A REPORT ON

IMPACT OF LOCKDOWN ON AMBIENT AIR QUALITY

CENTRAL POLLUTION CONTROL BOARD

Ministry of Environment, Forest & Climate Change

GOVERNMENT OF INDIA

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शिव दास मीना, भा.प्र.से.
अध्यक्ष
Shiv Das Meena, I. A. S.
Chairman

केन्द्रीय प्रदूषण नियंत्रण बोर्ड
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार
CENTRAL POLLUTION CONTROL BOARD
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE, GOVT. OF INDIA

F O R E W O R D

Central Pollution Control Board (CPCB), as per the mandate under the Air (Prevention and Control of Pollution) Act, 1981, collects and disseminates information in respect of matters relating to air pollution.

The lockdown, imposed due to COVID-19 pandemic, placed restrictions on the operation of several sectors in the country. As a result, an improvement in air quality has been reported from several cities in the country. The present report contains the analysis of the air quality data, derived from continuous ambient air quality stations for the pre-lockdown period, lockdown phases-I and II, and for corresponding periods in 2019. The interpretation of trends, observed for $PM_{2.5}$, PM_{10}, SO_2, NO_2, Benzene and Air Quality Index, has been presented in the reports for major towns and cities across India such as Delhi, Gurugram, Noida, Mumbai, Kolkata, Bengaluru, Patna and others. Further, the findings of a study awarded by CPCB to IIT Kanpur, on Real time source apportionment for Delhi, have also been studied in the context of the impact of different sources on the air quality of Delhi during different phases of lockdown. In addition, satellite derived $PM_{2.5}$ was also examined to obtain an estimate for air quality improvement over the entire country.

The contribution made by my colleagues Sh. V. K. Shukla, Additional Director and Sh. Gautam Kumar Sharma, Scientist 'B' in preparing the report under the supervision of Dr. Prashant Gargava, Member Secretary is appreciated. Cooperation extended by other divisions of CPCB, and collaborating agencies such as IIT Delhi and IIT Kanpur are gratefully acknowledged.

Hope the report shall be of use to all concerned.

(Shiv Das Meena)

Dated : 18.09.2020

'परिवेश भवन' पूर्वी अर्जुन नगर दिल्ली-110 032, भारत
'Parivesh Bhawan', East Arjun Nagar, Delhi-110 032, India
Tel. +91-11-22307233, Tele Fax : +91-11-22304948, e-mail: ccb.cpcb@nic.in

Contributors

Guidance	**Dr. Prashant Gargava,** **Member Secretary, CPCB**
Principal Coordinator	**Sh. V. K. Shukla,** **Divisional Head, Air Quality Monitoring Division**
Data Analysis and Report Preparation	**Sh. Gautam Kumar Sharma, Scientist 'B'** **Ms. Nidhi Shukla, Senior Research Fellow** **Ms. Parinita Baruah, Senior Research Fellow**
Data Compilation, Scrutiny and Validation	**Sh. Fasiur Rehman, Scientist 'C'** **Sh. Sahodhar, Senior Research Fellow** **Air Laboratory**
Data Providers	**Air laboratory CPCB, State Pollution Control Boards/Pollution Control Committees, IMD, Universities and other Agencies**
Printing Supervision	**M. K. Chaudhary, Satish Kumar**

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1. INTRODUCTION

The nationwide Lockdown, imposed from the midnight of 24th March 2020, in view of COVID-19 pandemic, has resulted in significant improvement in air quality in the country, as revealed by data analysis and comparison of data for time before enforcement of restrictions, and the corresponding time periods in the previous year. The Lockdown was announced after a 14-hour voluntary curfew called "Janata curfew" which was observed on 22nd March 2020. On 14th April 2020, the nationwide lockdown was extended until 03rd May 2020, with conditional relaxation, such as opening up of government offices, operation of industrial estates and Special Economic Zones (SEZs), construction works and brick kilns in rural areas, etc., in the regions where the pandemic spread had been contained. The major sectors contributing to air pollution are transport, industries, power plants, construction activities, biomass & refuse burning, road dust resuspension and residential activities. In addition, certain activities such as operation of DG sets, restaurant, landfill fires, etc. also contribute to air pollution. Under the nationwide lockdown, all transport services – road, air and rail were suspended with exceptions for essential services. Sectors like industrial establishments, construction activities, commercial and hospitality services, etc. were also suspended. As a result of the curtailment of emissions from various sources, air quality improvement has been noted in many towns and cities across the nation. The examination of data, obtained from studies awarded by CPCB, have corroborated the findings that air quality levels improved during the lockdown periods.

2. METHODOLOGY

Data generated from Continuous Ambient Air Quality Monitoring (CAAQM) network has been analysed for Delhi and its neighbouring major NCR towns i.e. Faridabad, Gurugram, Noida and Ghaziabad. Further, CAAQM data has also been analysed for a few major metropolitan cities i.e. Mumbai, Bengaluru, Kolkata, Chennai, Indore, Patna and Singrauli, for the same period as above so as to obtain air quality trends. Air Quality Data has been studied in three phases: Pre-lockdown phase (1st - 21st March 2020), Lockdown phase-I (25th March – 19th April 2020) and Lockdown phase-II (20th April – 3rd May 2020). Though phase-II of lockdown began from 15th April, as per Government guidelines, since selected additional activities were allowed from 20th April 2020 onwards, Lockdown phase-II period has been considered from 20th April to 3rd May 2020. Since Janata curfew was imposed on 22nd March 2020 and several states had started imposing restrictions in the next few days, the period from 22nd March to 24th March 2020 has not been considered.

Fig. 1 Map Highlighting 12 Cities under study

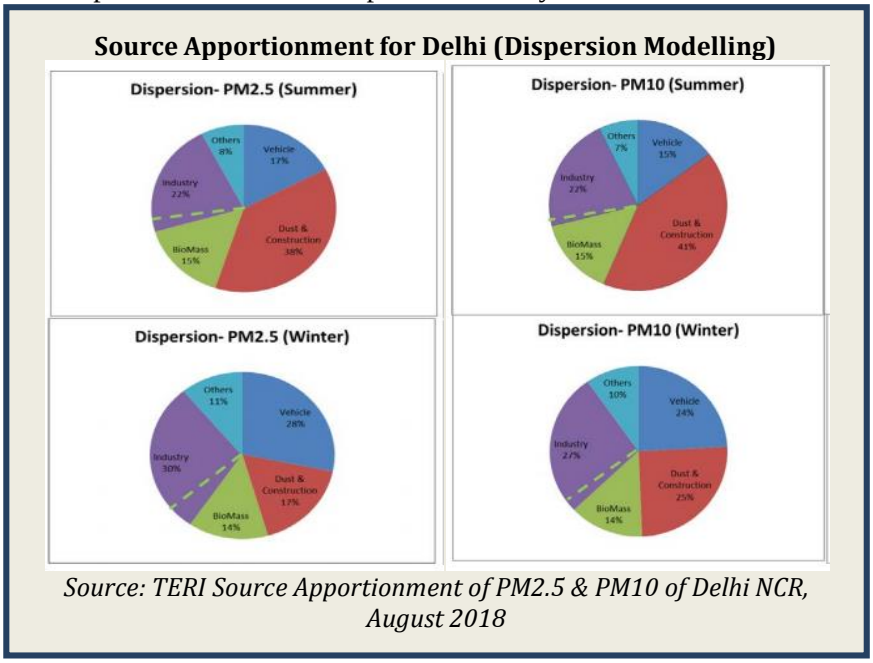
A comparative analysis has also been done for the corresponding time periods in 2019, to assess the quantum of improvement during the lockdown periods. Since meteorology plays a major role in influencing ambient air quality, average wind speed, wind direction and mixing height have also been compared for Delhi. However, meteorological parameters for other cities have not been considered. Air Quality Index values as per CPCB bulletin have been analysed to observe the general trend of air quality improvement in the country. The findings of study awarded by CPCB to IIT Kanpur on Real time source apportionment for Delhi, conducted during 19th February to 18th May 2020, have also been examined. This study carried out source apportionment of highly resolved $PM_{2.5}$, using the Positive Matrix Factorization (PMF) approach, resulting in prediction of source-wise emission inventory, along with their time-varying contribution. Satellite based $PM_{2.5}$ data under the project entitled "Satellite based near real time monitoring of ambient $PM_{2.5}$ at national scale for air quality management", initiated by CPCB in collaboration with Indian Institute of Technology (IIT), Delhi under National Clean Air Programme (NCAP) has also been considered to gain insights into the quantum of improvement observed nationally.

It is also important to mention, at the very outset, that augmentation of the monitoring network has taken place in most cities in the last one year. Thus, it may be the case that reduction or improvement in pollutant concentrations may also be affected by spatial averaging, due to the presence of multiple stations in a city.

3. EFFECT OF LOCKDOWN IN DELHI

3.1 Analysis of continuous ambient air quality monitoring data

During both the phases of the lockdown period, as a result of combination of reduced vehicles on roads, functioning of only essential commercial units and prevailing weather conditions, significant reduction in $PM_{2.5}$, PM_{10} and NO_2 levels were observed. As reported in source apportionment study conducted by TERI & ARAI, 2018, during summers, dust & construction activities (38-42%), transport sector (15-17%) and industry (22%), are major source of particulate matter in Delhi. Considerable improvement in air quality levels were seen as compared to the same time periods in last year. It has also been noted that air quality levels were improved even during the pre-lockdown period in 2020. This may be due to meteorological conditions as well as the fact that a few restrictions such as those on cinema halls, schools, colleges, etc. were already in place during the first half of March. In terms of Particulate Matter levels, while $PM_{2.5}$ reduced by 24% during the pre-lockdown phase, it further reduced by almost 50% during both lockdown phases as compared to levels observed during 2019. PM_{10} reduced by a massive 60%, with NO_2 levels falling by 64%, Benzene by 62% and SO_2 by 35%, during the second phase of lockdown as compared to levels in the same time period in 2019.



Source: TERI Source Apportionment of PM2.5 & PM10 of Delhi NCR, August 2018

Reduction in pollutant concentrations have also been witnessed in comparison to pre-lockdown levels. 38% and 33% reduction in $PM_{2.5}$ and 37% and 30% reduction in PM_{10} was observed during the lockdown phase-I and lockdown phase-II periods respectively, as compared to pre-lockdown levels.

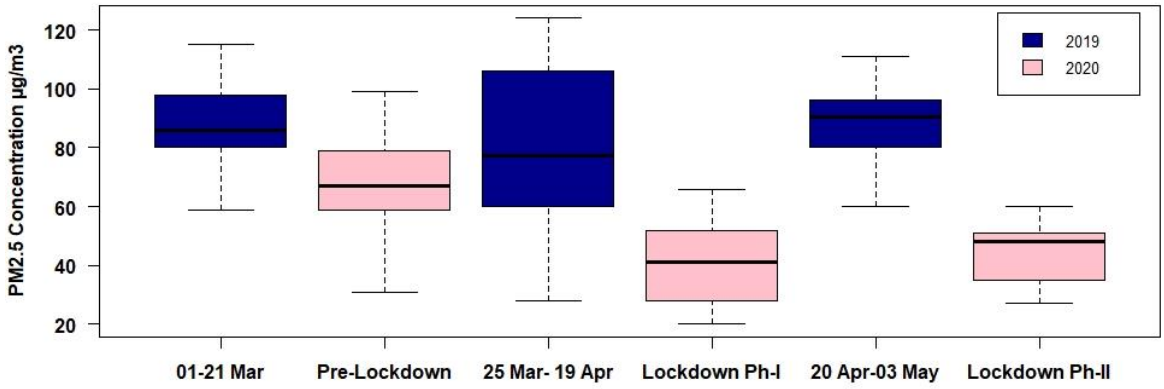
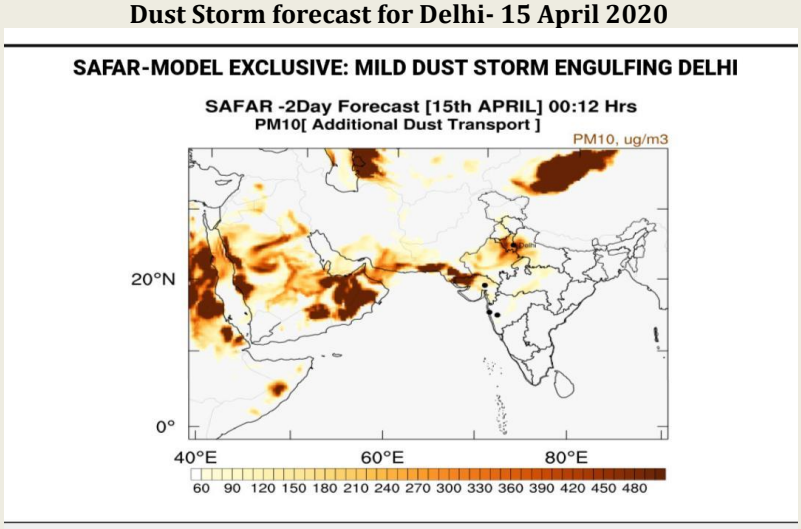


Fig 2.: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 - Delhi

$PM_{2.5}$ and PM_{10} levels were seen to rise in the second week of the phase-I of lockdown which may primarily be attributed to change in meteorological conditions. Due to the onset of summers, temperature has started to increase with average temperature of 20.9 ºC on 16th March 2020 to 30.4 ºC on 1st May 2020, leading to dry and dusty conditions. Moreover, it was reported that a mild dust storm from western part of the country and the gulf regions hit Delhi on 14th - 15th April 2020, thus rapidly increasing the PM_{10} levels in Delhi and NCR.

Dust Storm forecast for Delhi- 15 April 2020



Source: System of Air Quality Forecasting And Research (SAFAR)

However, 24 Hourly Average $PM_{2.5}$ and PM_{10} were within National Ambient Air Quality Standards (NAAQS) for 39 and 20 days respectively, out of 40 days of the lockdown period in 2020, increasing from 8 days and 2 days observed in 2019 respectively, as in Table 1.

Table 1: Number of days meeting NAAQS for $PM_{2.5}$, PM_{10}, NO_2 & SO_2 during 25th March – 3rd May 2019 & 2020 - Delhi

Parameter/Year	2019 (40 days)	2020 (40 days)	24 hourly standard
$PM_{2.5}$	8	**39**	**60 $\mu g/m^3$**
PM_{10}	2	**20**	**100 $\mu g/m^3$**
SO_2	40	**40**	**80 $\mu g/m^3$**
NO_2	40	**40**	**80 $\mu g/m^3$**

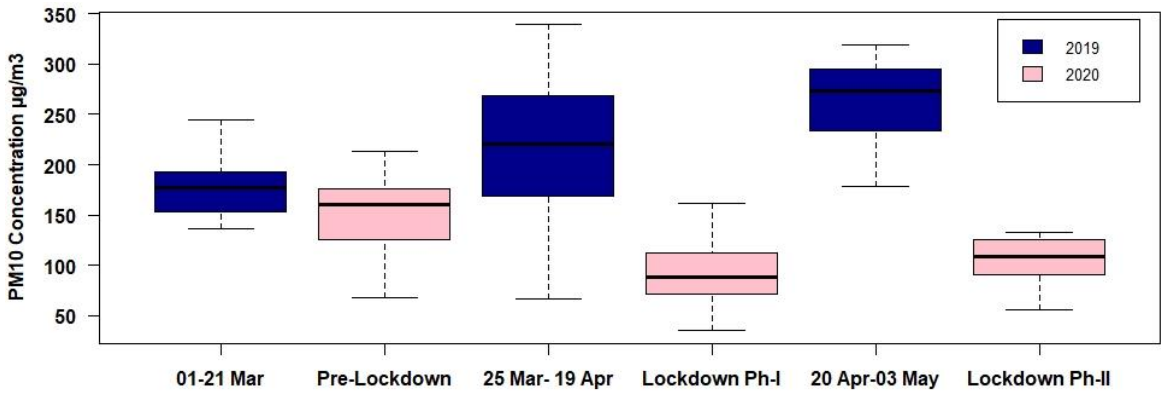


Fig 3.: Box Plot of PM_{10} Concentrations during 25th March – 3rd 2019 & 2020 - Delhi

Since 81% of Delhi's NOx comes from the transport sector (as per TERI Emission Inventory, 2018), restrictions on vehicular activity led to a 48% reduction in NO_2 levels during the first phase of lockdown and further improved to a reduction of 52% during the second phase of lockdown, as compared to pre-lockdown levels. The range of NO_2 values during the lockdown periods has greatly reduced, suggesting absence of prominent sources. Though 24 hourly NO_2 levels remained within NAAQS in the lockdown periods and the same periods in 2019, the maximum 24-hourly value of NO_2 during the lockdown periods was less than half the peak value observed during the same period in 2019. Similar trend was observed for Benzene levels, indicating the diminished presence of vehicular activity. Since there were restrictions on the transport sector and other industrial operations, which are the two major sources of Benzene emissions, 50% and 39% reduction in Benzene levels has been observed during the two phases of lockdown.

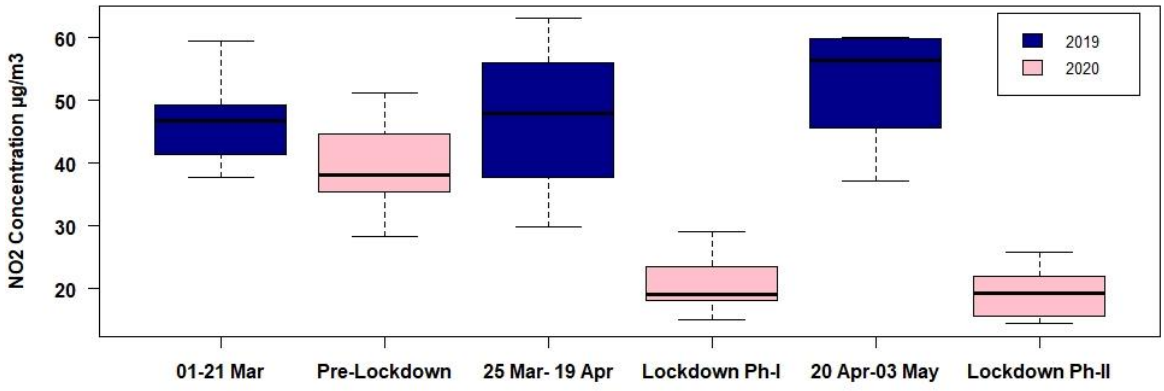


Fig 4.: Box Plot of NO_2 Concentrations during 25th March – 3rd May, 2019 & 2020 - Delhi

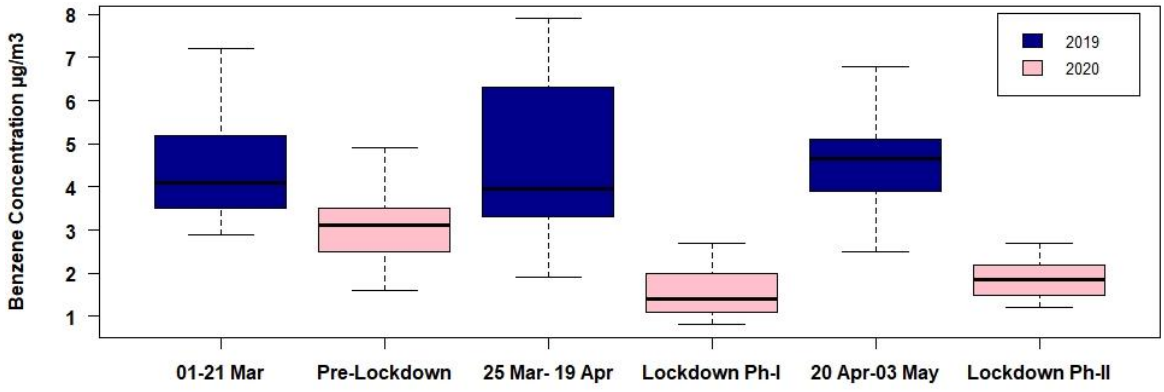


Fig 5.: Box Plot of Benzene Concentrations during 25th March – 3rd May2019 & 2020 - Delhi

SO_2 levels decreased by 6% in the phase-I of lockdown but remained similar to pre-lockdown levels during lockdown phase-II, seemingly due to operation of industries in the surrounding areas. Further, over 70% of Delhi's SO_2 originates from power plants located around Delhi (as per TERI Emission Inventory, 2018) which were operational during lockdown period, with factors like electricity generated, coal consumption, etc. influencing the emissions from the plants. Since summers have kicked in, it may be likely that electricity demand may also have increased. However, this needs further data to conclusively derive a reason.

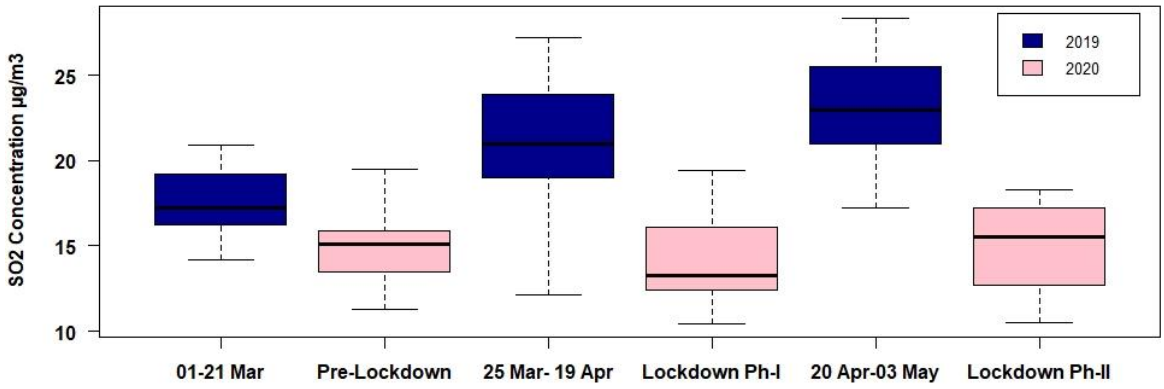


Fig 6.: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 - Delhi

It is important to mention here that the impact of meteorological factors was slightly favorable in 2020, with average mixing height and wind speed improved for pre-lockdown and lockdown phases, against the same time periods in 2019. Wind speed and mixing height was also higher in the first phase of lockdown as compared to pre-lockdown levels. Light to moderate rains were also recorded in Delhi-NCR on 5th March, 14th March, 27th March, 28th – 29th March, 17th and 18th April, 25th and 26th April and 3rd May during 2020, assisting in air quality improvement.

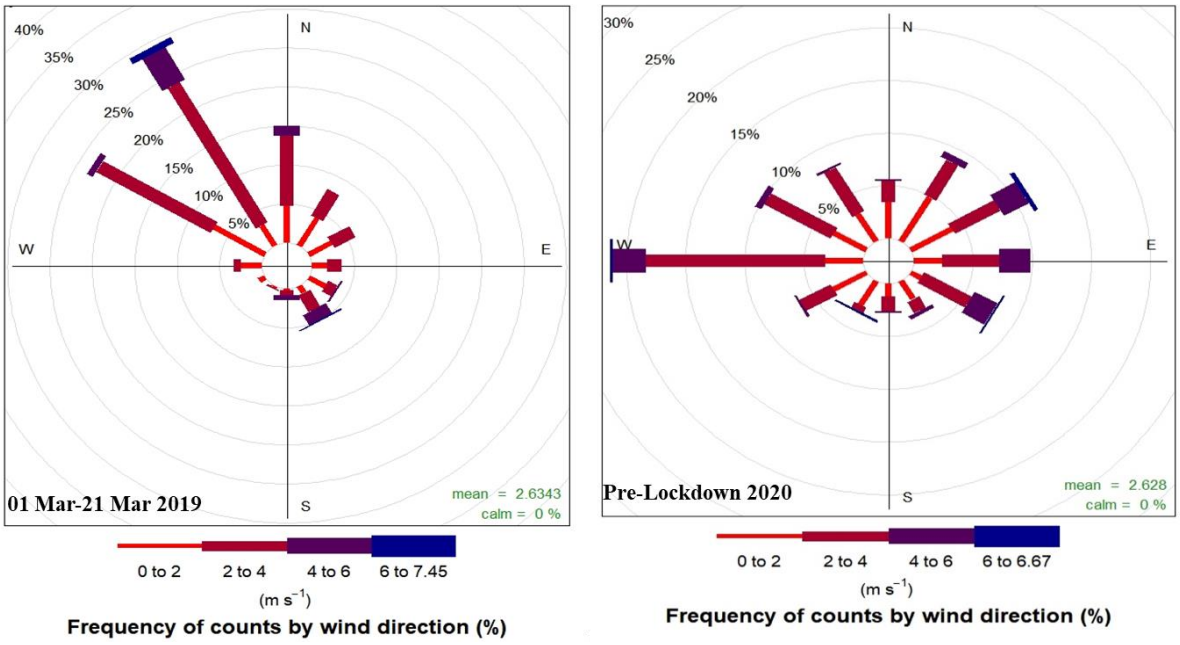


Fig 7.: Wind rose during 1st March – 21st March 2019 & 2020 - Delhi

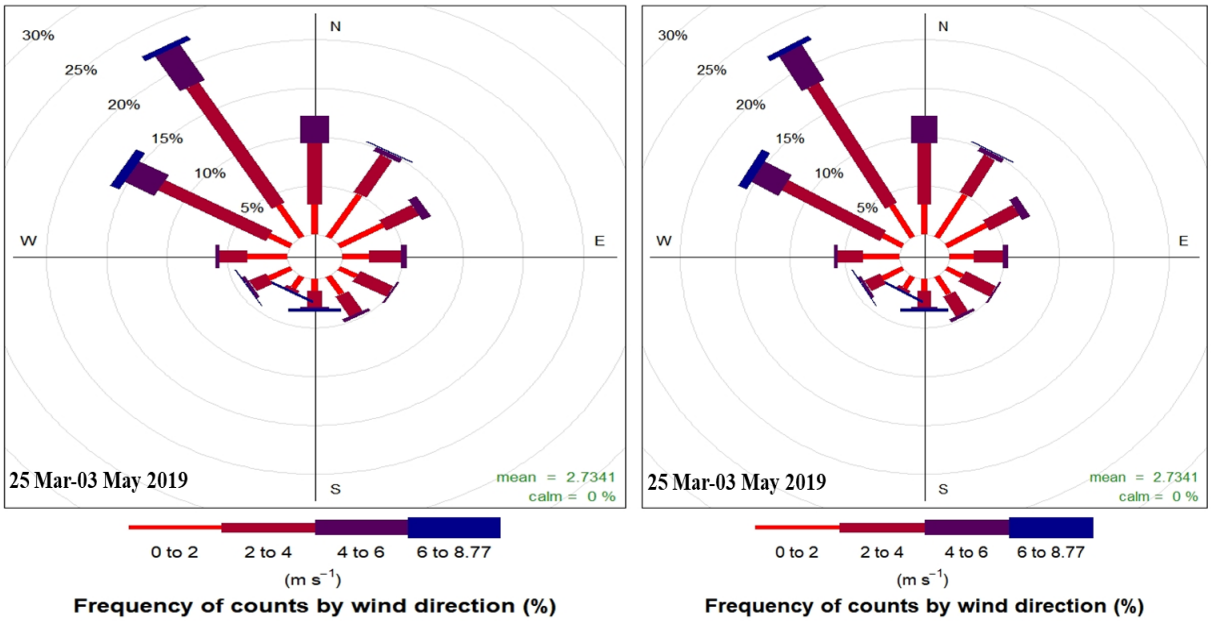


Fig 8.: Wind rose during 25th March – 3rd May 2019 & 2020 - Delhi

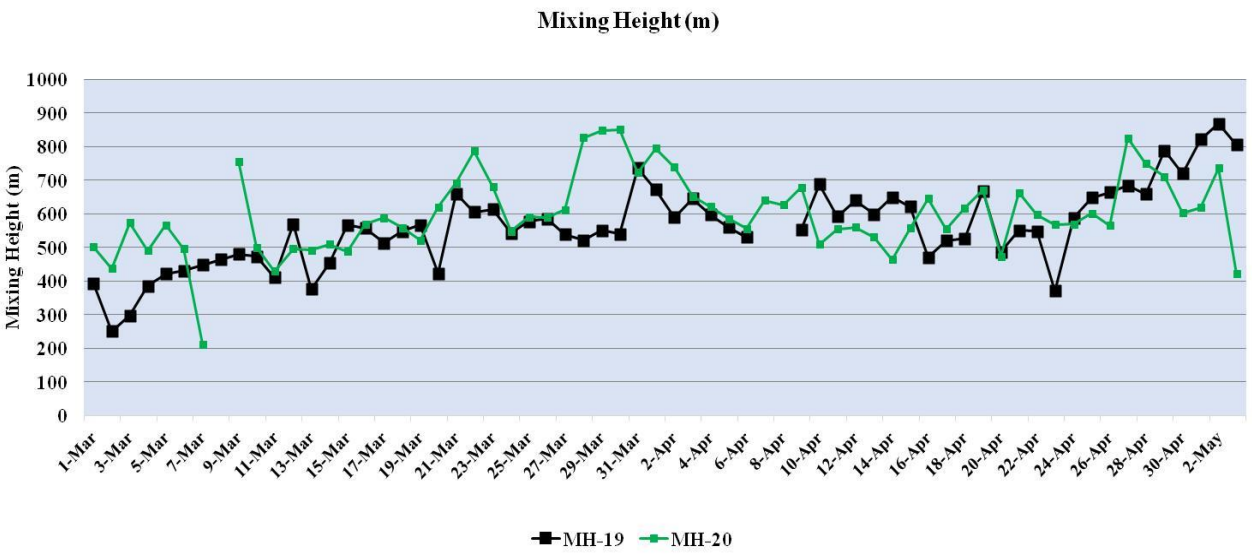


Fig 9.: Variation of Mixing Height during 1st March – 3rd May 2019 & 2020 - Delhi

However, with increase in temperature due to onset of summers and with high wind speed, there is an increased possibility of localized lifting of dust, thereby negatively affecting air quality. This is indicated in the $PM_{2.5}/PM_{10}$ ratio graph. Since the size of particulate matter depends on the type of emission source, $PM_{2.5}/PM_{10}$ can help to indicate the relative contribution of sources. When the ratio is higher, it indicates greater contribution of finer particles, which typically originate from anthropogenic activities or by complex reactions leading to secondary particle formation. Industrial areas and places with higher vehicular movement are generally characterized by higher ratios. A lower ratio may indicate local lifting or transport of dust particles. The ratio graph for the lockdown periods and the same periods in 2019, clearly indicates that the coarser particle (dust) is playing a dominant role in Delhi's Air Quality. The ratio fell drastically after 10th April 2020 and almost reached 0.3 on 15th April 2020, primarily due to a mild dust storm from the Gulf regions (reported by IITM) hitting Delhi, thus significantly increasing the PM_{10} concentrations in Delhi. PM Ratio during the lockdown periods appears to be mostly higher than the ratio for the same periods in 2019, despite the fact that absolute concentrations of both $PM_{2.5}$ and PM_{10} decreased in 2020. This implies that during the lockdown periods, the rate of decrease for PM_{10} was higher than that of $PM_{2.5}$. Further, during 2019, the ratio appears to be following a decreasing trend and seems more consistent. This is in agreement with the argument that as summers set in, the contribution of coarse particles (PM_{10}) increases due to localized dust lifting in high wind speed conditions, thus, decrease in ratio. However, during 2020, the ratio is fluctuating and seems to be decreasing, albeit rather slowly, which may be due to the already reduced values of particulate matter concentrations, since the major pollution sources are absent during the lockdown periods. The fluctuations might be due to influence of meteorological conditions since emissions from major sources have been curtailed, as stated above.

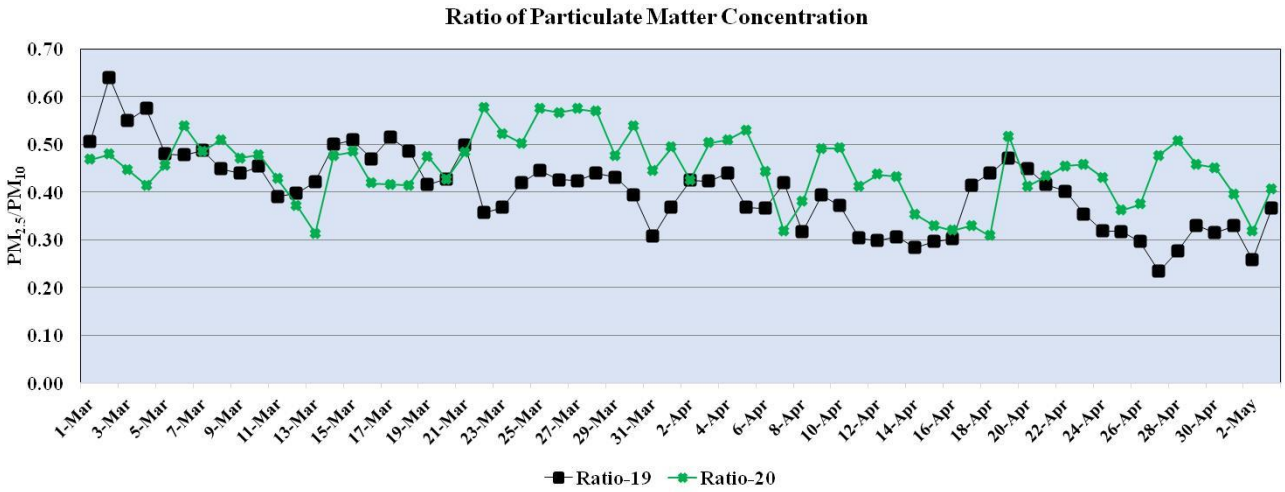


Fig 10.: Comparison of $PM_{2.5}/PM_{10}$ Ratio during 1st March- 3rd May 2019 & 2020

Analysis of the change in ratio of a few locations across Delhi reaffirm the finding that improvement in levels of PM_{10} are much more than that of $PM_{2.5}$.

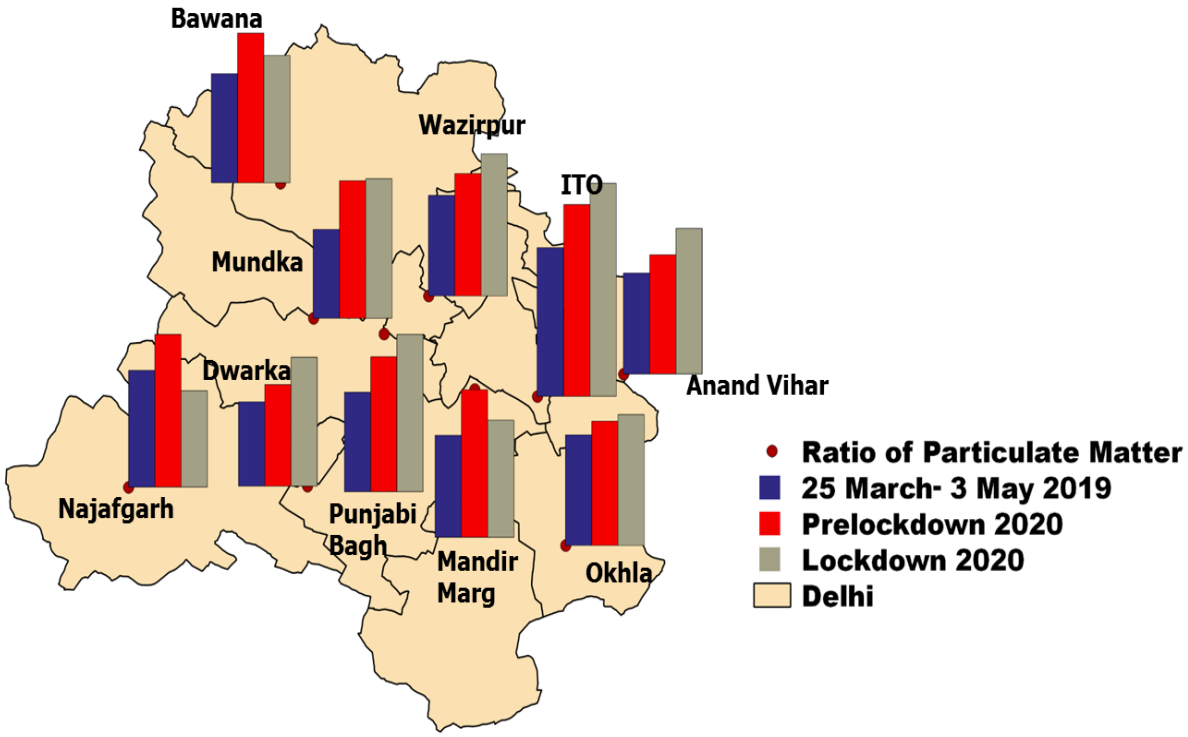


Fig. 11: Change in $PM_{2.5}/PM_{10}$ Ratio during 25th March – 3rd May 2019 & Pre-lockdown and lockdown 2020 for select locations

Areas such as Dwarka, ITO and Anand Vihar have significant vehicular activity. The ratio during the lockdown period as compared to the corresponding period in 2019 increased, indicating that restrictions on anthropogenic sources led to better control on PM_{10} during the lockdown. It may also be stated that an appreciable number of vehicles, albeit less, were present on roads of Delhi during the entire lockdown period. It appears that coarser fraction has decreased at a faster rate in areas with significant traffic impact. Since road dust resuspension and C&D activities constitute a major portion of PM_{10}, and both of these sources were visibly absent during lockdown, levels of PM_{10} were considerably decreased. For instance, at ITO, while $PM_{2.5}$ decreased by 25% in the lockdown period as compared to the corresponding period in 2019, PM_{10}-$PM_{2.5}$, i.e. the contribution of coarser portion (dust) in PM_{10}, decreased by 70%.

Similarly, locations such as Najafgarh and Mandir Marg saw a decrease in ratio as compared to corresponding period in 2019 which may be due to more prominent impact of localised dust lifting.

3.2 AQI Data Analysis

Air Quality Indices are calculated for cities all over India using data from CAAQM stations. CPCB publishes daily AQI bulletin at 4 PM for the cities with CAAQM stations. AQI data for Delhi clearly depicts the improvement in air quality, with a greater number of days falling under Good and Satisfactory AQI categories. Since Good and Satisfactory categories have their breakpoints within the National Ambient Air Quality Standards, it may be reasonable to state that Delhi had more days within National standards during the lockdown period as compared to the same periods in 2019.

What is AQI?

Air Quality Index is a tool for effective communication of air quality status to people in terms, which are easy to understand. It transforms complex air quality data of various pollutants into a single number (index value), nomenclature and colour.

There are six AQI categories, namely Good, Satisfactory, Moderate, Poor, Very Poor, and Severe. Each of these category is based on ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints). AQ sub-index and health breakpoints are evolved for eight pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb) for which short-term (upto 24-hours) National Ambient Air Quality Standards are prescribed.

AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 24-hr	O_3 8-hr	CO 8-hr (mg/m^3)	SO_2 24-hr	NH_3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6 –1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1- 10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

**One hourly monitoring (for mathematical calculation only)*

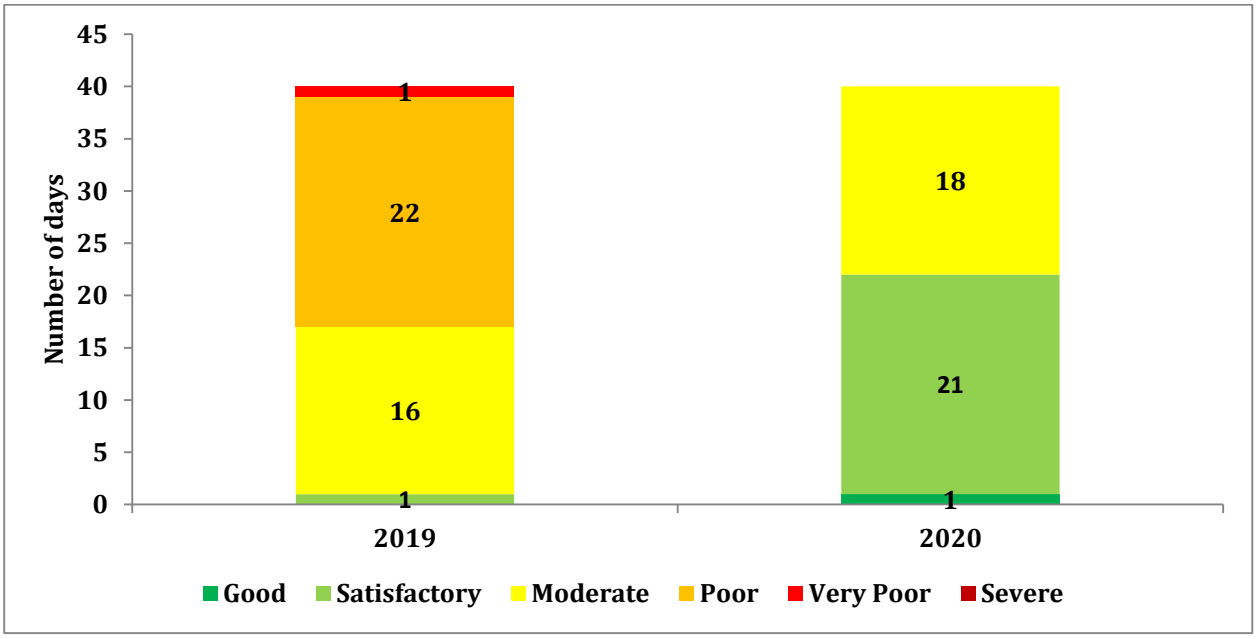


Fig 12.: Comparative AQI during 25th March – 3rd May 2019 and 2020 for Delhi

In Delhi, the number of 'Good', 'Satisfactory' and 'Moderate' AQI days increased to 40 in 2020 against 17 in 2019, and there were zero 'Poor', 'Very Poor' and 'Severe' AQI days in 2020 against 23 in 2019, during 25th March to 3rd May, i.e. when lockdown was imposed in 2020.

3.3 Spatial analysis and Impact on Hotspots

Station-wise $PM_{2.5}$ data for Delhi during the study periods for 2019 and 2020 were plotted. Interpolation was carried out to visualize the impact of lockdown on Particulate Matter levels over Delhi.

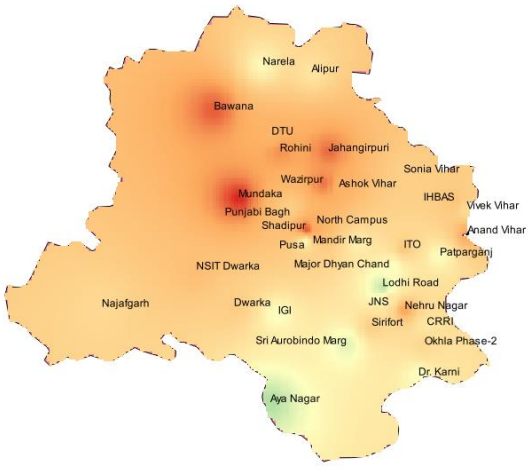


Fig.13: $PM_{2.5}$: 1st March – 21st March 2019

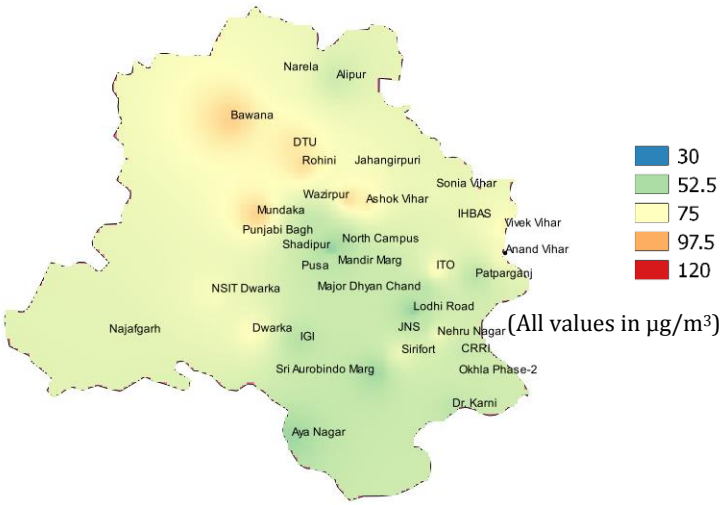


Fig. 14: $PM_{2.5}$: Pre-lockdown 2020

Fig. 14 clearly indicates an overall reduction in $PM_{2.5}$ levels, even in the pre-lockdown stage, which may be due to favorable meteorological conditions and imposition of a few early restrictions.

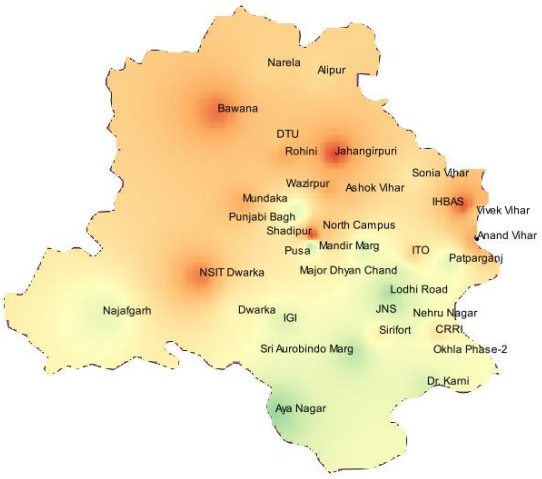


Fig. 15: $PM_{2.5}$: 25th Mar- 19th Apr 2019

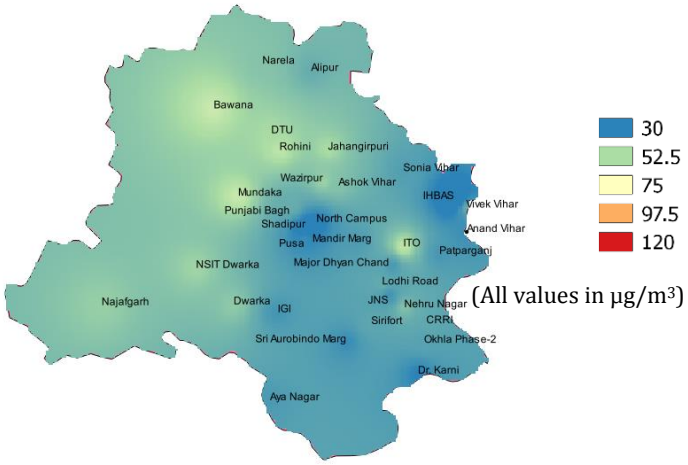


Fig.16:$PM_{2.5}$: Lockdown phase-I

Areas such as Dwarka, Anand Vihar and Okhla witnessed major reduction in particulate matter levels. ITO, a major traffic junction, saw 32% reduction in $PM_{2.5}$ levels observed during the first phase of lockdown, as compared to levels during 2019. Similarly, restrictions on operations of industries in Mundka, led to 38% reduction in $PM_{2.5}$ levels in the first phase of lockdown. Reduction of $PM_{2.5}$ levels over Delhi during the first phase of lockdown, against the levels during 2019, ranged from 24% to 89% with IHBAS recording the maximum reduction.

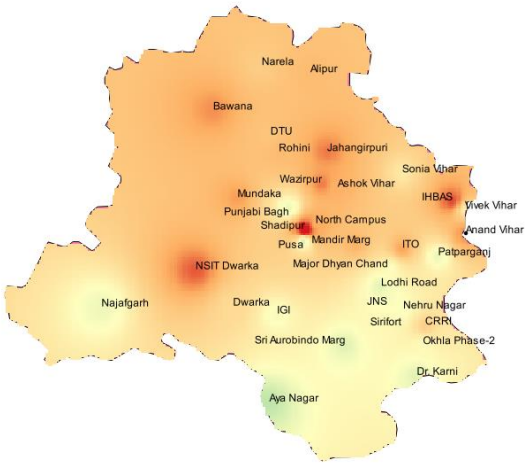


Fig. 17:$PM_{2.5}$: 20th Apr-3rd May 2019

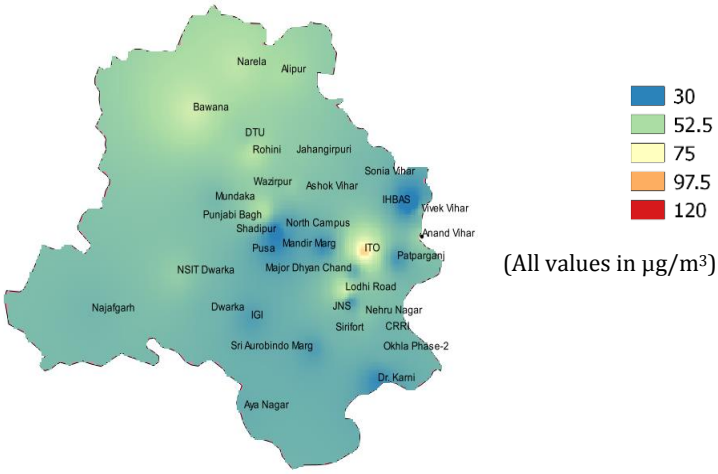


Fig. 18:$PM_{2.5}$: Lockdown phase -II

North Campus, home to several colleges and institutions which were closed during the lockdown, recorded 71% and 61% reduction in $PM_{2.5}$ levels during the first and second phase of lockdown respectively. Shadipur, a residential and industrial area saw 83% reduction in $PM_{2.5}$ levels in the second phase of lockdown. Dwarka has substantial presence of residential cum institutional sites with substantial traffic movements, a sharp decline in $PM_{2.5}$ levels by 50%, as compared to 2019, affirm that traffic restrictions and closure of commercial areas were instrumental in improving air quality.

What are pollution hotspots of Delhi?

Delhi Government on the basis of annual average of PM_{10} and $PM_{2.5}$ identified 13 hotspots in Delhi. These were OkhlaPhase-II, Dwarka, Ashok Vihar, Poothkhurd/Bawana, Narela, Mundka, Punjabi Bagh, Wazirpur, Rohini, Vivek Vihar, Anand Vihar, R.K. Puram and Jahangirpuri. Micro Level Action Plans for hotspots were prepared and implemented. Deputy Commissioners were identified as Officer In-charge for each hotspot for implementation of micro level action plan.

Noticeable reduction in $PM_{2.5}$, PM_{10} and NO_2 levels in hotspots of Delhi was observed during the lockdown period. Pollutant concentration during the lockdown phases I and II (25th March – 3rd May 2020) was compared with concentration in the same period of last year.

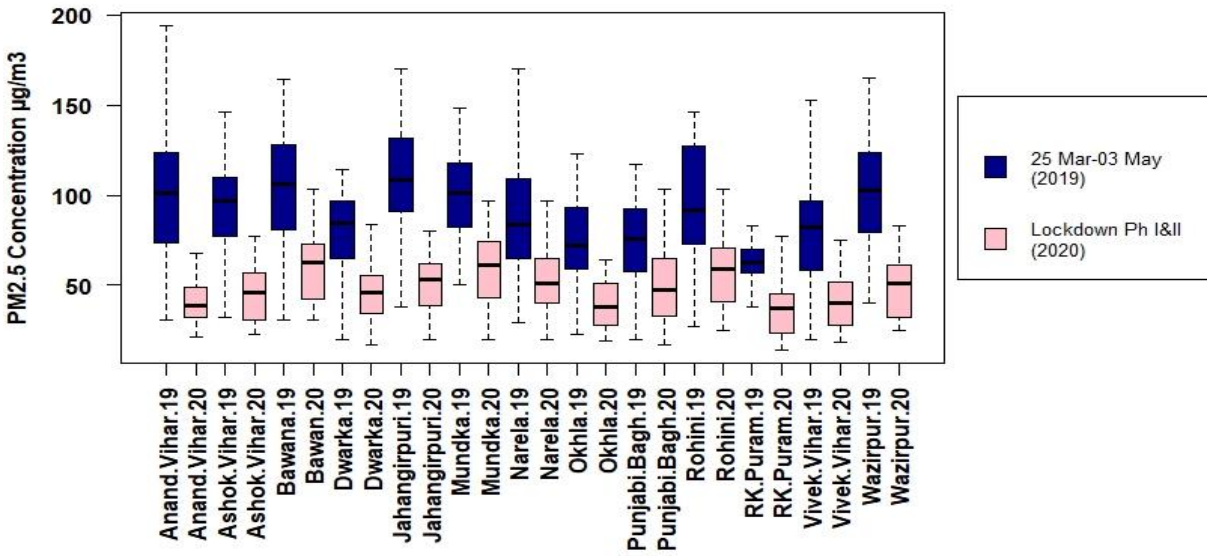


Fig.19: Box plots for $PM_{2.5}$ levels during 25th March – 3rd May in 2019 & 2020 for hotspots of Delhi

Reduction in $PM_{2.5}$ levels during lockdown periods was observed for all hotspots of Delhi, as compared to 2019 levels, in all likelihood due to restrictions on operations of industrial and commercial areas and, vehicular activity. Even though there were data gaps for Anand Vihar and Narela, considerable reduction in $PM_{2.5}$ levels was observed for the days on which data was available. Reduction varied from 54% reduction in$PM_{2.5}$ levels in Jahangirpuri to 26% reduction in $PM_{2.5}$ levels in Punjabi Bagh.

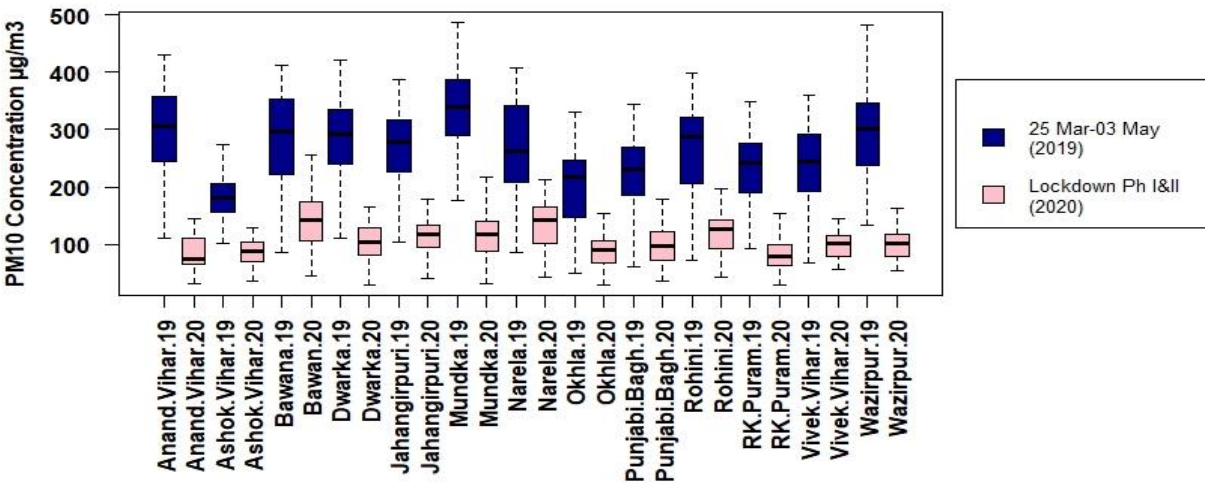


Fig.20: Box plots for PM_{10} levels during 25th March – 3rd May in 2019 & 2020 for hotspots of Delhi

Similar or higher levels of reduction was seen for PM_{10} in the hotspots of Delhi, with Dwarka, Mundka, Wazirpur and RK Puram observing over 60% reduction during the lockdown periods as compared to the levels during the same period in last year. This may be attributed to reduced road dust resuspension due to minimal vehicular movement and restriction of C&D activities.

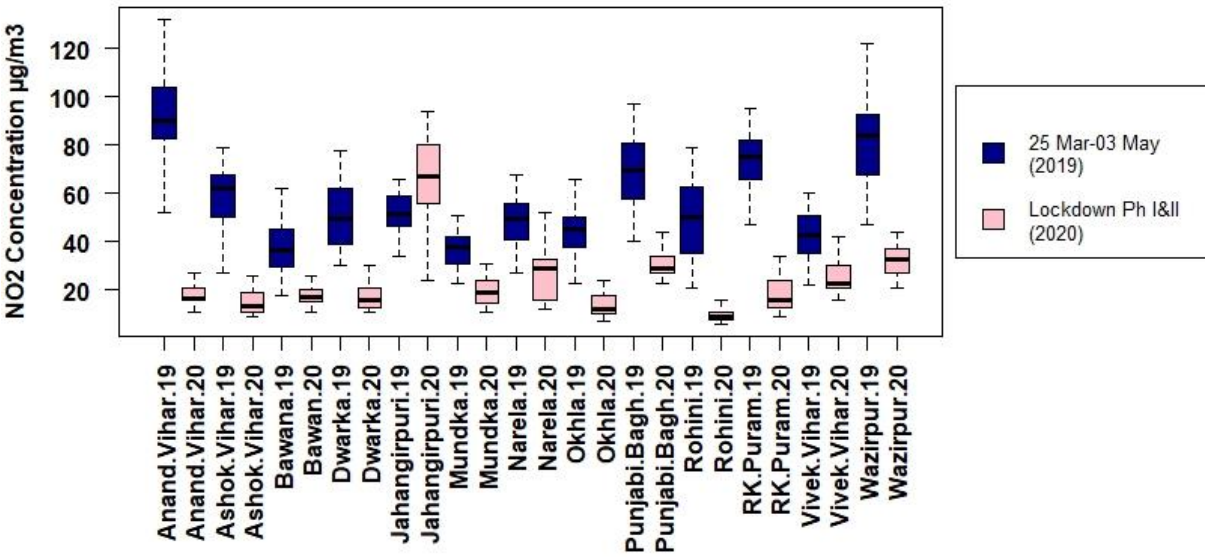


Fig.21: Box plots for NO_2 levels during 25th March – 3rd May in 2019 & 2020 for hotspots of Delhi

Sizeable improvement in NO_2 levels was observed across the hotspots as compared to 2019 levels, except Jahangirpuri. Jahangirpuri is located near a major inter-state traffic junction. Inter-state

movement of essential goods might be responsible for the increase. However, other areas such as Rohini, Ashok Vihar and R K Puram witnessed over 70% reduction in NO_2 levels during the lockdown periods as against 2019 levels, primarily due to reduced vehicular activity.

3.4 Real Time Source Apportionment Study for Delhi

A source apportionment study of $PM_{2.5}$ in New Delhi was conducted by IIT Kanpur & IIT Delhi as a part of an ongoing study funded by CPCB in 04 phases i.e. Pre-lockdown (19th February – 24th March 2020), Lockdown Phase - 1 (25th March– 17th April 2020), Lockdown Phase - 2 (18th April – 3rd May 2020) and Lockdown Phase - 3 (4th May – 18th May 2020). The study was implemented using the Positive Matrix Factorization (PMF) approach, and the modelled concentrations were compared with actual observations for validation. The PMF algorithm was implemented using the EPA PMF v 5.1 and Sofi Pro both of which are built on the Multilinear Engine (ME) -2 solution model. Additionally, back trajectory analysis has been used to account for regional transport of pollutants.

Sampling was conducted at the Indian Institute of Technology (IIT), Delhi campus located in South Delhi. The Xact 625i Ambient Metals Monitor equipped with a $PM_{2.5}$ inlet was employed for measurement of inorganic elemental concentrations with an hourly time resolution. Black Carbon (BC) concentrations were measured using a multichannel Aethalometer with an hourly time resolution. Also, an Aerosol Chemical Speciation Monitor with vacuum aerodynamic diameters smaller than 2.5µm (NRPM2.5) was deployed for measuring concentration of organic aerosols along with ammonium, sulphate, nitrate and chloride ionic concentration.

The study revealed that sources associated with vehicular emissions, domestic/local coal combustion, waste incineration and urban organic aerosols reduced sharply from the pre-lockdown phase into lockdown phase-I and were found to steadily rise back with increasing relaxations in the lockdown.

During lockdown phase 1 wherein maximum restrictions were imposed, contribution of vehicular emissions reduced to 5% from 19% during pre-lockdown phase. It was also observed that contribution from vehicular emissions to inorganic species in $PM_{2.5}$ were found to be an appreciable amount (14%) only in the pre-lockdown phase, while for all consequent phases the factor was found to contribute only in trace amounts. Similarly, both the coal combustion and waste incineration factors, which were found to be originating from local/domestic sources decreased steadily.

Percentage of Black Carbon which is primarily contributed from biomass burning and traffic emissions in total $PM_{2.5}$ composition was observed to drop from 12% during pre-lockdown period to 6-8% during lockdown phases. Biomass Burning factor was found to steadily rise from Lockdown.

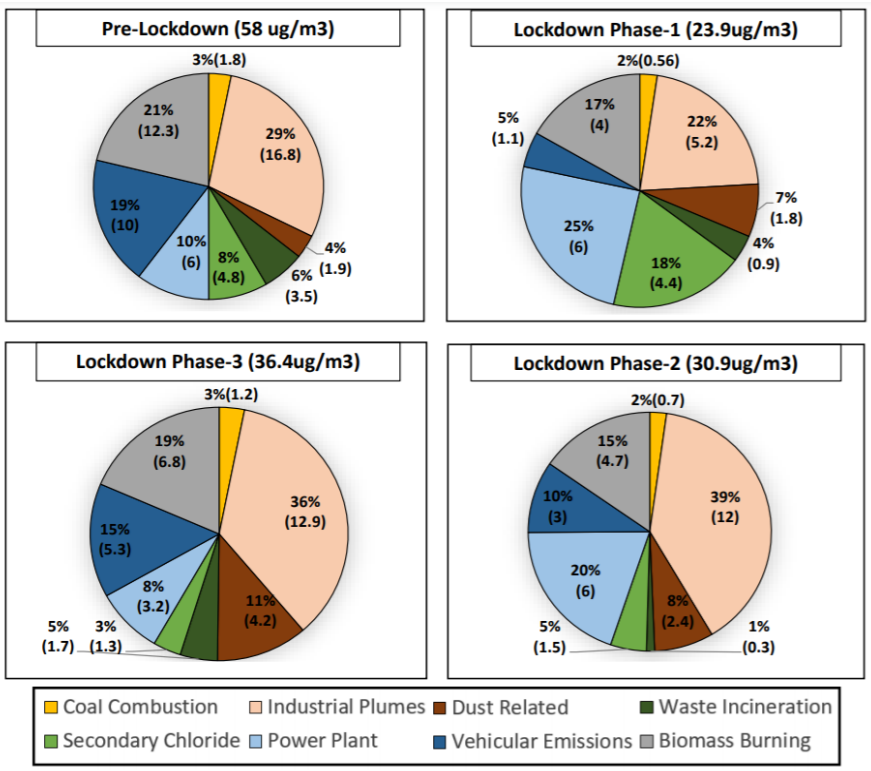


Fig. 22: Source Contributions to total $PM_{2.5}$ during Pre-Lockdown v/s Lockdown, IIT Kanpur Study

Phase-1 reaching maxima in phase-3 and can be mainly attributed to increase in crop residue burning towards start of May.

Contribution from power plants increased during lockdown phase 1 (25%) & phase 3 (20%) as compared to pre lockdown phase (10%) although the concentrations were similar due to decrease in contribution from other anthropogenic sources. In terms of contribution to inorganic species of $PM_{2.5}$, the power plants factor initially saw a dip in concentration due to reduced/limited operations at predicted sources, but was found to increase towards start of phase-2 and remained constant in phase-2, while decreases in phase-3 due to change in meteorological conditions.

The study revealed that sources associated with vehicular emissions, domestic/local coal combustion, waste incineration and urban organic aerosols reduced sharply from the pre-lockdown phase into lockdown phase-I and were found to steadily rise back with increasing relaxations in the lockdown.

Although contribution of industrial plumes to absolute concentrations was lower during lockdown phases its contribution during lockdown phases 1- 3 increased from 22% - 39% due to gradually increasing operations. Secondary chloride seemingly remains unaffected by the lockdown, as the absolute concentration remain constant from pre-lockdown up till phase-2.

Dust related contributions was seen to increase during lockdown phase 2 to 3 when episodes of dust storms were also reported.

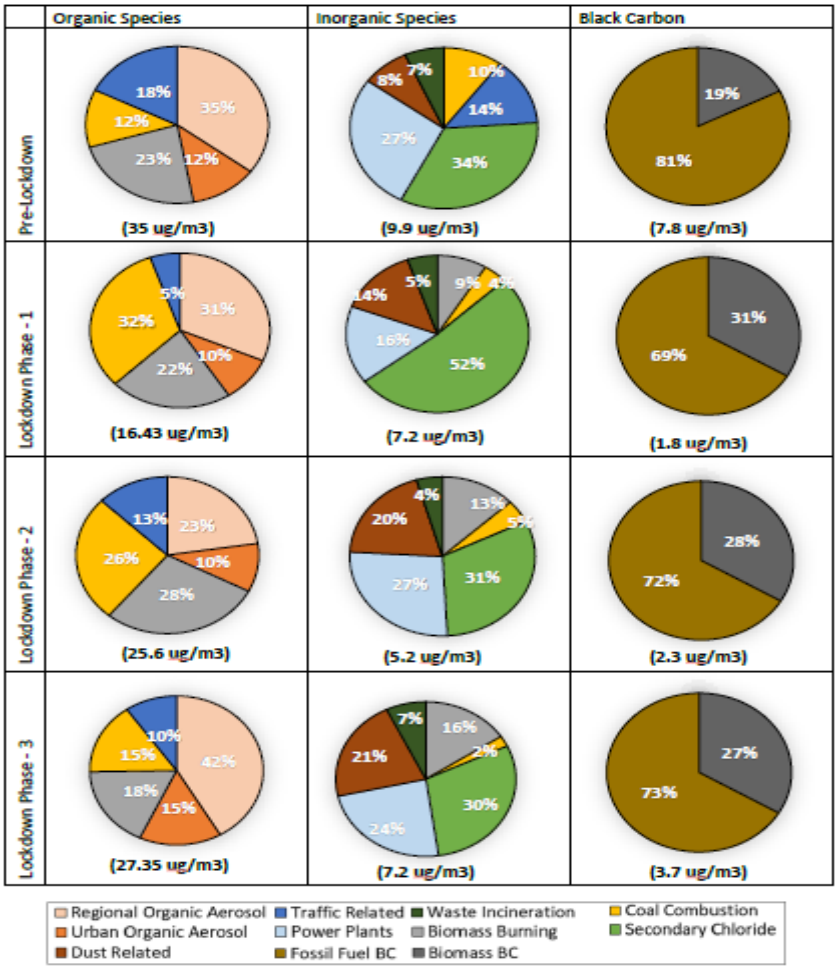


Fig. 23: Source Contributions of Organics, Elements and Black Carbon during Pre-lockdown and Lockdown Phases, IIT Kanpur Study

4. EFFECT OF LOCKDOWN IN MAJOR NCR TOWNS

The air pollution reduction trend in NCR towns was similar to that of NCT of Delhi with reduction in certain pollutants, more prominent in NCR towns. Over 50% reduction in $PM_{2.5}$ and PM_{10} levels were observed during the first phase of lockdown in most neighboring towns with sharp improvement in Gurugram with 61% reduction in PM_{10} levels and Ghaziabad with 54% reduction in $PM_{2.5}$ levels as compared to 2019 levels. The reduction in $PM_{2.5}$ levels was even more pronounced in the second phase of lockdown in Faridabad, with 70% reduction in $PM_{2.5}$ levels against 2019 levels for the same period, while it was less prominent or remained at similar levels in other towns. PM_{10} levels further reduced by over 60% in Gurugram, Noida and Ghaziabad, in the second phase of lockdown, as compared to 2019 levels, in all likelihood due to restriction on dust generating activities. Significant reduction in NO_2 levels was observed in Noida (57%) and Ghaziabad (67%) during the first phase of lockdown, when compared with 2019 levels. The reduction was as prominent in the second phase of the lockdown with these towns observing similar or higher reduction in NO_2 levels, implying that the number of on-road vehicles might not have increased considerably. However, the same was not observed in Gurugram, where NO_2 emissions increased during pre-lockdown and phase-I of lockdown, and decreased just by 20% during the second phase of lockdown, as compared to the levels during same periods in 2019. SO_2 levels were seen to decrease in Noida (50%) and Ghaziabad (46%) in the first phase of lockdown while on the other hand Gurugram showed an increase in SO_2 levels, which may be due to its proximity to thermal power plants. Further, monitoring network in Gurugram has increased from 02 stations in 2019 to 04 stations in 2020, leading to better spatial coverage. Moreover, while Delhi's industries have largely switched over to gas-based and other less polluting energy systems, some industries in NCR might still be using unclean fuels like coal, biomass, etc.

Significant reduction in NO2 levels was observed in Noida (57%) and Ghaziabad (67%) during the first phase of lockdown, when compared with 2019 levels. The reduction was as prominent in the second phase of the lockdown with these towns observing similar or higher reduction in NO_2 levels, implying that the number of on-road vehicles have not increased considerably.

In terms of Benzene levels, Noida and Ghaziabad recorded an enormous reduction of 67% and 80% respectively during the first phase of lockdown and 62% and 47% in the second phase of lockdown, as compared to levels during 2019 in the same periods. However, Benzene levels were seen to increase in Faridabad and Gurugram during both phases of lockdown, as compared to pre-lockdown levels. The operation of certain units or processes (chemical/pharmaceutical/paints) utilizing benzene, and other solvents, etc. in Faridabad and Gurugram cannot be ruled out and may be responsible for the increase in Benzene levels. It is also important to mention that there are lesser number of real time air quality monitoring stations in NCR towns as compared to Delhi and the impact of localized sources on ambient

air quality data is always a possibility which may require further data for complete analysis. Moreover, in absence of complete data on scale of industrial operation in various categories except power plants and essential activities like food, bakery, dairy, etc., it may be difficult to assess the impact of these sources on air quality at this point of time.

The overall improvement in air quality in major NCR towns can be easily visualized using Air Quality Index data. The major NCR towns i.e. Faridabad, Ghaziabad, Gurugram and Noida depicted greater number of days in Good and Satisfactory AQI categories, in comparison with the same time period in 2019. Moreover, the same period in 2019 showed at least one very poor AQI day, while the lockdown period had no very poor AQI day and just a few poor AQI days, most of which occurred during middle of April, when a mild dust storm had hit the Delhi-NCR region.

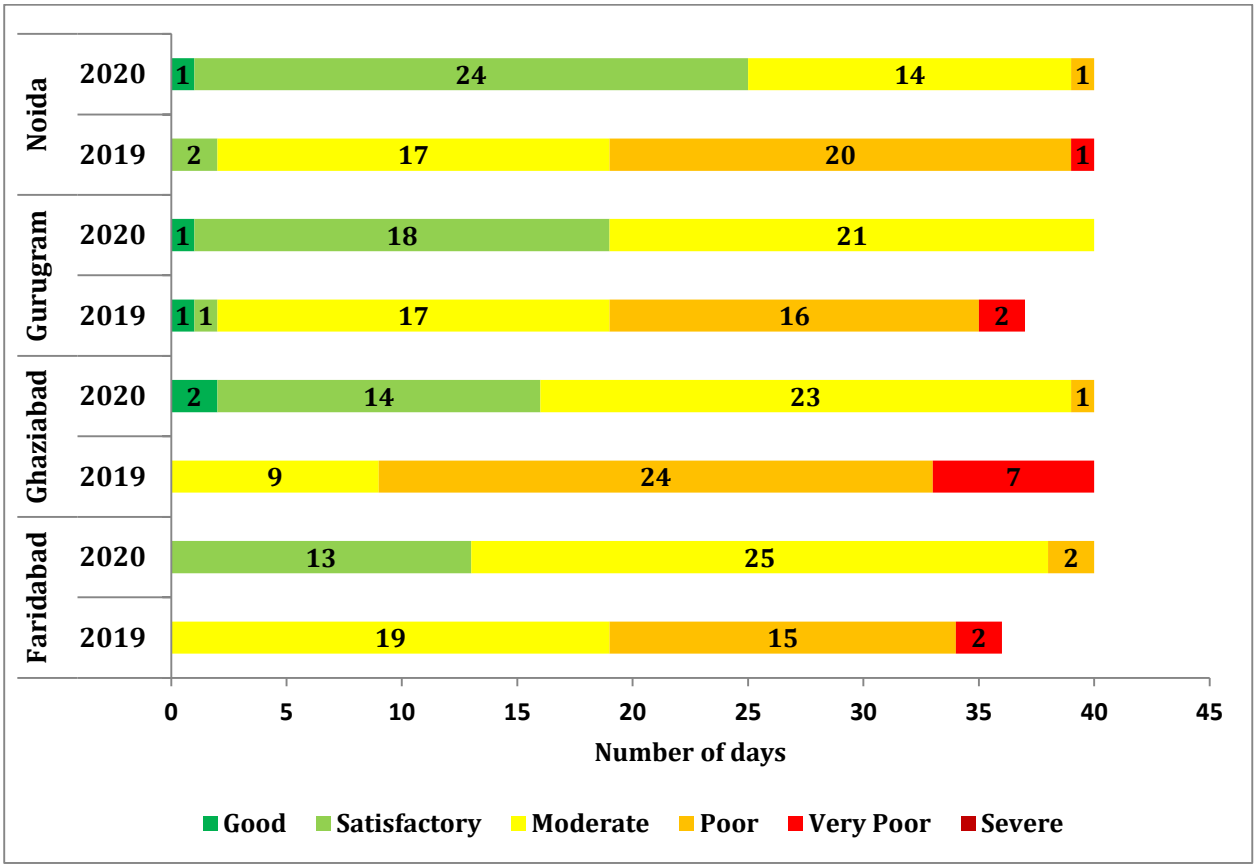


Fig. 24: Comparative AQI during 25th March – 3rd May 2019 and 2020 for Faridabad, Ghaziabad, Gurugram and Noida

The trends for neighboring NCR towns are presented in detail in subsequent paras,

4.1 FARIDABAD

Like other cities, the impact of restrictions was visible in Faridabad in clear reduction in particulate matter and SO_2 levels. Out of 40-day lockdown period ,city witnessed 24 hourly $PM_{2.5}$ levels (37 days) within National Ambient Air Quality Standards (NAAQS), increasing from 09 days and 20 days in 2019 in the same period respectively. SO_2 and $PM_{2.5}$ levels reduced noticeably by an average of 55% and 49% during both phases of lockdown values as compared to pre-lockdown levels. Data for NO_2 seemed to be inconsistent and has not been considered in the analysis. PM_{10} levels reduced by 45% and 34% in the first and second phase of lockdown respectively, as compared to pre-lockdown levels.

The data trends for Faridabad are as presented below,

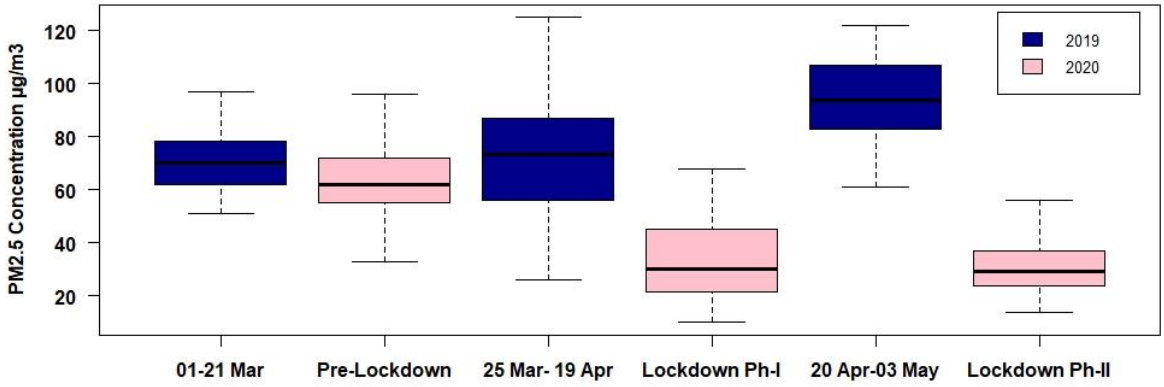


Fig 25.: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 - Faridabad

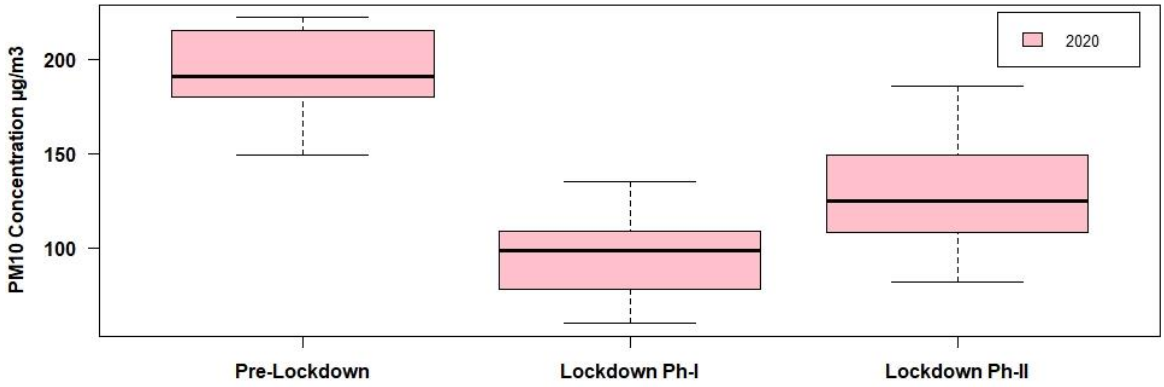


Fig 26.: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2020 - Faridabad

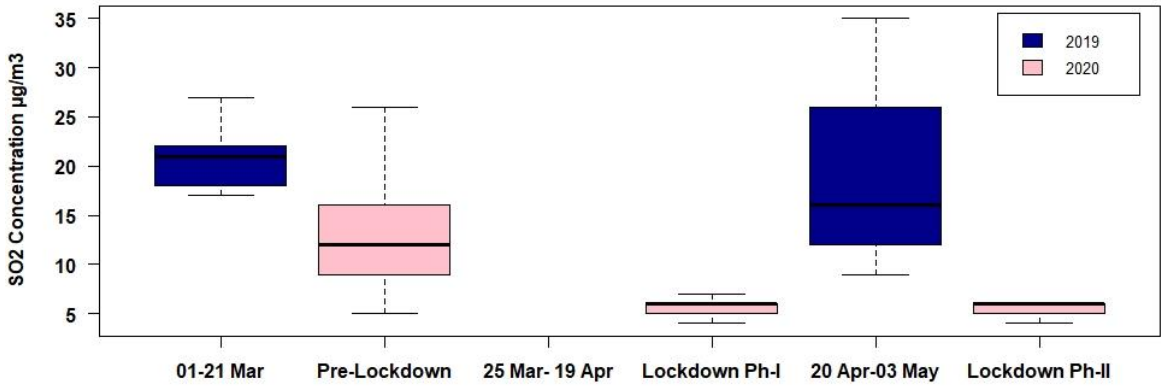


Fig. 27.: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 - Faridabad*

**Data for SO_2 for 25th March – 19th April was not available*

4.2 GURUGRAM

NO_2 and SO_2 levels remained below National Ambient Air Quality Standards on all days during the lockdown, while $PM_{2.5}$ and PM_{10} levels were within NAAQS on 38 and 29 days in the 40-day lockdown period. The reduction in PM_{10} levels are higher as compared to pre-lockdown levels as compared to $PM_{2.5}$ levels. Since dust & construction activities contribute 49% to $PM_{2.5}$ and 52% to PM_{10} in Gurugram (TERI Source Apportionment study, 2018), it is likely that road dust resuspension due to vehicle restrictions might have come down resulting in lower emissions with 39% and 41% reduction in 24 hourly $PM_{2.5}$ and PM_{10} levels during lockdown phase-I but was only 26% and 34% for 24 hourly $PM_{2.5}$ and PM_{10} respectively in lockdown phase-II. The reduced impact, in all likelihood, may be due to the onset of dry and windy conditions. 24 hourly NO_2 levels reduced by 45% during both phases of lockdown, as compared to pre-lockdown levels. It is possible that benzene levels, which showed an increase during both phases of lockdown as compared to pre-lockdown levels, may be influenced by the location of the station recording it, thus not accounting for spatial variability. While SO_2 levels increased in the second phase by 34%, it decreased by 21% during the second phase of lockdown, as compared to pre-lockdown levels.

The data trends for Gurugram are presented in Fig-28-31.

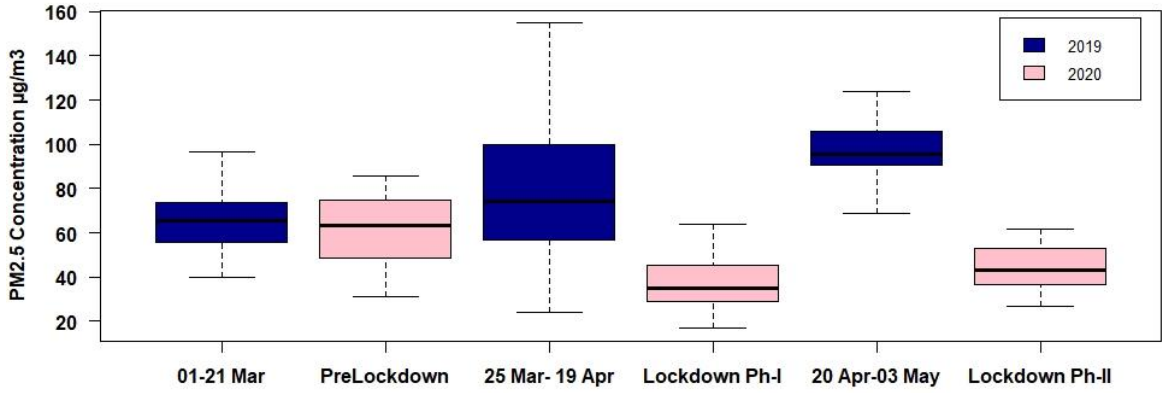


Fig 28.: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 - Gurugram

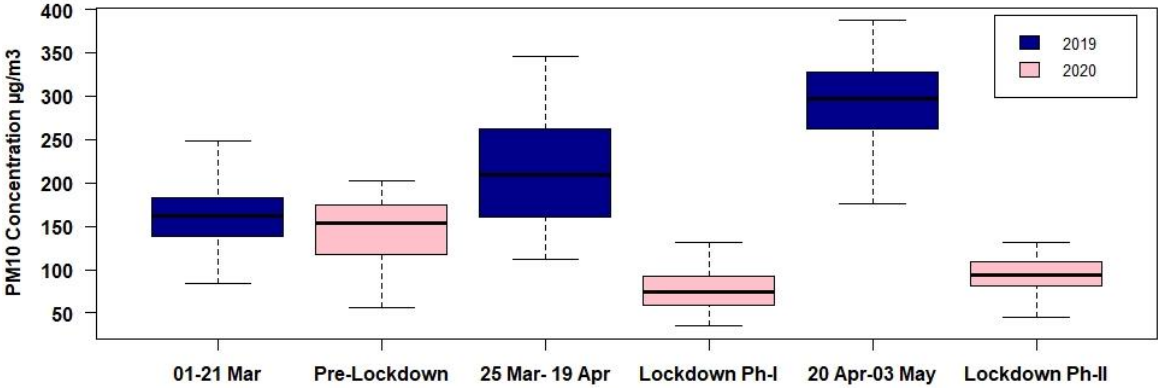


Fig 29.: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2019 & 2020 - Gurugram

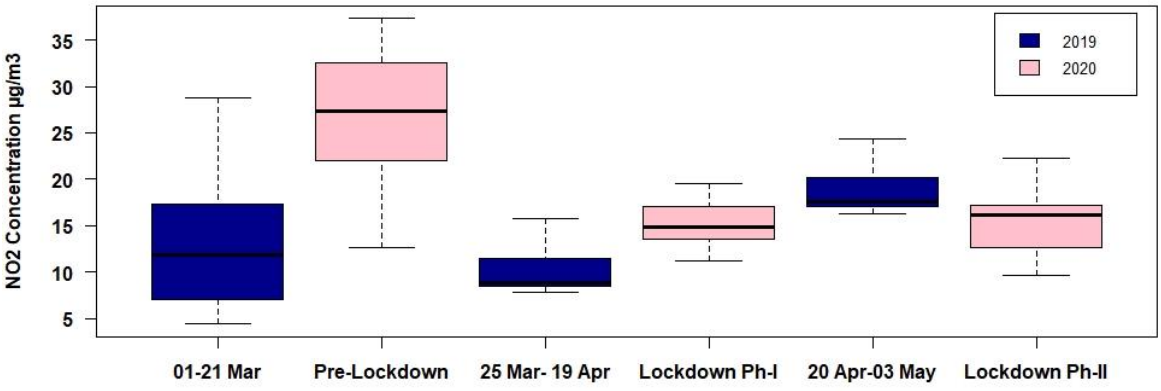


Fig 30.: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 - Gurugram

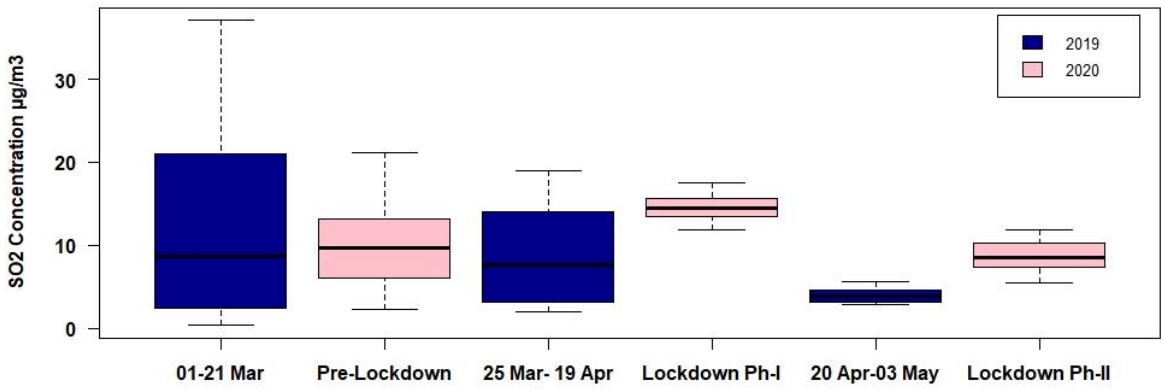


Fig 31.: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 - Gurugram

4.3 GHAZIABAD

SO_2 and NO_2 levels remained below National Ambient Air Quality Standards on all days during the lockdown, while $PM_{2.5}$ levels were above NAAQS for 10 days in the 40-day lockdown period, up from 5 days within NAAQS in the corresponding period in 2019. Reduction in $PM_{2.5}$ and PM_{10} levels was lower during the second phase of lockdown than the first phase of lockdown, as compared to pre-lockdown levels. The increase may be due to the onset of summers and increased vehicular activity. This is corroborated by the decrease in NO_2 levels as NO_2 levels decreased by 51% and 47% in the first phase and second phase of lockdown respectively, as compared to pre-lockdown levels. Benzene levels followed a similar pattern, with 73% and 43% reduction in first and second phase of lockdown, against pre-lockdown levels respectively. It can be deduced that while major reduction in benzene levels during the first phase of lockdown indicated closure of some large-scale benzene utilizing/generating source like paint, petro products, plastics, resins, synthetic fibers, rubber lubricants, dyes, detergents, drugs and pesticides in Ghaziabad region, some of those units might have reopened during the second phase.

SO_2 levels which had increased by 19% in the first phase of lockdown, decreased by 30% in the second phase of lockdown, as compared to pre-lockdown levels. Data about the industries operational during these periods is required to understand the reason behind this.

The data trends for Ghaziabad are as presented below,

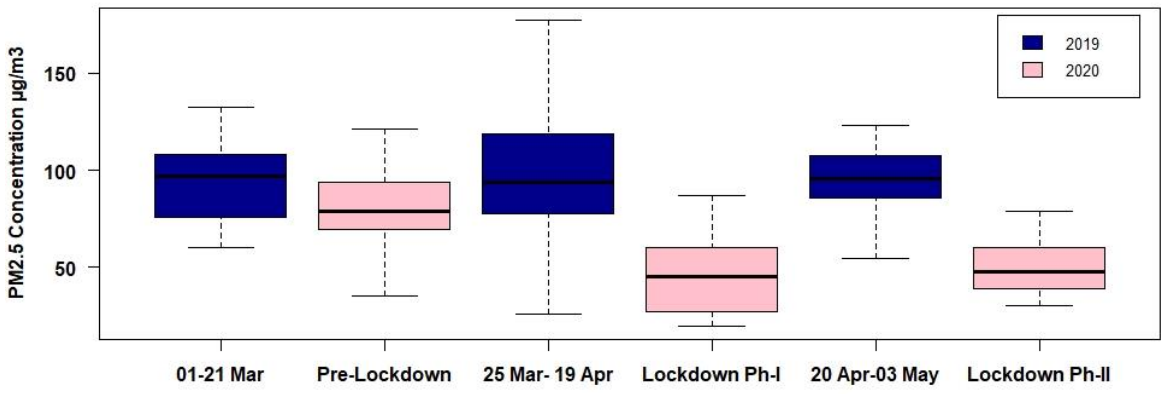


Fig 32.: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 – Ghaziabad

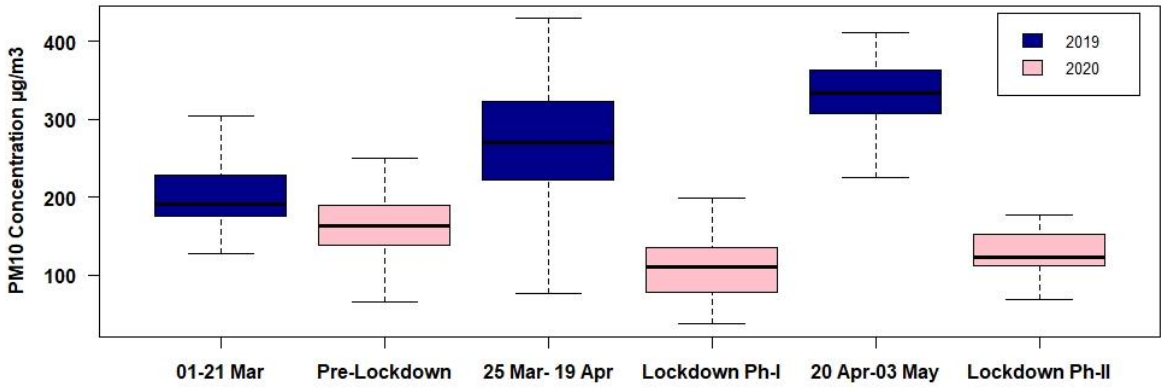


Fig 33.: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2019 & 2020 – Ghaziabad

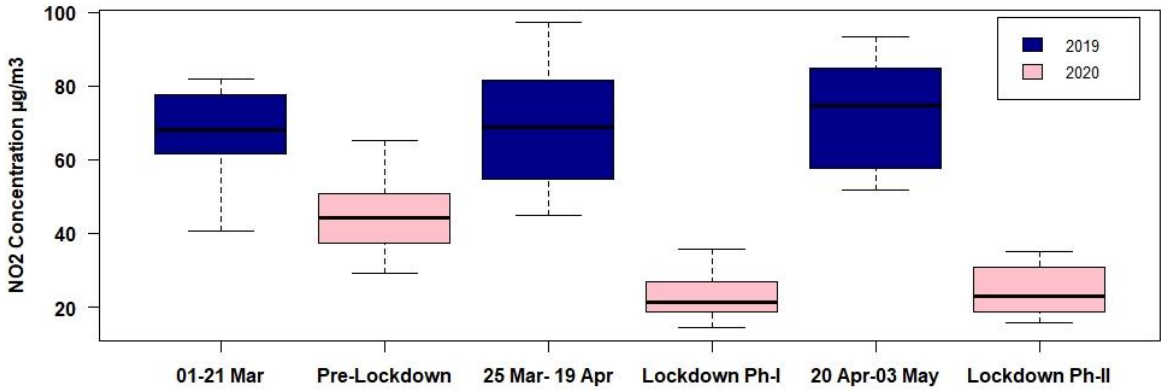


Fig 34.: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Ghaziabad

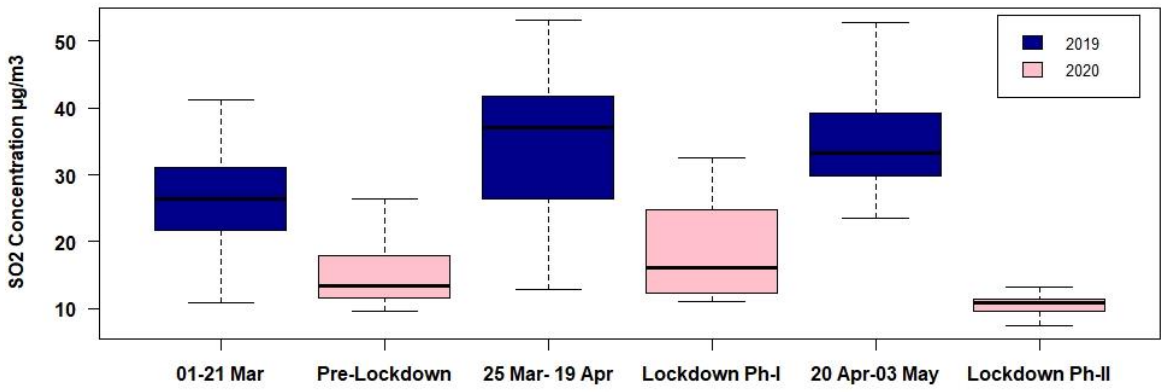


Fig 35.: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Ghaziabad

4.4 NOIDA

Positive effects of lockdown on air pollution levels were observed in Noida, as emission levels reduced from the pre-lockdown period with over 29% reduction in $PM_{2.5}$ and PM_{10} in the second phase of lockdown. 24-hourly average $PM_{2.5}$ and PM_{10} concentrations remained within NAAQS for 36 and 24 days respectively out of the 40 days in the lockdown period, an increase from just 07 days and 01 day in 2019 for the same period. NO_2 and SO_2 levels remained within NAAQS on all days of the lockdown period with NO_2 levels decreasing by over 55% in both phases of lockdown period. Benzene levels followed a similar pattern with over 47% reduction during lockdown period as compared to pre-lockdown levels, in all possibility due to the restrictions on vehicular activity and industrial operations. While dust (road, soil, construction) is a major emission source in Noida contributing 46% to $PM_{2.5}$ (TERI source apportionment study, 2018), considerable reduction in $PM_{2.5}$ levels with 24 hourly values decreasing by 42% in the first phase of lockdown, suggest reduced contribution of road dust resuspension & C&D activities. While overall SO_2 levels remained similar to the pre-lockdown levels during the first phase of lockdown, a decrease of 15% was observed in the second phase of lockdown, as compared to pre-lockdown levels. It may be said that thermal power plants located in NCR and use of fuels like coal and biomass/wood, etc. in industrial and household activities including operation of some brick kilns, sugar and distilleries, might be responsible for the reduced impact on SO_2 levels in Noida.

The data trends for Noida are as presented below.

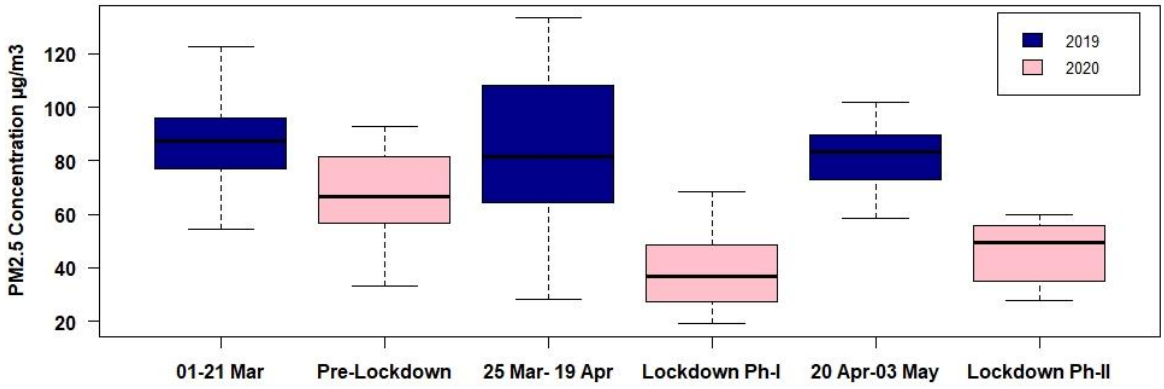


Fig 36: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 – Noida

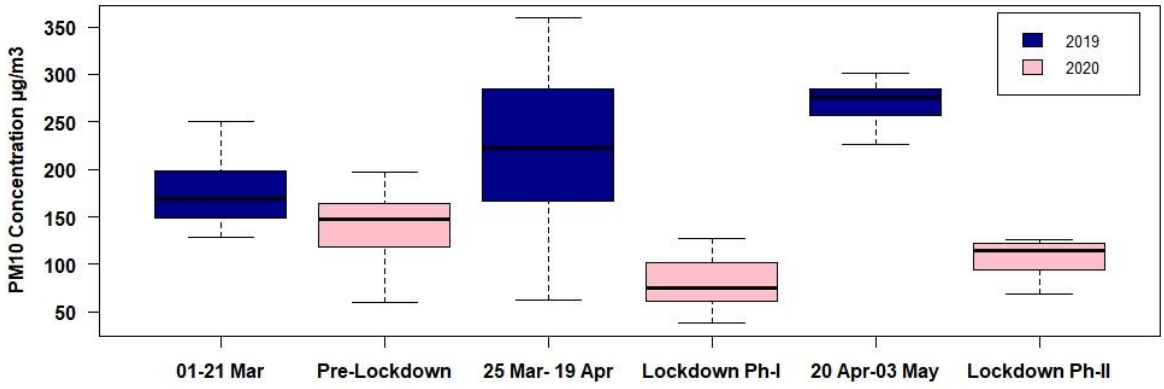


Fig 37: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2019 & 2020 – Noida

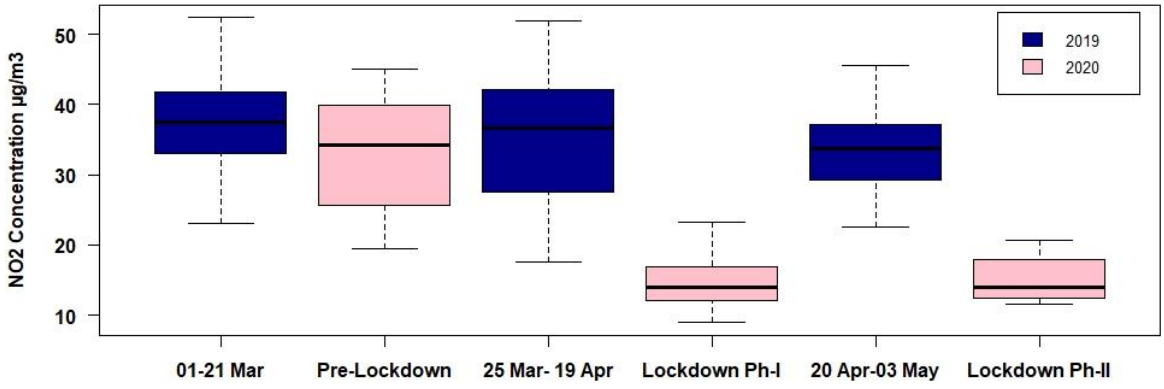


Fig 38: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Noida

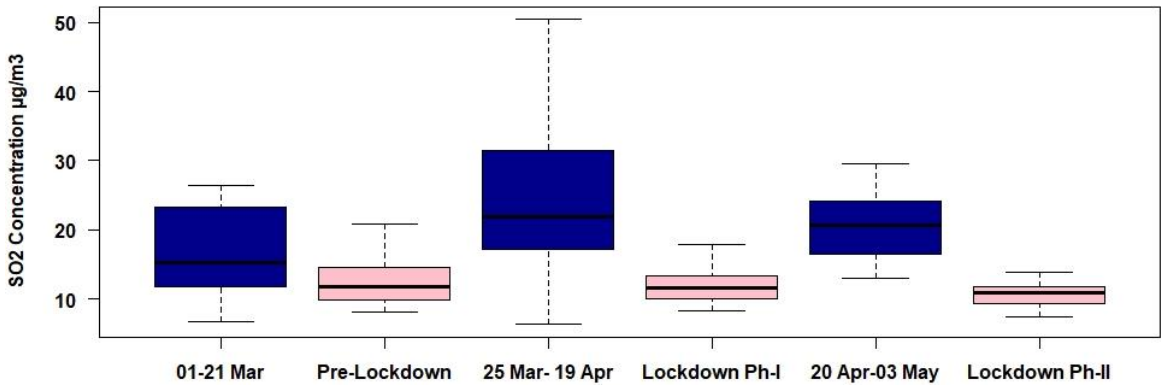


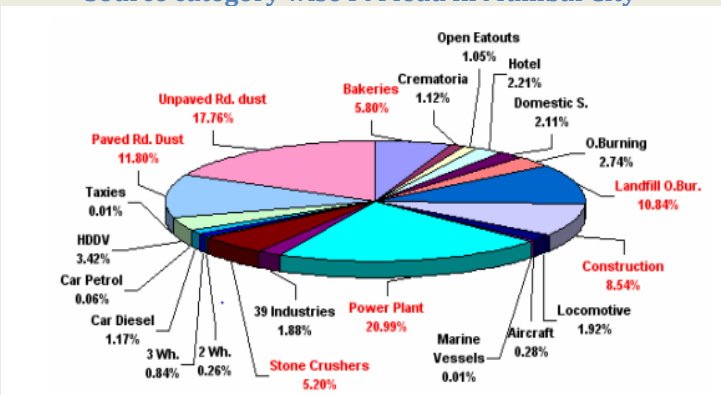
Fig 39: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Noida

5. AIR QUALITY TREND ANALYSIS IN OTHER CITIES DURING LOCKDOWN PERIOD

5.1 MUMBAI

During the lockdown period, significant reduction in PM_{10} and NO_2 levels were observed. Mumbai experiences different meteorological variations as compared to other urban metropolises, since it is located on the coast. It is to be noted that levels of SO_2, NO_2, $PM_{2.5}$ and PM_{10} were higher in the pre-lockdown levels as compared to the same period in 2019, which may be due to increased industrial and vehicular activity. However, once lockdown was imposed, a reduction of 68% in SO_2 levels, 56% in NO_2 levels and 20% reduction in PM_{10} levels were seen during phase-I of lockdown, against 2019 levels. The reduction in NO_2 and PM_{10} levels further increased in the second phase of lockdown to 69% and 40% respectively, when compared to the same time period in 2019. $PM_{2.5}$ levels increased in the first phase of lockdown by 5% but decreased by 9% in the second phase of lockdown, as compared to levels during 2019. The larger reduction in the second phase of lockdown may be due to the fact that while on April 17th 2020, the administration had permitted E-commerce companies, electrical and electronic supplies, sweet shops, confectionaries, courier services, activity related to agriculture products, restaurants with take away and construction activity to operate, the relaxations were revoked on 22nd April.

Source category wise PM load in Mumbai City



Source: Air Quality Assessment, Emissions Inventory and Source Apportionment Studies : Mumbai, CPCB, November 2010

The quantum of reduction w.r.t. to 2019 in SO_2 levels decreased during the second phase of lockdown to 48%, which may be due to operation of some additional industrial units in the second phase. Benzene levels increased in all phases of lockdown, compared to levels during the same period in 2019. As per emission inventory of Mumbai (CPCB, 2010), 39 types of industries (excluding power plants) contribute to over 50% of SO_2. It is possible that certain industries especially those consuming/releasing benzene might have started operating. Local influence of emissions on monitoring stations is also a possibility.

24-hourly average $PM_{2.5}$, PM_{10}, SO_2 and NO_2 levels were within National Ambient Air Quality Standards for all days in the lockdown period.

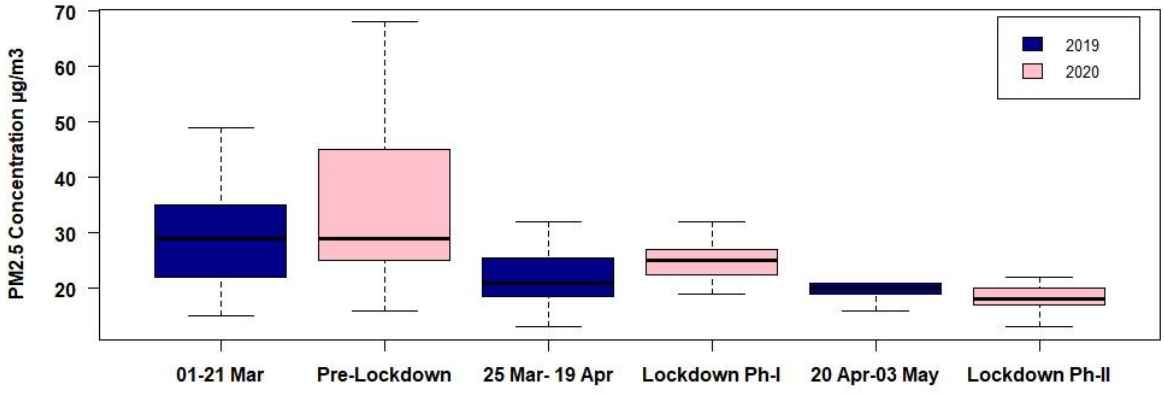


Fig 40: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 – Mumbai

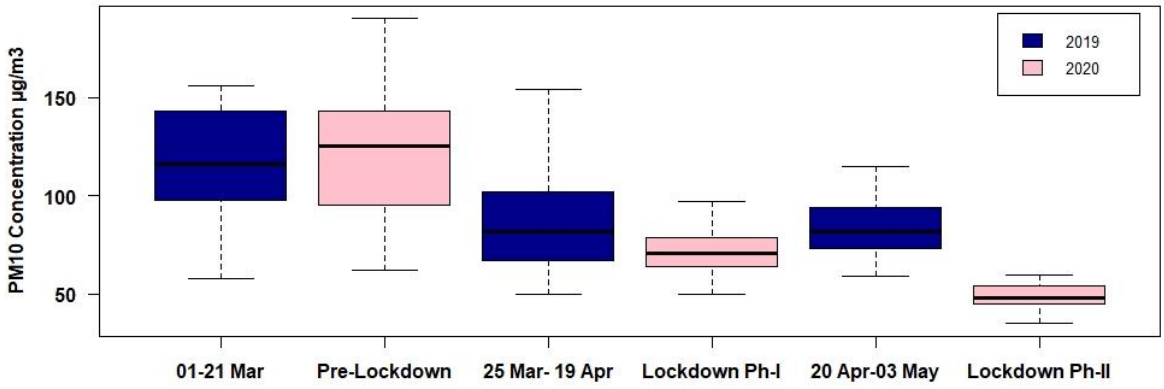


Fig 41: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2019 & 2020 – Mumbai

Overall, 29% reduction in $PM_{2.5}$ and 41% reduction in PM_{10} was observed during the first phase of the lockdown period, which further increased to 47% reduction in $PM_{2.5}$ and 59% reduction in PM_{10} in phase-II of lockdown, as compared to pre-lockdown levels, seemingly due to restriction on construction activities, less road dust resuspension and to some extent curb on industrial activities. The absence of non-essential vehicles and combustion activities in industrial and commercial sites during the period may be attributable to the decline.

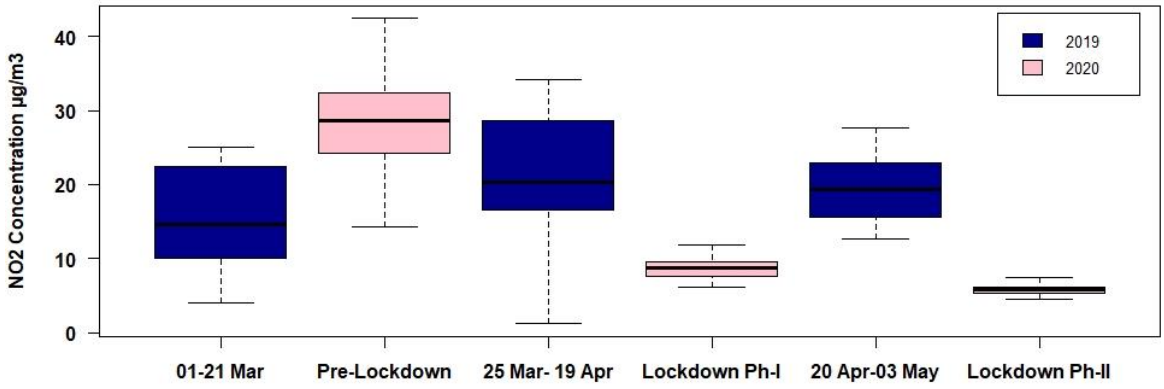


Fig 42: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Mumbai

Similarly, there was a sharp decrease of 79% reduction in NO_2 levels in the second phase of lockdown from 71% in the first phase, compared to the pre-lockdown levels, underscoring the absence of vehicular emissions.

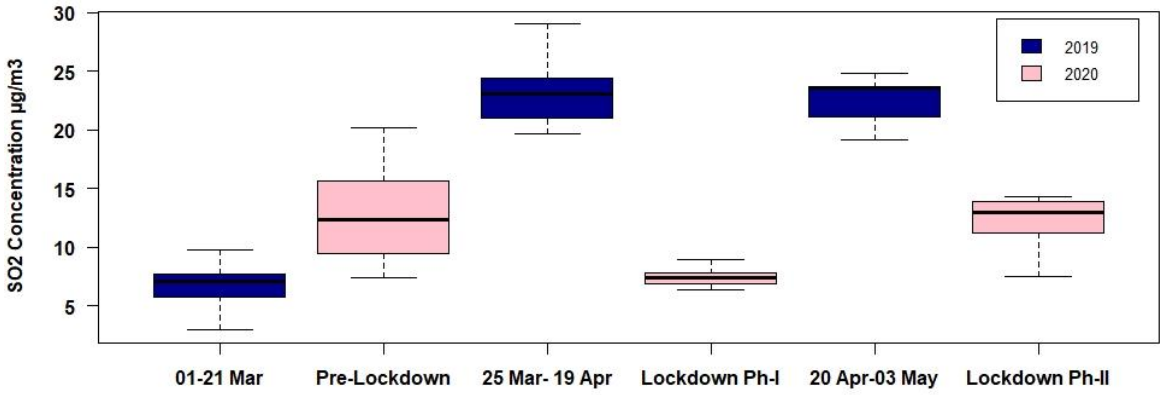


Fig 43: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Mumbai

SO_2 levels decreased by 41% in the first phase of lockdown and by 7% in the second phase of lockdown, when compared with pre-lockdown levels. Benzene levels reduced during both phases of lockdown, however, the quantum of reduction against pre-lockdown levels was lower in the second phase of lockdown, following a similar pattern as SO_2 levels. This may be due to operation of certain industries in the vicinity during the second phase of lockdown.

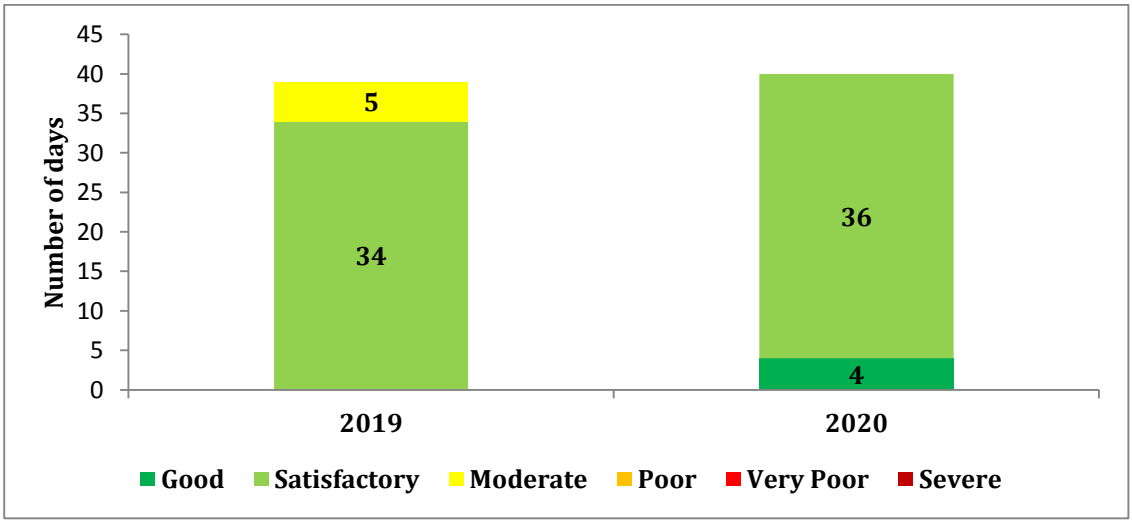


Fig 44.: Comparative AQI during 25th March – 3rd May 2019 and 2020 for Mumbai

In terms of AQI levels, Mumbai recorded all 40 days of lockdown period within National Ambient Air Quality Standards as AQI remained in Good-Satisfactory categories.

5.2 KOLKATA

Kolkata, the seventh most populous city in India as well as a major commercial and financial hub saw substantial reduction in pollutant concentrations during lockdown. NO_2, $PM_{2.5}$, PM_{10} and Benzene levels saw reduction in pre-lockdown, lockdown phase-I and lockdown phase-II, against the levels observed in 2019, with the quantum of reduction improving in each stage for most of the pollutants. Kolkata is situated quite close to the Bay of Bengal, and subsequently is prone to influences of phenomena like sea breeze, etc.

Analysis of AQI data for Kolkata reveals that Kolkata witnessed 12 'Good' AQI days during the 40-day lockdown period, rising from 4 'Good' AQI days seen during the same period in 2019.

During the second phase of lockdown, over 58% reduction in $PM_{2.5}$ and 68% in PM_{10} levels were observed, compared to 2019 levels, much increased than the 31% and 36% reduction for the same pollutants seen in the first phase of lockdown. This may be attributed to restrictions on industrial operations and construction activities along with reduced dust resuspension. Further, 63% reduction in NO_2 levels and 51% reduction in Benzene levels was observed during phase-II of lockdown, indicating the reduction in number of on-road vehicles. Since the pandemic situation was reported as very serious in Kolkata even after 20th April 2020, it is likely that not much relaxations were provided and the administration strictly enforced the lockdown, which is why the air quality improved even in the second phase of lockdown. However, SO_2 levels increased by 24% and 37% in the first and second phase of lockdown as compared to 2019 levels respectively. This may be due to the presence of power plants and their operational variations in the surrounding areas.

Despite the increase in SO_2 levels as compared to last year, 24-hourly average $PM_{2.5}$, PM_{10}, SO_2 and NO_2 levels were within National Ambient Air Quality Standards for all days in the lockdown period.

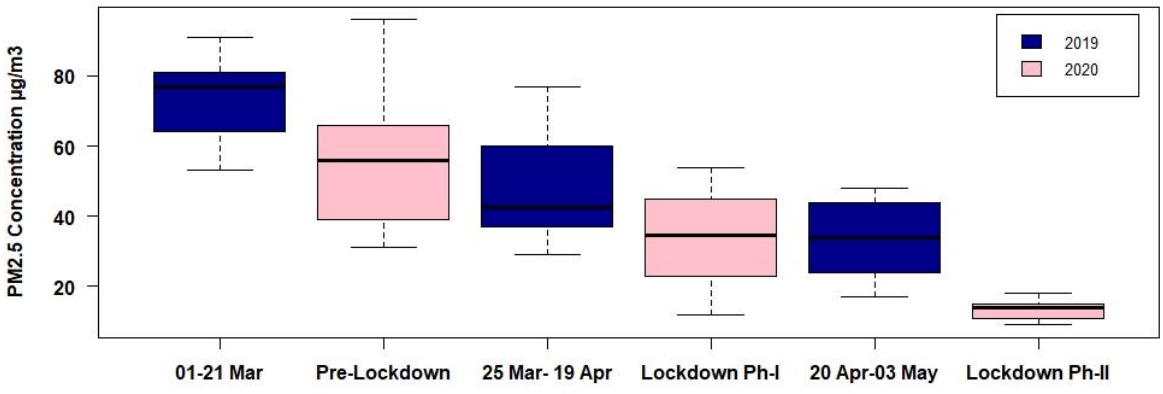


Fig 45: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 – Kolkata

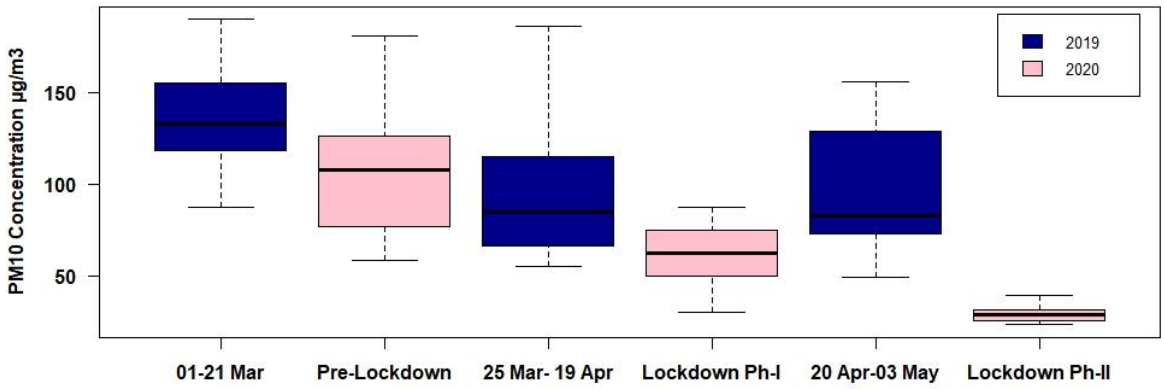


Fig 46: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2019 & 2020 – Kolkata

It is worth mentioning at the very outset, that levels during lockdown phase-I further reduced during lockdown phase-II for all major pollutants studied in this section. PM_{10} levels dropped by 72% during the second phase of lockdown as compared to pre-lockdown levels, which may be attributed to restriction on construction activities and reduced road dust resuspension due to less vehicular movement. A similar decline was seen for $PM_{2.5}$ with concentration falling by 40% and 75% in the first and second phase of lockdown respectively, against pre-lockdown levels, which might be due to the absence of non-essential vehicles and combustion activities in industrial and commercial sites. The range of $PM_{2.5}$ and PM_{10} variation during the second phase of lockdown was markedly reduced, signifying the absence of major sources.

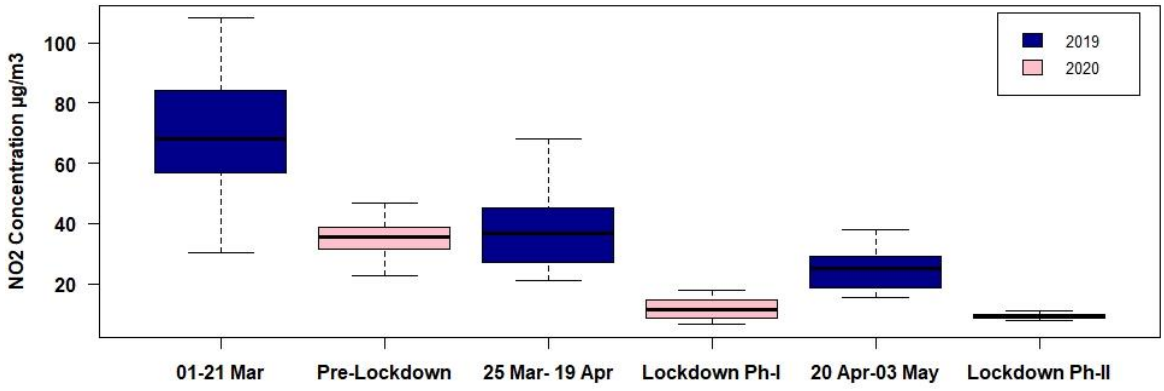


Fig 47: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Kolkata

NO_2 levels which had already reduced by 67% in the first phase of lockdown further reduced by 74% of their pre-lockdown levels, due to restrictions on vehicular movement. As a result, the variation of NO_2 values was almost negligible. Similar trend was observed for Benzene, with average values reducing by almost 78% in the second phase of lockdown, improving from 67% in the first phase, as compared to pre-lockdown levels.

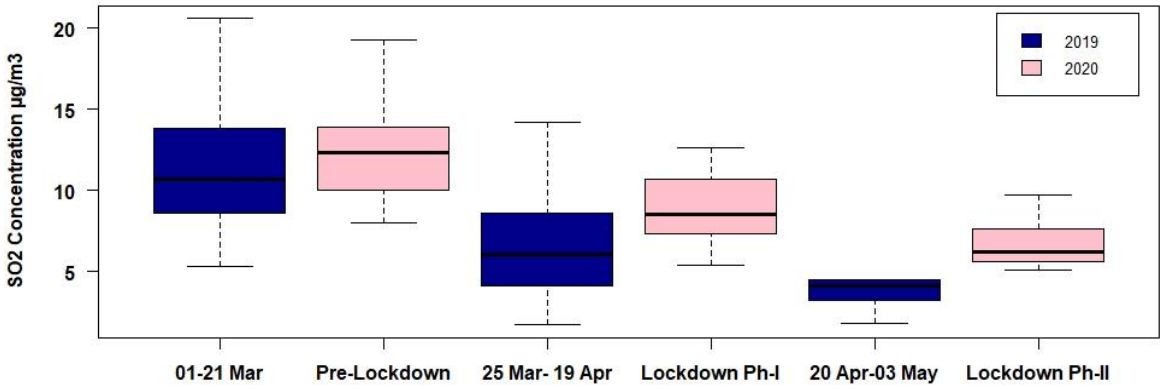


Fig 48: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Kolkata

SO_2 levels during lockdown period, though higher than the levels seen last year, saw a reduction as compared to pre-lockdown levels. The reduction of 26% and 46% in SO_2 levels in first phase and second phase of lockdown, against pre-lockdown levels.

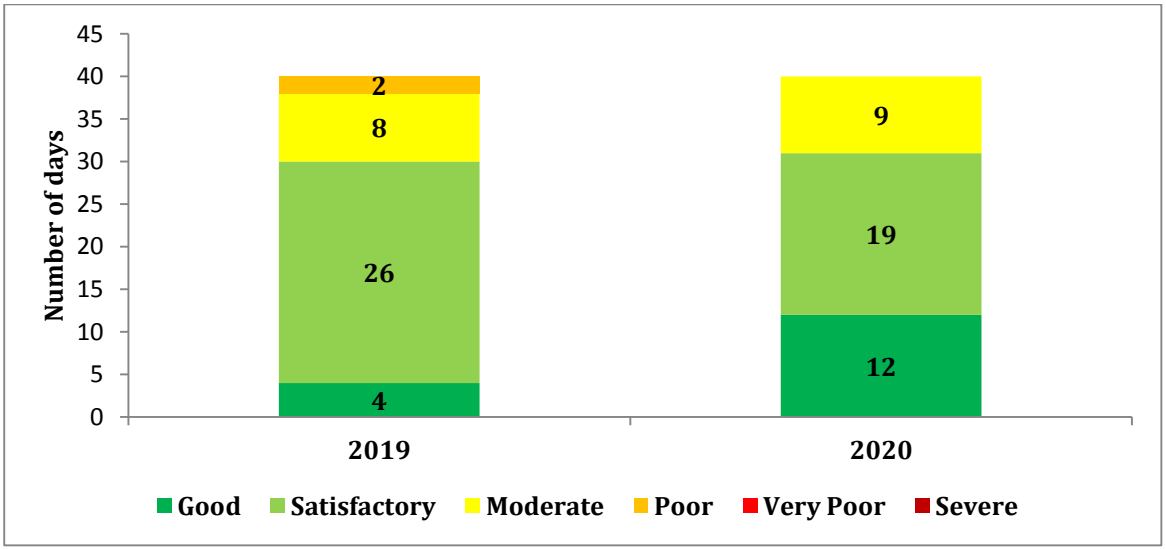


Fig 49.: Comparative AQI during 25th March – 3rd May 2019 and 2020 for Kolkata

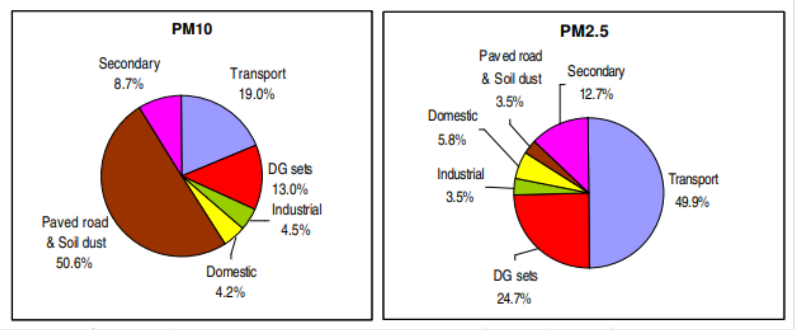
Air Quality Index gives an overall picture of ambient air quality in a city. Analysis of AQI data for Kolkata reveals that Kolkata witnessed 12 'Good' AQI days during the 40-day lockdown period, rising from 4 'Good' AQI days seen during the same period in 2019. No 'poor' AQI days were observed during lockdown period in 2020.

5.3 BENGALURU

Significant reduction in $PM_{2.5}$, PM_{10} and NO_2 levels were observed during the lockdown period, as a result of combination of reduced vehicles on the road and functioning of only essential commercial units. Overall, 48% reduction in PM_{10} and 59% reduction in $PM_{2.5}$ was observed during the second phase of lockdown period, as compared to 2019 levels. The reduction was less in PM_{10} and NO_2 levels

during the second phase of lockdown against 2019 levels, as compared to the reduction observed in the first phase of lockdown. Due to the restrictions imposed on vehicular movement and industrial activity, a 57% reduction in NO_2 levels and 54% reduction in Benzene levels was observed during phase-II of lockdown down from 67% and 76% reduction for the respective pollutants seen during the first phase of lockdown, compared to the same time periods in 2019. This may be due to relaxations in lockdown and subsequently, vehicular activity might have increased. As a result, dust especially due to resuspension and construction activities, might have increased resulting in increase in PM_{10} levels during second phase of lockdown.

PM10 and PM2.5 source contribution in Bengaluru city



Source: Air Quality Assessment, Emissions Inventory and Source Apportionment Studies : Bengaluru, CPCB, 2010

However, increase of 14%, 2% and 29% was seen in SO_2 levels during pre-lockdown, lockdown phase-I and lockdown phase-II of the lockdown period, against corresponding 2019 levels. It is possible that use of fuels like coal and biomass/wood etc. in industrial and household activities and local combustion sources, might be influencing SO_2 levels in Bengaluru.

24-hourly average $PM_{2.5}$, PM_{10}, SO_2 and NO_2 levels were within National Ambient Air Quality Standards for all days in the lockdown period.

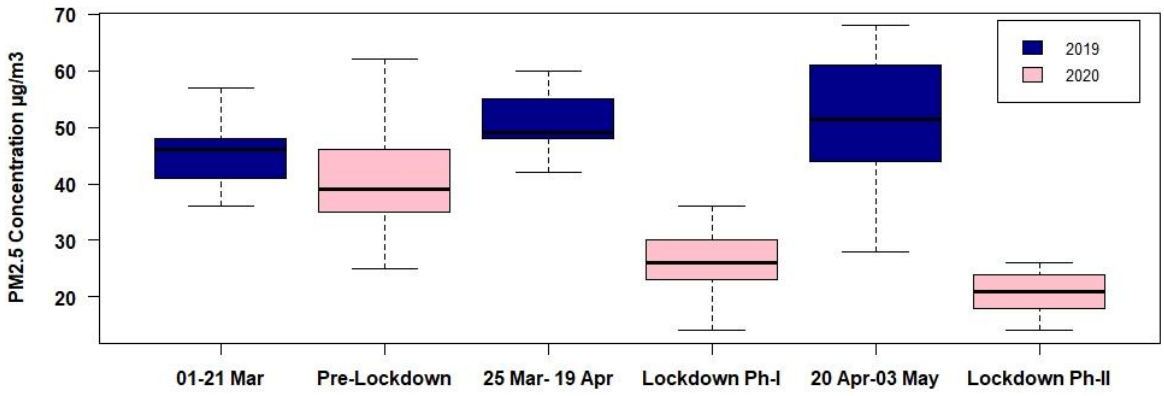


Fig 50: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 – Bengaluru

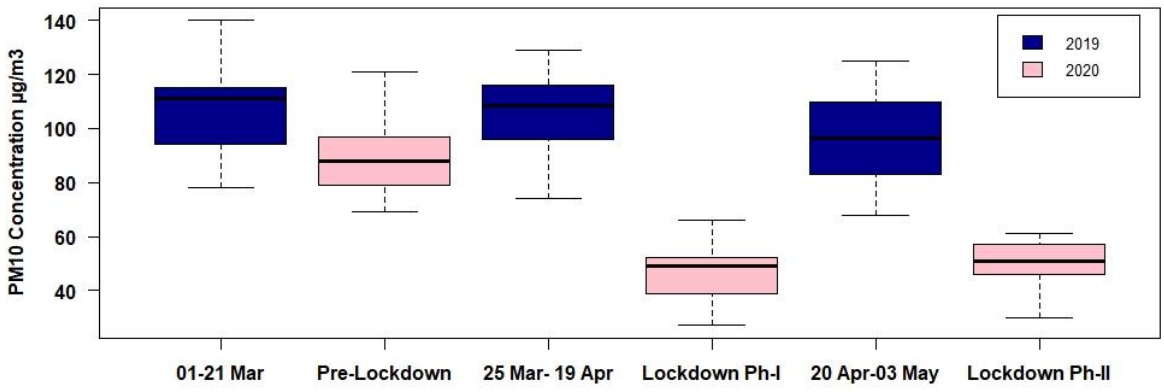


Fig 51: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2019 & 2020 – Bengaluru

The quantum of reduction in PM_{10} was lesser in lockdown phase-II (45%) than phase-I (50%) as compared to pre-lockdown levels. A decline was seen for $PM_{2.5}$ with average concentration reducing by 39% in the first phase of lockdown and further by 53% in lockdown phase-II as compared to pre-lockdown levels. The increased reduction in second phase of lockdown indicates the prominent role being played by dust sources, which may be due to onset of summer season.

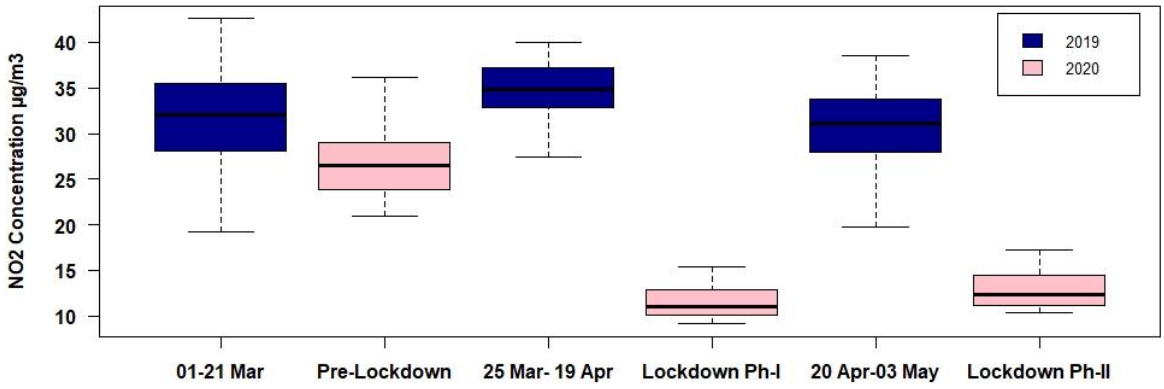


Fig 52: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Bengaluru

Average NO_2 levels during the second phase of lockdown period reduced by 51% as compared to the pre-lockdown period as against the 57% reduction seen in lockdown phase-I. Variation in NO_2 levels was also reduced during lockdown indicating decreased activity of major sources. Benzene levels had decreased by 6% in the first phase of lockdown, however, it increased by 5% during the second phase, as compared to pre-lockdown levels. Rise in benzene levels along with rise in NO_2 levels during the second phase may be due to increased vehicular activity or industrial operations.

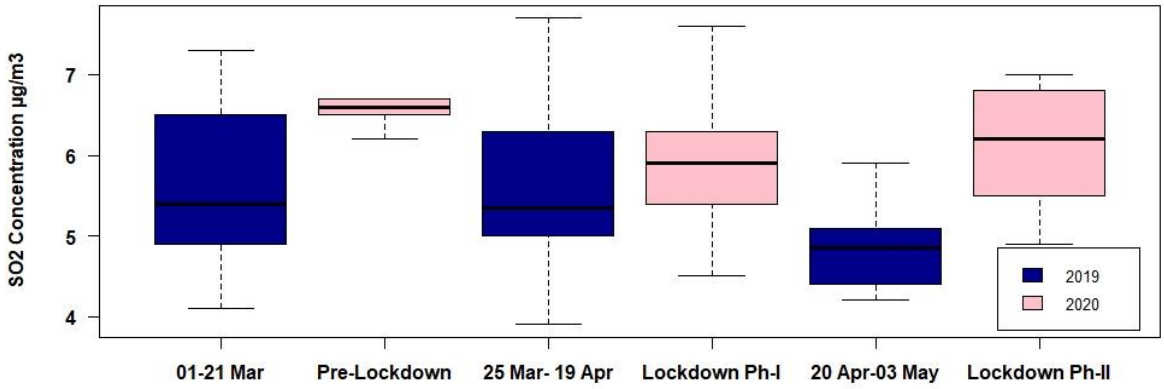


Fig 53: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Bengaluru

There was only minimal reduction (10%) in 24 hourly SO_2 values during the first phase of lockdown, which further reduced to 4% in the second phase of lockdown, as compared to pre-lockdown levels. Not only has there been an increase as compared to 2019 levels, the reduction as compared to pre-lockdown levels has also been relatively muted. This implies that the major sources of SO_2 in Bengaluru might still be operational, despite the lockdown and requires further investigation.

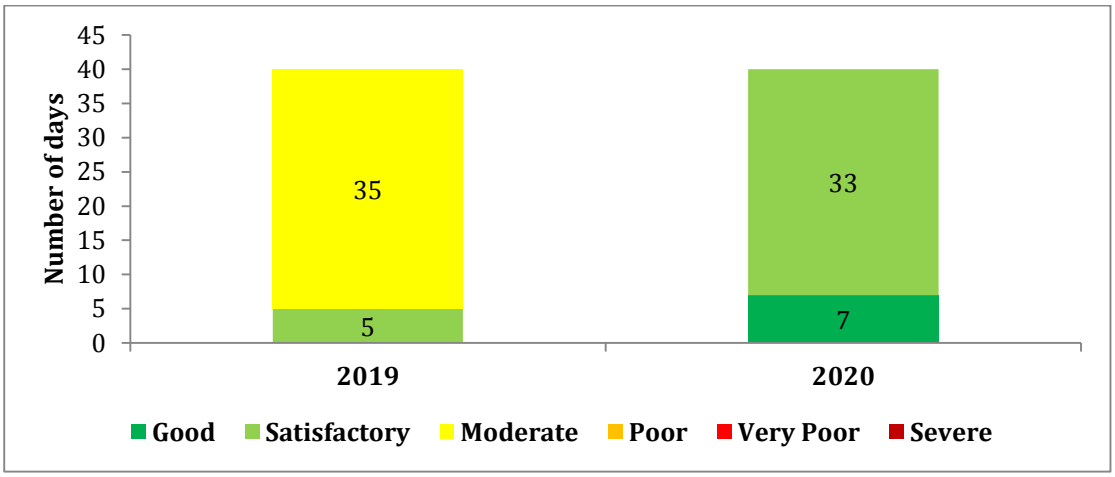


Fig 54.: Comparative AQI during 25th March – 3rd May 2019 and 2020 for Bengaluru

All days in the lockdown period witnessed Good-Satisfactory AQI categories, unlike in 2019 when most of the days were in Moderate AQI category.

5.4 PATNA

Patna witnessed major reduction in pollutant levels in the second phase of lockdown period. Overall, 60% reduction in $PM_{2.5}$ and 70% reduction in NO_2 levels was observed during the second phase of lockdown, compared to the same period in 2019, a drastic improvement compared to the 19% reduction ($PM_{2.5}$) and an increase of 20% (NO_2) seen in phase-I of lockdown.

There is less decline in $PM_{2.5}$ and Benzene levels and an increase in NO_2 levels in phase-I of lockdown against 2019 levels, reasons for which are difficult to ascertain without additional data like meteorology. The increase in NO_2 levels may be due to higher vehicular movement as a result of labor migration. SO_2 levels during pre-lockdown and lockdown phases reduced by 76%, as compared to 2019 levels.

SO_2 levels during pre-lockdown and lockdown phases reduced by 76%, as compared to 2019 levels.

SO_2 and NO_2 levels remained within National Ambient Air Quality Standards for all of the days in the lockdown period. While $PM_{2.5}$ levels were over NAAQS on just one day, PM_{10} levels remained within NAAQS for 23 days in the 40-day lockdown period.

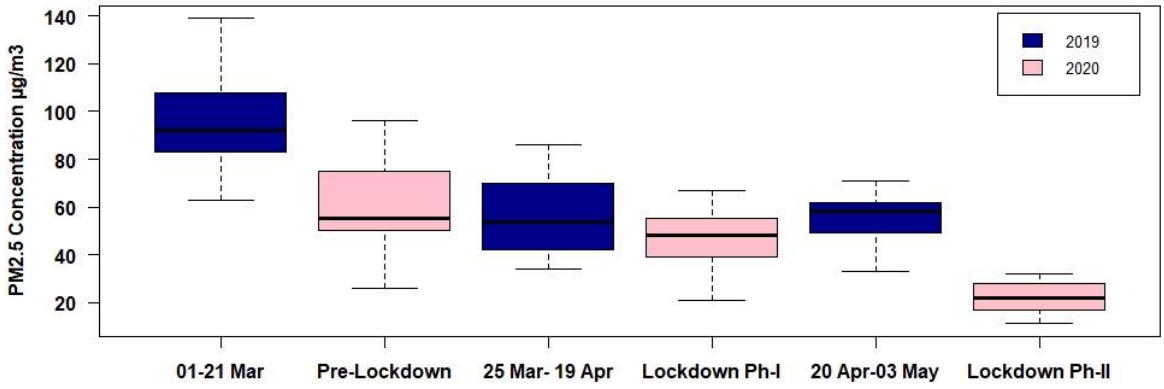


Fig 55: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 – Patna

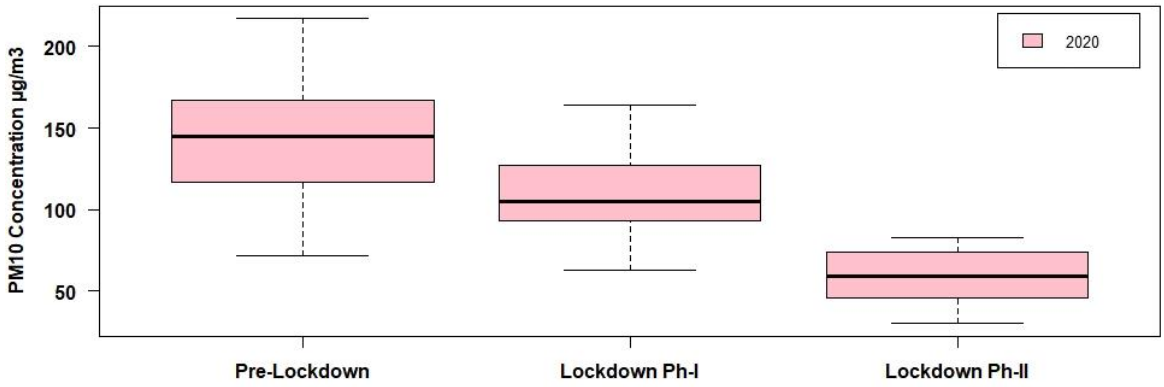


Fig 56: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2020 – Patna

During the first phase of lockdown, $PM_{2.5}$ and PM_{10} levels dropped only by 24% and 21% respectively, which further decreased by 64% and 59% during phase-II of lockdown, as compared to pre-lockdown levels. Accordingly, it can be deduced that restrictions of lockdown were more effective during second phase of lockdown. Similar levels of reduction probably indicate control on common sources such as transport sector, industrial and commercial sector, etc.

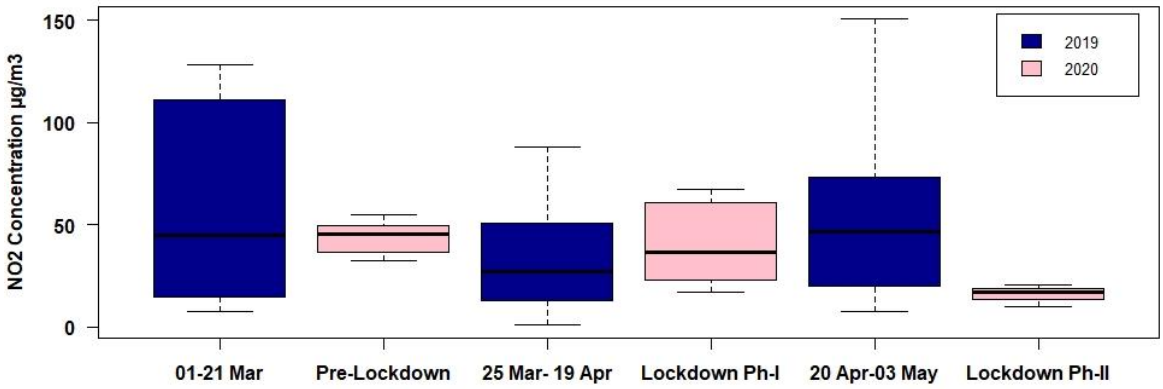


Fig 57: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Patna

Like in the case of PM_{10} and $PM_{2.5}$, the quantum of improvement for NO_2 was higher during the second phase of lockdown (63%) than the first phase of lockdown (7%), when compared to pre-lockdown levels. Further, it is also observed that variation of NO_2 levels reduced during pre-lockdown, increased during the first phase of lockdown, but decreased again in the second phase of lockdown. DG Sets and Transport sector have been reported as major sources of NOx in Patna. Benzene levels decreased by 53% and 52% in the first and second phase of lockdown, compared to pre-lockdown levels. It may be possible that use of DG sets, and vehicular movement might be responsible for the reduced impact in first phase of lockdown.

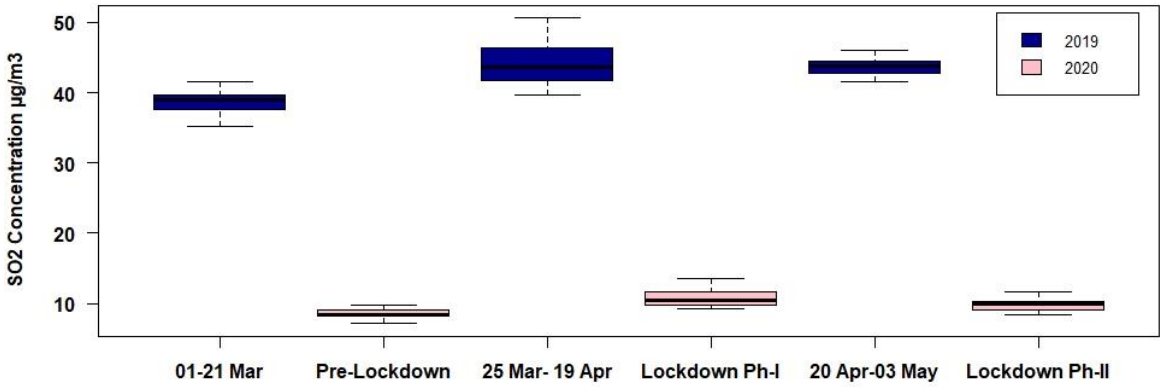


Fig 58: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Patna

Though SO_2 levels have decreased drastically as compared to the same periods in 2019, an increase during lockdown was noted as compared to pre-lockdown levels. SO_2 levels increased by 29% in the first phase of lockdown, but only by 18% during the second phase of lockdown, against pre-lockdown levels. The trend of SO_2 need to be further investigated with more information on likely sources including on-ground data, as it is defying general trend observed during lockdown. This may be due to the augmentation of monitoring network that took place this year and the resulting increase in spatial coverage of SO_2 levels for the city.

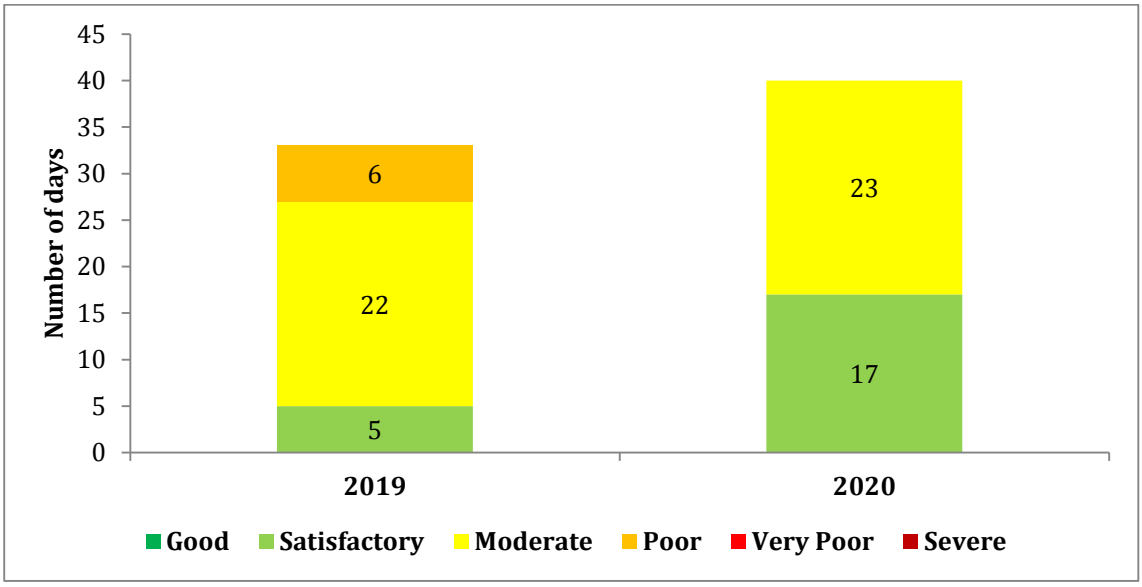


Fig 59.: Comparative AQI during 25th March – 3rd May 2019 and 2020 for Patna

Despite the mixed trends in pollutant concentrations in Patna during lockdown period, AQI did not enter into poor or higher AQI category during the lockdown periods, unlike in the same periods during 2019. Patna observed 17 Satisfactory AQI days during lockdown period as against 5 Satisfactory days in the corresponding period in 2019.

5.5 INDORE

The impact of lockdown in Indore was prominent especially for NO_2 and SO_2 which showed 56% and 37% reduction during first phase of lockdown respectively, seemingly due to the reduction in the number of on-road vehicles and restrictions on industrial operations, as against pre-lockdown levels. The reduction in $PM_{2.5}$ also increased to 30%, compared to pre-lockdown levels whereas it was just 5% in the first phase of lockdown. It is important to mention that there is only one real time air quality monitoring station in Indore and the impact of localized sources on air quality data is always a possibility. Further, data from the station was not available till September 2019. Benzene levels were also not available at the CAAQM station.

A gradual increase in $PM_{2.5}$ and PM_{10} in the second week of April was observed which may be attributed to dust and operation of some combustion sources using coal/biomass. The decrease in SO_2 levels (37%) was almost the same in both the phases of lockdown, which may be attributed to the restriction on industrial operations. It was reported that due to the rising number of coronavirus cases, no relaxations were provided in Indore. This may be the reason why an almost consistent decrease has been witnessed in Indore during lockdown period.

SO_2 and NO_2 levels remained within National Ambient Air Quality Standards for all of the days in the lockdown period. While $PM_{2.5}$ levels exceeded NAAQS on just five days, PM_{10} levels remained within NAAQS for 22 days in the 40-day lockdown period.

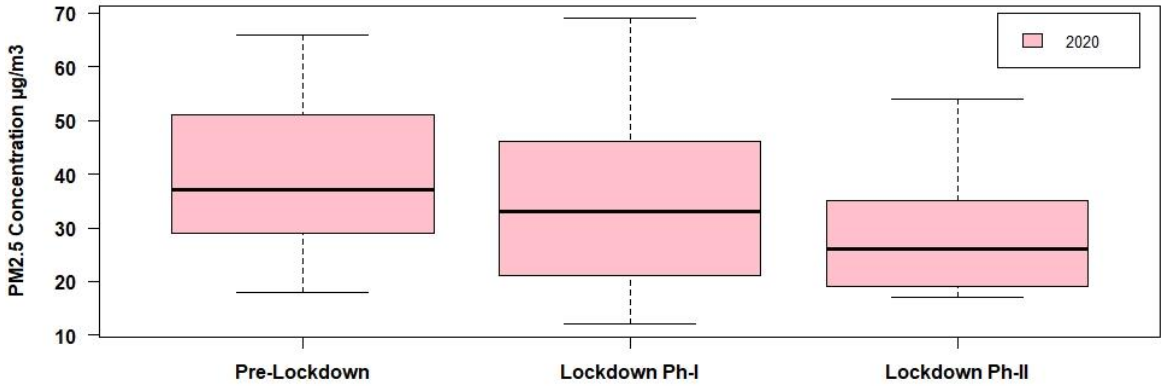


Fig 60: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2020 – Indore

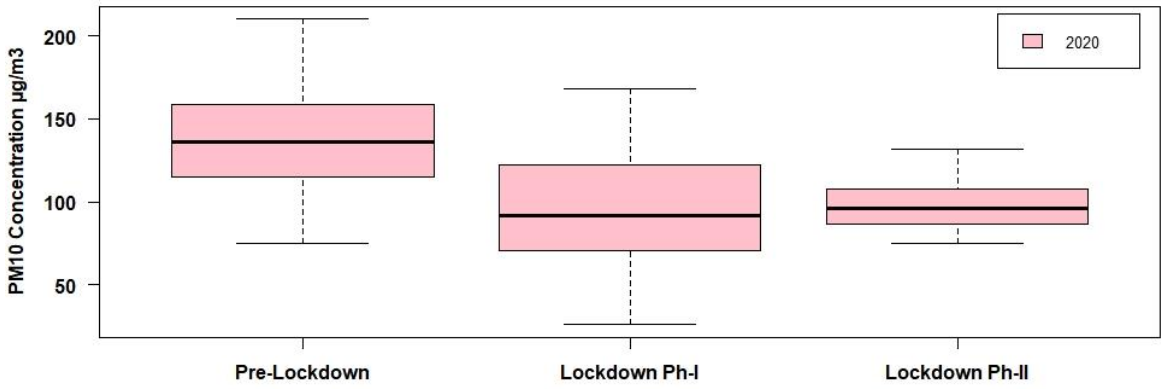


Fig 61: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2020 – Indore

During the second phase of lockdown, $PM_{2.5}$ values were lower than both pre-lockdown levels and values during phase-I of lockdown while PM_{10} levels were almost comparable or higher than the levels observed during phase-I of lockdown. The variation in $PM_{2.5}$ and PM_{10} levels during the second phase of lockdown, was also lesser than that in first phase of lockdown, probably due to enhanced restrictions and subsequently, the absence of major sources.

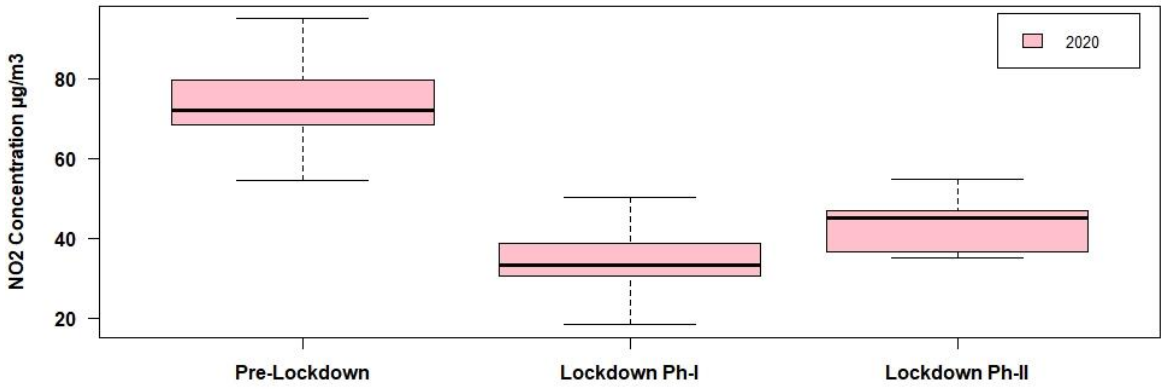


Fig 62: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2020 – Indore

NO_2 levels increased in the second phase of lockdown as compared to the first phase of lockdown. Further, the variation in NO_2 levels also increased slightly in the second phase of lockdown. Transport sector, usage of DG sets and industrial operations have been reported as prominent sources of NOx in Indore. However, it is difficult to conclude the precise activity which might be responsible for the reduced impact in phase-II of lockdown.

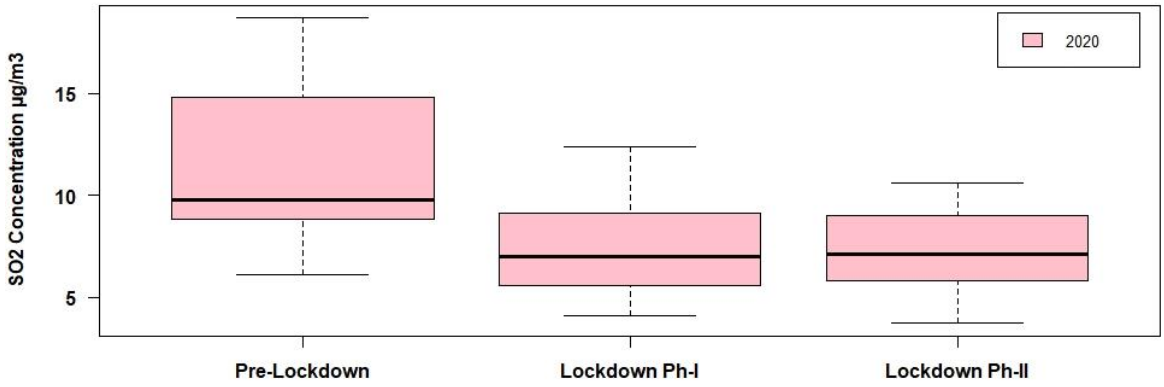


Fig 63: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2020 – Indore

Overall SO_2 levels remained similar in both phases of lockdown, indicating that sources of SO_2 in Indore were under similar control measures during both the phases of lockdown.

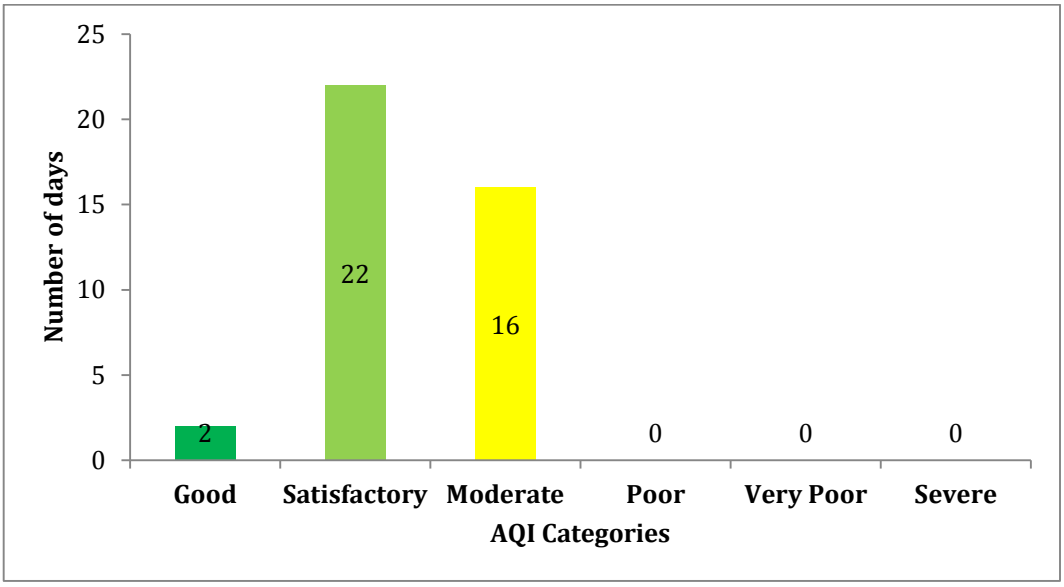


Fig 64.: Comparative AQI during 25th March – 3rd May 2020 for in Indore

Though AQI data for the corresponding period in 2019 was not available, it is observed that 24 days out of 40 days in the lockdown period recorded AQI in Good-Satisfactory categories, with the rest of the days in Moderate category.

5.6 CHENNAI

Improvement in air quality of Chennai was observed during pre-lockdown, lockdown phase-I and lockdown phase-II with 30%, 19% and 28% decrease in SO_2 concentrations respectively in 2020 as compared to 2019. Similarly, $PM_{2.5}$ levels reduced by 47%, 36% and 53% during pre-lockdown, lockdown phase I and lockdown phase II respectively in 2020 as compared to 2019. However, levels of NO_2 were lesser by 64% in 2020 during pre-lockdown phase but increase in NO_2 levels by 18% and 30% during lockdown phases I & II respectively was observed during 2020, as against 2019 levels.

Reduction in $PM_{2.5}$ levels can be largely attributed to decrease in emissions from various combustion sources such as open burning and transport sector with restricted mobility to workplaces, transit stations, schools and colleges. Meteorological variations along with the influence from Bay of Bengal might also be playing a role in ambient air quality changes in the city. Lower $PM_{2.5}$ and SO_2 levels can be also attributed to reduced power plants, industrial and commercial activities in the city. Although lower than previous year, the levels of $PM_{2.5}$ and SO_2 gradually increased during lock down phase I with increase in partial anthropogenic activities. It has been reported that a tightened lockdown was imposed in Chennai from April 24 to May 03, 2020 and maximum decrease was also observed during lockdown phase II when total restrictions were in effect.

However, NO_2 concentrations were higher by 18% and 30% during lockdown phase I and II possibly due to emissions from intensified traffic and industrial plumes as industries were allowed to operate

with reduced strength. Since two of the CAAQM stations are located in Manali, Chennai which is an industrial area having significant presence of chemical and petrochemical industries, it is possible that the industrial operations in the area might be influencing the NO_2 levels in Chennai.

Benzene levels were very high on 23rd April 2020 which is available only at one station i.e. Manali village, which is an industrial area. Although increase in Benzene levels were observed during 2020 as compared to previous year, gradual decrease in percent change was observed during lock down phase I & II. This may be attributed to increased industrial activities in 2020 as compared to 2019 and restricted emissions during lockdown periods.

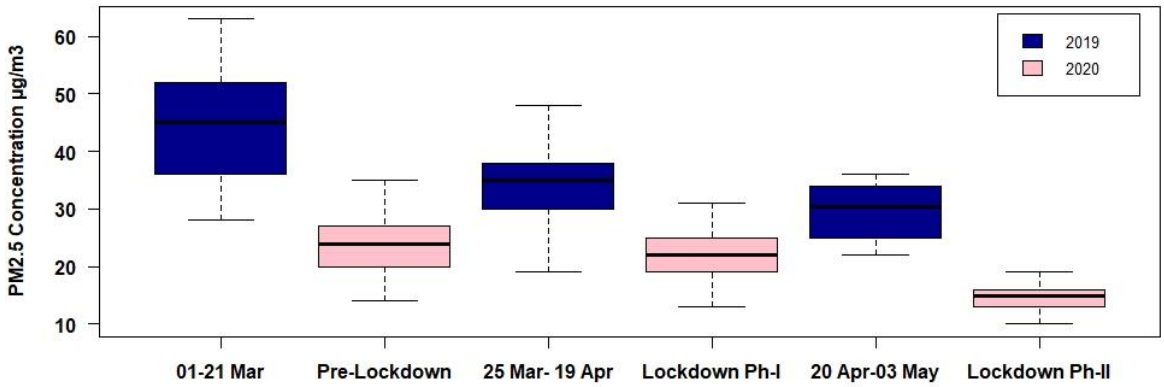


Fig 65: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2020 – Chennai

$PM_{2.5}$ concentrations were reported to decrease by 8% during lockdown phase I and by 42% during lockdown phase II as compared to pre-lockdown phase in 2020. PM_{10} values were not available during the study period and however, consistent decrease was observed during 28th March to 30th April, 2020 when data was available. This may be attributable to restriction in C&D activities in the city.

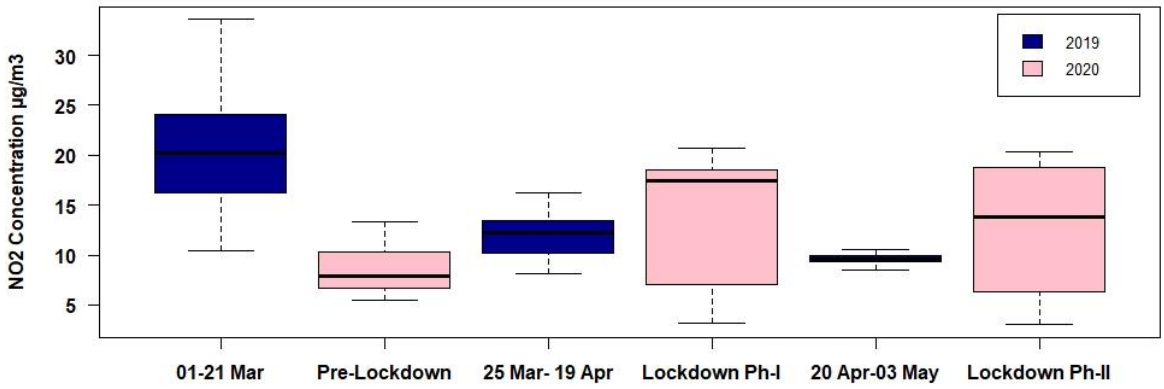


Fig 66: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Chennai

NO_2 levels increased by 72% and 51% during lockdown phase I & II respectively. Emissions from power plants, brick kilns, industries and traffic contribute significantly to particulate as well as gaseous pollutants. Although power plant emissions decreased as per media reports industrial activities and

associated commuting may have led to increase in NO_2 levels. However, NO_2 and $PM_{2.5}$ remained with the NAAQS during the study period.

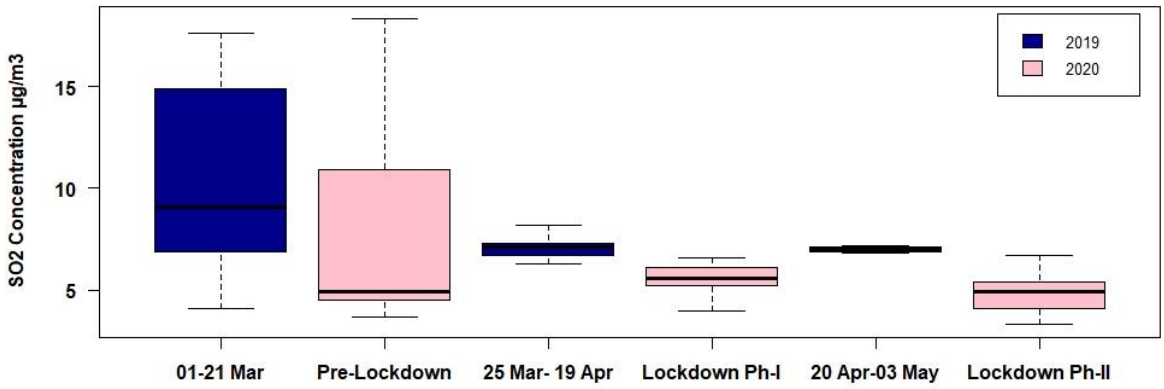


Fig 67: Box Plot of SO_2 Concentrations during 25th March – 3rd May 2019 &2020 – Chennai

SO_2 concentrations were also reported to decrease by 21% during lockdown phase I and by 32% during lockdown phase II as compared to pre-lockdown phase in 2020.

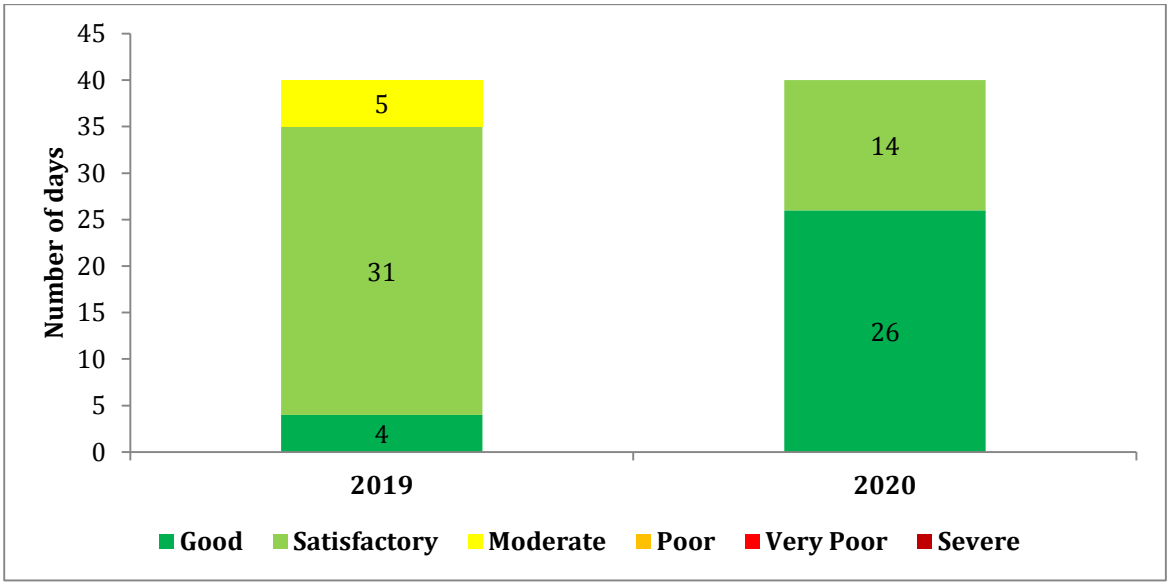


Fig 68.: Comparative AQI during 25th March – 3rd May 2019 and 2020 for Chennai

Air quality of Chennai showed a positive shift in AQI during lockdown phases in 2020 as compared to 2019. Improvement in AQI was reported with 26 Good days in 2020 as against 04 Good days in 2019. Number of Satisfactory days reduced to 14 in 2020 as against 31 in 2019 with more number days shifting to Good category during lockdown and 0 Moderate days were reported in 2020 as against 05 Moderate days in 2019.

5.7 SINGRAULI

Wide variations in pollutant levels during both phases of lockdown were observed. Decrease in average concentration of 03 pollutants (PM_{10}, $PM_{2.5}$, NO_2) was observed across all 03 phases i.e. during pre-lockdown, lockdown I and lockdown II phase in 2020 as compared to 2019. Maximum year on year reduction during the same time period was estimated during lockdown phase II with 45% decrease in PM_{10}, 36% decrease in $PM_{2.5}$ and 7% decrease in NO_2 levels in 2020. However, although 9% decrease during pre-lockdown phase was observed in 2020 as compared to 2019, 31% and 49% increase in SO_2 concentrations during lockdown I & II period respectively was observed in 2020 as compared to 2019.

This may be attributed to the coal mines and coal-fired thermal power plant, operational in the area. Coal-fired thermal power plants are major emitters of particulates, and other gaseous pollutants. The increase may also be due to variation in meteorology and the operational changes in power plant like power generated or coal consumed each day. Further, with onset of rising temperatures during summers, power demand may have increased relatively. As a result, it cannot be conclusively stated without availability of data.

Since thermal power plants were operational during the lockdown, the average concentration of SO_2 during the lockdown period increased by 41% in the second phase of lockdown, up from 28% in the first phase of lockdown as compared to the pre-lockdown period.

24 hourly average NO_2 levels were within National Ambient Air Quality Standards for all days in the lockdown period while SO_2 levels were above NAAQS on 1 day. PM_{10} levels remained above NAAQS on most days (38 days) in the lockdown period whereas $PM_{2.5}$ was within NAAQS on 17 days. It is important to note that PM_{10} levels had remained above NAAQS for most of the days even in the pre-lockdown period and in the previous year.

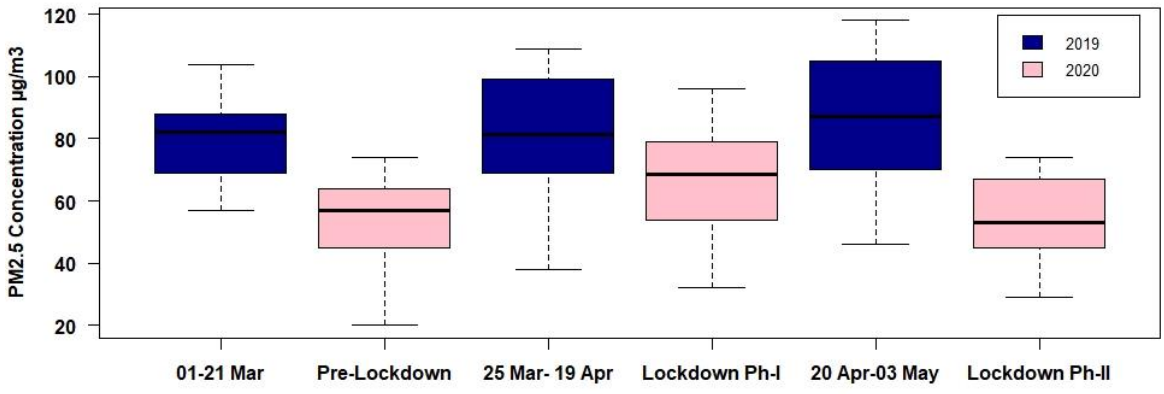


Fig 69: Box Plot of $PM_{2.5}$ Concentrations during 25th March – 3rd May 2019 & 2020 – Singrauli

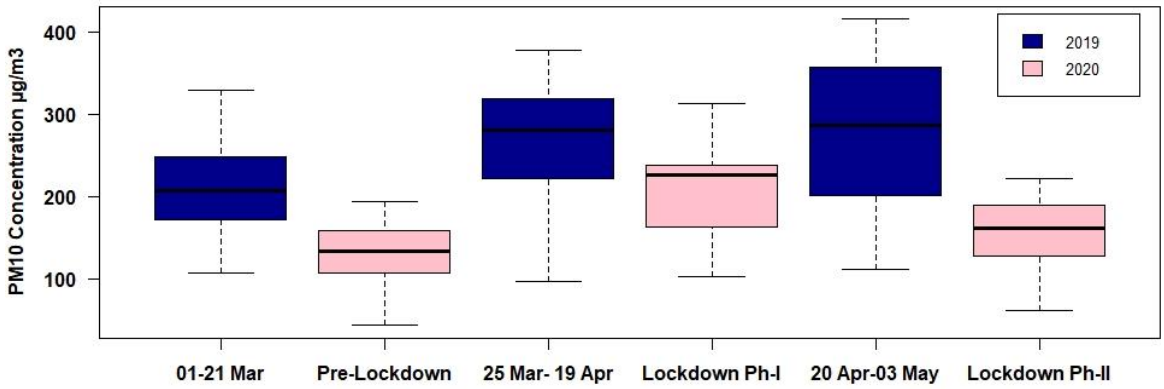


Fig 70: Box Plot of PM_{10} Concentrations during 25th March – 3rd May 2019 & 2020 – Singrauli

PM_{10} levels during the first and second phase of lockdown rose by 59% and 15% respectively, as compared to pre-lockdown levels, while $PM_{2.5}$ rose by 22% in phase-I but marginally decreased (1%) in phase-II. However, the variation in $PM_{2.5}$ and PM_{10} has somewhat reduced in the second phase of lockdown and is similar to pre-lockdown period. The operation of industrial sites in the vicinity during the period may be attributable to the rise, including the impact of airborne fly ash particles and coal dust in dry conditions.

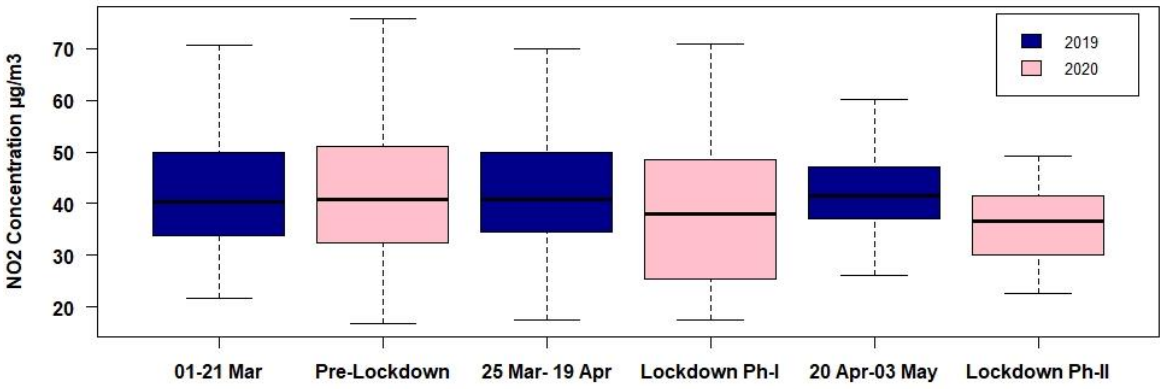


Fig 71: Box Plot of NO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Singrauli

NO_2 levels during the second phase of lockdown reduced slightly by 10%, as compared to pre-lockdown levels. The reduced quantum of reduction in NO_2 levels is indicative of the fact that the major sources of NO_2 might still be operational in Singrauli and that the reduction may be a result of changes in the operation of the sources or meteorological changes.

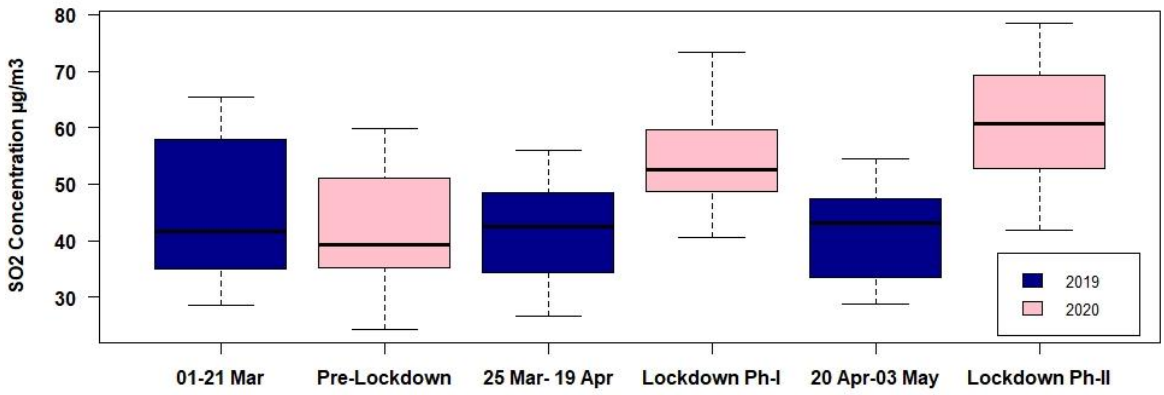


Fig 72: Box Plot for SO_2 Concentrations during 25th March – 3rd May 2019 & 2020 – Singrauli

Since thermal power plants were operational during the lockdown phase, the 24 hourly SO_2 concentration during the lockdown period increased by 41% in the second phase of lockdown, up from 28% in the first phase of lockdown as compared to the pre-lockdown period. The variation again indicates the presence of the major SO_2 emitter, i.e. operational power plants in the vicinity. More data like meteorology, power generated, coal consumed, etc. are required to ascertain the reasons for increase in overall levels of SO_2.

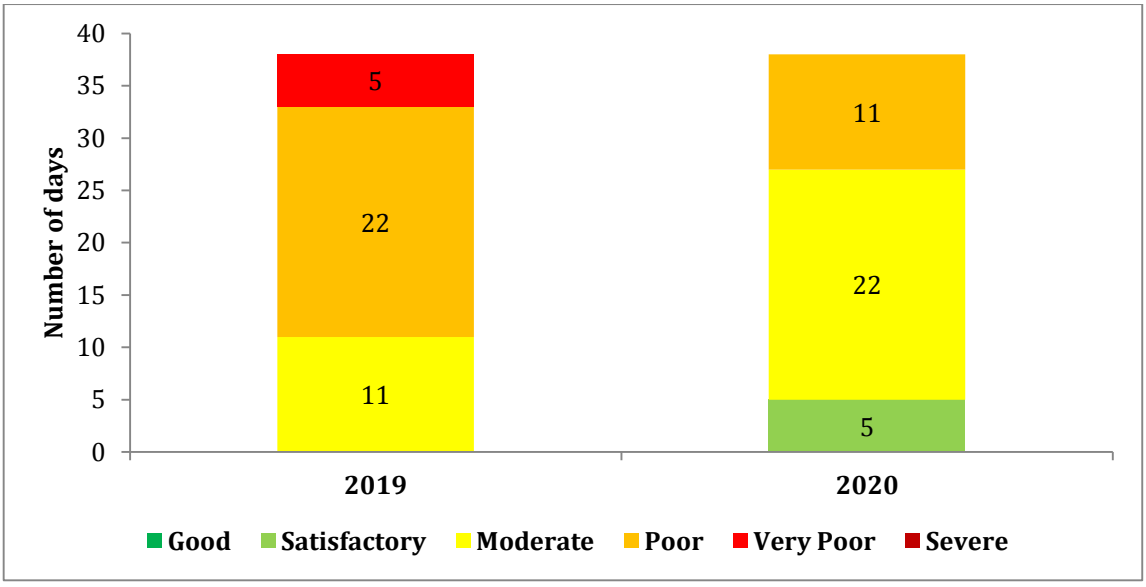


Fig 73: Comparative AQI during 25th March – 3rd May 2019 and 2020 for Singrauli

In terms of Air Quality Index, out of 40 days in the lockdown period, 27 days were in the Satisfactory-moderate categories. Further, unlike last year, there were no Very Poor category days in the study period.

6. ASSESSMENT OF SATELLITE BASED $PM_{2.5}$ DATA

Impact of lockdown on fine particulate matter ($PM_{2.5}$) across India has been also examined as a part of a study to utilize satellite-based aerosol optical depth data for monitoring of $PM_{2.5}$ by IIT Delhi in collaboration with CPCB. An indicative assessment for five time periods - one month (February 19th-March 24th, 2020) for the pre-lockdown period and the four phases of lockdown i.e. Phase 1(Mar 25th -Apr 14th), Phase 2 (Apr 15th -May 3rd), Phase 3 (May 4th -May 17th), Phase 4 (May 18th -May 31st) was carried out.

The initial improvement in air quality during the first phase of lockdown could not be sustained in the subsequent phases over a large part of the country due to sustained emissions from household sources and open biomass burning.

Average ambient $PM_{2.5}$ exposure in the first phase of lockdown decreased drastically (below 50 µg m-3) over the west and east Indo-Gangetic Plain (IGP), slightly decreased in South India, Northeast India and North India and remained high over West India and a large part of Central India from east-to-west coast. In the second phase, $PM_{2.5}$ increased mainly over the east IGP and a large part of South India, while the Central India hotspot disappeared. $PM_{2.5}$ dropped everywhere in the third phase before recovering above the annual NAAQS in parts of IGP, East and South India in the fourth phase.

Region	Pre-lockdown Feb 25-Mar 24	Phase 1 Mar 25-Apr 14	Phase 2 Apr 15-May 3	Phase 3 May 4-May 17	Phase 4 May 18-May 31
North India	48, +8%	29, -30%	42, -1%	31, -20%	34, -20%
Western IGP	114, +43%	46, -33%	57, -13%	48, -27%	61, -11%
NE India	68, -13%	54, -16%	43, -13%	37, -25%	46, -8%
Central India	93, +7%	76, -2%	70, 0%	48, -20%	55, -13%
South India	98, +7%	68, -16%	74, -5%	60, -17%	65, -13%
West India	88, +2%	75, -6%	73, -7%	58, -15%	63, -13%
Eastern IGP	105, +21%	56, -25%	73, +1%	53, -17%	65, -2%
India	87, +7%	59, -18%	61, -6%	47, -21%	55, -12%

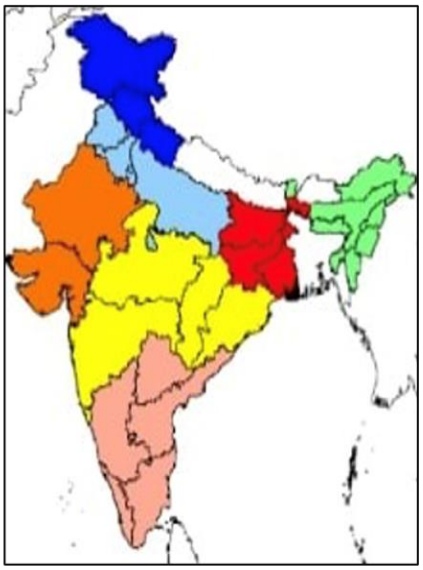


Fig.74 : Population-weighted (first number) ambient $PM_{2.5}$ (in µg m-3) and (second number) its change (in %) relative to the last five years (2015-2019) in the seven geographical regions of India during the pre-lockdown and the four phases of lockdown in 2020

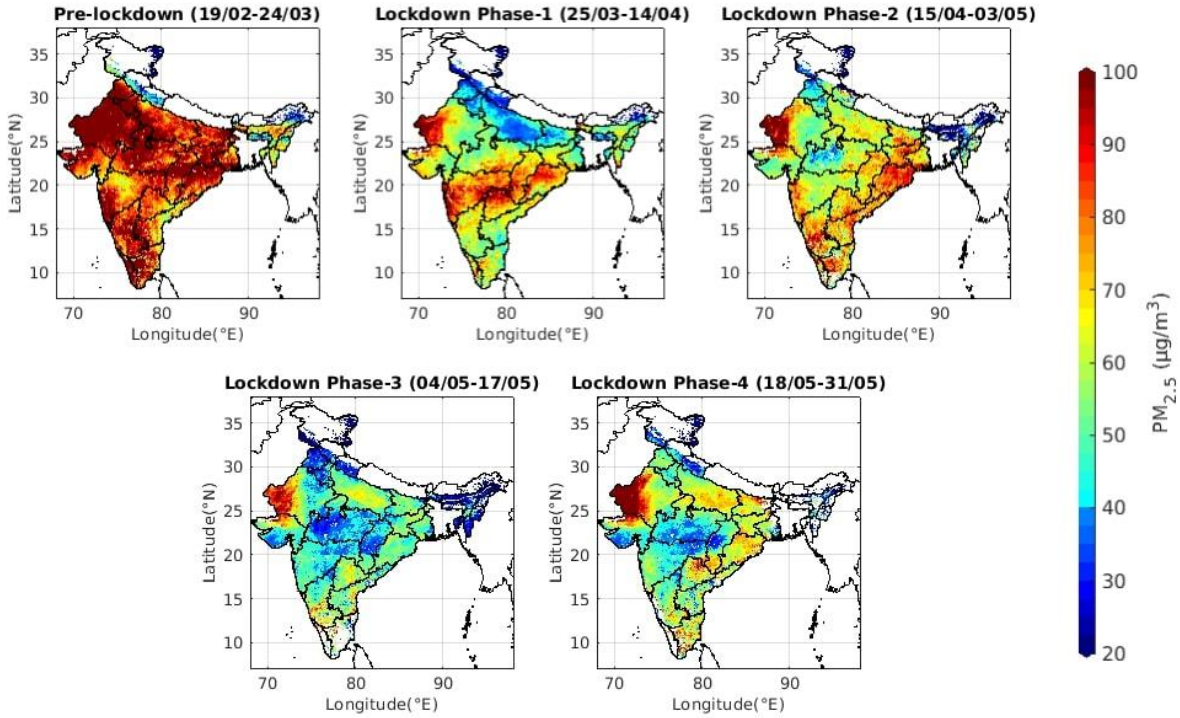


Fig.75: Spatial pattern of ambient $PM_{2.5}$ Concentrations during the pre-lockdown and 04 phases of lockdown in India.

This analysis also reveals that the magnitude of improvement in regional air quality in terms of $PM_{2.5}$ is not as large as reported by city-level studies using only ground-based measurements. In cities, significant reduction in traffic and other local sources was reported, and quantifiable reductions were reported. However, at the regional and national level, sources such as solid fuel use and agricultural burning continue to be important. During the lockdown, household emissions likely remained unperturbed and may have increased as people spent most of their time indoors; agricultural burning was also practiced after the wheat harvesting. Both of these sources contributed to regional $PM_{2.5}$ and perhaps also to the downwind urban areas through secondary aerosol formation.

Comparing the months immediately before and after the imposition of the lockdown on March 25, population-weighted $PM_{2.5}$ decreased by 36% from 87 µg m-3 to 56 µg m-3, as compared to a 20% decrease during the same periods (81 µg m-3 to 65 µg m-3) in the last five years; thereby suggesting an additional 16% improvement due to the lockdown. The initial improvement in air quality during the first phase of lockdown could not be sustained in the subsequent phases over a large part of the country due to sustained emissions from household sources and open biomass burning.

7. SUMMARY

The lockdown imposed during COVID-19 pandemic led to a positive effect on air quality in cities across India. While pollutant concentrations varied from city to city, depending upon major sources and prominent pollutants, general improvement in Air Quality Index (AQI) was observed during the lockdown period as against the same period last year as depicted in Annexure-I. It is important to note that meteorological conditions, local sources near monitoring stations and distribution of monitoring network across a city also impact ambient air quality.

Cities in Delhi-NCR observed similar levels of reduction, which may be due to the fact that they lie within the same airshed. Source apportionment study of $PM_{2.5}$ in Delhi revealed that sources associated with vehicular emissions, domestic/local coal combustion, waste incineration and urban organic aerosols reduced sharply from the pre-lockdown phase into lockdown phase-I and were found to steadily rise back with increasing relaxations in the lockdown. However, concentration of all pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, Benzene) were lesser in Delhi and 04 NCR cities during 2020 as compared to 2019 except for NO_2 levels in Gurugram in 2020 during lockdown phase I and SO_2 levels during lockdown phase I &II.

Improvement was also observed in other cities - Mumbai, Chennai, Patna, Kolkata, Bengaluru, Indore and Singrauli. The improvement might also have been influenced by the location and number of monitoring stations as well as prevailing meteorological conditions, and topography. While cities like Delhi and Indore are landlocked, influence of the sea affects the atmospheric chemistry of cities like Mumbai, Chennai and Kolkata. Decrease in SO_2 levels were observed in all cities except Kolkata, Bengaluru and Singrauli in 2020 as compared to levels in 2019.

Significant improvement in NO_2 levels were also reported in majority of the cities except for Chennai and Patna in 2020 as against the same period in 2019.

Reduction in $PM_{2.5}$ levels was observed in all cities during pre-lockdown and first lockdown period except for Mumbai. However, reductions were achieved in Mumbai too during the second phase of lockdown. Similar reductions in PM_{10} was observed in all cities except Mumbai during pre-lockdown period in 2020 as against 2019 along with year on year reductions in PM_{10} levels in all cities during both lockdown phases.

Comparison of pollutant levels before and during lockdown phase I & II in 2020 shows significant reductions in NO_2, $PM_{2.5}$ and PM_{10} in all cities. Reductions were also reported in Benzene for all cities except Bengaluru during lockdown phase I and II respectively. SO_2 levels also decreased in all cities except in Patna and Singrauli during both the lockdown phases.

Apart from meteorological factors, focused implementation of actions under city action plans may have resulted in better air quality in cities during 2020 as compared to 2019 especially in terms of Particulate Matter. Conditional operation of industries and associated reductions in mobility as well as reductions in overall emissions from transport sector may have led to significant decrease in SO_2, NO_2 and Benzene levels also impacting secondary particulate formation. Effect of power plants in local as well as regional pollutant levels was observed in cities with coal-based power plants near the city.

The assessment of satellite derived $PM_{2.5}$ data indicated the role played by solid fuel use and agricultural burning at the regional and national level, leading to increased $PM_{2.5}$ levels in some areas, which perhaps also moved to the downwind urban areas through secondary aerosol formation. However, an additional 16% improvement due to the lockdown was suggested, when the months immediately before and after the imposition of the lockdown on March 25 were compared for population-weighted $PM_{2.5}$.

8. CONCLUSION

Although significant improvement in air quality was observed during lockdown due to restricted anthropogenic activities, such air quality management strategies come with considerable economic costs. Irreversible emission reductions through sustainable process changes and long-term objectives is crucial for achieving good air quality levels. However, as impact of various anthropogenic activities is now being quantified, actions that can be integrated in business as usual scenarios needs to be identified, with emphasis on reduction of emissions at source including dust control, vehicular emissions, industrial operations, etc. Lessons learnt from the COVID-19 pandemic can be utilized to target source specific actions leading to maximum improvement in ambient air quality. Further, socio-economic development and industrialization also needs to be in tandem with the carrying capacity of a city. Major insights from COVID 19 Lockdown for air quality management are:

- Management of traffic emissions

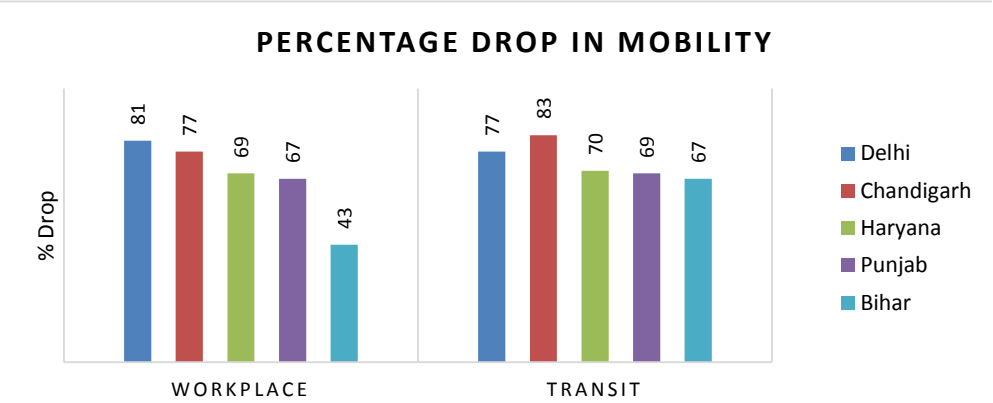
(a) Change in technology - expansion of clean fuel automobiles, retrofitment of old vehicles

(b) Stringent enforcement - vehicle emission inspection programmes, congestion management

(c) Change in behavior – reduce workplace/school/ college mobility, promote digital innovation

Change in mobility patterns can lead to improved air quality management.

- *Across India, workplaces mobility dropped by −56.7% and by 81.3% in Delhi during lockdown period (from 24th March to 30th April 2020) from the baseline average (from 15th February to 23rd March 2020) which also corroborates with the period of least contribution to $PM_{2.5}$ levels from traffic emissions.*
- *Across India, transit station mobility i.e. visit public transport facilities dropped by −66% (up to 30th April, 2020) and by 77.7% in Delhi from the baseline average.*



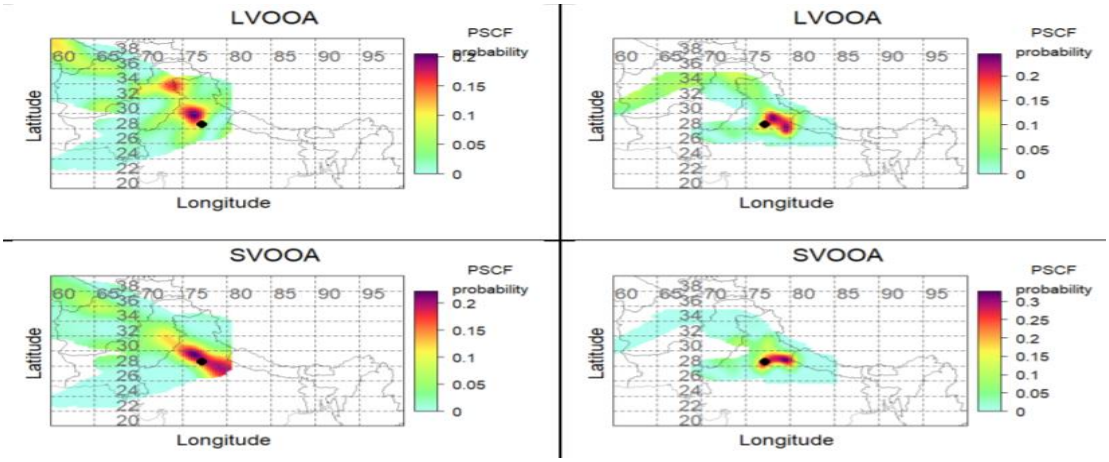
Source: Lockdown for COVID-19 and its impact on community mobility in India: An analysis of the COVID-19 Community Mobility Reports, 2020 by Saha et al.

- Management of biomass burning
  (a) Public outreach – increase mass interaction on health impact of open burning
  (b) Implementation of fiscal incentives at grass roots – end to end incentives to small farmers to facilitate green stubble management practices, free access to LPG cylinders for cooking to women in poor households, use of biomass pellets

Use of agricultural residues in power plants and agricultural residues pellets in local households shall lead to 8% and 7% reduction in $PM_{2.5}$ levels by 2025
Source: TERI ARAI Source Apportionment Study, 2018

- Management of industrial/ commercial emissions
  (a) Change in technology – SOx and NOx abatement technologies, Fugitive emission control
  (b) Stringent enforcement – shutting down of inefficient power plants, close monitoring of Online Continuous Emission Monitoring Systems (OCEMS) and implementation of quality assurance /checks

Potential Source Contribution Function (PSCF) incorporates meteorological information to determine areas of the potential source contribution. During lockdown phases in Delhi contribution of Regional Organic Aerosol (orLVOOA) and Urban Organic Aerosol (or SVOOA), quantifying secondary or oxidized organic aerosols was observed. (Black dot represents IIT Delhi Site) showing transport of pollutants as per wind direction.



Source: Source Apportionment of $PM_{2.5}$ in New Delhi during the Covid-19 Lockdown, IIT Kanpur-Delhi

  (c) Clean energy – expansion of clean fuel infrastructure to ensure its availability in industrial areas, integrating clean sources of energy into traditional grids, shifting of eateries to clean fuel
  (d) Innovative Financial Instruments – reduce emissions from industrial clusters through emission trading schemes.

- Management of Critical Air Quality Conditions

  (a) Emergency Response Systems (ERS) – ERS in line with Graded Response Action Plan (GRAP) notified in Delhi NCR is being prepared and implemented in 122 non-attainment cities. These plans may be reviewed to include actions that led to maximum reductions.

  (b) Airshed Approach – Defining regional airsheds to control polluting sources beyond city boundaries to counter long range transport of pollutants.

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Annexure I

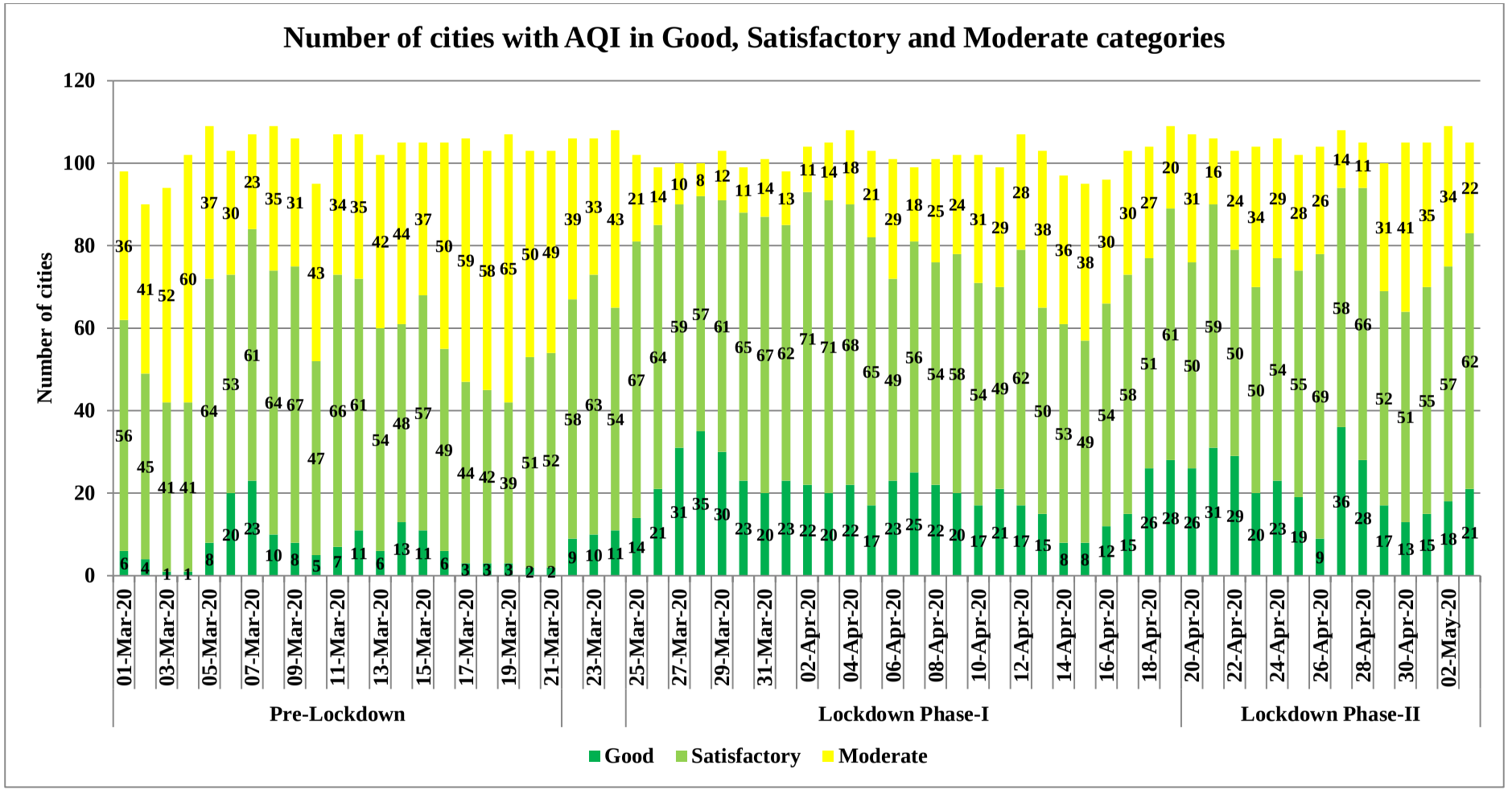
Comparative AQI Status from 01 March to 03 May, 2020
(based on CPCB AQI Bulletin, published at 4 PM)

Date	No of cities for which data is available	No. of cities in AQI category						No. of cities with AQI in range of Good to Satisfactory	No. Of cities with AQI in Moderate Category	No. of cities with AQI in range of Poor to Severe
		Good	Satisfactory	Moderate	Poor	Very Poor	Severe			
01-Mar-20	105	6	56	36	7	0	0	**62**	**36**	**7**
02-Mar-20	105	4	45	41	15	0	0	**49**	**41**	**15**
03-Mar-20	112	1	41	52	18	0	0	**42**	**52**	**18**
04-Mar-20	115	1	41	60	13	0	0	**42**	**60**	**13**
05-Mar-20	110	8	64	37	1	0	0	**72**	**37**	**1**
06-Mar-20	103	20	53	30	0	0	0	**73**	**30**	**0**
07-Mar-20	107	23	61	23	0	0	0	**84**	**23**	**0**
08-Mar-20	112	10	64	35	3	0	0	**74**	**35**	**3**
09-Mar-20	107	8	67	31	1	0	0	**75**	**31**	**1**
10-Mar-20	105	5	47	43	10	0	0	**52**	**43**	**10**
11-Mar-20	107	7	66	34	0	0	0	**73**	**34**	**0**
12-Mar-20	110	11	61	35	3	0	0	**72**	**35**	**3**
13-Mar-20	107	6	54	42	5	0	0	**60**	**42**	**5**
14-Mar-20	108	13	48	44	3	0	0	**61**	**44**	**3**
15-Mar-20	109	11	57	37	4	0	0	**68**	**37**	**4**
16-Mar-20	108	6	49	50	3	0	0	**55**	**50**	3
17-Mar-20	111	3	44	59	5	0	0	**47**	**59**	5
18-Mar-20	112	3	42	58	9	0	0	**45**	**58**	9
19-Mar-20	115	3	39	65	8	0	0	**42**	**65**	8
20-Mar-20	115	2	51	50	12	0	0	**53**	**50**	12

21-Mar-20	112	2	52	49	9	0	0	**54**	**49**	9
22-Mar-20 (Janata Curfew)	114	9	58	39	8	0	0	**67**	**39**	8
23-Mar-20	108	10	63	33	2	0	0	**73**	**33**	2
24-Mar-20	110	11	54	43	2	0	0	**65**	**43**	2
National Lockdown in effect due to COVID-19 Pandemic										
25-Mar-20	104	14	67	21	2	0	0	**81**	**21**	2
26-Mar-20	102	21	64	14	3	0	0	**85**	**14**	3
27-Mar-20	103	31	59	10	3	0	0	**90**	**10**	3
28-Mar-20	101	35	57	8	1	0	0	**92**	**8**	1
29-Mar-20	103	30	61	12	0	0	0	**91**	**12**	0
30-Mar-20	99	23	65	11	0	0	0	**88**	**11**	0
31-Mar-20	103	20	67	14	2	0	0	**87**	**14**	2
01-Apr-20	100	23	62	13	2	0	0	**85**	**13**	2
02-Apr-20	105	22	71	11	1	0	0	**93**	**11**	1
03-Apr-20	105	20	71	14	0	0	0	**91**	**14**	0
04-Apr-20	109	22	68	18	1	0	0	**90**	**18**	1
05-Apr-20	104	17	65	21	1	0	0	**82**	**21**	1
06-Apr-20	102	23	49	29	1	0	0	**72**	**29**	1
07-Apr-20	101	25	56	18	2	0	0	**81**	**18**	2
08-Apr-20	102	22	54	25	1	0	0	**76**	**25**	1
09-Apr-20	102	20	58	24	0	0	0	**78**	**24**	0
10-Apr-20	104	17	54	31	2	0	0	**71**	**31**	2
11-Apr-20	103	21	49	29	4	0	0	**70**	**29**	4
12-Apr-20	108	17	62	28	1	0	0	**79**	**28**	1
13-Apr-20	104	15	50	38	1	0	0	**65**	**38**	1
14-Apr-20	102	8	53	36	5	0	0	**61**	**36**	5
15-Apr-20	105	8	49	38	10	0	0	**57**	**38**	10

16-Apr-20	107	12	54	30	9	2	0	**66**	**30**	**11**
17-Apr-20	105	15	58	30	2	0	0	**73**	**30**	**2**
18-Apr-20	105	26	51	27	1	0	0	**77**	**27**	**1**
19-Apr-20	109	28	61	20	0	0	0	**89**	**20**	**0**
Relaxations provided in Nationwide Lockdown										
20-Apr-20	107	26	50	31	0	0	0	**76**	**31**	**0**
21-Apr-20	106	31	59	16	0	0	0	**90**	**16**	**0**
22-Apr-20	104	29	50	24	1	0	0	**79**	**24**	**1**
23-Apr-20	105	20	50	34	1	0	0	**70**	**34**	**1**
24-Apr-20	107	23	54	29	1	0	0	**77**	**29**	**1**
25-Apr-20	105	19	55	28	3	0	0	**74**	**28**	**3**
26-Apr-20	105	9	69	26	1	0	0	**78**	**26**	**1**
27-Apr-20	108	36	58	14	0	0	0	**94**	**14**	**0**
28-Apr-20	105	28	66	11	0	0	0	**94**	**11**	**0**
29-Apr-20	102	17	52	31	2	0	0	**69**	**31**	**2**
30-Apr-20	109	13	51	41	3	1	0	**64**	**41**	**4**
01-May-20	108	15	55	35	2	1	0	**70**	**35**	**3**
02-May-20	110	18	57	34	1	0	0	**75**	**34**	**1**
03-May-20	105	21	62	22	0	0	0	**83**	**22**	**0**

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


Number of cities with AQI in Good, Satisfactory and Moderate categories
Number of cities
120
100
80
60
40
20
0
01-Mar-20
03-Mar-20
05-Mar-20
07-Mar-20
09-Mar-20
11-Mar-20
13-Mar-20
15-Mar-20
17-Mar-20
19-Mar-20
21-Mar-20
23-Mar-20
25-Mar-20
27-Mar-20
29-Mar-20
31-Mar-20
02-Apr-20
04-Apr-20
06-Apr-20
08-Apr-20
10-Apr-20
12-Apr-20
14-Apr-20
16-Apr-20
18-Apr-20
20-Apr-20
22-Apr-20
24-Apr-20
26-Apr-20
28-Apr-20
30-Apr-20
02-May-20
Pre-Lockdown
Lockdown Phase-I
Lockdown Phase-II
Good
Satisfactory
Moderate

CENTRAL POLLUTION CONTROL BOARD

Ministry of Environment, Forest & Climate Change

GOVERNMENT OF INDIA

'**Parivesh Bhawan**' East Arjun nagar, delhi - 110 032 India

Phone : 011 4310 2030; twitter handle 011 43102485

website : www.cpcb.nic.in

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multicolourservices@gmail.com