DATA VISUALIZATION AND ANALYTICS

OF $PM_{2.5}$ AIR POLLUTION IN 5 INDIAN CITIES

(JUNE 2019 TO NOVEMBER 2019)

Project Title: Measurement & dissemination of air quality data using low cost monitors in 10 cities

December 2019

atmos
real-time air quality
Respirer Living Sciences

SHAKTI
SUSTAINABLE ENERGY FOUNDATION

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

Acknowledgement

Respirer Living Sciences Pvt. Ltd. and IIT Kanpur would like to thank Shakti Sustainable Energy Foundation for providing funding and strategic assistance in the establishment of Atmos network in 10 Indian cities. The analyses this report presents is premised on the data from the Atmos monitors.

Shakti Sustainable Energy Foundation (Shakti) works to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following sectors: clean power, energy efficiency, sustainable urban transport, climate policy and clean energy finance.

Disclaimer

Data access

All data used in this report is freely available to view & download via http://atmos.urbansciences.in and on the CPCB website. For feedback, suggestions, $PM_{2.5}$ datasets and API access to the data, email – research@urbansciences.in

Authors - Ravi Sahu[+], Nakul Mehta[#], Ronak Sutaria[#]

[+]IIT Kanpur. [#]Respirer Living Sciences Pvt. Ltd.

atmos
real-time air quality

Introduction

The project titled “Measurement and Calibration of Air Quality Monitors in 10 cities of India” (known as the “10 city project”) is a collaborative project between Respirer Living Sciences Pvt Ltd (known online as “UrbanSciences”) and Prof SN Tripathi’s team at IIT Kanpur under funding and strategic assistance from Shakti Sustainable Energy Foundation (SSEF).

This is one of the first projects in India which has developed a nationwide realtime $PM_{2.5}$ monitoring network which has been scientifically evaluated in multiple locations.

The specific 10 city project has entailed deploying Atmos monitors in the following cities: Ahmedabad, Bhopal, Chandigarh, Dehradun, Delhi/Gurugram, Jaipur, Kanpur, Raipur, Ranchi, Patna, Varanasi. Air pollution in additional cities like Mumbai & Lucknow have been closely tracked by the team due to strong local presence of the team preparing this report in those cities.

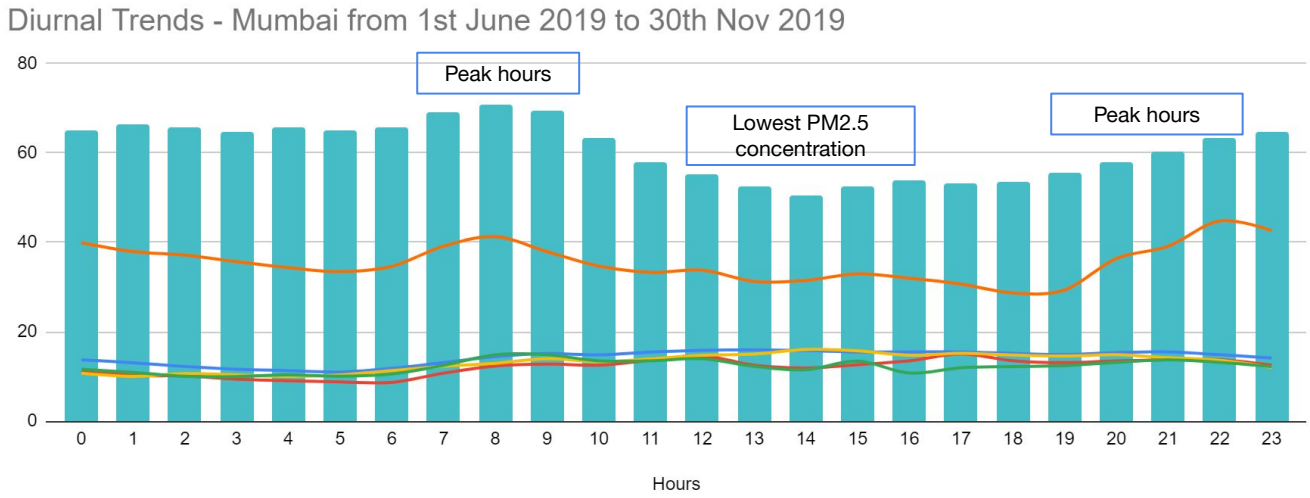
Data from 5 of cities – Mumbai, Lucknow, Raipur, Jaipur and Ahmedabad have been evaluated in this report. Regulatory grade PM2.5 data from CPCB monitors have also been used to prepare this report - to provide strong basis of the air pollution trends in these cities. Long-term trends like temporal analytics, diurnal trends, Calendar visualization and data availability have been shown. Analysis using regulatory grade monitors provide baseline information for each of the cities mentioned in this report.

In summary, the report highlights the long-term spatial and temporal trends in air quality levels for each of the cities in the report. Additional work using dense low-cost air quality sensor monitoring technology can augment & enhance the results presented here.

Mumbai

According to United Nations, as of 2018, Mumbai (presently capital of Maharashtra) was the second most populous city in India after the Delhi city. It was the seventh most populous city in the world as well. Mumbai is also the financial, commercial and entertainment capital of India.
Air pollution alone cost Maharashtra state reportedly 1,08,038 lives in year 2017, the second highest in the country, according to a published study in the Lancet Planetary Health. Maharashtra saw 86.9 air pollution-related deaths for every 1,00,000 people.

Regulatory Monitor: 10 sites[1]
Population: 20.19 million[2]
City GDP: $ 368 Bn[3]
Population Density: 26,900 per sq. km[4]
Number of registered motor vehicles in thousand (MH state data): 27870[5]

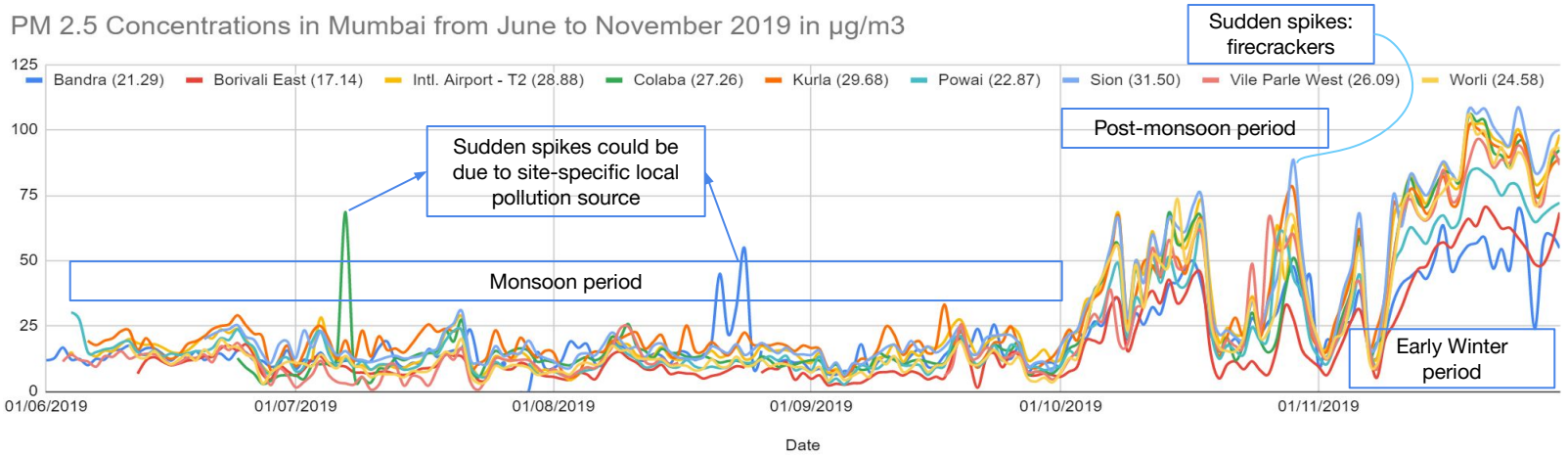


Daily average PM2.5 concentration in Nov (61 µg/m3) is twice to that of Oct & ~4 folds of Jun -Sep

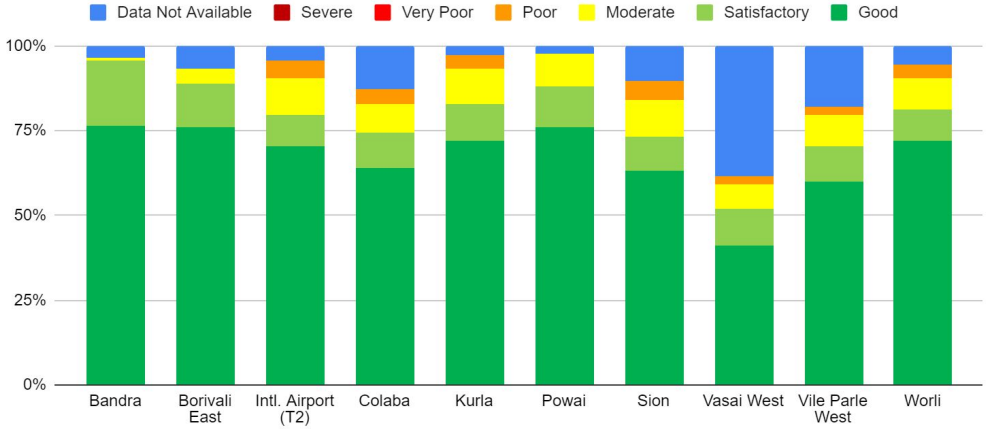
References:
1 - Central Pollution Control Board (CPCB)
2 - http://worldpopulationreview.com/world-cities/mumbai-population/
3 - https://en.wikipedia.org › wiki › Economy_of_Mumbai
4 - http://demographia.com/db-worldua.pdf
5 - http://mospi.nic.in/statistical-year-book-india/2018/189 (Data till 2016)
Picture Credit: Lonely planet

atmos
real-time air quality

PM 2.5 Concentrations in Mumbai from June to November 2019 in µg/m3



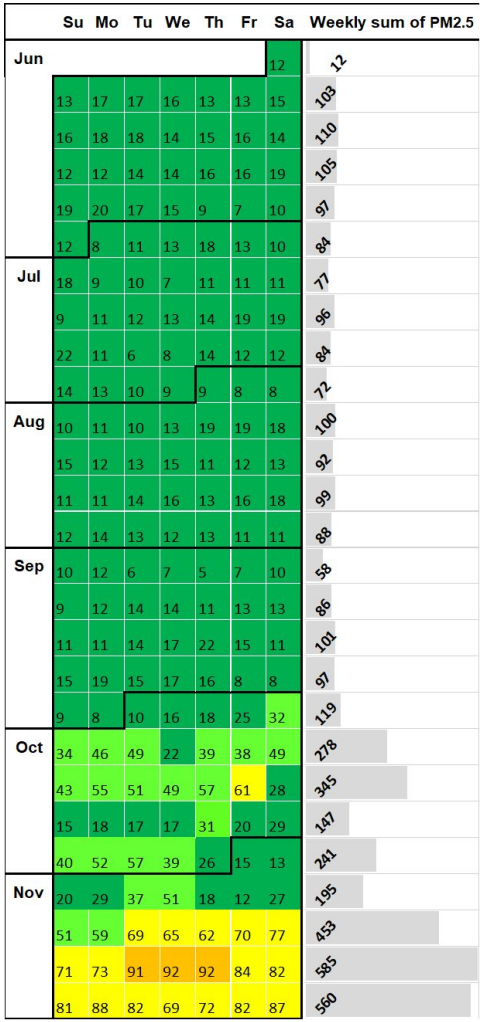
Mumbai CPCB Monitors Uptime



*Zoom-in to see the location and names.

atmos
real-time air quality

Monthly glance - Calendar Plot: PM 2.5 Values (µg/m3) from June to November 2019



Air Quality in Mumbai: A Snapshot

The city showed the lowest $PM_{2.5}$ levels across (best air quality) the 5 cities evaluated in this report. From 19th to 21st November, most polluted days with measured PM2.5 concentrations during this period ranging in between 58 to 108 µg/m3 at different considered sites. An average peak $PM_{2.5}$ level of 92 µg/m3 was seen in November (21 November).

PM2.5 Concentration Time-series: Despite spikes in pollution levels, Mumbai records 'cleanest Diwali air' among the five Indian cities. In general, from June to September 2019, the PM2.5 concentration levels remained very low, and it considerably increases October onwards.

Calendar Heatmap and uptime plot:

The calendar visualization shows the seasonal $PM_{2.5}$ variations across the six-month duration (June to November) and is mostly rain dominated (June to September). Clear 24 hourly averaged PM2.5 trend can be seen with the transition from good air quality to satisfactory levels happening in November. Both heat map and monitors uptime plot shows that the average 77%, 11%, 9%, and 2% period during the measured six months represents an air quality is good, (142 days) satisfactory (20 days), moderate (17 days), and poor (3 days) categories, respectively. Apart from being a coastal city, rain occurred from June till September, which might have resulted in better air quality in Mumbai in comparison to other cities. Overall, weekdays are more polluted in comparison to weekends.

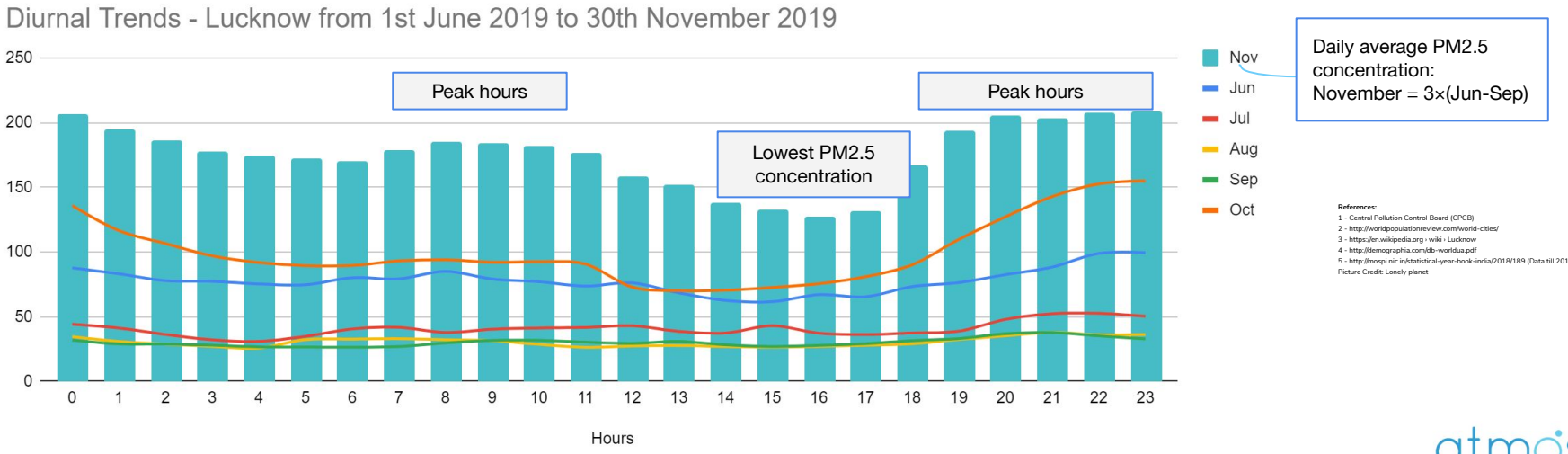
Diurnal Chart Analysis:

The city has typical urban morning peaks in $PM_{2.5}$ concentration levels from 6 to 8 am and evening peaks from 7 to 11 pm. The diurnal pattern suggests that traffic is a predominant source of pollution during these days. $PM_{2.5}$ levels in the afternoon period (between 2 to 4 pm) is observed. In June to September, monsoon is probably responsible for the flat diurnals maintained at low PM levels.

Lucknow

Lucknow, one of cities in northern India, is the capital of the state of Uttar Pradesh. This is the second largest city of northern India and is one of the most famous tourist attractions of the country. The area of the city is 310.1 km^2. It occurs in middle Indo Gangetic Plain (IGP).

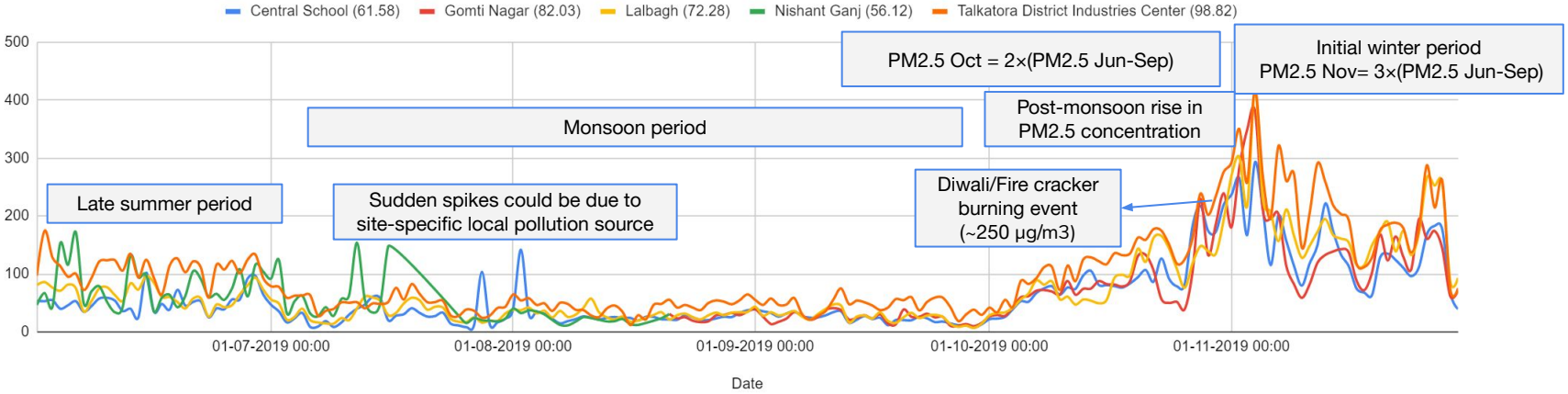
Regulatory Monitor: 5 sites[1]
Population: 2.8 Million[2]
City GDP: $230 Bn (state data)[3]
Population Density: 8,100 per sq. km[4]
Number of registered motor vehicles in thousand (state data): 23,936[5]



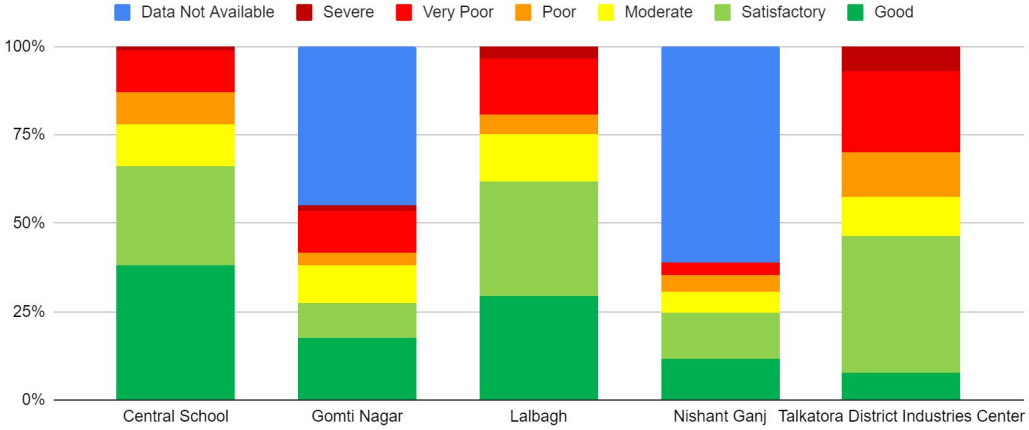
References:
1 - Central Pollution Control Board (CPCB)
2 - http://worldpopulationreview.com/world-cities/
3 - https://en.wikipedia.org › wiki › Lucknow
4 - http://demographia.com/db-worldua.pdf
5 - http://mospi.nic.in/statistical-year-book-india/2018/189 (Data till 2016)
Picture Credit: Lonely planet

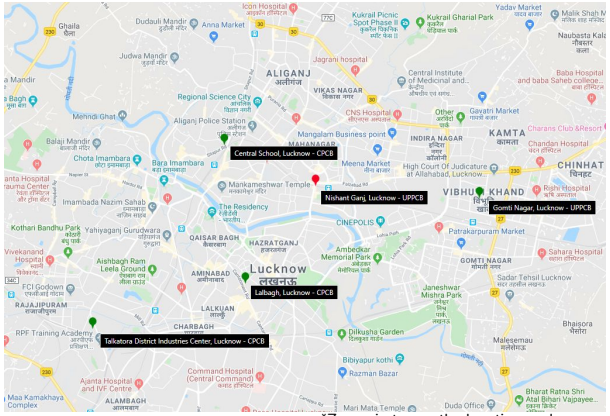
atmos
real-time air quality

PM 2.5 Concentrations in Lucknow from June to November 2019 in µg/m3



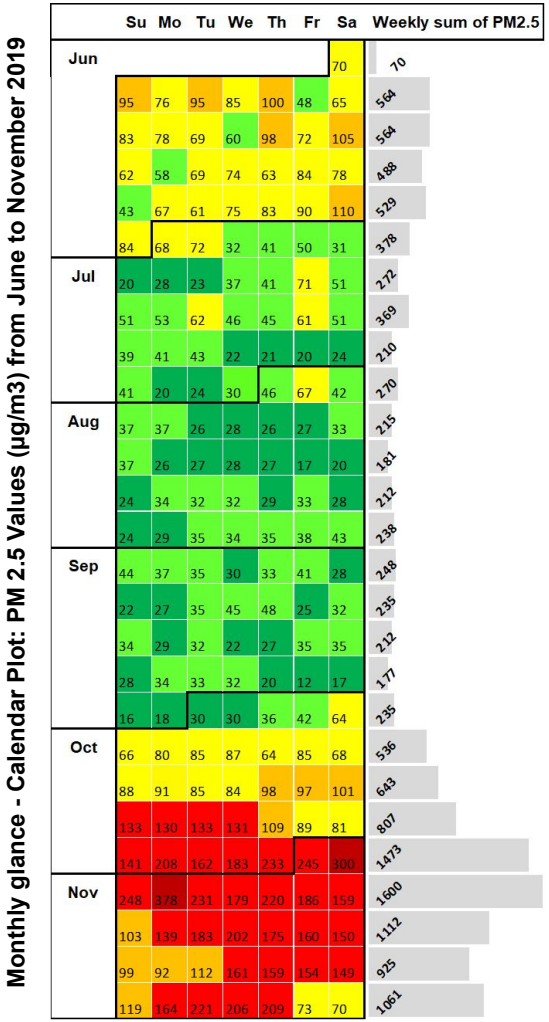
Lucknow CPCB Monitor Uptime





*Zoom-in to see the location and names.

atmos
real-time air quality



Air Quality in Lucknow: A Snapshot:
The city showed the highest PM2.5 levels across the 5 cities evaluated in this report. From mid-October, Lucknow has encountered avery poor PM2.5 category. City PM2.5 seasonal variation can be clearly seen; in the summer season (June), moderate to a poor category is observed. July to September, which is monsoon season showed the least polluted period, post-monsoon (October) showed an increment in PM level with time, which leads to moderate to poor categories and most polluted days measured for PM2.5 concentrations during the winter period (here November). In November, daily concentration reached up to 378 µg/m3 (severe category).

PM2.5 Concentration Time-series: Spikes in pollution levels is observed in the Diwali festival period. Lucknow recorded the highest concentration among the five Indian cities during every respective season. Being in the downwind direction of Delhi, the extreme haze events are also observed in Lucknow, especially at the end of October and November. PM2.5 recorded concentrations have crossed 400 µg/m3 mark in Lucknow. In general, from June to September 2019, the PM2.5 concentration levels remained very low, and it considerably increases October onwards.

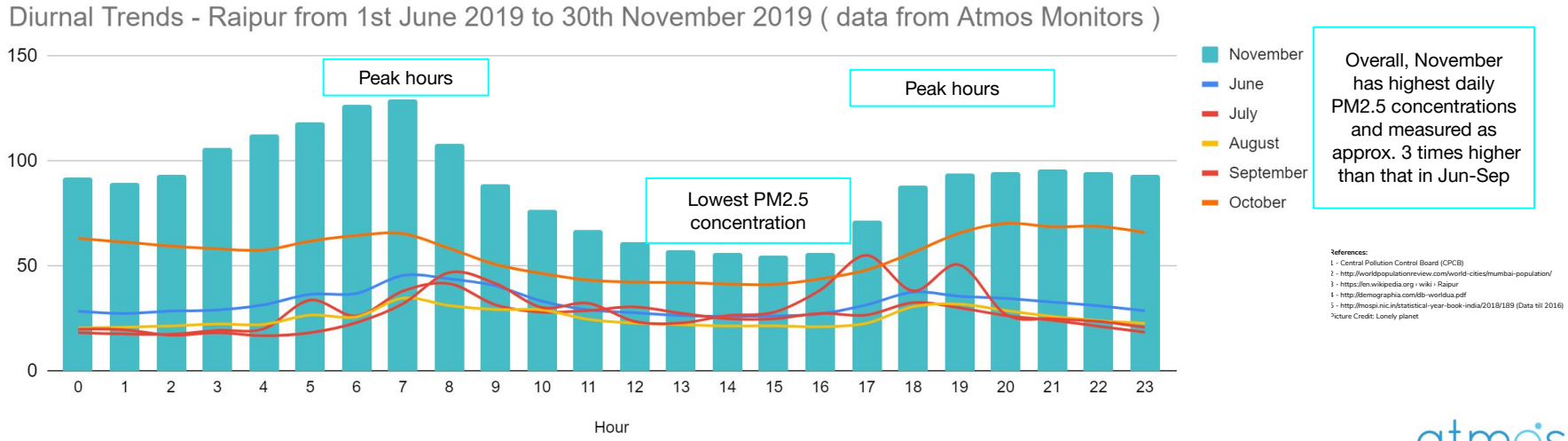
Calendar Heatmap:
The calendar visualization shows the seasonal PM2.5 variations across the six-month duration (June to November). Heat map for June showed summer has moderate to poor category and is mostly rain dominated (July to September). Clear 24 hourly averaged PM2.5 trend can be seen with the transition from good air quality to satisfactory to moderate to poor to very poor and finally to severe from October to November. Average 22%, 30%, 23%, 8%, 16% and 1% period during the measured six months represents an air quality is good (40 days), satisfactory (54 days), moderate (42 days), poor (15 days), very poor (30 days) and severe (2 days) categories, respectively. Several studies showed that biomass burning in Punjab and Haryana regions affects Delhi air quality, which further moves in the downwind direction and deteriorates Lucknow's ambient air.

Diurnal Chart Analysis:
The city has morning peaks in PM2.5 concentration levels from 7 to 11 am and evening peaks from 7 to 11 pm which is mostly peak hours for traffic. PM2.5 levels in the afternoon period (between 3 to 5 pm) is observed.

Raipur

The capital of Chhattisgarh, Raipur is the largest city in the state. With more than hundreds of steel mills and six steel plants, Raipur is also one of the largest industrial centers of the country. Raipur got into the suspect distinction of one among the ten most polluted cities a few years ago with alarming levels of air pollution and bringing it to the international air quality discussions.

Regulatory Monitor: None[1]
Population: 1.7 Million[2]
City GDP: $ 2.3 Bn[3]
Population Density: 310 per sq. km[4]
Number of registered motor vehicles in thousands (state data): 4810[5]

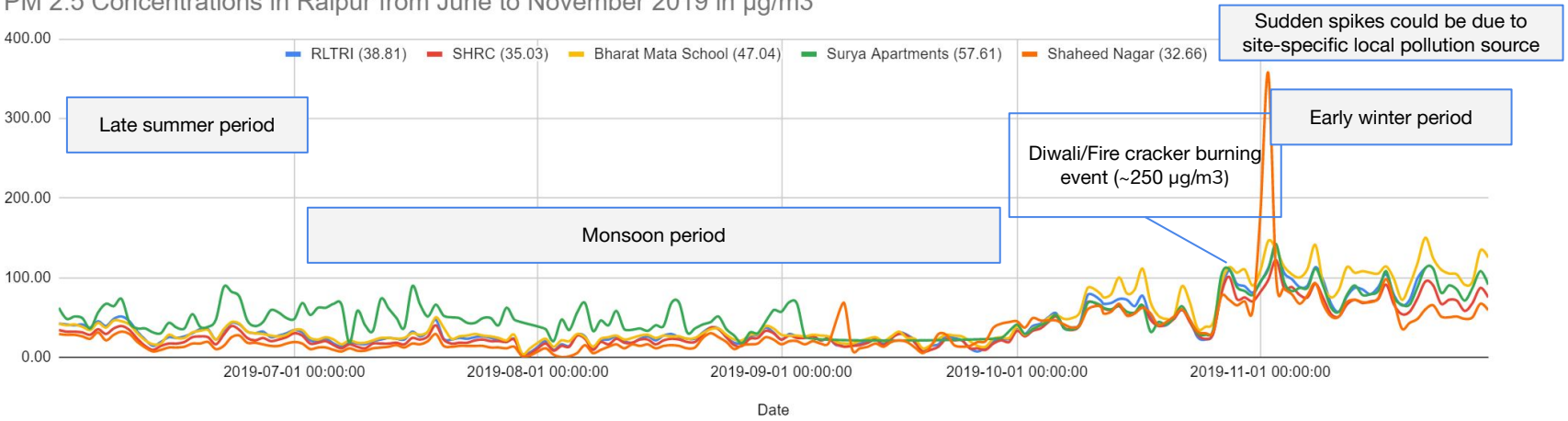


Overall, November has highest daily PM2.5 concentrations and measured as approx. 3 times higher than that in Jun-Sep

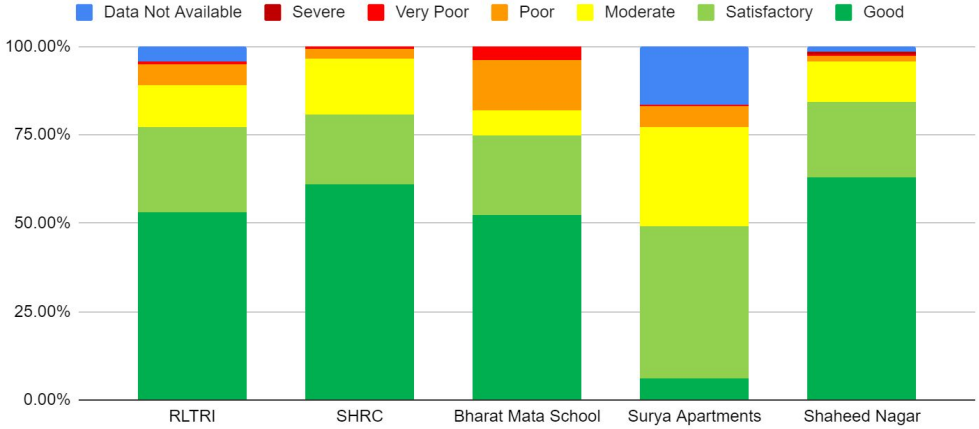
References:
1 - Central Pollution Control Board (CPCB)
2 - http://worldpopulationreview.com/world-cities/mumbai-population/
3 - https://en.wikipedia.org › wiki › Raipur
4 - http://demographia.com/db-worldua.pdf
5 - http://mospi.nic.in/statistical-year-book-india/2018/189 (Data till 2016)
Picture Credit: Lonely planet

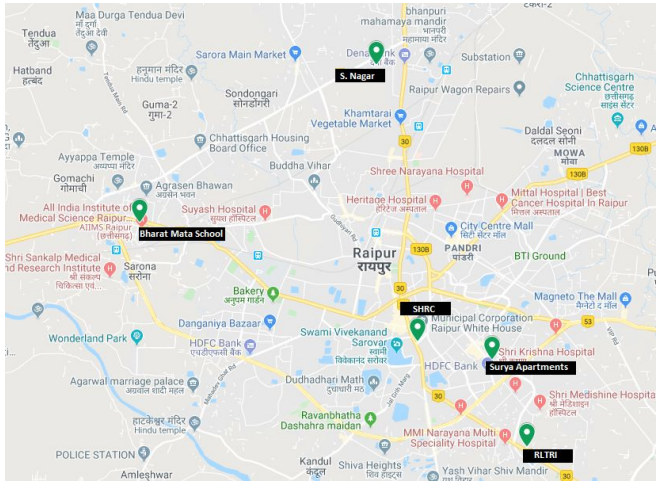
atmos
real-time air quality

PM 2.5 Concentrations in Raipur from June to November 2019 in µg/m3



Raipur Atmos Device Uptime

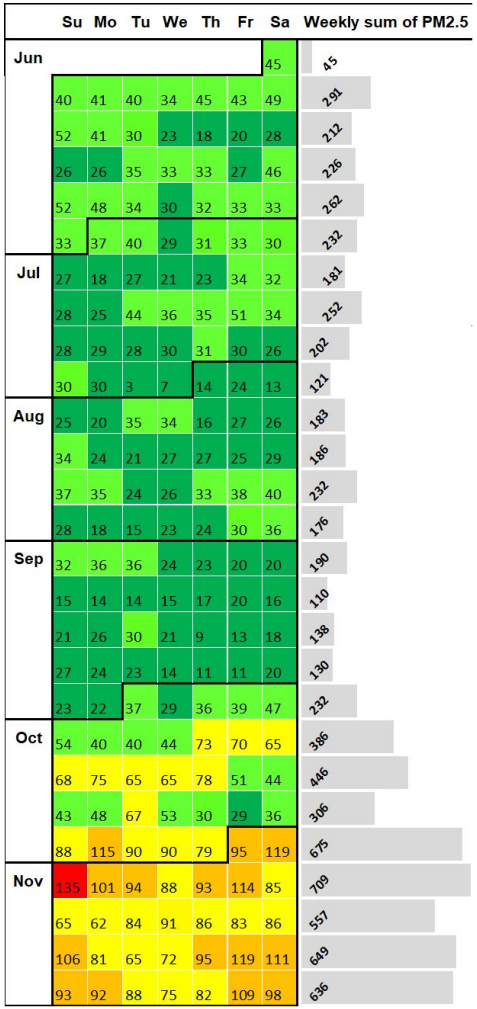




*Zoom-in to see the location and names.

atmos
real-time air quality

Monthly glance - Calendar Plot: PM 2.5 Values (µg/m3) from June to November 2019



Air Quality in Raipur: A Snapshot

The city showed the intermediate PM2.5 levels across the 5 cities evaluated in this report. From the Diwali festival onwards November, air quality in the city is deteriorated. The city registered 100% measured 24-hourly-PM2.5 concentration ranging above 60 µg/m3 in November; mostly, the concentration measured on the post-Diwali week in October end and November first week are estimated highest during the six months.

PM2.5 Concentration Time-series: Higher pollution levels are, in general, can be seen after triggering spikes for the increasing pollution levels recorded for Diwali day. Among the five Indian cities, Raipur showed 2nd best air quality during the last six months. In general, from June to September, 2019 the PM2.5 concentration levels remained, low and it increases up to 2 folds in its comparison at around Diwali days onwards. The average pM2.5 concentration measured in the Raipur is 43.5± 27.8 µg/m3.

Calendar Heatmap:

The calendar visualization shows the seasonal PM2.5 variations across the six-month duration; end of the summer followed by monsoon (June to mid-September) and post- monsoon (mid-September to October) followed by winter in November. Clear 24 hourly averaged PM2.5 trend can be seen with the transition from good air quality to satisfactory levels happening in November. The average 40%, 36%, 15%, 8%, and 1% periods during the measured six months represents an air quality of good, (74 days) satisfactory (65 days), moderate (28 days), poor (15 days) and very poor (1 day) types, respectively. Overall, weekdays are less-polluted in comparison to weekends. In the city, all the time, the measured 24-hourly-PM2.5 concentrations ranged <60 µg/m3 in between June to September, and in November, it is mostly polluted.

Diurnal Chart Analysis:

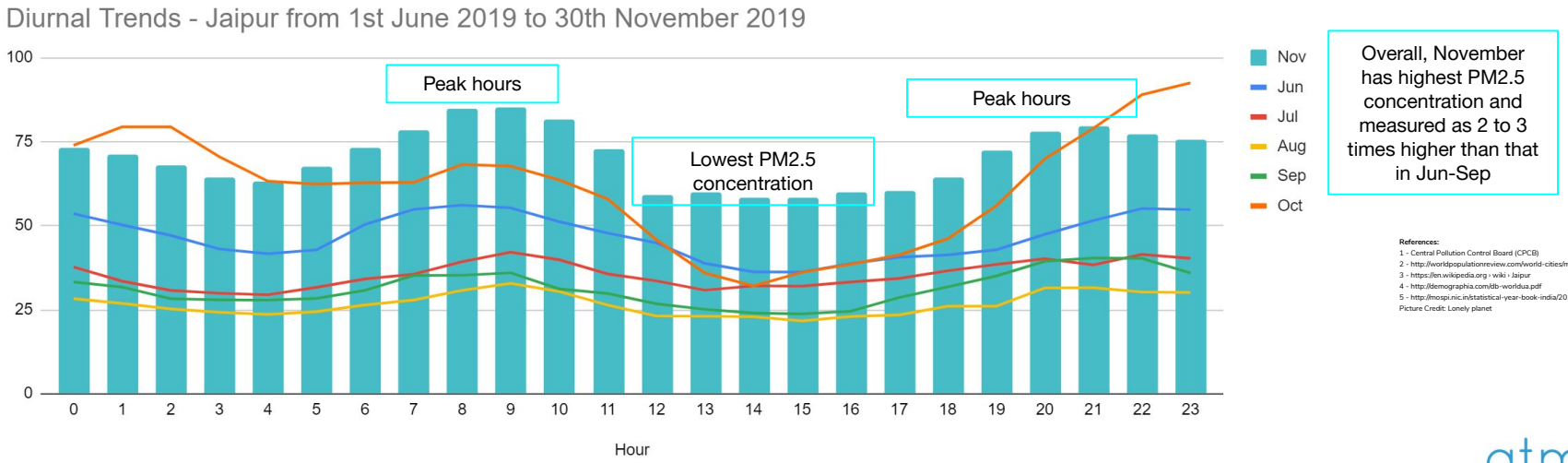
The city has typical urban morning peaks in PM2.5 concentration levels from 6-9 am and evening peaks from 5-8 pm, which is mostly peak hours for commuting typical city traffic. But in November, pollution levels are higher between 5-8 am and again increase from 5-9 pm; least PM2.5 concentration measured at 2-4 pm.

atmos
real-time air quality

Jaipur

Jaipur is the capital and the largest city of the Indian state of Rajasthan. As of 2011, the city had a population of 3.1 million, making it the tenth most populous city in the country. Jaipur is also known as the Pink City, due to the dominant color scheme of its buildings. It is located 268 km from the national capital New Delhi. In the 2008 Conde Nast Traveller Readers Choice Survey, Jaipur was ranked the 7th best place to visit in Asia. Jaipur is the most polluted city in the desert state, says the report.

Regulatory Monitor: 3 sites[1]
Population: 3.1 Million[2]
City GDP: $32 Bn (state data)[3]
Population Density: 6,500 per sq. km[4]
Number of registered motor vehicles in thousand (state data): 13632[5]

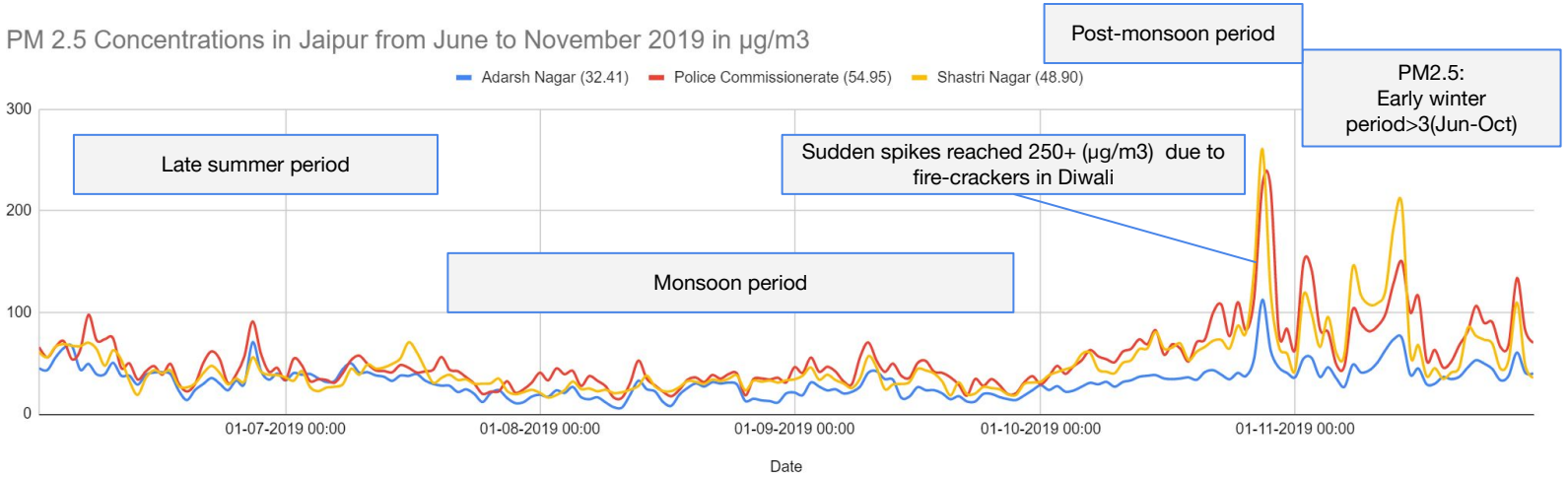


Overall, November has highest PM2.5 concentration and measured as 2 to 3 times higher than that in Jun-Sep

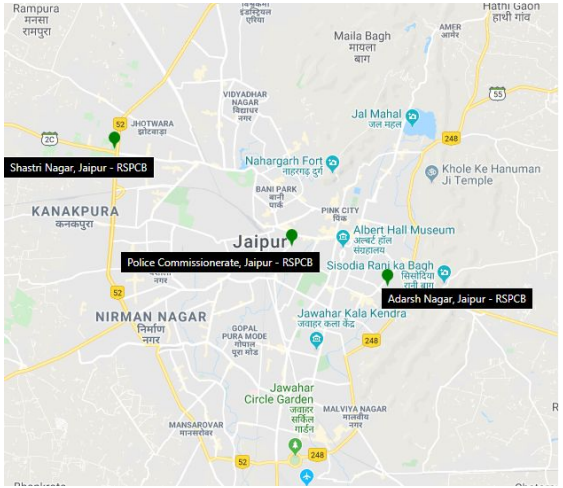
References:
1 - Central Pollution Control Board (CPCB)
2 - http://worldpopulationreview.com/world-cities/mumbai-population/
3 - https://en.wikipedia.org › wiki › Jaipur
4 - http://demographia.com/db-worldua.pdf
5 - http://mospi.nic.in/statistical-year-book-india/2018/189 (Data till 2016)
Picture Credit: Lonely planet

atmos
real-time air quality

PM 2.5 Concentrations in Jaipur from June to November 2019 in µg/m3



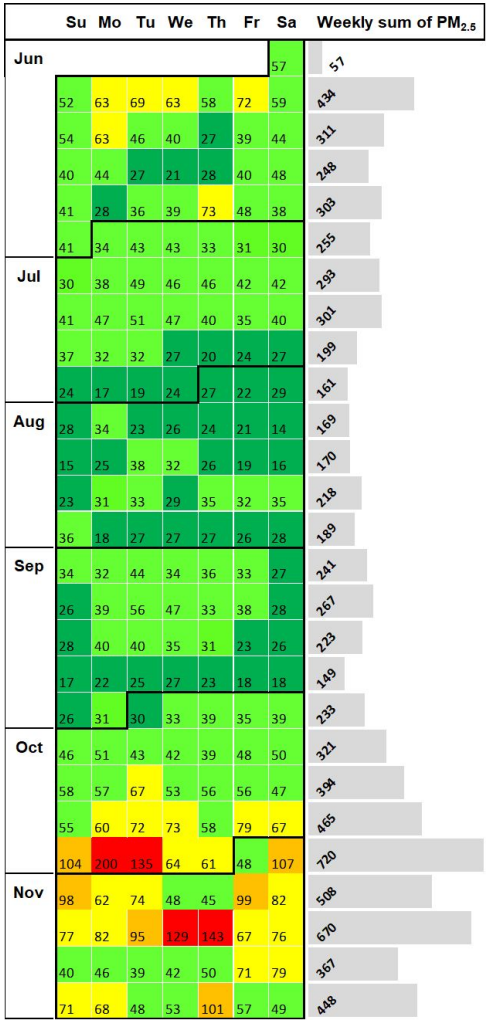
Jaipur CPCB Device Uptime



*Zoom-in to see the location and names.

atmos
real-time air quality

Monthly glance - Calendar Plot: PM 2.5 Values (µg/m3) from June to November 2019



Air Quality in Jaipur: A Snapshot

The city is among the 3rd highest in the list of 5 cities evaluated in this report for its PM2.5 concentration levels. From mid-October, Jaipur has encountered a very poor PM2.5 category. City PM2.5 seasonal variation can be seen; in the summer season, (June) moderate to a poor category is observed. July to September, which is monsoon season showed the least polluted period, post-monsoon (October) showed an increment in PM level with time, which leads to moderate to poor categories and most polluted days measured for PM2.5 concentrations during the winter period (here November). At the end of October, on Diwali, the daily concentration of PM2.5 reached up to 200 µg/m3 (severe category).

PM2.5 Concentration Time-series: During the Diwali time, the highest spikes in PM2.5 pollution levels are observed in the Diwali festival period. Evidence of firecracker burning can be very well observed from 26th to 28th October. The highest PM2.5 recorded concentrations during the Diwali event crossed 250 µg/m3 scale in Jaipur. In general, from June to mid-October 2019, the PM2.5 concentration levels remained very low, and it considerably increases afterward.

Calendar Heatmap and Uptime Plot:

The calendar visualization shows the seasonal PM2.5 variations across the six-month duration (June to November). Heat map for June to mid-October showed summer has a mostly satisfactory category and is mostly during the rain period, it is good (end of July to August). Due to the long rain period till September, the air quality is found improved in that month as well (similar to Ahmedabad and Mumbai). Among the six months, the evaluation shows November as the maximum polluted. Average 27%, 54%, 14%, 3%, and 2% period during the measured six months represents an air quality is good (50 days), satisfactory (98 days), moderate (25 days), poor (6 days), and very poor (4 days) categories, respectively. Uptime plot also shows a very good amount of data is covered during the six months.

Diurnal Chart Analysis:

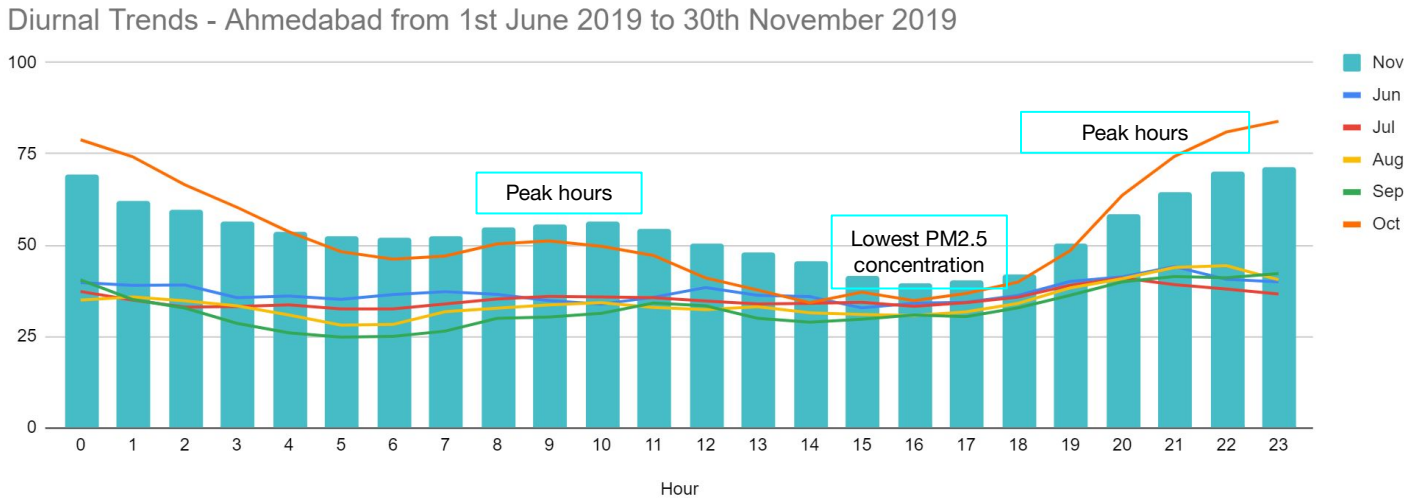
The city has morning peaks in PM2.5 concentration levels from 7 to 9 am and evening peaks from 6 to 9 pm, which is mostly peak hours for traffic. PM2.5 levels in the afternoon period (between 3 to 5 pm) is observed. During Diwali time, possibly firecracker burning in the night has affected the overall diurnal pattern of the months, which shows continuous augmentation in PM concentration even after 9 pm as well.

atmos
real-time air quality

Ahmedabad

Ahmedabad is the largest city and former capital of the Indian state of Gujarat. It is the administrative headquarters of the Ahmedabad district and the seat of the Gujarat High Court. Ahmedabad's population of 5,633,927 makes it the fifth-most populous city in India, and the encompassing urban agglomeration population is the seventh-most populous in India. Ahmedabad is located on the banks of the Sabarmati River, 30 km from the state capital Gandhinagar, which is its twin city. Ahmedabad has emerged as an important economic and industrial hub in India.

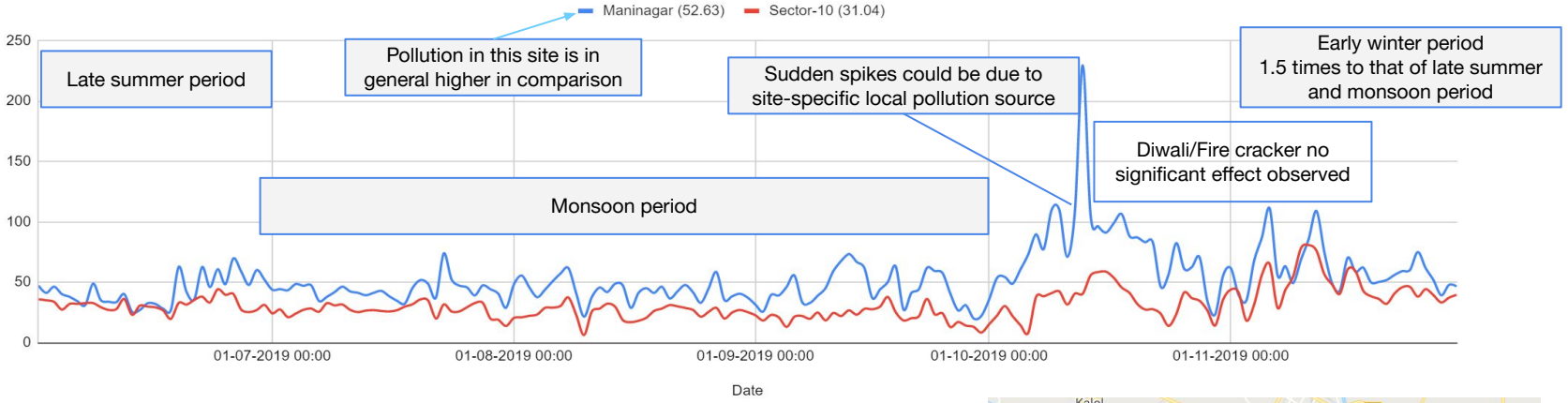
Regulatory Monitor: 2 sites[1]
Population: 5.571 Million[2]
City GDP: $64 Bn (state data)[3]
Population Density: 9,900 per sq. km[4]
Number of registered motor vehicles in thousand (state data): 20361[5]



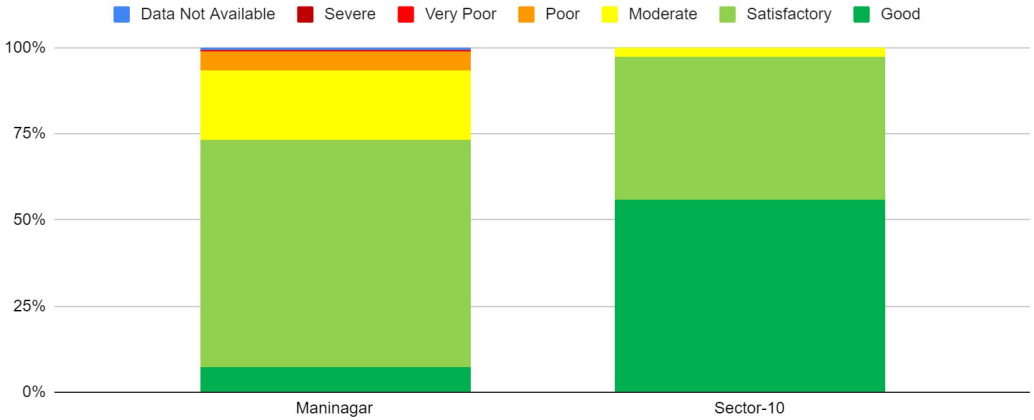
References:
1 - Central Pollution Control Board (CPCB)
2 - http://worldpopulationreview.com/world-cities/mumbai-population/
3 - https://en.wikipedia.org › wiki › Ahmedabad
4 - http://demographia.com/db-worldua.pdf
5 - http://mospi.nic.in/statistical-year-book-india/2018/189 (Data till 2016)
Picture Credit: Lonely planet

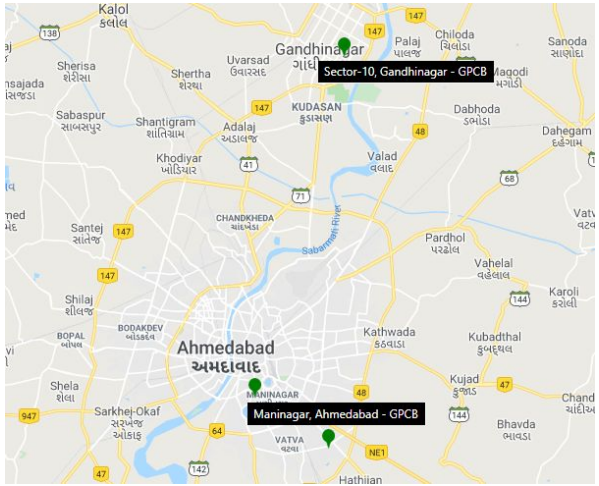
atmos
real-time air quality

PM 2.5 Concentrations in Ahmedabad from June to November 2019 in µg/m3



Ahmedabad CPCB Device Uptime

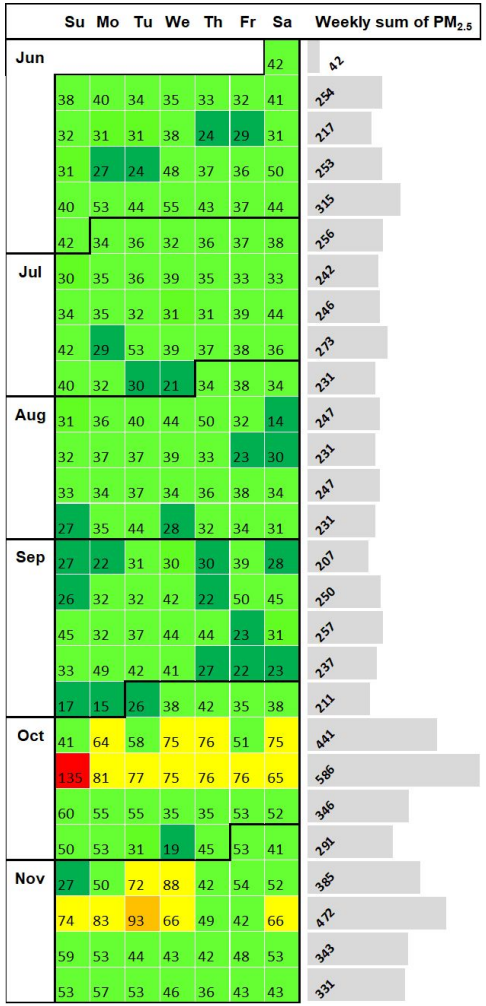




*Zoom-in to see the location and names.

atmos
real-time air quality

Monthly glance - Calendar Plot: PM 2.5 Values (µg/m3) from June to November 2019



Air Quality in Ahmedabad: A Snapshot

The city showed the 2nd best PM2.5 levels (2nd lowest polluted city) among the 5 cities evaluated in this report (after Mumbai). Throughout the measurement period (from June to November), Ahmedabad's air quality is as good as that of Mumbai. Again, as some portion of the district, Ahmedabad is associated with the Arabian ocean, and because of being a coastal city, its air quality is good most of the time. No significant seasonal variation is observed in Ahmedabad's PM2.5 concentrations. Surprisingly, no influence of Diwali appeared during the evaluated period of 2019.

PM2.5 Concentration Time-series: Peaks for PM 2.5 concentration >100 µg/m3 in the six-month duration appeared very few times (7 times on a daily hour basis) and that too only in one of the two sites. The other site monitored data are significantly lower than the other one. The average concentration of both the sites is plotted and described in the subsequent paragraph mentioning the Calendar heatmap.

During the Diwali time, no as such high peaks in PM2.5 pollution levels are observed. Generally, from June to November 2019, the PM2.5 concentration levels remained very low. The post-monsoon period in October showed a slight increase in concentration levels, which considerably dropped back to normal in November month.

Calendar Heatmap and Uptime Plot:

The calendar visualization shows the less influence of seasons on the city's PM2.5 concentrations across the six-month duration (June to November). Heat map and uptime plot show that mostly the air quality data remained available. It remained to a good or satisfactory level except for s few days in October and November months. October to mid-November are identified only having moderate category air quality, with the exception of only one day showing very poor air quality (12th Oct). Due to the more extended rain period till September, the air quality is found improved in that month as well (similar to Mumbai). Also, in late September, a deep depression formed near Gujarat and intensified into the cyclonic storm. Among the six months, the evaluation shows November as the maximum polluted. Average 90%, period during the measured a six months represents an air quality in either good (27 days) or satisfactory (138 days). Only 18 days are measured between moderate-very poor categories, respectively. Uptime plot also shows a very insignificant amount of data unavailability during the six months.

Diurnal Chart Analysis:

The city has morning peaks in PM2.5 concentration levels from 6 to 10 am and evening peaks from 7 to 10 pm. Lowest PM2.5 levels in the afternoon period (between 3 to 5 pm) are observed.