DATA VISUALIZATION AND ANALYTICS

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

(OCTOBER 2018 TO MAY 2019)

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

July 2019

atmos
real-time air quality
Respirer Living Sciences

SHAKTI
SUSTAINABLE ENERGY FOUNDATION

भारतीय प्रौद्योगिकी संस्थान कानपुर
INDIAN INSTITUTE OF TECHNOLOGY KANPUR

ACKNOWLEDGEMENT

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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.

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DATA ACCESS

All data used in this report is freely available to view & download via the realtime dashboard at –
http://atmos.urbansciences.in

For feedback, suggestions, $PM_{2.5}$ datasets and API access to the data, email – research@urbansciences.in

INTRODUCTION

The project titled “Measurement and Calibration of Air Quality Monitors in 10 Indian cities” (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). The goal of this project is to deploy 50 real-time air quality monitors (known as "Atmos") spread over 10 Indian cities, evaluate the performance of and provide contextual analytics of this data in periodic reports.

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 sensor based data from this air quality monitoring network has been published in peer-reviewed journals[1]. Additional evaluations of PM_{10} sensor data has been performed in lab and field conditions and the results of the same have been submitted for peer-review.

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. Data from 5 of these cities – Chandigarh, Kanpur, Patna, Raipur, Varanasi has been evaluated in this report.

The affordable air quality sensor based technology has been co-located with reference grade monitors in few cities like Chandigarh & Patna.

The below report provides a framework for data visualization and analytics for city level air quality monitoring reports. The diurnal findings, while in absolute values differ in each city, at a trend level are consistent across the cities. Other key highlights from the time-series visualizations and mean of the spatially distributed locations is provided and compared with modeled data findings.

In summary, the report highlights the relevance and usefulness of long-term and spatially dispersed deployments of affordable air quality sensor technology in the understanding of air quality conditions across a city.

[1] Zheng, T., Bergin, M.H., Johnson, K.K., Tripathi, S.N., Shirodkar, S., Landis, M.S., Sutaria, R. and Carlson, D.E., 2018. Field evaluation of low-cost particulate matter sensors in high-and low-concentration environments. Atmospheric Measurement Techniques, 11(8), pp.4823-4846.

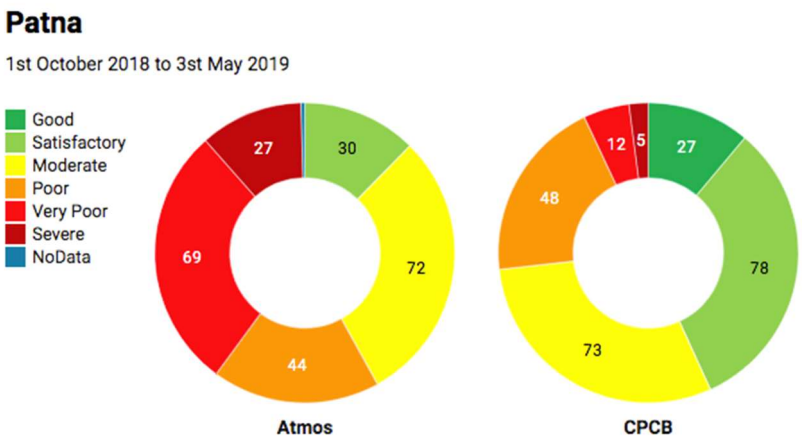
Patna

Patna is the capital and largest city of the state of Bihar in India. In May 2014, a WHO survey declared Patna the second most air polluted city in India, only after Delhi.

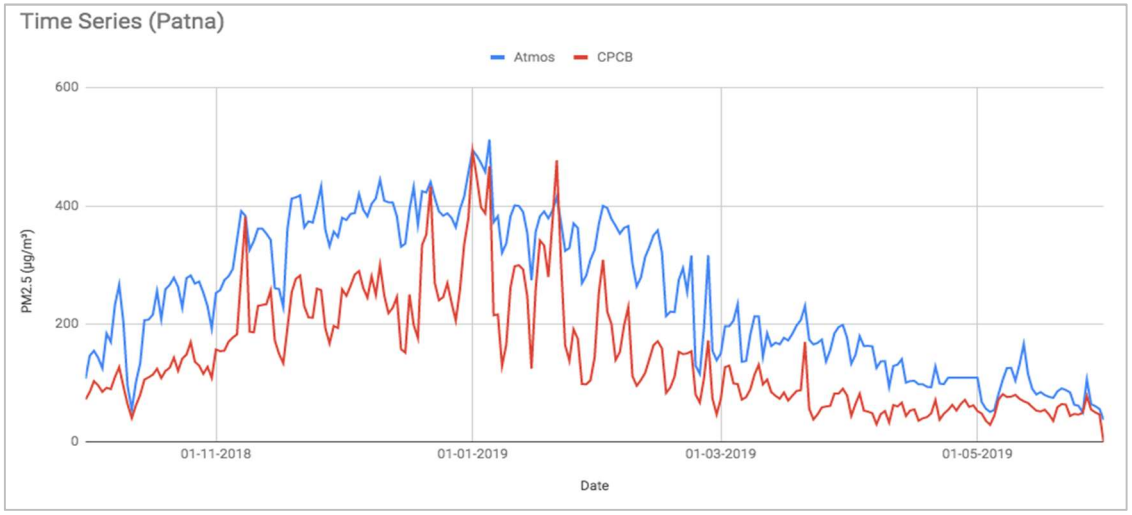
Smog denseness in Patna during winter seasons result in major air and rail traffic disruptions every year.

Regulatory Monitor: IGSC Planetarium [1]
Population: 2.952 Million[2]
City GDP: $19 Bn[2]
Population Density: 1,803 per sq. km[2]
Number of registered motor vehicles per 1000 (state data): 31[3]

Avg $PM_{2.5}$ - 1st Oct 2018 to 31st May 2019
162:Mithapur | 145:CEECC-ADRI | 142:Phulwari Sharif | 155:IGSC Planetarium | BAM:Planetarium



$PM_{2.5}$ Concentration in Days from October 2018 to May 2019 VS CPCB data



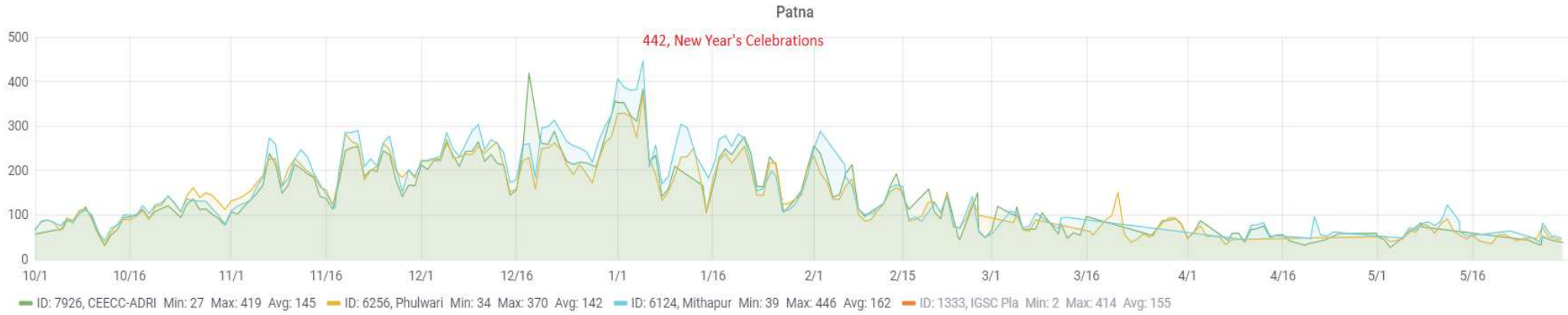
Inferences of Atmos Devices as against CPCB reference devices

1. Atmos monitors show a very consistent trend with the CPCB monitor installed in Patna.

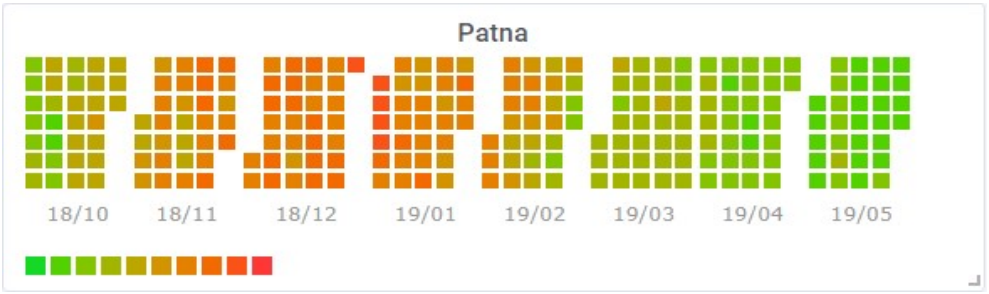
2. CPCB monitor in Patna is installed at IGSC Planetarium. An Atmos monitor has also been collocated at the same location. Results confirm that low-cost sensors show a very strong correlation with reference grade PM monitors.

References:
1 - Central Pollution Control Board (CPCB)
2 - Projections from census 2011 by indiapopulation2018.in
3 - Government data on registered motor vehicles from data.gov.in and *Megatrends: Accelerating urbanization in India*

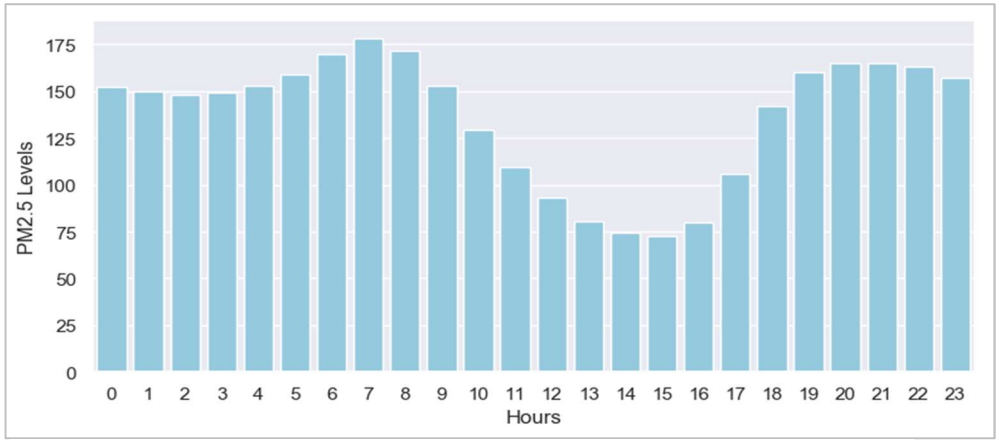
Picture Credit: Patna Museum © Photo Dharma/WikiCommons



Time Series: $PM_{2.5}$ Values from October 2018 to May 2019



Monthly glance - Calendar Plot: $PM_{2.5}$ Values from October 2018 to May 2019



Hourly averages - Diurnal Chart - $PM_{2.5}$ values from October 2018 to May 2019

Air Quality in Patna: Highlights

The city had a peak $PM_{2.5}$ of 442 µg/m^3 on New Year's day. December was particularly a bad air quality month with all days in the month in very poor or severe levels.

Evaluation with UrbanEmissions India APnA Findings

The modeled urban average ambient $PM_{2.5}$ concentration reported by the UE India APnA programme is 122.2 ± 23.1 µg/m^3. The findings from the ground-level monitoring with Atmos – Realtime Air Quality monitors for the given time-period is 151 ± 9.2 µg/m^3.

Diurnal Chart Analysis:

The city experienced the highest $PM_{2.5}$ levels of the day from morning 6 to 8 am of levels around 175 µg/m^3. The lowest levels of the day were between 2 to 3pm which were around 75 µg/m^3. The evening $PM_{2.5}$ levels starting 7pm tend to stay high through the night.

Calendar Plot:

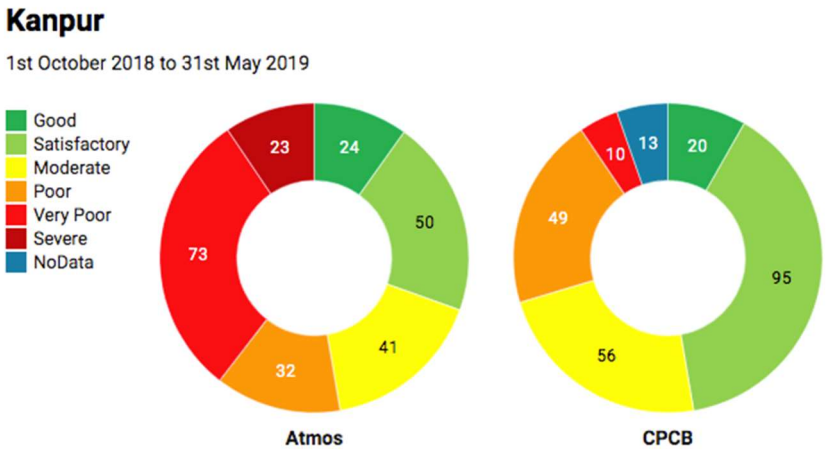
The period between October till February indicate higher concentrations of $PM_{2.5}$ which considerably lowers mid-February onwards.

Kanpur

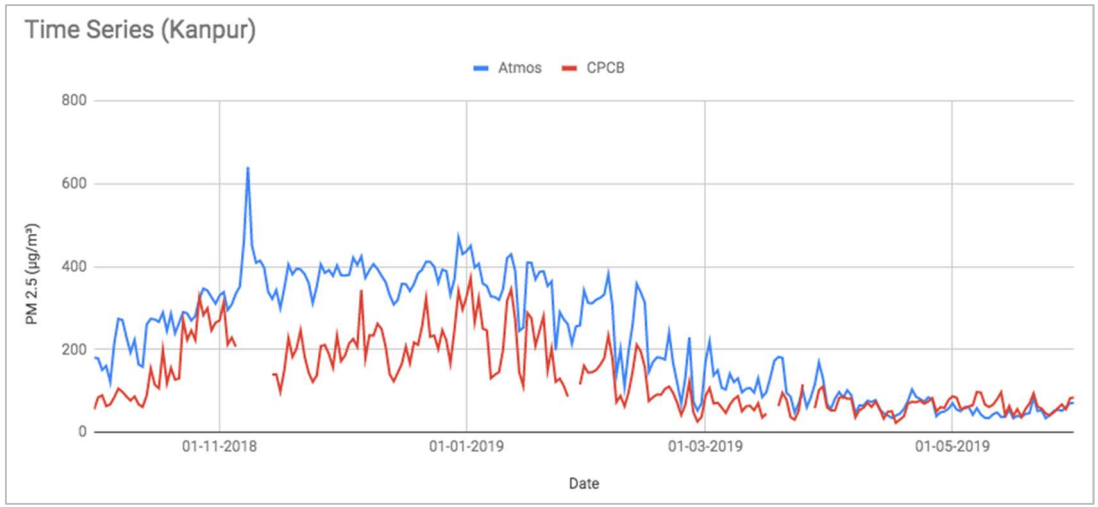
Kanpur garnered international attention when it became the city with the worst air pollution in the world in 2018 WHO rankings for the outdoor air quality.
A major city in the state of Uttar Pradesh, Kanpur is an industrial city known for its tanneries and textile industries also has the river Ganga passing through it. Uttar Pradesh is the state with the second highest burden of Chronic Pulmonary Obstructive Disease (COPD).

Regulatory Monitor: Nehru Nagar[1]
Population: 3.8 Million[2]
City GDP: $ 19 Bn[2]
Population Density: 1,449 per sq. km[3]
Number of registered motor vehicles per 1000 (state data): 76 [3]

Avg $PM_{2.5}$- 1st Oct 2018 to 31st May 2019
115:Indira Nagar | 73:Surendra Nagar | 117:Naubasta | 26:142:Govind Nagar | BAM:Nehru Nagar



$PM_{2.5}$ Concentration in Days from October 2018 to May 2019 VS CPCB data



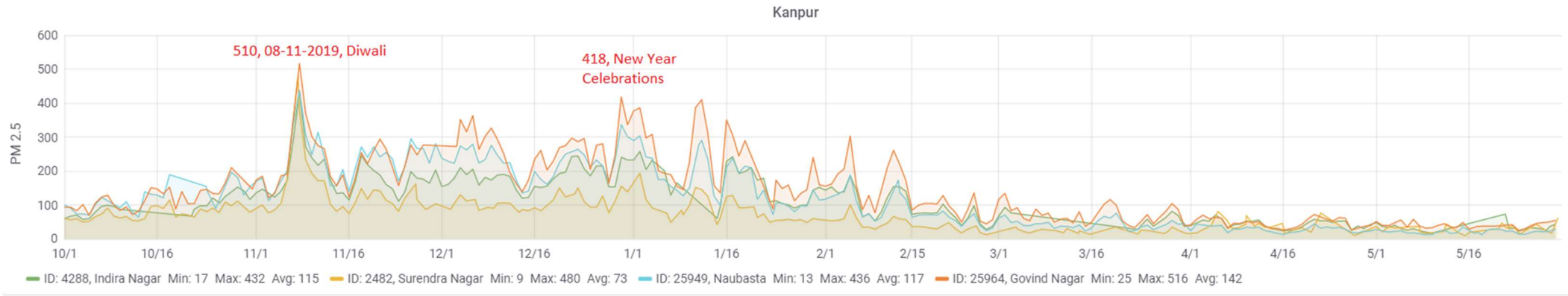
$PM_{2.5}$ Average of Atmos Devices as against CPCB reference devices

1. CPCB monitors have **few data gaps** most notably in 8-12 Nov (Diwali), 26-28 Feb, 8-10 March.

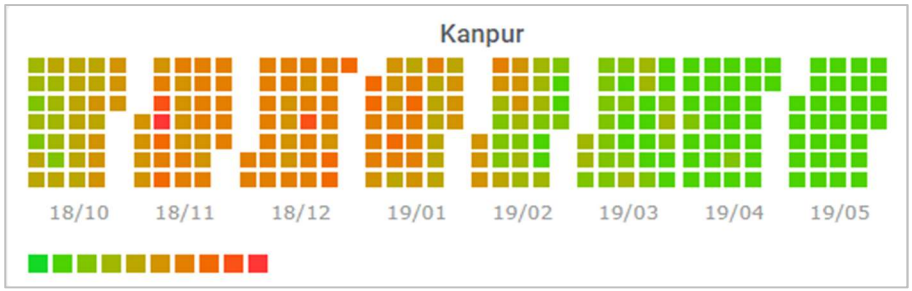
2. Consistent $PM_{2.5}$ trend can be seen between the CPCB monitor and the 4 Atmos monitors.

References:
1 - Central Pollution Control Board (CPCB)
2 - Projections from census 2011 by indiapopulation2018.in
3 - Government data on registered motor vehicles from data.gov.in and *Megatrends: Accelerating urbanization in India*

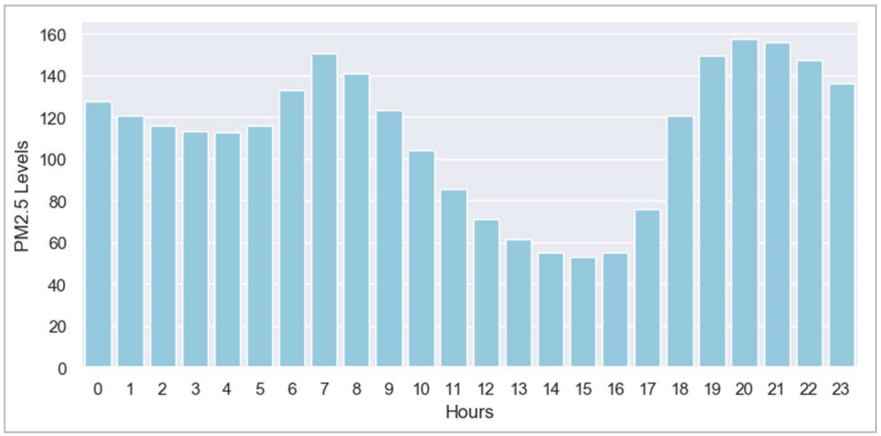
Picture Credit: Nooralammalik1977



Time Series: PM 2.5 Values from October 2018 to May 2019



Monthly glance - Calendar Plot: $PM_{2.5}$ Values from October 2018 to May 2019



Hourly averages - Diurnal Chart - $PM_{2.5}$ values from October 2018 to May 2019

Air Quality in Kanpur: A Snapshot

The city showed the highest $PM_{2.5}$ levels across the 5 cities evaluated in this report. A peak $PM_{2.5}$ level of 510 µg/m^3 was seen on Diwali day (8 Nov).

Evaluation with UrbanEmissions India APnA Findings

The modeled urban average ambient $PM_{2.5}$ concentration reported by the UE India APnA programme is 114.1 ± 25.6 µg/m^3. The findings from the ground-level monitoring with Atmos – Realtime Air Quality monitors for the given time-period is 111.7 ± 28.6 µg/m^3. The APnA programme also reports relatively lower regional $PM_{2.5}$ levels ~ 23%. This can be seen, in a way, from the higher variations in the ground level monitoring from across multiple locations.

Calendar Heatmap:

The calendar visualization shows the seasonal $PM_{2.5}$ variations across winter (December to February) and summer (March to May). Clear trend can be seen with the transition from poor air quality to satisfactory levels happening in February.

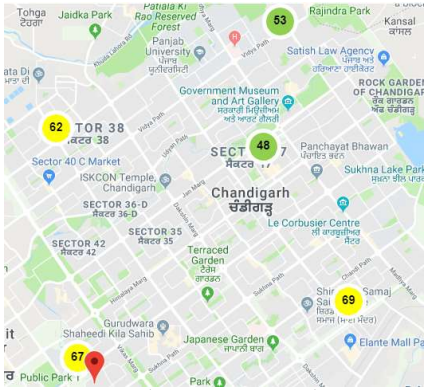
Diurnal Chart Analysis:

The city has morning peaks in $PM_{2.5}$ concentration levels from 6 to 8 am and evening peaks from 7 to 9 pm. $PM_{2.5}$ levels from 2 to 4pm are around 55 µg/m^3 which is almost 3x better than daily peak levels of ~ 150 µg/m^3.

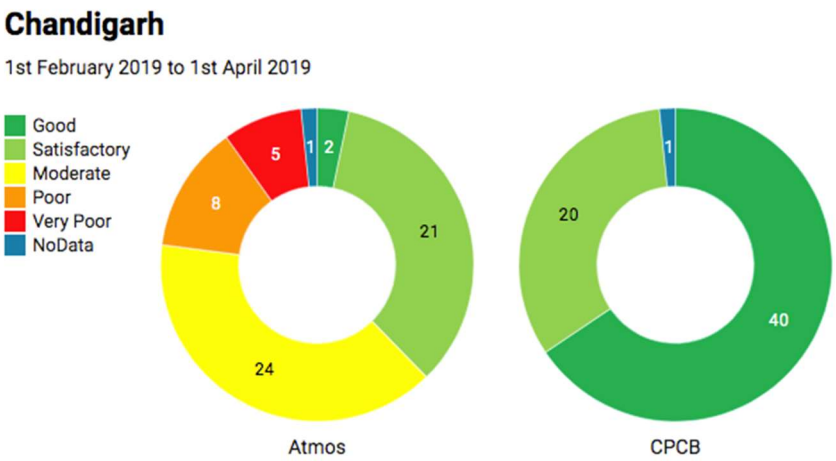
Chandigarh

Chandigarh is the capital city of Punjab and Haryana which is also one of the cleanest in the country. The city is known for its architectural marvels and several institutes of national importance.
The city has the highest vehicle density in India with 12 lakh two-four wheelers registered. The contribution of vehicular pollution is about 35-40% of total. [1]

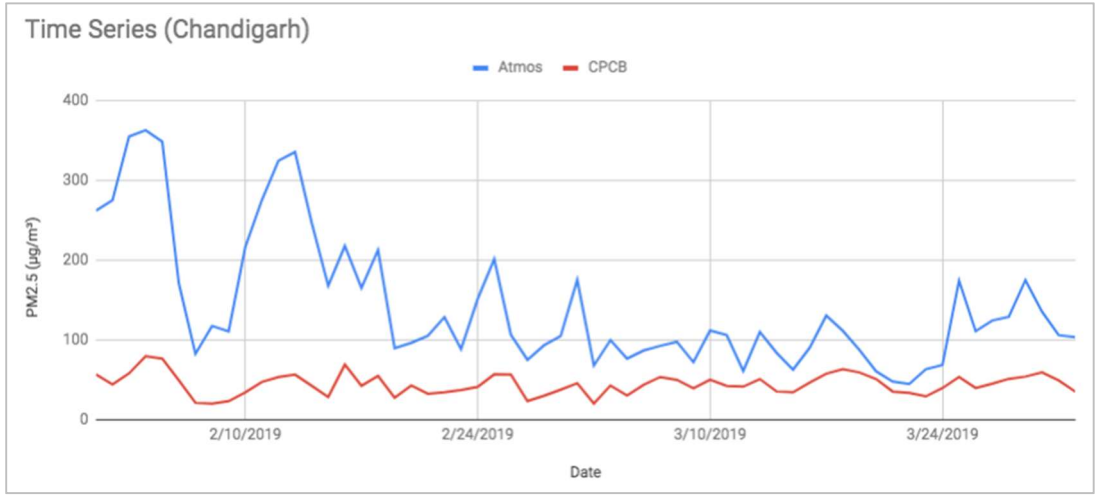
Regulatory Monitor: Sector 50[1]
Population: 1.2 Million [2]
City GDP: $ 4.6 Billion [2]
Population Density: 9252 per sq. km [2]
Number of registered motor vehicles per 1000 (state data): 277 [3]



Avg $PM_{2.5}$ - 1st Feb 2018 to 31st May 2019
53:Sector 12 | 62:IMTECH | 69:Industrial Area | 67:Sector 50 | 48:Sector 17 | BAM:Sector 50



$PM_{2.5}$ Concentration in Days from Feb 2018 to April 2019 VS CPCB data



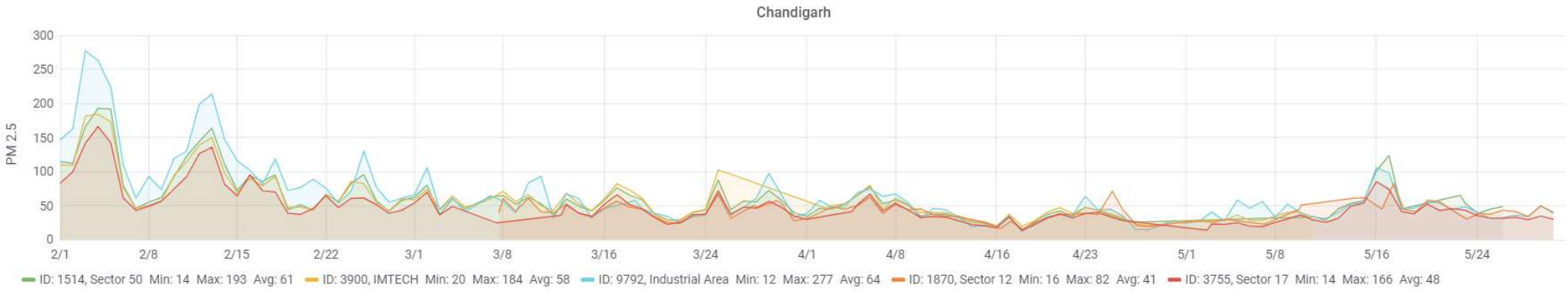
Inferences from Atmos – Realtime Air Quality Monitoring Network & CPCB Reference Monitor

1. Atmos data in above graph is average of 4 spatially distributed locations. The visualization provides a consolidated view of the city-level $PM_{2.5}$ levels for the given time-period. The CPCB data is from a single location at Sector 50.

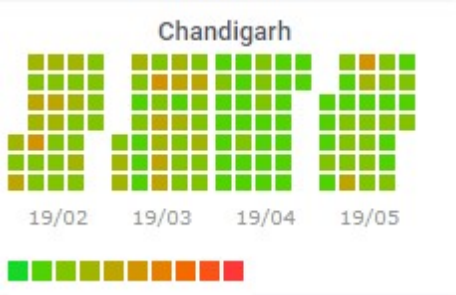
2. Atmos monitors from spatially distributed locations show a good degree of correlation and consistency. This indicates higher levels of regional pollution as compared to local pollution.

References:
1 - Chandigarh Pollution Control Committee (CPCC)
2 - Projections from census 2011 by indiapopulation2018.in
3 - Government data on registered motor vehicles from data.gov.in and *Megatrends: Accelerating urbanization in India*

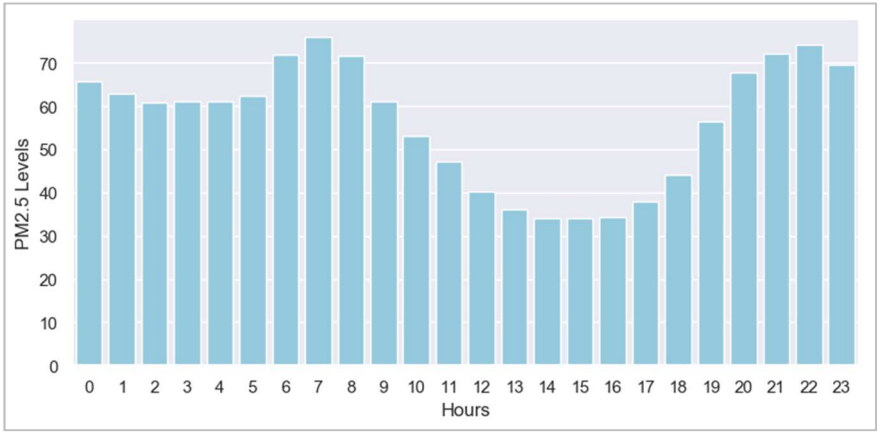
Picture Credit: Hindustan Times



Time Series: $PM_{2.5}$ Values from February 2019 to May 2019



Monthly glance - Calendar Plot: $PM_{2.5}$ Values from February 2019 to May 2019



Hourly averages - Diurnal Chart - $PM_{2.5}$ values from February 2019 to May 2019

Air Quality in Chandigarh: A Snapshot

The Atmos monitors were deployed by CPCC (Chandigarh Pollution Control Committee) in 4 locations across the city around February 1. The city has shown the lowest $PM_{2.5}$ levels across the 5 cities evaluated in this report.

Evaluation with UrbanEmissions India APnA Findings

The modeled urban average ambient $PM_{2.5}$ concentration reported by the UE India APnA programme is 58.1 ± 6.9 µg/m^3. The findings from the ground-level monitoring with Atmos – Realtime Air Quality monitors is 62.7 ± 7.1 µg/m^3. This is an important finding which shows strong consistency between the modeled and ground-level monitored data. The APnA findings also show a high percentage of $PM_{2.5}$ coming from outside the city – 51%. This is consistent with the spatio-temporal findings seen from the long-term time-series graphs and the spatial Map based data visualizations.

Diurnal Chart Analysis:

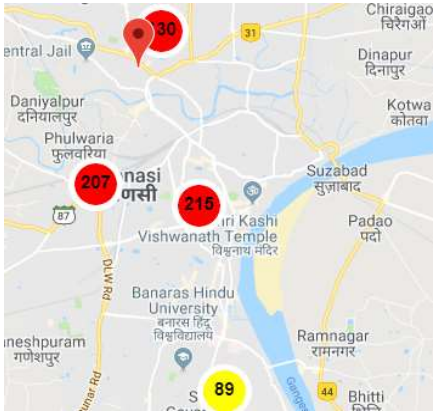
The city has morning peaks from 6 to 8 am and then the evening peak is from 9 to 11 pm. The morning levels of around 70 µg/m^3 are almost 2x higher than 2 to 4pm levels of around 35 µg/m^3.

Note: Atmos monitors were deployed by the CPCC (Chandigarh Pollution Control Committee) in the month of Feb 2019. All analysis presented here is from the date of deployment in the city.

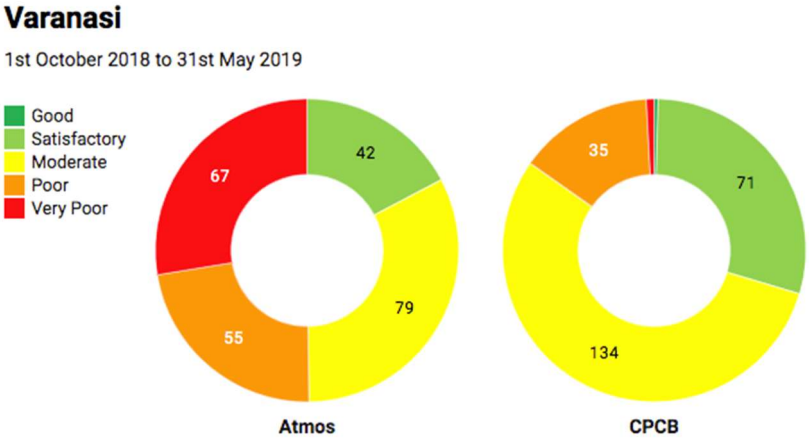
Varanasi

Varanasi is a city in Uttar Pradesh dating to the 11th century B.C. Regarded as the spiritual capital of India, the city draws pilgrims throughout the year. The city economy revolves around pilgrimage tourism primarily.

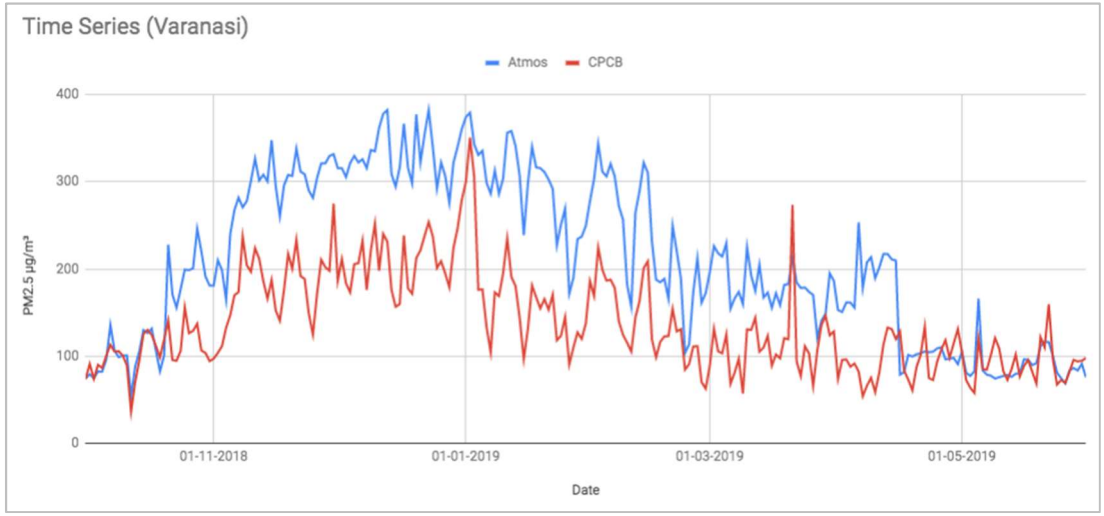
Regulatory Monitor: Ardali Bazar Rd [1]
Population: 2.5 Million[2]
City GDP : 2.3 Billion[2]
Population Density: 2,399 per sq. km[2]
Number of registered motor vehicles per 1000 (state data): 76[3]



Avg $PM_{2.5}$ - 1st Oct 2018 to 31st May 2019
130:Lahartara | 207:Orderly bazaar | 89:IESD-BHU | 215:Kamachcha | BAM:Ardali Bazar Rd



$PM_{2.5}$ Concentration in Days from October 2018 to May 2019 VS CPCB data



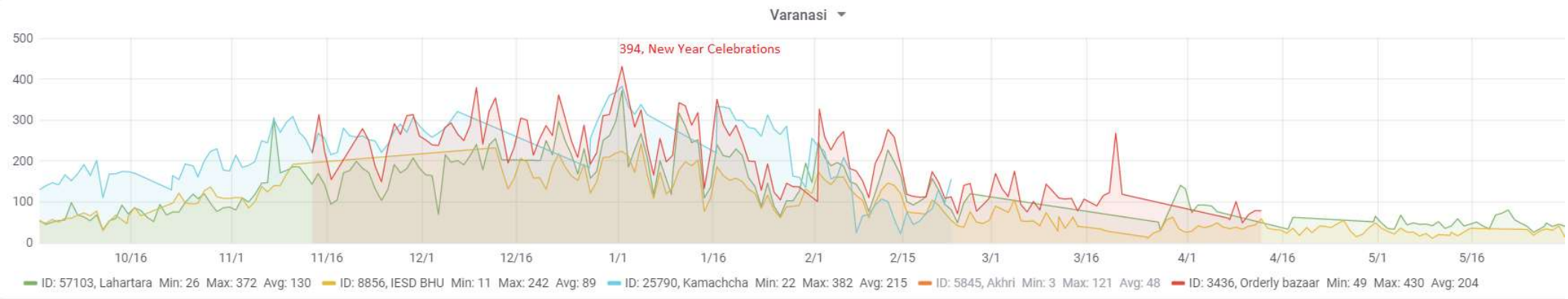
Inferences of Atmos Devices as against CPCB reference devices

1. The CPCB reference monitors in Varanasi show a very consistent trend with the 4 Atmos monitors installed in the city.

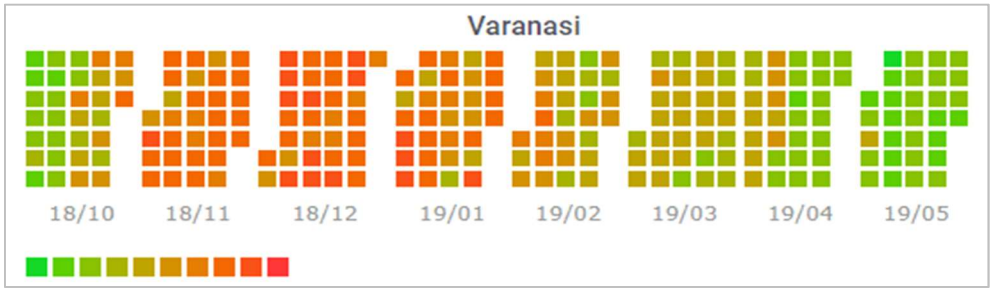
2. The spatially dispersed Atmos monitors across the city show that the Northern part of the city experiences much worse apo

References:
1 - Central Pollution Control Board (CPCB)
2 - Projections from census 2011 by indiapollution2018.in
3 - Government data on registered motor vehicles from data.gov.in and *Megatrends: Accelerating urbanization in India*

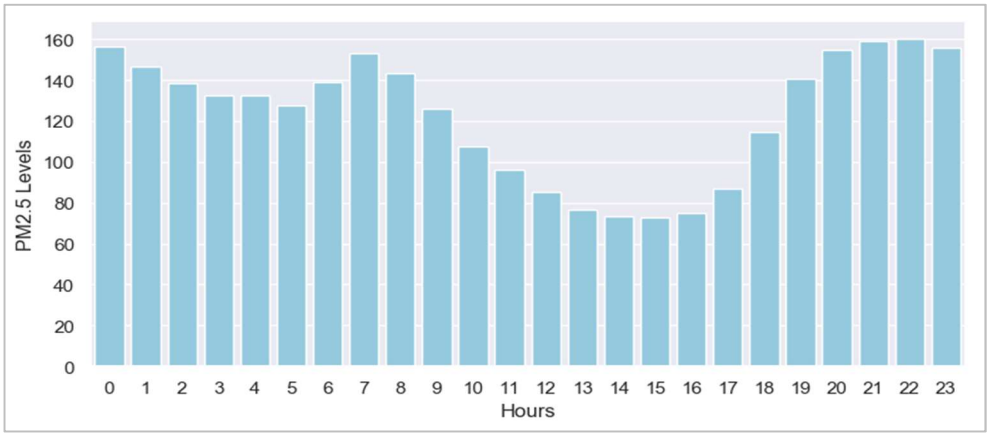
Picture Credit lonelyplanet.com



Time Series: $PM_{2.5}$ Values from October 2018 to May 2019



Monthly glance - Calendar Plot: $PM_{2.5}$ Values from October 2018 to May 2019



Hourly averages - Diurnal Chart - $PM_{2.5}$ values from October 2018 to May 2019

Air Quality in Varanasi: Highlights

Poor air quality days in Varanasi tends to start earlier than other cities. The months of November and December show consistently very poor air quality levels.

Evaluation with UrbanEmissions India APnA Findings

The modeled urban average ambient $PM_{2.5}$ concentration reported by the UE India APnA programme is 78.4 ± 10.3 µg/m^3. The findings from the ground-level monitoring with Atmos – Realtime Air Quality monitors for the given time-period is 160 ± 61 µg/m^3.

Diurnal plots:

The city experienced the highest $PM_{2.5}$ levels of the day from morning 6 to 8 am of levels around 150 µg/m^3. The lowest levels of the day were between 2 to 4 pm which were around 75 µg/m^3. The evening $PM_{2.5}$ levels starting 7pm tend to stay high till mid-night and then PM levels drop.

Calendar Plot:

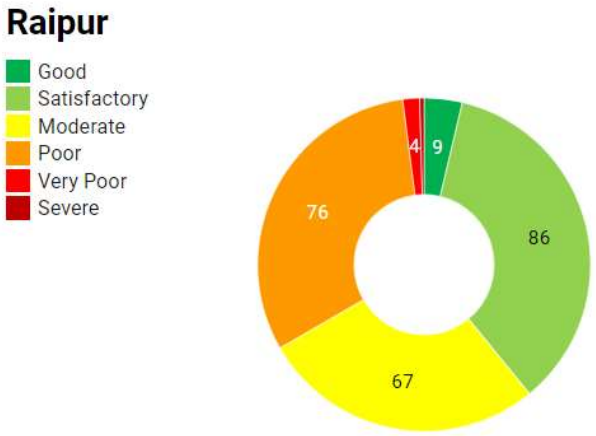
As can be seen on the calendar plot, the $PM_{2.5}$ levels in the city of Varansi did not have a single good air quality day for the entire 2 months of Winter (November and December).

Raipur

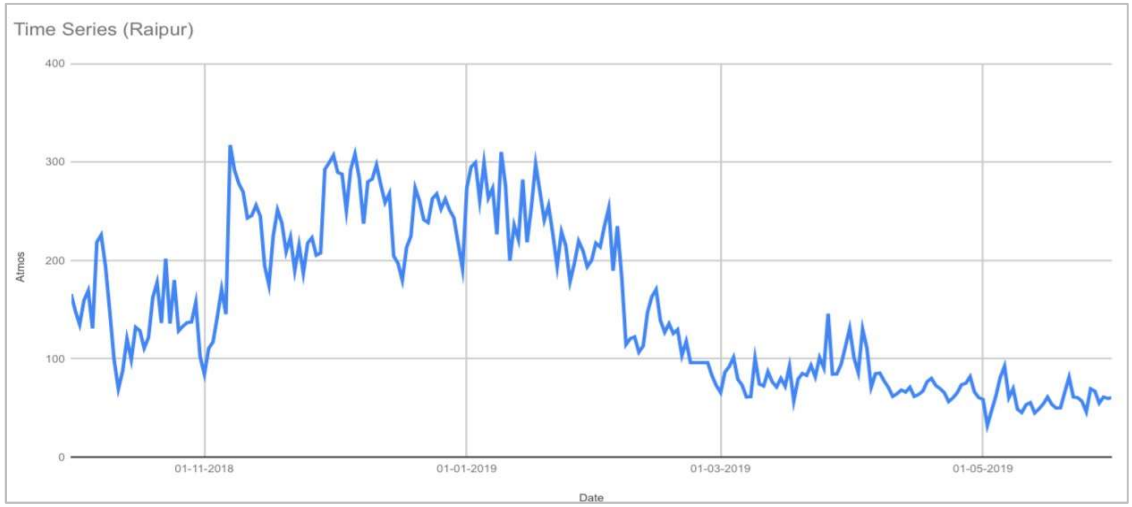
The capital of Chhattisgarh, Raipur is the largest city in the state. With more than hundreds of steel mills and six steel plants, Raipur is also one of the largest industrial centres of the country. Raipur got into the dubious distinction of one among the ten most polluted cities a few years ago with 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[2]
Population Density: 310 per sq. km[2]
Number of registered motor vehicles per 1000 (state data): 126[3]

Avg $PM_{2.5}$ - 1st Oct 2018 to 31st May 2019
67:RLTRI | 73:SHRC | 68:Surya Apartments | 82:Bharat Mata School



$PM_{2.5}$ Concentration in Days from October 2018 to May 2019
(There are no CPCB monitors in Raipur)



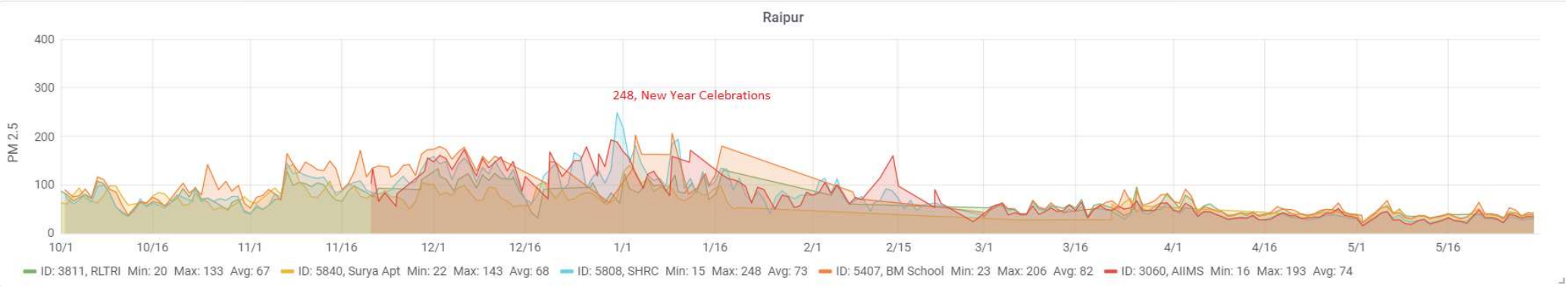
$PM_{2.5}$ Average of Atmos Devices

1. Raipur has no CPCB monitor data available for correlation.

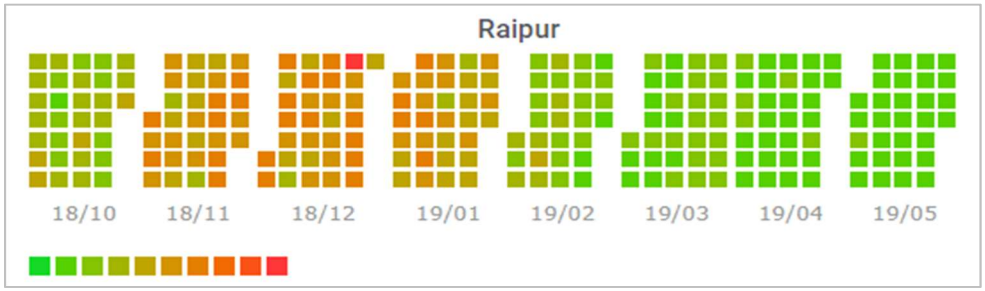
2. Peak levels begin around 1st week of November and continues till first week of February.

References:
1 - Central Pollution Control Board (CPCB)
2 - Projections from census 2011 by indiapopulation2018.in
3 - Government data on registered motor vehicles from data.gov.in and *Megatrends: Accelerating urbanization in India*

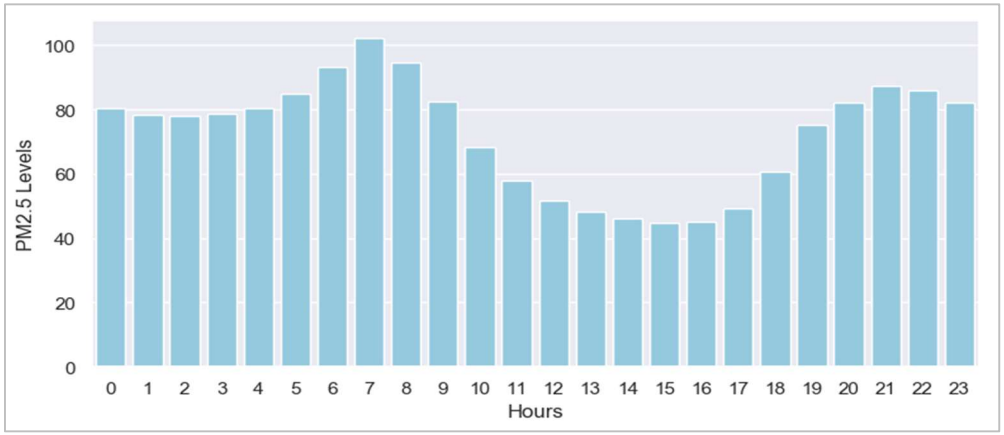
Picture Credit: The Better India



Time Series: $PM_{2.5}$ Values from October 2018 to May 2019



Monthly glance - Calendar Plot: $PM_{2.5}$ Values from October 2018 to May 2019



Hourly averages - Diurnal Chart - $PM_{2.5}$ values from October 2018 to May 2019

Air Quality in Raipur: Highlights

The city did not show a significant peak in $PM_{2.5}$ levels during the Diwali week. This could indicate fewer fire-crackers being burnt in the city as compared to most other cities that have been evaluated. More ground level verifications need to be done for this.

Evaluation with UrbanEmissions India APnA Findings

The modeled urban average ambient $PM_{2.5}$ concentration reported by the UE India APnA programme is 82.3 ± 21.8 µg/m^3. The findings from the ground-level monitoring with Atmos – Realtime Air Quality monitors for the given time-period is 72.5 ± 6.8 µg/m^3.

Diurnal Chart Analysis:

The morning peaks in Raipur from 6 to 8 am of around 90 to 100 µg/m^3 are almost 2x times worse than the $PM_{2.5}$ levels between 2pm to 4pm which are around 45 µg/m^3. Late evening to night levels were around 80 µg/m^3.

Calendar Plot:

Seasonal variations can be seen with air quality starting to worsen around early November with the worst air quality levels in December and early January. $PM_{2.5}$ levels start improving substantially from February onwards.