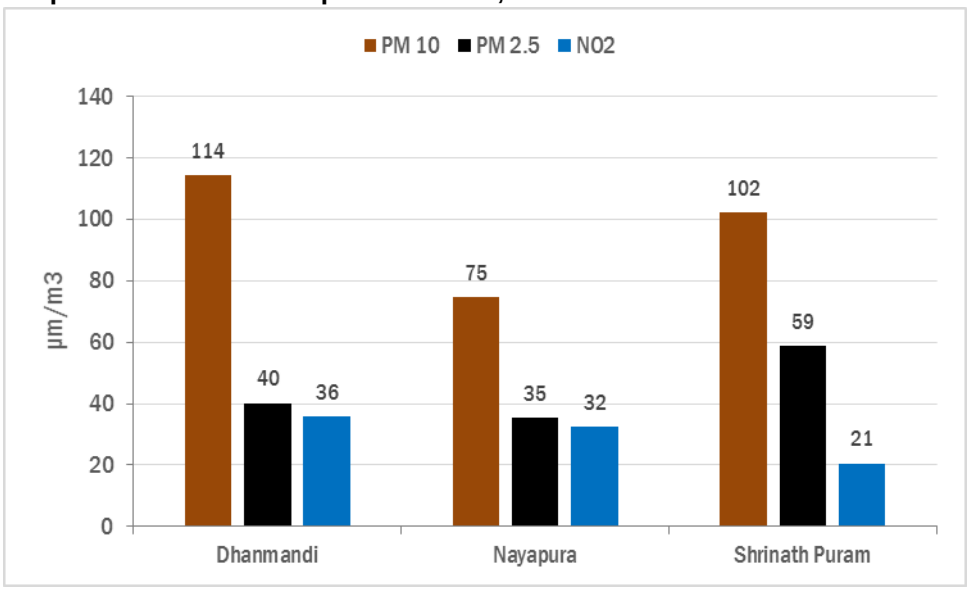
Graph 17b: Summer hotspots for ground-level ozone and CO in Jodhpur



Note: Based on exceedances recorded at the monitoring stations that have been operational since March 2023. Exceedance is computed as daily maximum 8-hr average crossing the 8-hr standard for ground-level ozone and carbon monoxide respectively. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

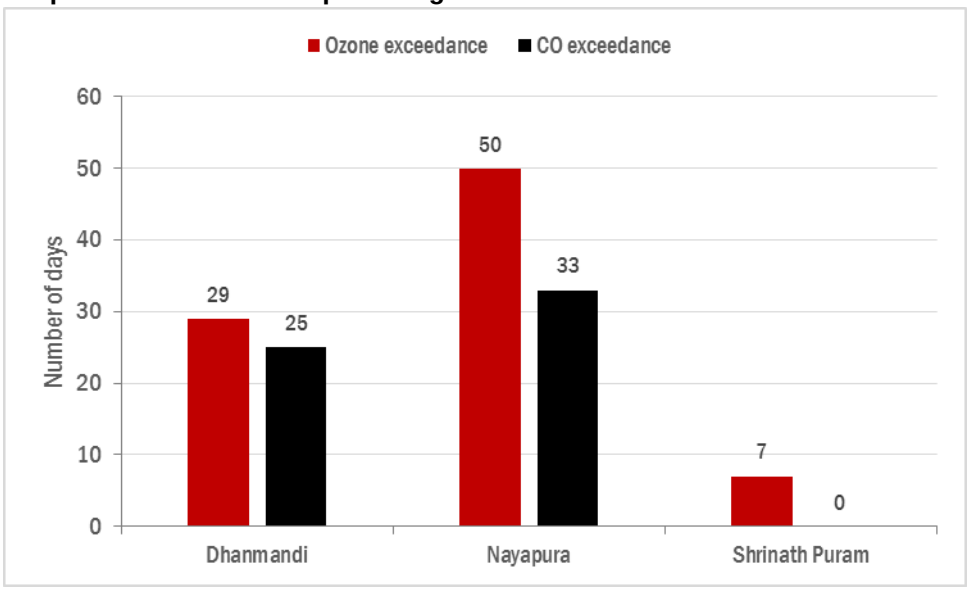
Pollution hotspots within Kota: Dhanmandi is hotspot for PM10 and NO2 in Kota. Shrinath Puram is the hotspot for PM2.5. Nayapura reported most ground-level ozone and CO exceedances this summer (See *Graph 18a: Summer hotspots for PM10, PM2.5 and NO2 in Kota & Graph 18b: Summer hotspots for ground-level ozone and CO in Kota*).

Graph 18a: Summer hotspots for PM10, PM2.5 and NO2 in Kota



Note: Based on mean of seasonal average recorded at the monitoring stations operational since March 2023. Daily value for PM2.5, PM10 and NO2 is based on 24-hr average. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

Graph 18b: Summer hotspots for ground-level ozone and CO in Kota



Note: Based on exceedances recorded at the monitoring stations that have been operational since March 2023. Exceedance is computed as daily maximum 8-hr average crossing the 8-hr standard for ground-level ozone and carbon monoxide respectively. Summer is defined as March to May. Data till 31 May 2023.
Source: CSE analysis of CPCB realtime data.

Way forward

While particulate pollution – both PM10 and PM2.5 – are on the rise in the non-attainment cities, gaseous pollutants including NO2, ozone, and CO are also beginning to record a rising trend. This can lead to a multipollutant crisis in the state. This requires widespread aggressive measures to reduce particulate pollution but also early preventive action to control gaseous emissions from the sources.

It is necessary to scale up with speed the implementation of the multi-sector clean air action plan at the city and the state level. The implementation of clean air action plans for the non-attainment cities as well as state clean air action plan are already underway. This will require further enhancement to strengthen the sectoral strategies to meet the sectoral targets.

- Need massive clean energy transition in industry, transport, power plants, and households.
- State-wide action to scale up electrification of vehicles, and promote usage of public transport, walking and cycling.
- Massive circular economy across the state to collect segregated waste, recover material from all streams of waste for recycling and remediation of legacy waste to eliminate burning of waste and dust particles.