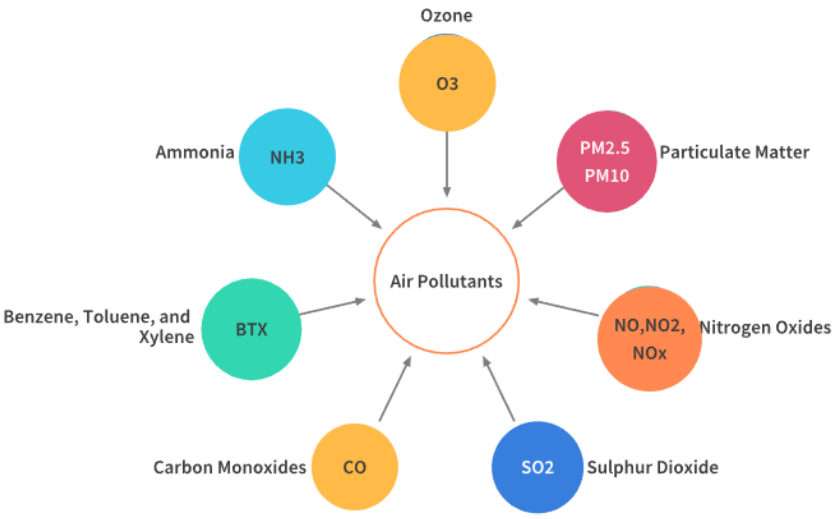
Covid-19: Impact of Air Pollution before and after lockdown

By Meet Vanani

Abstraction:
This data analysis report consists of deep analysis of major pollutants in 24 cities causing air pollution. Analysis is done from 2015-01-01 to 2020-05-01 of all 24 cities. This report also analyses about the yearly and monthly behaviour of major pollutants. With visualizations, it depicts the major impact of air pollution before and after lockdown in major cities. Before starting with the analysis and visualization, this report also explains about the major pollutants and from where they are emitted majorly.

Types of Air Pollutants

Let's first try and understand the various types of air pollutants in the datasets. On a broader level, these pollutants can be classified as:



- **Particulate matter (PM2.5 and PM10)** > Particulate matter is a mix of solids and liquids, including carbon, complex organic chemicals, sulphates, nitrates, mineral dust, and water suspended in the air. PM varies in size. Some particles, such as dust, soot, dirt or smoke are large or dark enough to be seen with the naked eye. But the most damaging particles are the smaller particles, known as PM10 and PM2.5. Source. The following diagram will help to understand the concept more concretely.

- **Nitrogen Oxides (NO, NO2, NOx)** > Nitrogen oxides are a group of seven gases and compounds composed of nitrogen and oxygen, sometimes collectively known as NOx gases. The two most common and hazardous oxides of nitrogen are nitric oxide (NO) and nitrogen dioxide (NO2)

- **Sulphur Dioxide (SO2)** > Sulphur dioxide, or SO2 is a colourless gas with a strong odour, similar to a just-struck match. It is formed when fuel containing sulphur, such as coal and oil, is burned, creating air pollution.

- **Carbon Monoxide (CO)** > Carbon monoxide is a colourless, highly poisonous gas. Under pressure, it becomes a liquid. It is produced by burning gasoline, natural gas, charcoal, wood, and other fuels.

- **Benzene, Toluene and Xylene (BTX)** > Benzene, toluene, xylene, and formaldehyde are well-known indoor air pollutants, especially after house decoration. They are also common pollutants in the working places of the plastic industry, chemical industry, and leather industry

- **Ammonia(NH3)** > Ammonia pollution is pollution by the chemical ammonia (NH3) – a compound of nitrogen and hydrogen which is a by-product of agriculture and industry.

- **Ozone(O3)** > Ground-level ozone is a colourless and highly irritating gas that forms just above the earth's surface. It is called a "secondary" pollutant because it is produced when two primary pollutants react in sunlight and stagnant air. These two primary pollutants are nitrogen oxides (NOx) and volatile organic compounds (VOCs)

What causes these pollutants?

- **Vehicles**: Transportation majorly emits Carbon Monoxide (CO) and Nitrogen Oxide (NO). It minorly emits Ozone(O3) and Particulate Matter (PM2.5 and PM10).

- **Industries**: Industries majorly emit Sulphur Dioxide (SO2), Carbon Monoxide (CO), Ammonia (NH3) and Particulate Matter (PM2.5 and PM10), BTX (Benzene, toluene, xylene)

Methodology

In this notebook, the analysis has been done in two parts:

- Analysis of the pollution level in India, over the years - from 2015 to 2020

This will a holistic view of how the pollutant levels have been rising in India and what is the current situation.

- Effect of Lockdown on the Pollution level in India

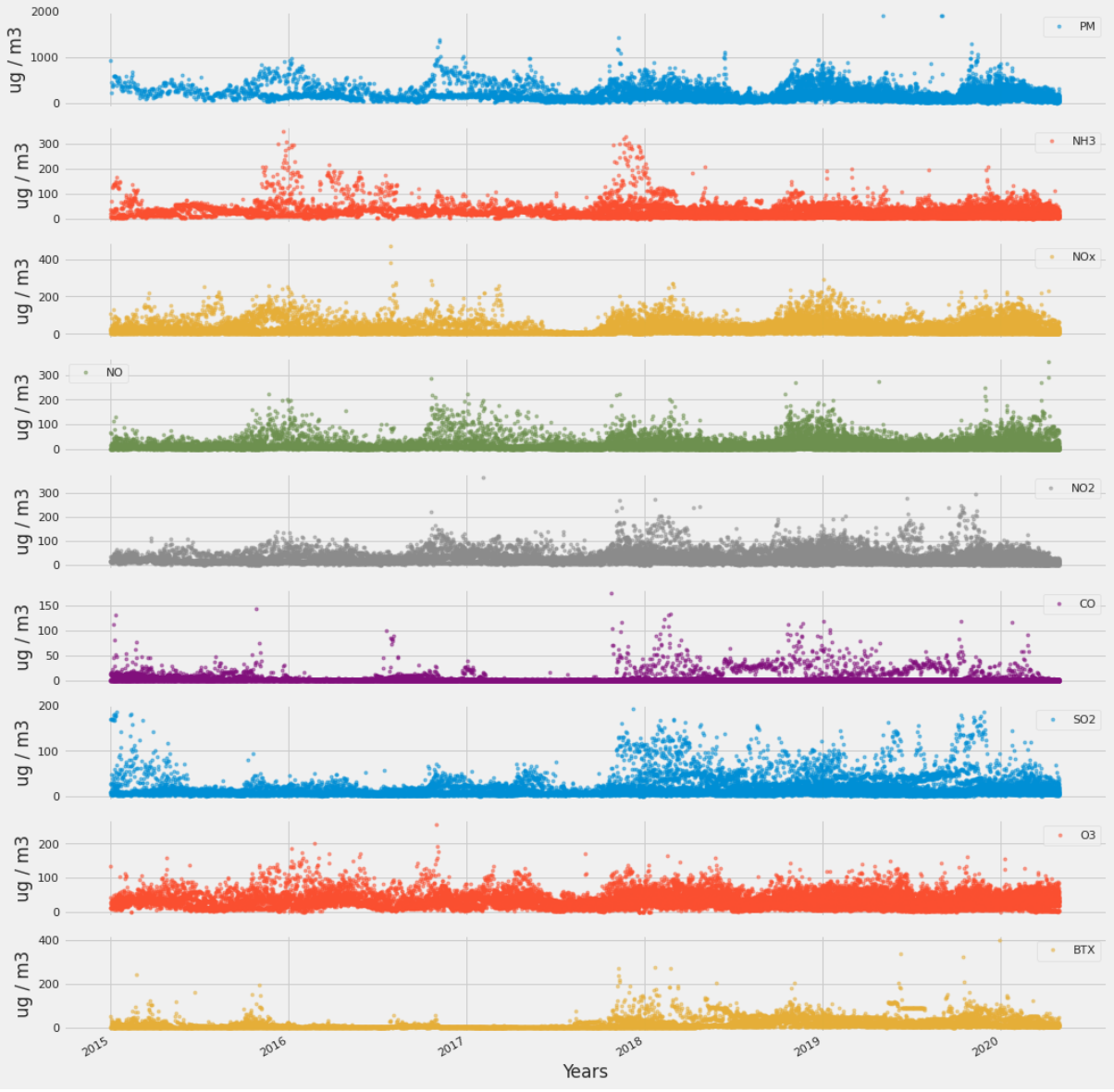
Here we shall examine the pollution level in India before and after the first stage of Lockdown. Also, we shall compare the pollution level around the same months in 2019, to see the difference, if any. Additionally, we could also examine the difference between the current dates

and the winter months (October, November) of 2019 when the pollution levels are generally the highest in Northern parts of India.

Analysing data under these different categories should give us a fair idea of the effect of Lockdown on the Indian pollution level.

1. Analysing City level data.

Visualising yearly data of all pollutants and study the behaviour of the pollutants

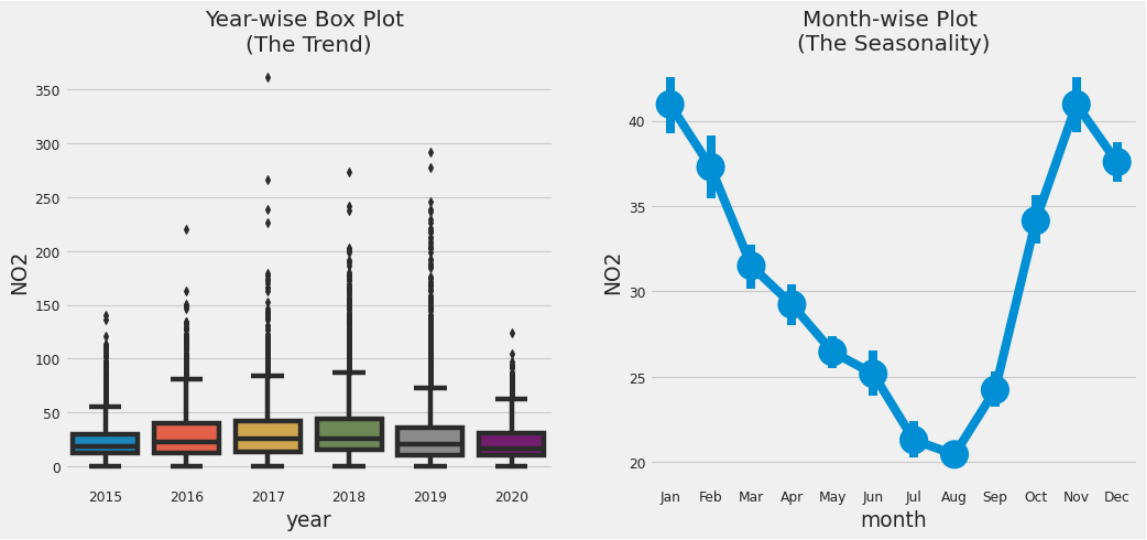


The main things we see in visualization are:

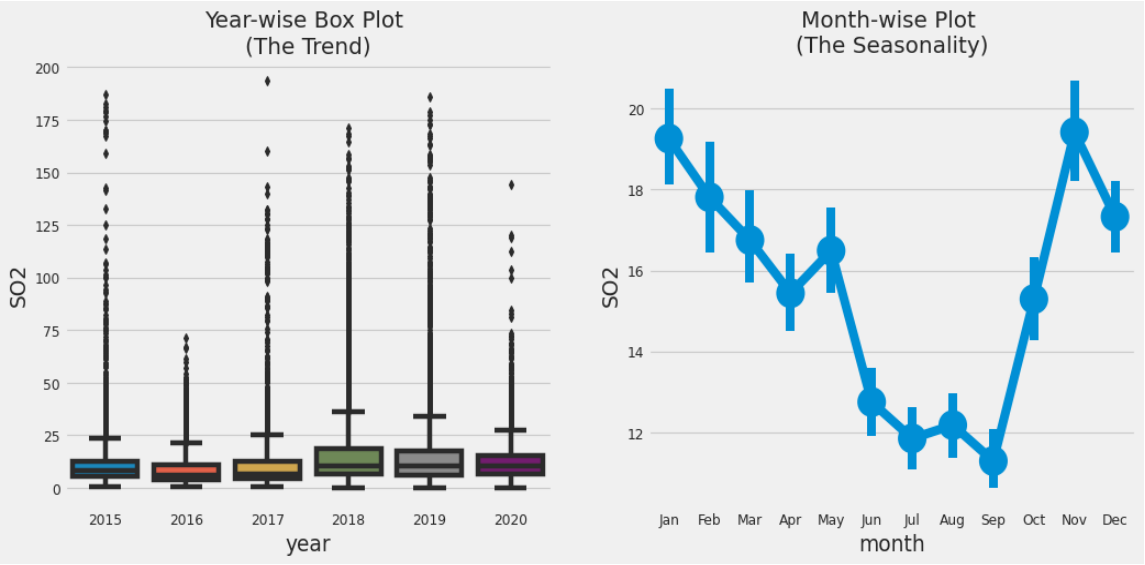
1. SO2 level has started increasing after 2017, although it had also seen a sudden rise in 2015 also. The same pattern is also reflected in BTX levels also. This sudden rise indicates that there are more Industries setting up after 2017 and also increase in emission of these pollutants.
2. CO and NO gradually increase after 2018 which clearly indicates that people were using more vehicles from 2018

This is just an overview. We will have to look deeper to get specific answers.

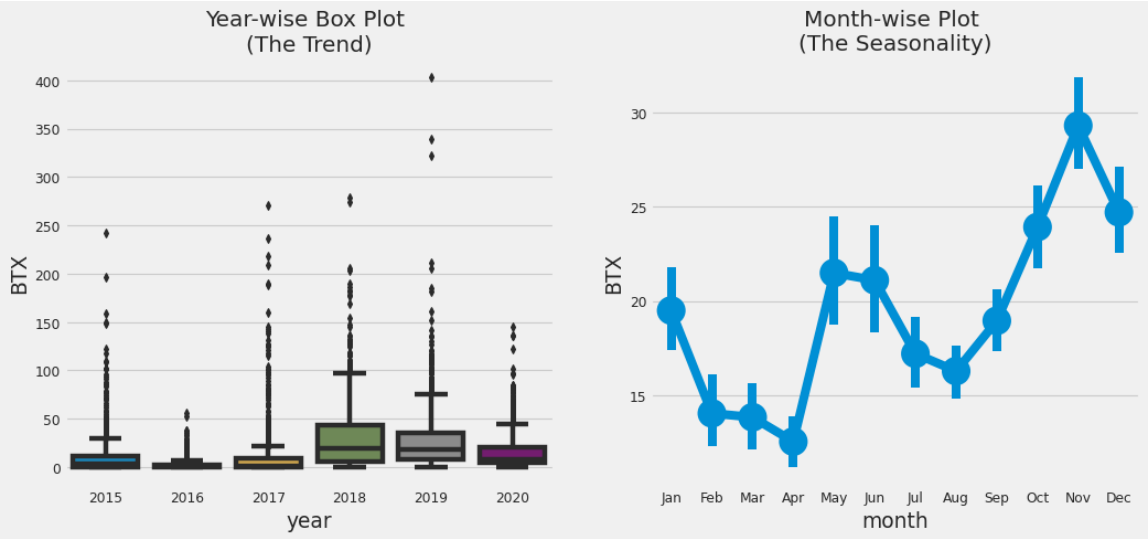
NO2



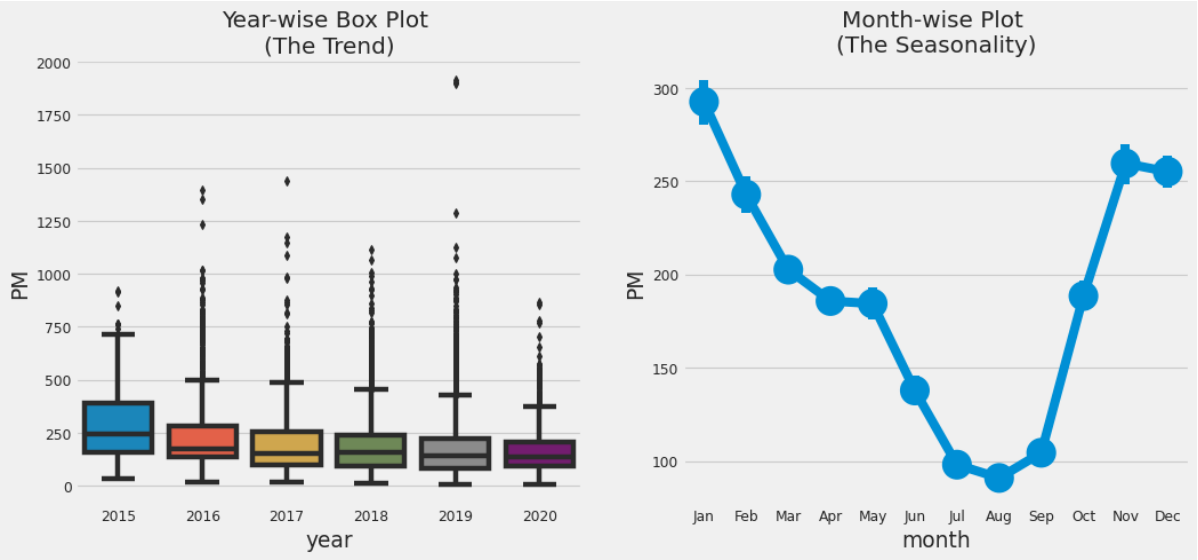
SO2



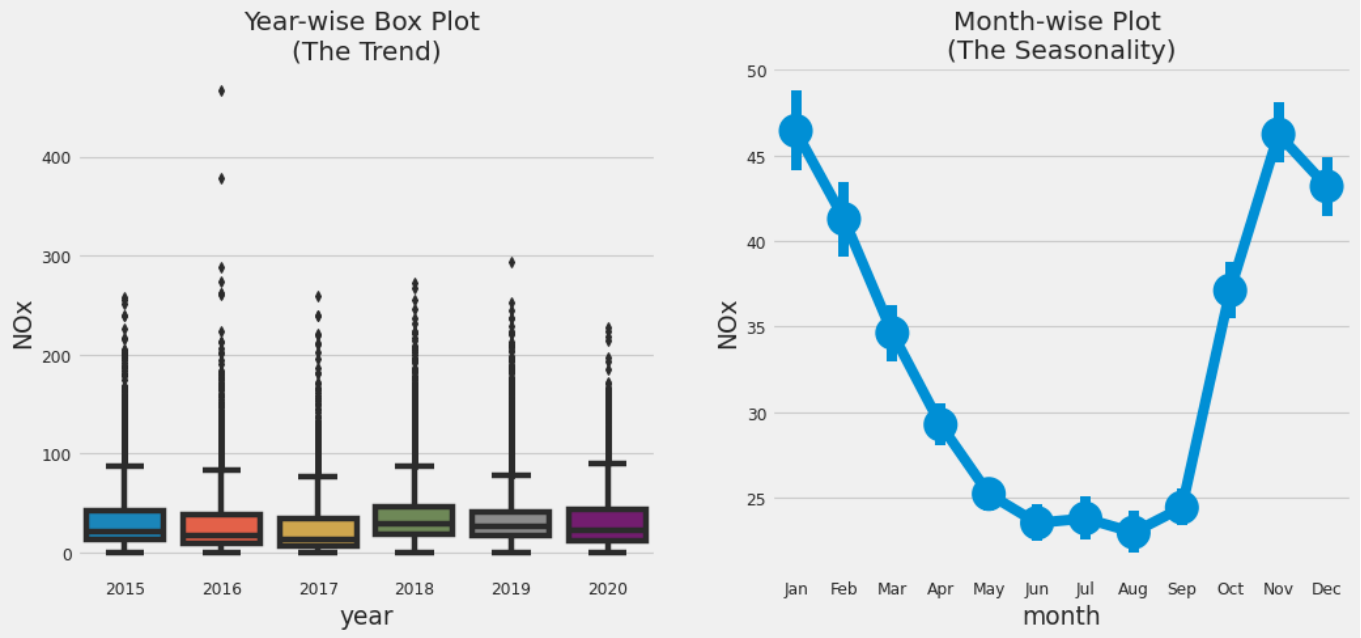
Benxene,Toulene,Xylene (BTX)



PM2.5 and PM10 (PM)



NOx


Year-wise Box Plot
(The Trend)
NOx
year
2015
2016
2017
2018
2019
2020
Month-wise Plot
(The Seasonality)
NOx
month
Jan
Feb
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Apr
May
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Oct
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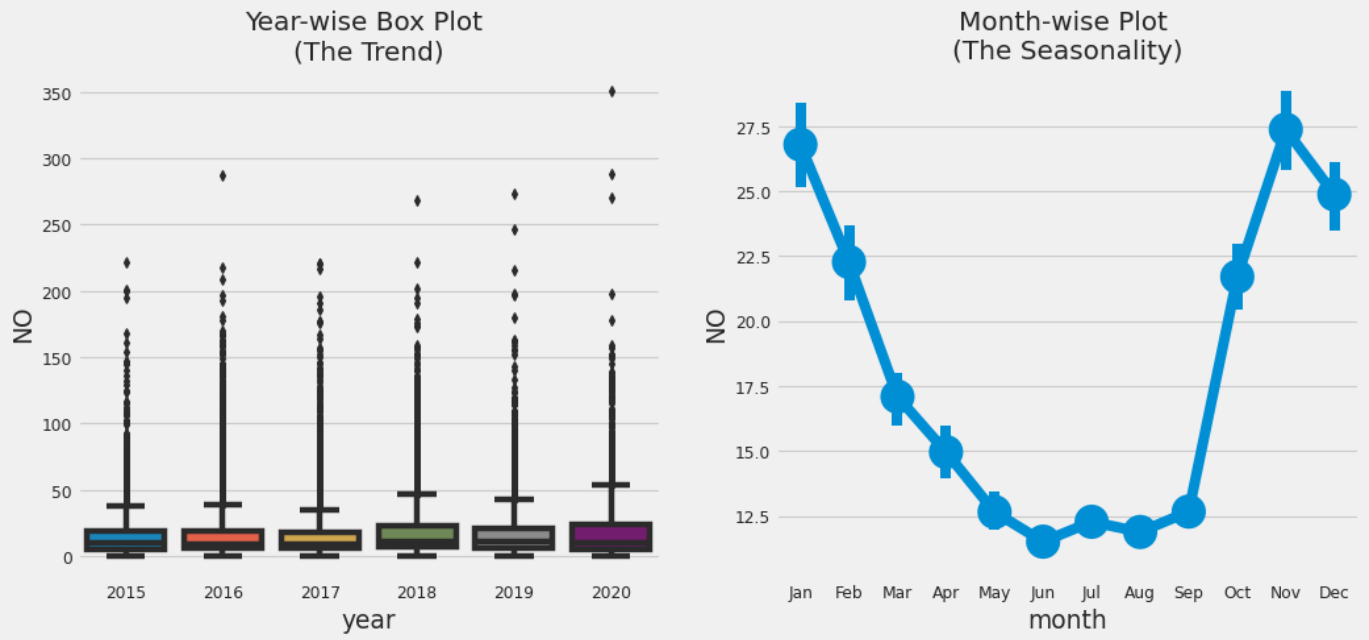
NO


Year-wise Box Plot
(The Trend)
NO
year
2015
2016
2017
2018
2019
2020
Month-wise Plot
(The Seasonality)
NO
month
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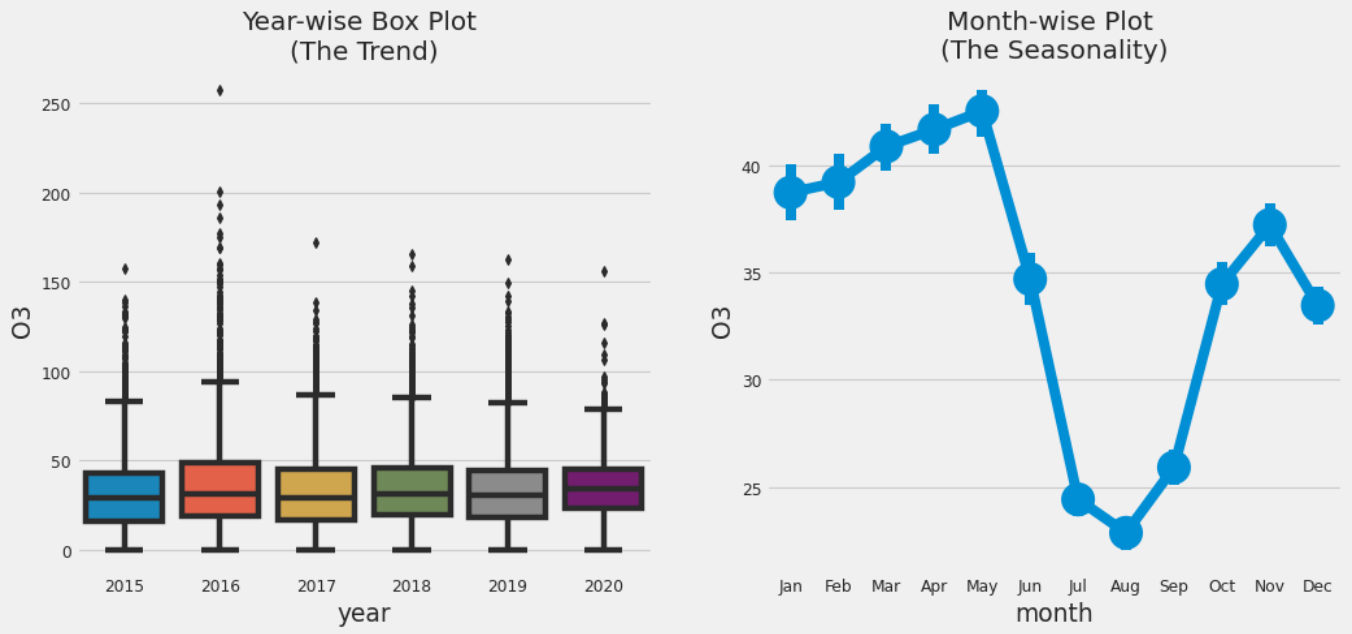
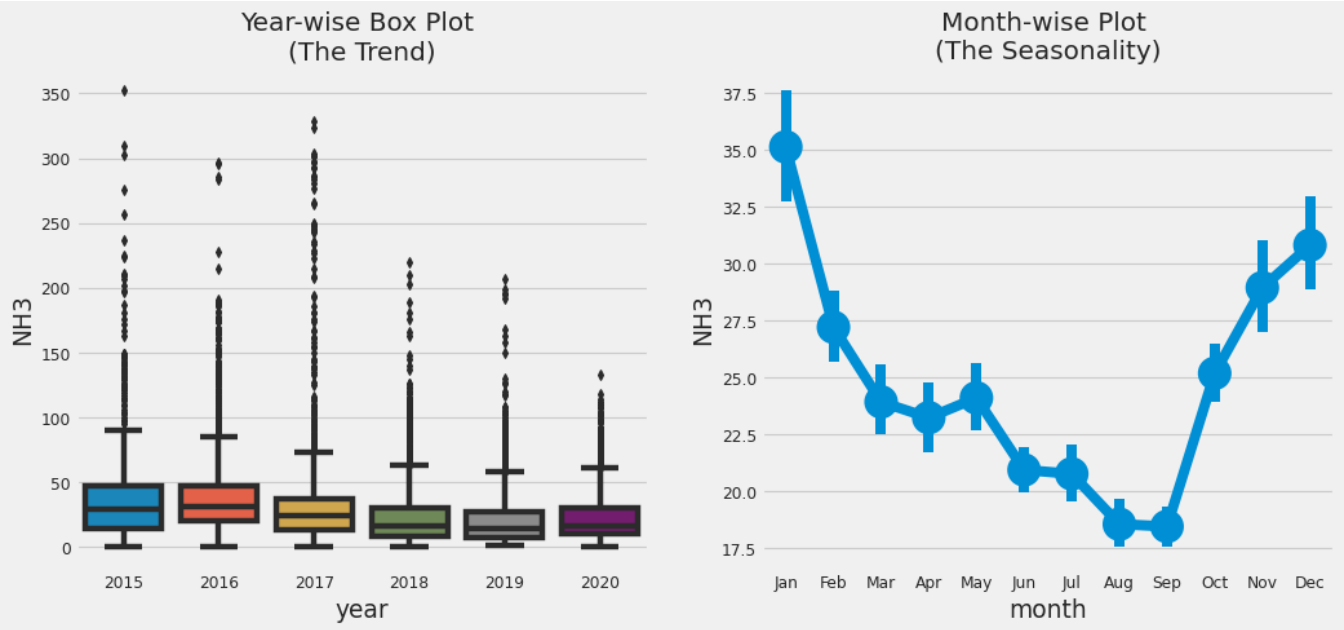
Dec

O3



NH3



By these yearly and monthly plots, we can say following thing:

- There is a clear trend that pollution level in India falls in the month of July and August. This might be majorly because monsoon season sets in during these months. The BTX levels additionally show a major decline around April.
- The pollution level then starts rising and reach highest levels in winter months. Again, it's during these months that a lot of crop residue burning takes place, especially in northern parts of India.
- SO2 level has started increasing after 2017, although it had also seen a sudden rise in 2015 also. The same pattern is also reflected in BTX levels also. This depicts that

Industries are gradually increasing from 2017 because emission of S)2 and BTX mainly comes from Industries.

- The median values of 2020 are generally less as compared to other years giving us a sense that there might be a reduction on pollution lately.
- Nitrogen Oxide (NO) is gradually increasing yearly and this depicts that number of usage of vehicles is increasing yearly. Also, emission of NO is high during Summer and Winters which clearly depicts that usage of vehicles is high during summers and winters as Vehicles emits NO in high volume

2. Most Polluted Cities in India

Let's now look at the Indian cities which contribute to maximum pollution. We shall output the top 10 cities in each pollutant category by mean concentration of the pollutant over the years. Government of India has laid down National Ambient Air Quality standards (NAAQS) for twelve air pollutants, namely, PM10, PM2.5, Carbon Monoxide (CO), Sulphur Dioxide (SO2), Nitrogen Dioxide (NO2), Ammonia (NH3), ground level Ozone (O3), Lead, Arsenic, Nickel, Benzene and Benzo (a) Pyrene. The relevant standards are mentioned below:

National Ambient Air Quality Standards

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and Other Areas	Ecologically Sensitive Area (notified by Central Government)
Sulphur Dioxide (SO_2), $\mu g/m^3$	Annual* 24 hours**	50 80	20 80
Nitrogen Dioxide (NO_2), $\mu g/m^3$	Annual* 24 hours**	40 80	30 80
Particulate Matter (size less than 10 µm) or PM_{10} $\mu g/m^3$	Annual* 24 hours**	60 100	60 100
Particulate Matter (size less than 2.5 µm) or $PM_{2.5}$ $\mu g/m^3$	Annual* 24 hours**	40 60	40 60
Ozone (O_3) $\mu g/m^3$	8 hours* 1 hour**	100 180	100 180
Lead (Pb) $\mu g/m^3$	Annual* 24 hours**	0.50 1.0	0.50 1.0
Carbon Monoxide (CO) mg/m^3	8 hours* 1 hour**	02 04	02 04
Ammonia (NH_3) $\mu g/m^3$	Annual* 24 hours**	100 400	100 400
Benzene (C_6H_6) $\mu g/m^3$	Annual*	5	5
Benzo(a)Pyrene (BaP)-particulate phase only, ng/m^3	Annual*	1	1
Arsenic(As), ng/m^3	Annual*	6	60
Nickel (Ni), ng/m^3	Annual*	20	20

Note:
* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.
** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time, they may exceed the limits but not on two consecutive days of monitoring.

	City	PM		City	NOx		City	NO		City	NO		City	O3
0	Delhi	358.080000	0	Kochi	78.340000	0	Kochi	83.070000	0	Kochi	83.070000	0	Bhopal	58.960000
1	Gurugram	300.000000	1	Kolkata	67.470000	1	Delhi	39.920000	1	Delhi	39.920000	1	Delhi	51.420000
2	Talcher	245.310000	2	Delhi	59.720000	2	Ernakulam	33.430000	2	Ernakulam	33.430000	2	Jaipur	45.940000
3	Patna	231.860000	3	Mumbai	56.170000	3	Mumbai	32.030000	3	Mumbai	32.030000	3	Ahmedabad	38.650000
4	Jorapokhar	200.460000	4	Guwahati	49.510000	4	Talcher	31.630000	4	Talcher	31.630000	4	Amaravati	38.560000
5	Guwahati	196.790000	5	Ahmedabad	48.830000	5	Patna	31.120000	5	Patna	31.120000	5	Patna	37.400000
6	Bhopal	193.090000	6	Patna	46.050000	6	Kolkata	28.740000	6	Kolkata	28.740000	6	Lucknow	36.880000
7	Kolkata	191.250000	7	Jaipur	40.990000	7	Ahmedabad	23.230000	7	Ahmedabad	23.230000	7	Thiruvananthapuram	35.160000
8	Brajrajnagar	187.860000	8	Amritsar	35.970000	8	Guwahati	22.420000	8	Guwahati	22.420000	8	Mumbai	34.530000
9	Jaipur	180.380000	9	Ernakulam	35.680000	9	Amritsar	18.530000	9	Amritsar	18.530000	9	Hyderabad	33.890000

	City	NH3		City	NO2		City	SO2		City	CO		City	BTX
0	Chennai	64.490000	0	Ahmedabad	60.590000	0	Ahmedabad	56.270000	0	Ahmedabad	23.180000	0	Kolkata	43.040000
1	Delhi	42.340000	1	Delhi	51.620000	1	Jorapokhar	34.530000	1	Lucknow	2.170000	1	Ahmedabad	37.100000
2	Gurugram	40.340000	2	Kolkata	43.040000	2	Talcher	29.060000	2	Delhi	2.010000	2	Delhi	27.260000
3	Brajrajnagar	36.740000	3	Patna	38.120000	3	Patna	22.750000	3	Talcher	1.880000	3	Patna	17.790000
4	Chandigarh	30.390000	4	Bhopal	37.490000	4	Kochi	18.400000	4	Bengaluru	1.870000	4	Gurugram	17.510000
5	Lucknow	30.320000	5	Lucknow	33.840000	5	Delhi	15.970000	5	Brajrajnagar	1.860000	5	Amritsar	14.810000
6	Jaipur	26.580000	6	Jaipur	33.330000	6	Mumbai	15.360000	6	Patna	1.570000	6	Hyderabad	10.710000
7	Patna	23.870000	7	Hyderabad	28.520000	7	Guwahati	14.580000	7	Ernakulam	1.370000	7	Chandigarh	10.050000
8	Aizawl	23.270000	8	Bengaluru	28.420000	8	Amaravati	14.470000	8	Gurugram	1.280000	8	Amaravati	3.470000
9	Bengaluru	22.480000	9	Mumbai	26.950000	9	Bhopal	13.440000	9	Kochi	1.170000	9	Ernakulam	2.340000

By these tables we can clearly assume:

- Patna, Delhi, Ahmedabad and Kolkata seem to top the charts. Ahmedabad has maximum concentrations of NO2, SO2 as well as CO levels.
- Kochi, Delhi, Ernakulam, Mumbai as high emission of NO which depicts that high usage of vehicles are there in these cities.
- Ahmedabad has high emission of BTX and SO2 which depicts these emissions come from Industries.
- Delhi has very high emission of PM which depicts high usage of vehicles as well as there are a greater number of Industries causing Air Pollution.

3. Effect of Lockdown on AQI

Let's now see how has the Lockdown affected the AQI levels in the prominent cities of India. For this we shall consider the data from 2019 onwards only. But before that let's understand what AQI is:

3.1 AQI: Air Quality Index

An air quality index (AQI) is used by government agencies [1] to communicate to the public how polluted the air currently is or how polluted it is forecast to become. There are six AQI categories, namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. The proposed AQI will consider eight pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb) for which short-term (up to 24-hourly averaging period) National Ambient Air Quality Standards are prescribed.[23] Based on the measured ambient concentrations, corresponding standards and likely health impact, a sub-index is calculated for each of these pollutants. The worst sub-index reflects overall AQI. Likely health impacts for different AQI categories and pollutants have also been suggested, with primary inputs from the medical experts in the group. The AQI values and corresponding ambient concentrations (health breakpoints) as well as associated likely health impacts for the identified eight pollutants are as follows:

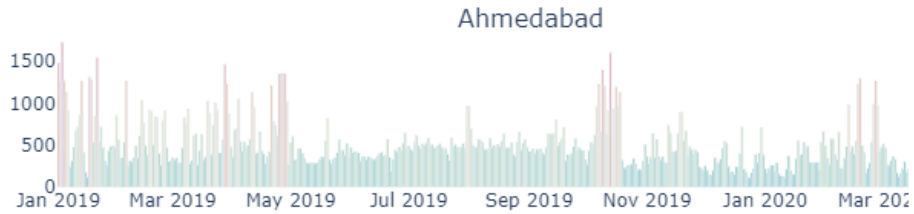
AQI	Remark	Color Code	Possible Health Impacts
0-50	Good		Minimal impact
51-100	Satisfactory		Minor breathing discomfort to sensitive people
101-200	Moderate		Breathing discomfort to the people with lungs, asthma and heart diseases
201-300	Poor		Breathing discomfort to most people on prolonged exposure
301-400	Very Poor		Respiratory illness on prolonged exposure
401-500	Severe		Affects healthy people and seriously impacts those with existing diseases

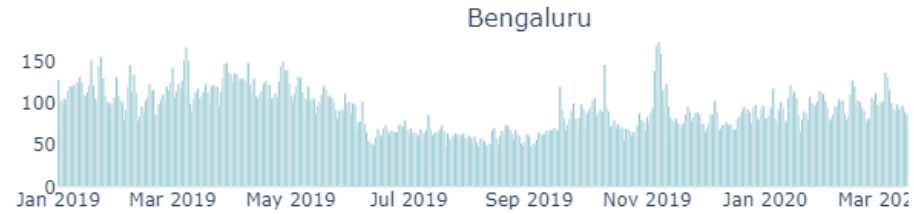
source: https://app.cpcbccr.com/AQI_India/

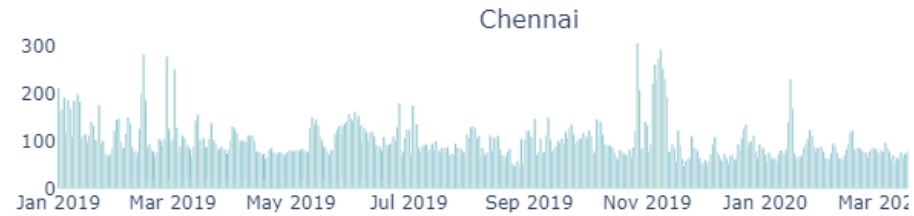
4.2 AQI for some of the major cities of India

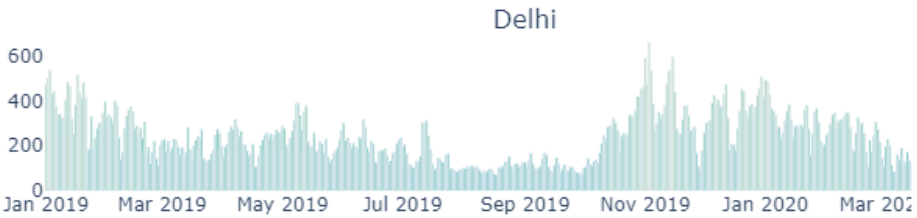
The cities that will be the subject of our study are - Ahmedabad, Delhi, Bengaluru, Mumbai, Hyderabad and Chennai.

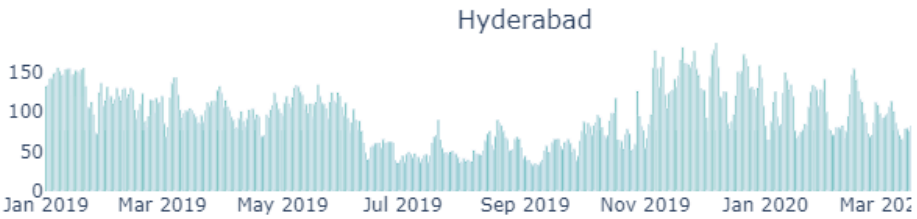
AQI Levels

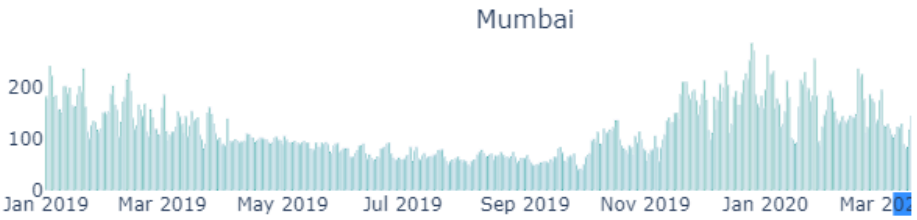

Ahmedabad
1500
1000
500
0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sep 2019
Nov 2019
Jan 2020
Mar 202


Bengaluru
150
100
50
0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sep 2019
Nov 2019
Jan 2020
Mar 202


Chennai
300
200
100
0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sep 2019
Nov 2019
Jan 2020
Mar 202


Delhi
600
400
200
0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sep 2019
Nov 2019
Jan 2020
Mar 202


Hyderabad
150
100
50
0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sep 2019
Nov 2019
Jan 2020
Mar 202


Mumbai
200
100
0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sep 2019
Nov 2019
Jan 2020
Mar 20

4.4 AQI before and after Lockdown

It'll be also interesting to see the difference in AQI before and after the Lockdown

```
AQI before Lockdown
 City
Ahmedabad    383.776471
Bengaluru     96.023529
Chennai       80.317647
Delhi        246.305882
Hyderabad     94.435294
Mumbai       148.776471


AQI after Lockdown
 City
Ahmedabad    127.972973
Bengaluru     68.513514
Chennai       62.189189
Delhi        107.378378
Hyderabad     65.675676
Mumbai        73.972973


"Ahmedabad's AQI levels"
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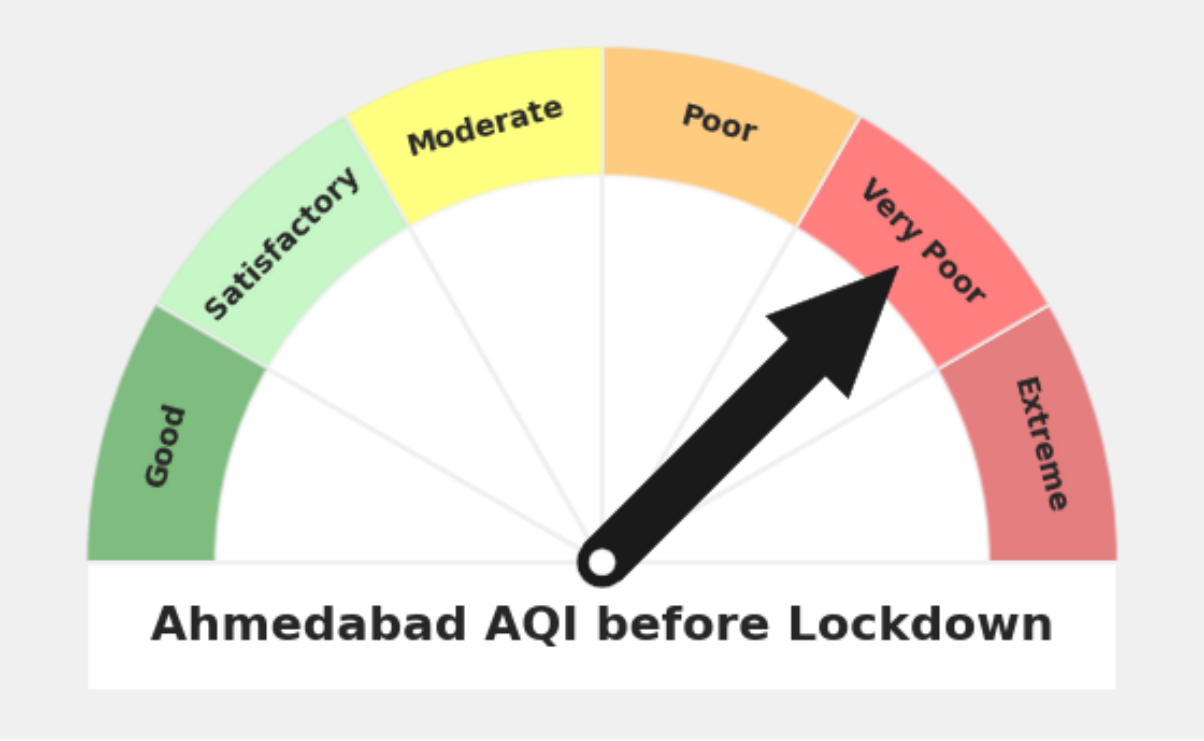
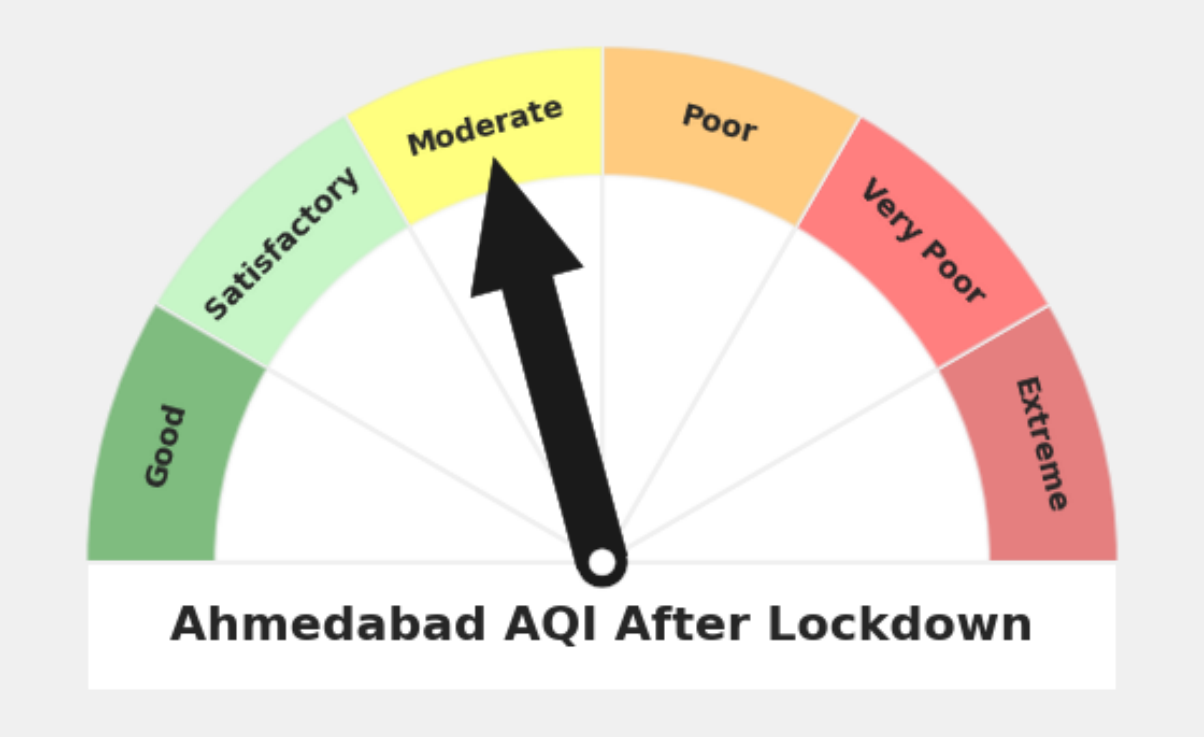
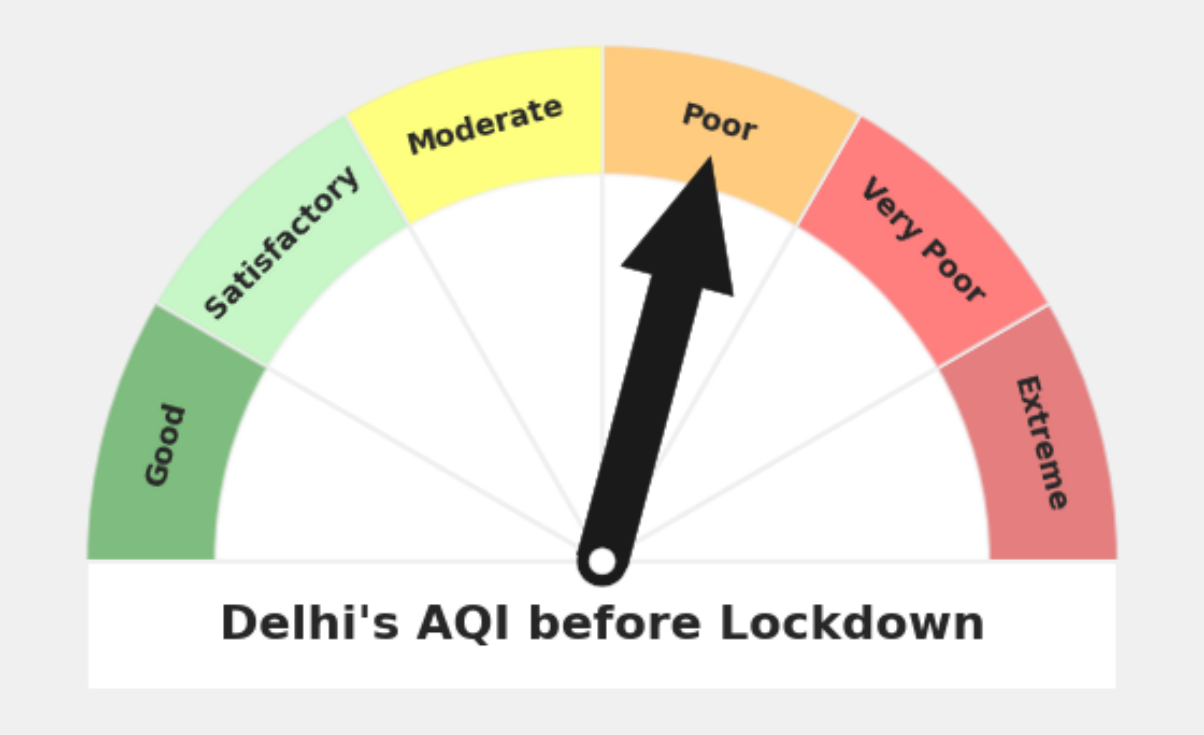
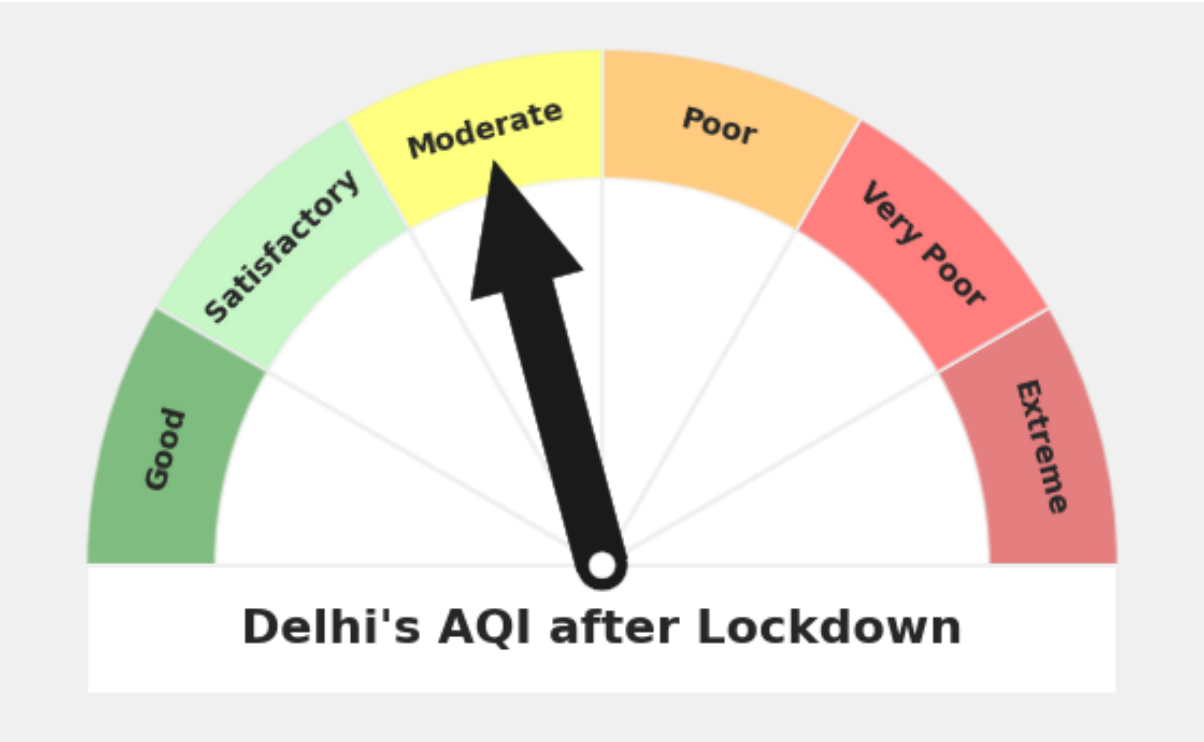


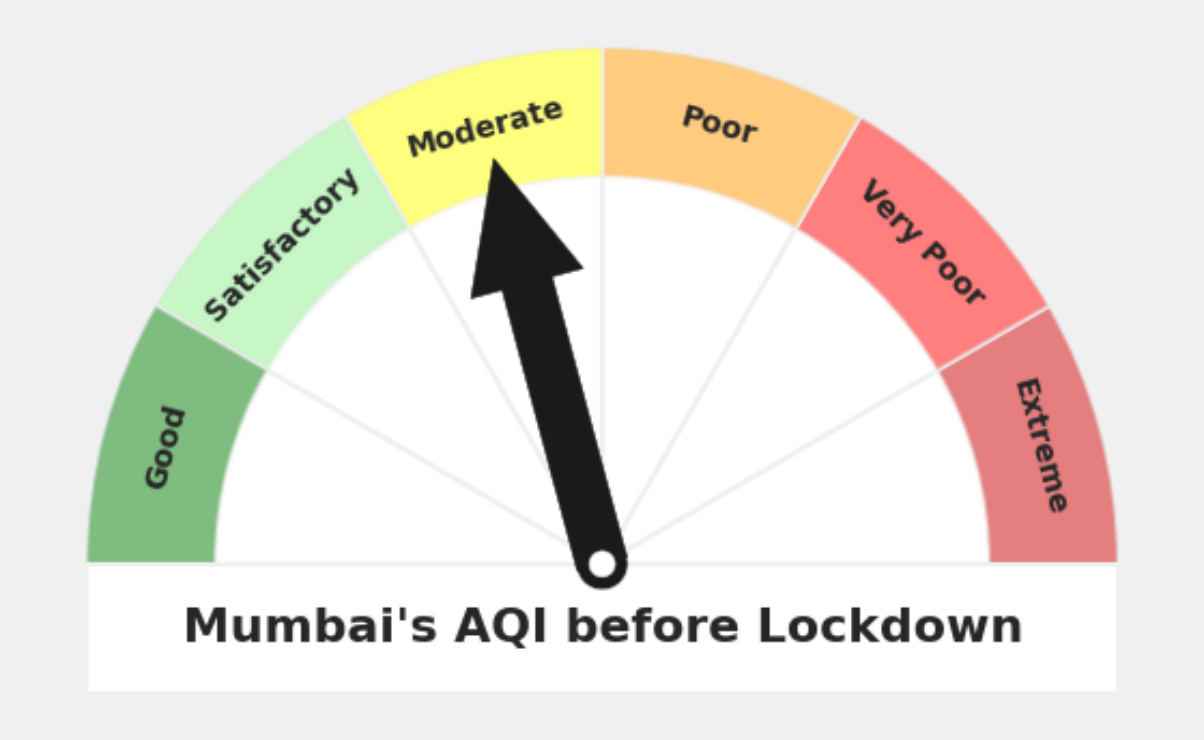


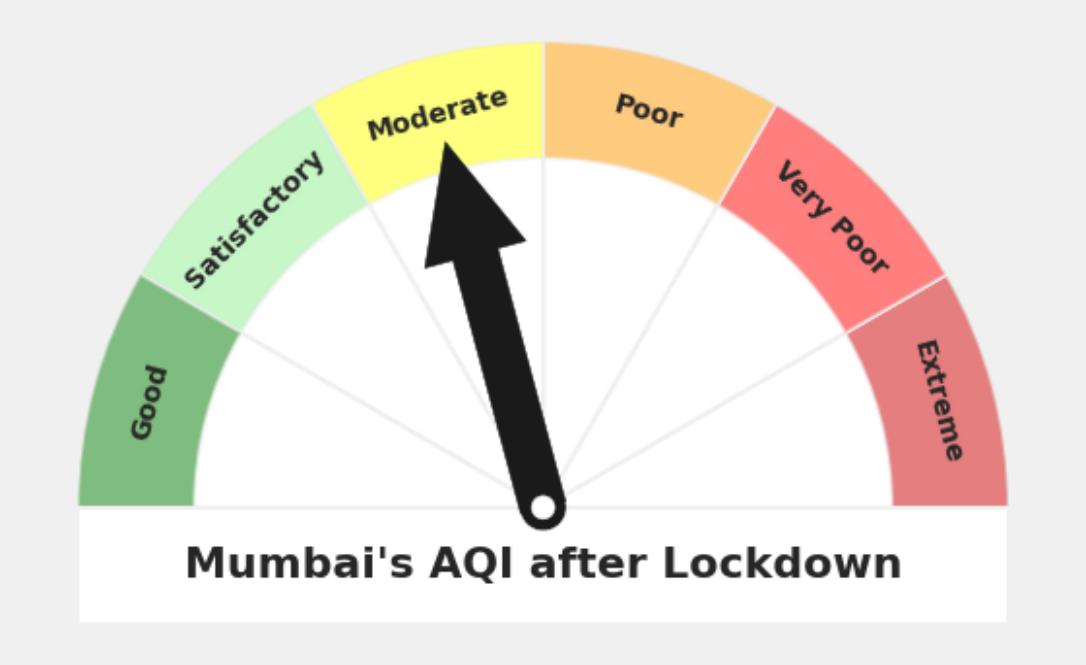
"Delhi's AQI levels"





"Mumbai's AQI levels"

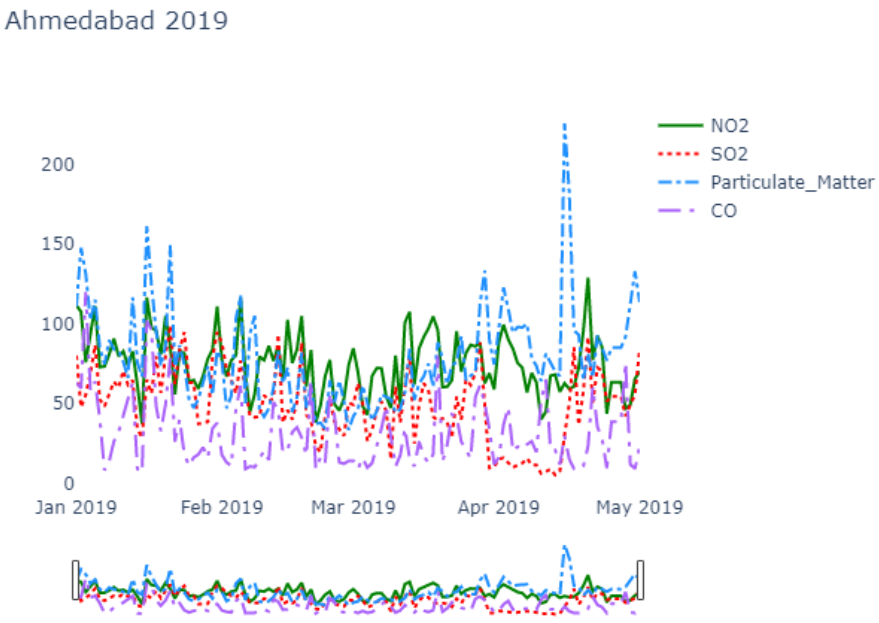




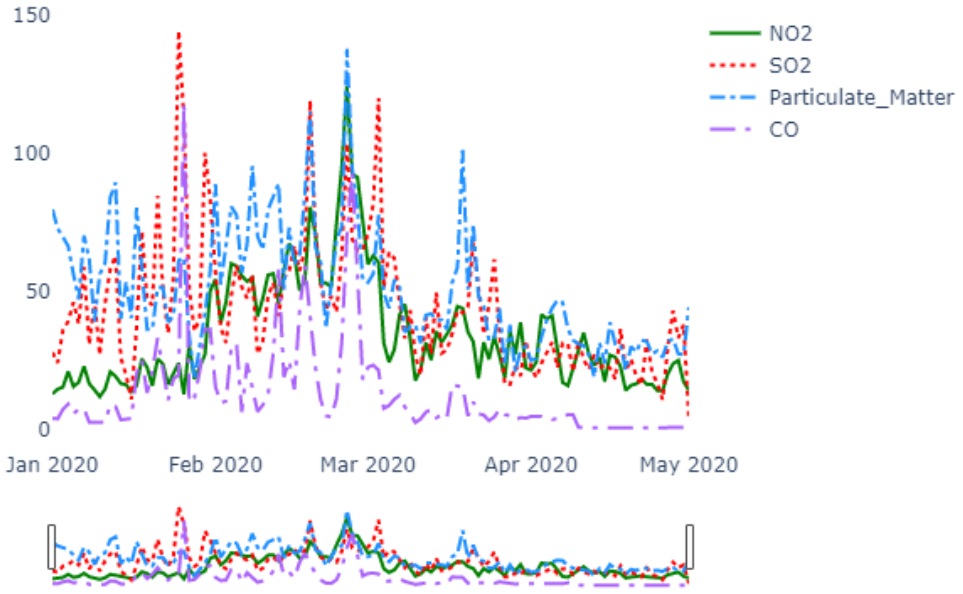
5. Effect of Lockdown on levels of Individual pollutants

Let's compare the level of pollutants between January and April between between 2020 and 2019. This will give an idea whether the pollution levels have actually subsided or the pollution actually remains low during the onset of summer in India.

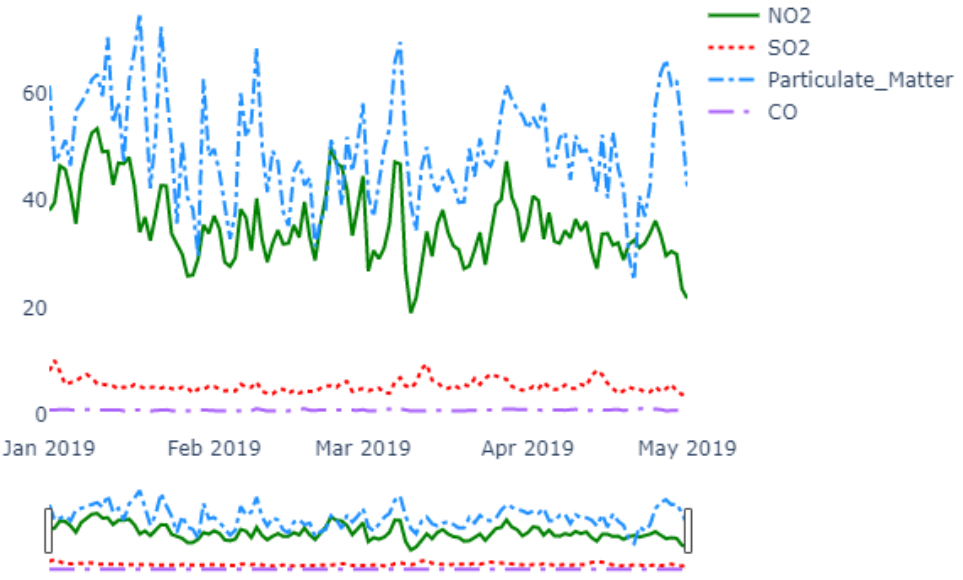
5.1 A comparison between pollution levels in 2020 VS 2019



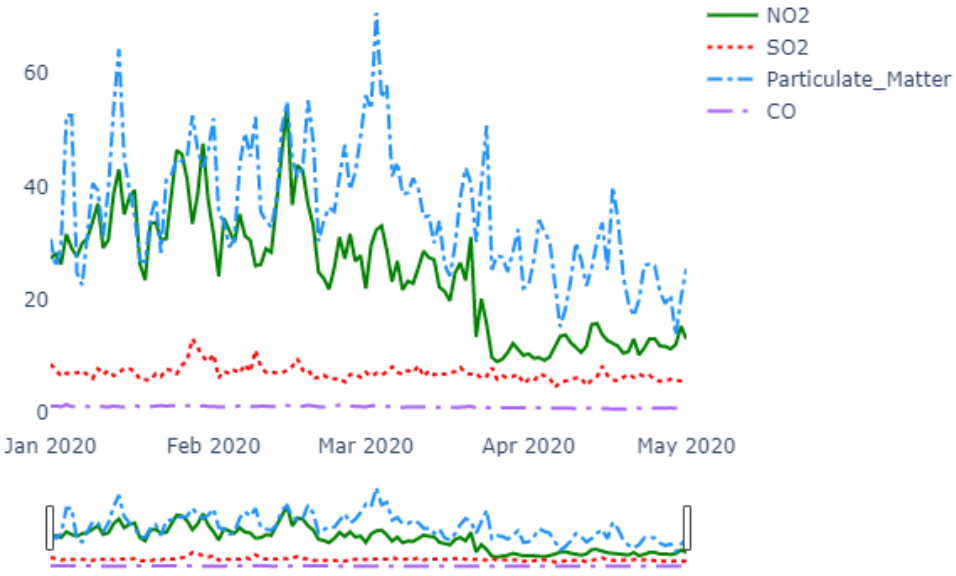
Ahmedabad 2020



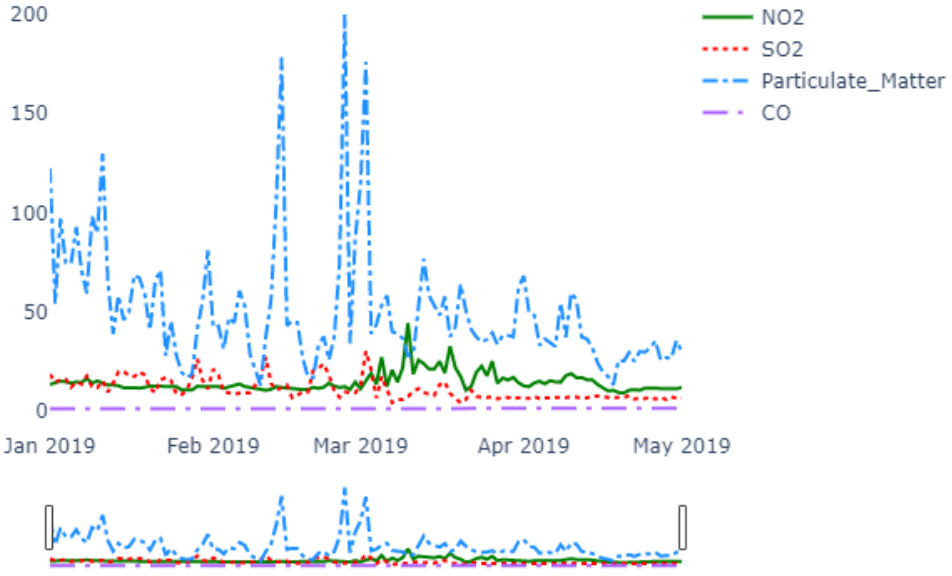
Bengaluru 2019



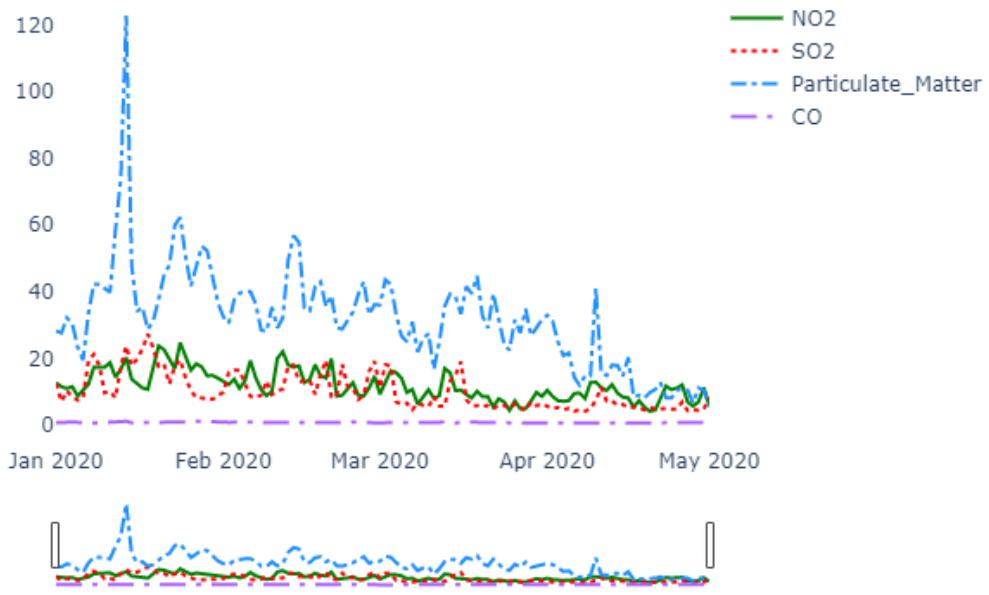
Bengaluru 2020



Chennai 2019



Chennai 2020



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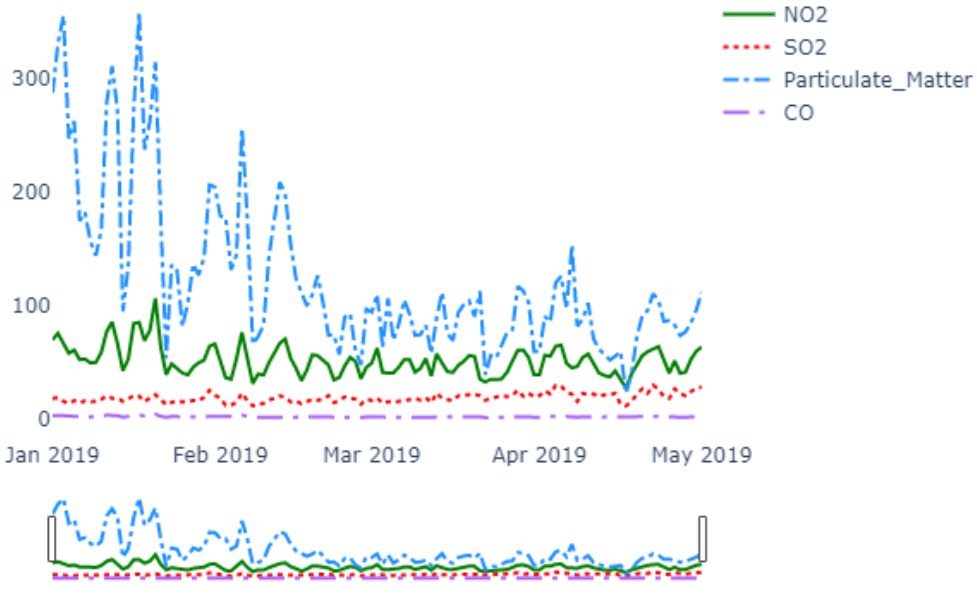

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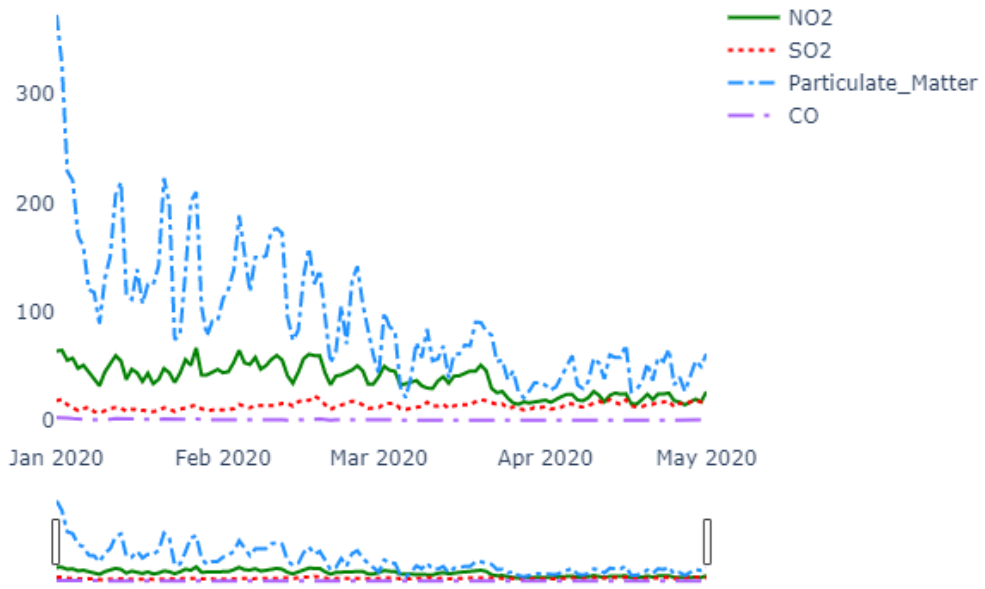
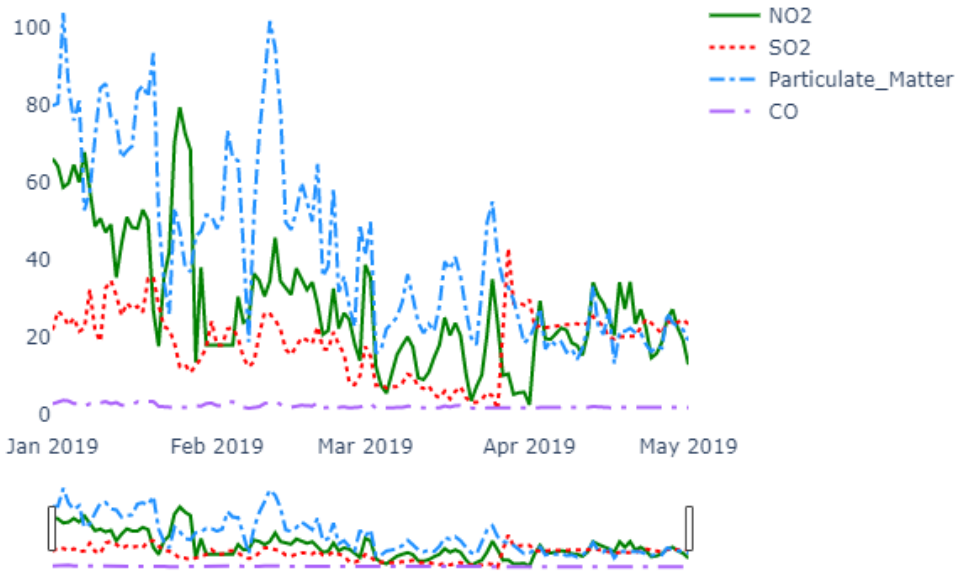


Mumbai 2019



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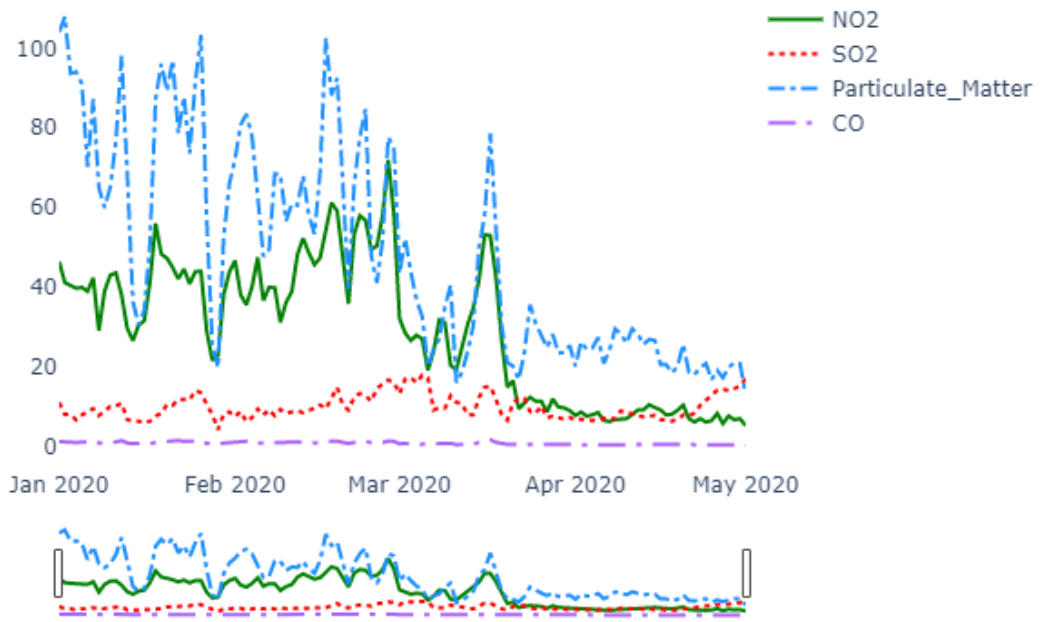
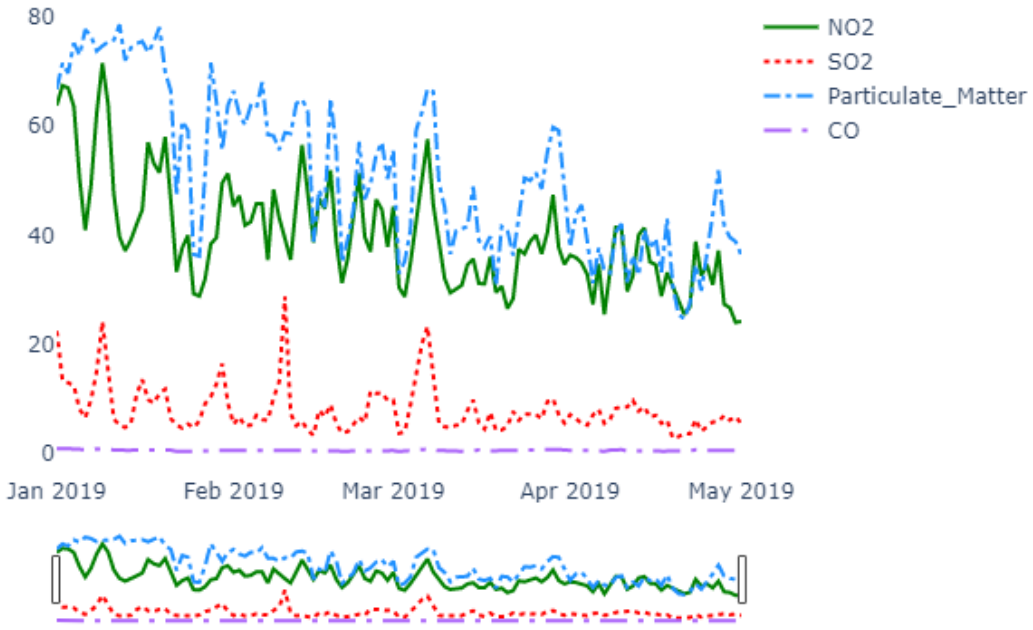
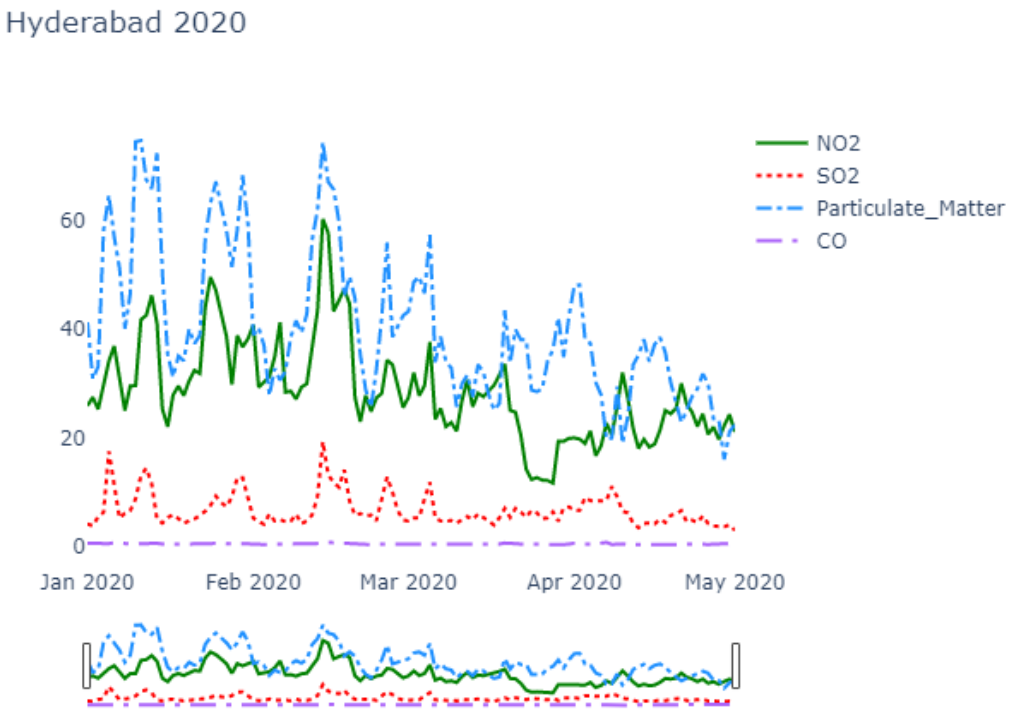


Hyderabad 2019





- It is interesting to note that the Pollution level in India generally drops down as summer approaches. This can also be corroborated by the graphs above.
- However, the reduction in march 2020 is more pronounced as compared to march 2019

Conclusion:

Since 2016, the major pollutants were increasing gradually till the lockdown. We clearly see the reduction in emission of major pollutants which are causing air pollution due to lockdown as most of the industries are closed and usage of vehicles are very less. However it is difficult to predict till when this lockdown will remain in India but by looking at the current situation of Covid-19 in India, we can predict that there will be partial opening of the cities in India from lockdown. This will take few months which clearly indicate further decrease in air pollution.

References:

1. Data source: https://www.kaggle.com/rohanrao/air-quality-data-in-india/kernels
2. Information source: Wikipedia and Google
3. Other important source: https://app.cpcbccr.com/AQI_India/

For more data visualization and data analysis code visit: https://github.com/meetv123/Covid-Impact-of-Air-Pollution-before-and-after-lockdown