COVID-19 Impact on Air Quality of Twenty-Three Most Polluted Indian Cities and Lessons to Implement Post-lockdown

Ankit Dasgotra, Vishal Kumar Singh, Gurpreet Singh, S. M. Tauseef, N. A. Siddiqui, and Suvendu Manna

1 Introduction

China, the United States and India are always considered as the main three air polluting countries in the world contributing 30%, 15% and 7% of world air pollution, respectively [1]. Also, China and India are the world's highest populated countries having combine 38 % of world's population. Coronavirus affected almost every part of the world resulted in implementing lockdown in major impacted cities. The first case was reported by china at the ending of December 2019 having its main epicentre Wuhan. COVID-19 lockdown restricted the human and vehicle moment due to sealed borders across states; industries go on shut-down stage and production got impacted majorly. These factors help nature to rejuvenate itself by reducing the air pollution to a greater extent. Air pollution is majorly measured by six factors i.e., Air Quality Index (AQI) and five air pollutants (SO_2, PM2.5, PM10, NO_2, and CO) [2]. PM2.5 and PM10 are atmospheric particulate matter having diameter equivalent or less than 2.5 μm and 10 μm, respectively. These two factors along with AQI are the main parameters to calculate air pollution quality and in general, PM2.5 level is monitored to observe the air pollution [3, 4, 5] AQI is calculated as Eq. 1 [6] (Fig. 1):

$$AQI = \frac{(PM_O - PM_L) \times (AQI_H - AQI_L)}{PM_H - PM_L} + AQI_L \quad (1)$$

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Fig. 1 Graphical abstract representation

Here,

AQI	Air Quality Index
PM_0	Observed twenty-four-hour average concentration in $\frac{\mu g}{m^3}$
PM_H	maximum concentration of AQI colour category that contains PM_0
PM_L	minimum concentration of AQI colour category that contains PM_0
AQI_H	maximum air quality index value for colour that corresponds to PM_0
AQI_L	minimum air quality index value for colour category that corresponds to PM_0

Colour category corresponds to AQI sections of health concerns as there are six categories for specific numeric value i.e., green (0–50), yellow (51–100), orange (101–150), red (151–200), purple (201–300) and maroon (301–500) [6]. Generally, red, purple and maroon colour categories are considered dangerous resulting in some serious health issues in living beings. PM maximum and minimum concentration can be categorized as mentioned in Table 1.

Recently, researchers focused on many aspects of COVID-19 pandemic related to many environmental issues and collect data for analysing the impact. Some studies are being published on-air quality-related topics covering COVID-19 epicentre city Wuhan and major COVID-19 impacted countries [2, 7, 8]. Some articles reflect air pollution problems that occurred in past in top three polluting countries, i.e., China [9, 10] and India [11]. Also, some of the recent publications covered air quality

Table 1 Air quality index breakpoint table

Category	Good (AQI: 0–50)	Moderate (AQI: 51–100)	Unhealthy for sensitive groups (AQI: 101–150)	Unhealthy (AQI: 151–200)	Very unhealthy (AQI: 201–300)	Hazardous (AQI: 301–500)
PM_2 ($\mu g/m^3$) 24 h avg	0–12	12.1–35.4	35.5–55.4	55.5–150.4	150.5–250.4	250.5–500.4
PM_{10} ($\mu g/m^3$) 24 h avg	0–54	55–154	155–254	255–354	355–424	425–604

studies in India and the impact of lockdown on major COVID-19 affected cities [3, 4, 12]. According to data aggregated from over 60,000 data points considering the main pollutant factor PM2.5, it has been noticed that 26 Indian cities are included in the top 50 polluted cities in the world in 2019. In our study, PM2.5, PM10 level of 23 most polluted Indian cities were compared during the lockdown and before the lockdown period. Lockdown related to COVID-19 has been initiated in India on 22 March 2020 imposing 14-h lockdown followed by Lockdown 1.0 from 24 March 2020 to 14 April 2020. This has been extended further as Lockdown 2.0 till 3 May 2020. In this article, the data between 22 March 2019 to 3 May 2019 and 22 March 2020 to 3 May 2020 were compared to monitor the AQI.

2 Sources of PM2.5 and PM10 Emissions in India

Transportation, industrial pollution and burning waste are the major sources of PM2.5 emission, and Brick Kilns contributes to 8–9% of industrial pollution in India. References reported that major PM10 emission existed from dust and burning waste having 45% and 17% source, respectively. Detailed data are shown in Fig. 2 [13–15].

Figures 3 and 4 show PM2.5 and PM10 emission comparison of 23 Indian polluted cities for Lockdown 1.0 and Lockdown 2.0 within the same period of last year's data. Average data have been compared for 23 most polluted Indian cities where some cities showing more than 50 % reduction in emissions. Ghaziabad has been reported as world's most polluted city [16] having 94.56 $\mu g/m^3$ of PM2.5 emission and 284.62 $\mu g/m^3$ of PM10 emission as average data collected for fixed period, i.e., 22 March 2019 to 3 May 2019. Surprisingly, it was noticed that for the same period in 2020 the PM2.5 and PM10 level reduced drastically. This data set pointing to the fact that lockdown could be a solution to control air pollution. Control of traffic and air pollutants from industries during the lockdown period and their impact on the air quality is evident from the comparison presented in Figures 2 and 3. Lockdown 1.0 and Lockdown 2.0 restricted Ghaziabad's PM2.5 emission to 58.43 $\mu g/m^3$ and PM10 emission to 123.65 $\mu g/m^3$. These data give us a rough estimation that approximately

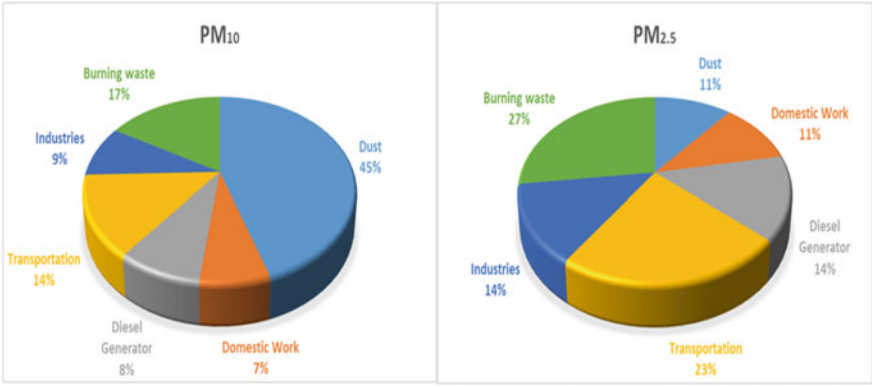

Fig. 2 PM10 and PM2.5 sources in India with their respective stats [13–15]

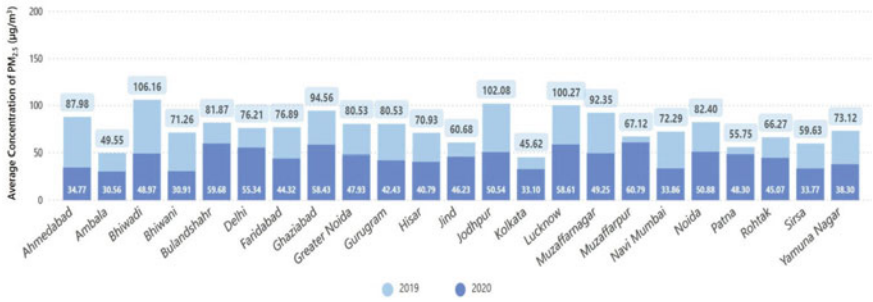

Fig. 3 Comparison of PM2.5 emission data between 22 March 2019 to 3 May 2019 and 22 March 2020 to 3 May 2020 in Indian major polluted cities [17]

38 and 57% reduction in PM2.5 and PM10 emissions took place in Ghaziabad, respectively.

Referring AQI equation and Table 1, the colour category was estimated of the city's air quality index. Based on the emission of the PM2.5 and PM10 the AQI for

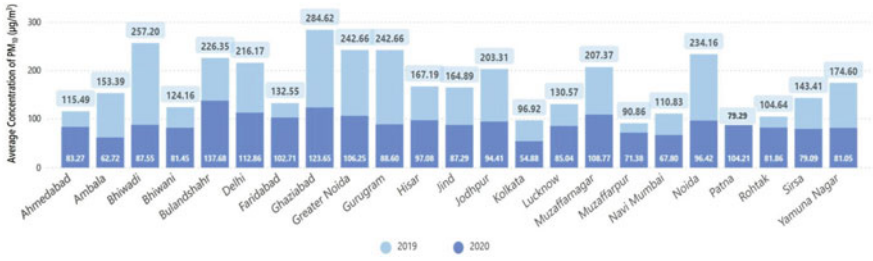

Fig. 4 Comparison of PM10 emission data between 22 March 2019 to 3 May 2019 and 22 March 2020 to 3 May 2020 in Indian major polluted cities [17]

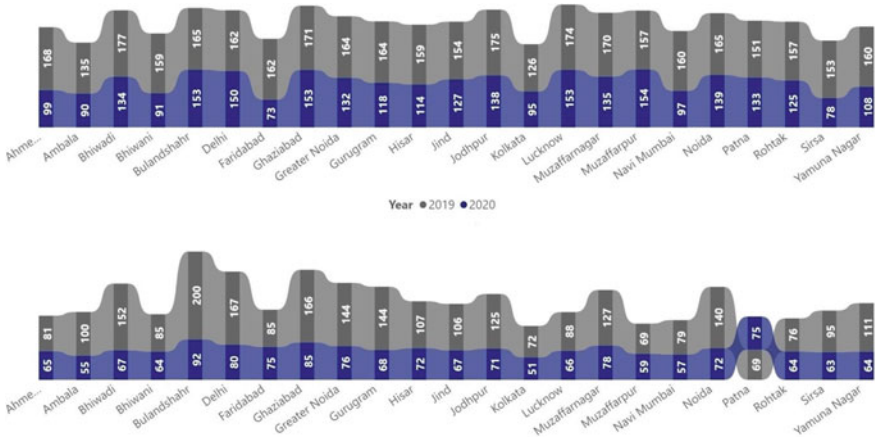

Fig. 5 Comparison of AQI of PM2.5 (above) and PM10 (below) for major polluted cities between 22 March 2019 to 3 May 2019 and 22 March 2020 to 3 May 2020 [17]

the polluted cities are compared and shown in Fig. 5. The data indicated the significant improvement in the air quality of all the cities posts lockdown due to restriction in almost all types of anthropogenic activities responsible for air pollution. While in the case of Patna city there has been variation observed in PM10 during the lockdown period which predominantly differs from the other cities. This is possibly indicating that in Patna the lockdown could not be implemented efficiently. As per the referenced Table 1, it could be said that the AQI of most of the cities shifted to unhealthy (red) to moderate (yellow) post-lockdown.

3 City Wise Data Comparison

Day-wise average PM emissions in major polluted Indian cities during 22 March–3 May 2019 and Lockdown 1.0, 2.0 are presented with Figs. 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 (See supplementary information presented at end). The data indicated that PM emissions reduced in the range of 25% and 65% due to lockdown in all the 23 Indian cities. These figures also indicated that some cities like Kolkata, Lucknow, Muzaffarpur and Bulandshahr are among the few cities which showed high PM level for the initial periods of lockdown whereas others showed high PM level at last few days. These pointing out how efficiently the lockdown was maintained day wise throughout the periods in different parts of India. These also indicate that the lockdown is not completely successful and more stringently the lockdown should be implemented in Indian cities to tackle the COVID-19 pandemic.

4 Lessons Learned and Proposal for Post-Lockdown Strategies

Green colour air quality index is categorized as a good and healthy zone. Last year's PM2.5 and PM10 emission level revealed that most of these polluted cities were marked in the red and purple zone as it referred with Table 1. The PM level for the same period this year showed that those cities air quality is mostly green, yellow and/or orange zone. COVID-19 affect badly to human health and GDP of almost all countries. But from the environmental point of view, this could be our ray of hope to clean our environment. Lockdown restricted traffic, industries and manufacturing units as people got more concerned about coronavirus transmission. Social distancing and stay at home policies have been applied all-over India as cases are still growing continuously. Global images have shown a tremendous reduction in air pollution and greenhouse gas emissions got minimal to a greater extent [2, 7, 8, 18]. Through this data analysis and comparison, we have shown our concern for global environmental conditions taking India as an example. Following points can be proposed for a fixed period every year once COVID-19 lockdown gets over.

a. 15-day vacation type lockdown can be implemented every six months imposing restrictions on personal vehicles and main polluting industries like brick kilns, etc. People will be advised to stay at their homes and to avoid unusual travel. This can help in emission reduction and nature can heel meanwhile. Effective planning will be needed here as the economy cannot be affected too much.
b. As an alternative personal vehicle, adopt cycling for short travels and public vehicles for long routes if needed. This will minimize the PM2.5 emission mainly and PM10 emission to some extent. Dust is the main source of PM10 emission, so unwanted crowd gathering and movement restriction during a fixed period will minimize its existence. Also, waste material dumping should be encouraged instead of burning it.
c. Vocational lockdown for a proposed period will state crowd/vehicle movement on hold and this will give time to municipal organizations for sanitizing or cleaning the area. Maintenance work can also be proposed more effectively.

However, implementation of these could create an economic crisis. Thus, proper legislation, a rigorous discussion is necessary to develop a sustainable economic crisis management strategy. Global fraternity and environmental policymaker should formulate strategies to minimize the economic crisis due to the propose lockdown.

5 Conclusion

Current pandemic crisis not only risk human health but also put economic growth on hold globally. However, the other side of the situation was found to be satisfying and way beyond our imagination. The comparison presented in this article indicated a

significant improvement in the air quality of the previously known most polluted 23 Indian cities. Also, analysis of the day-by-day data pointed out that not all the cities implemented the lockdown in the same way. Nevertheless, this lockdown mother nature gets the much-needed time to heal itself. As it is a temporarily influence on the environment, but international/national fraternity and policymakers should take lessons from this lockdown situation to plan future strategies to reduce pollution.

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Supplementary Information

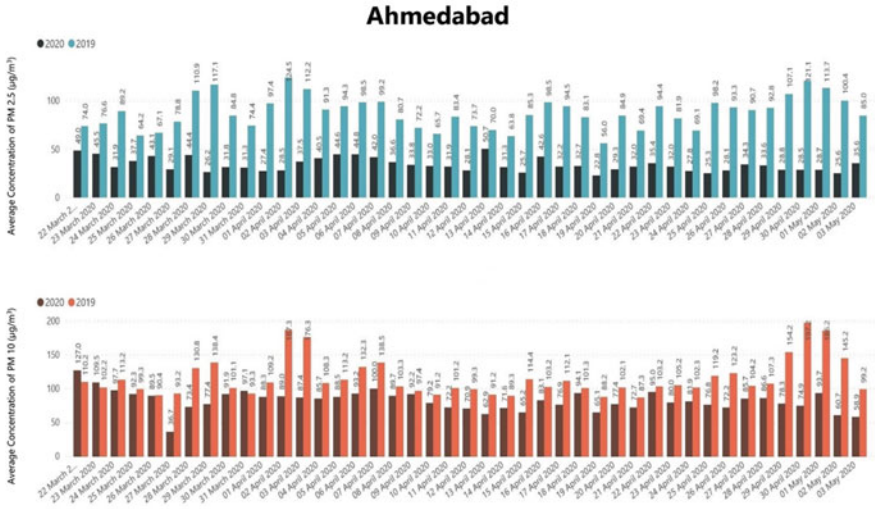

Fig. 6 $PM_{2.5}$ and PM_{10} emissions in Ahmedabad, India before and after lockdown

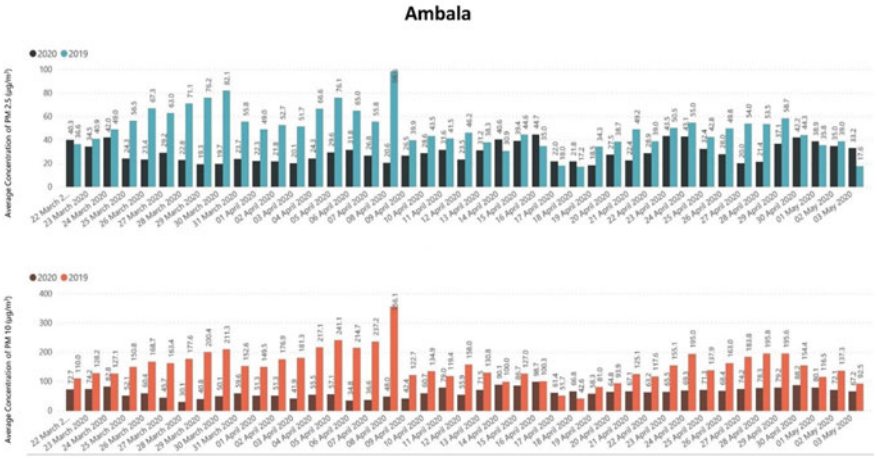

Fig. 7 $PM_{2.5}$ and PM_{10} emissions in Ambala, India before and after lockdown

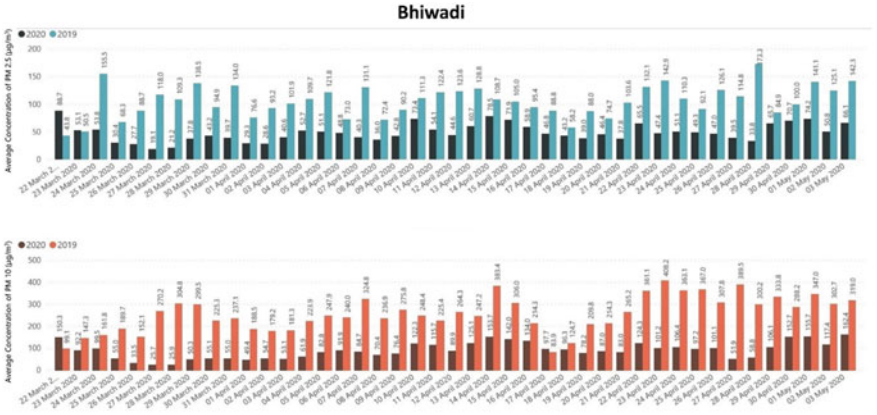

Fig. 8 $PM_{2.5}$ and PM_{10} emissions in Bhiwadi, India before and after lockdown

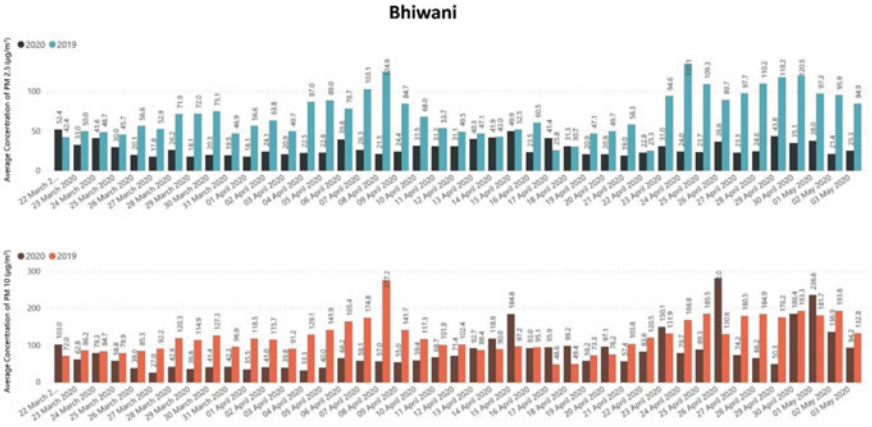

Fig. 9 $PM_{2.5}$ and PM_{10} emissions in Bhiwani, India before and after lockdown

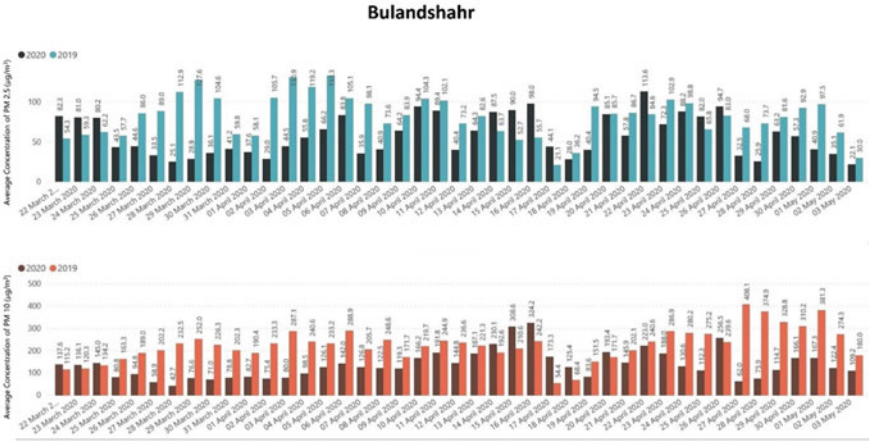

Fig. 10 $PM_{2.5}$ and PM_{10} emissions in Bulandshahr, India before and after lockdown

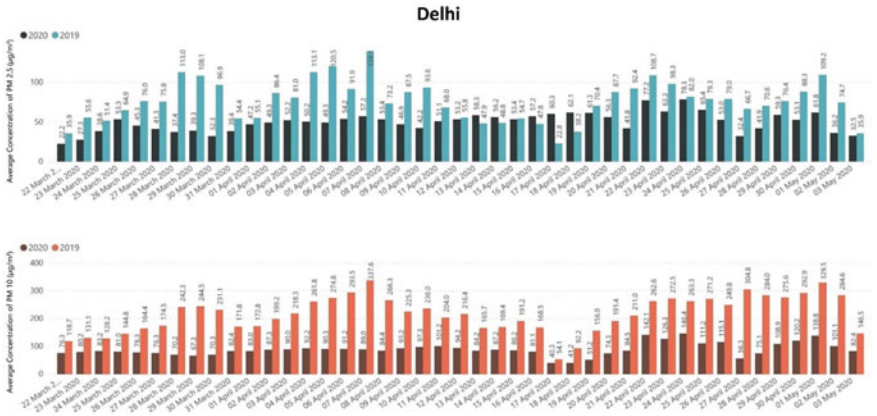

Fig. 11 $PM_{2.5}$ and PM_{10} emissions in Delhi, India before and after lockdown

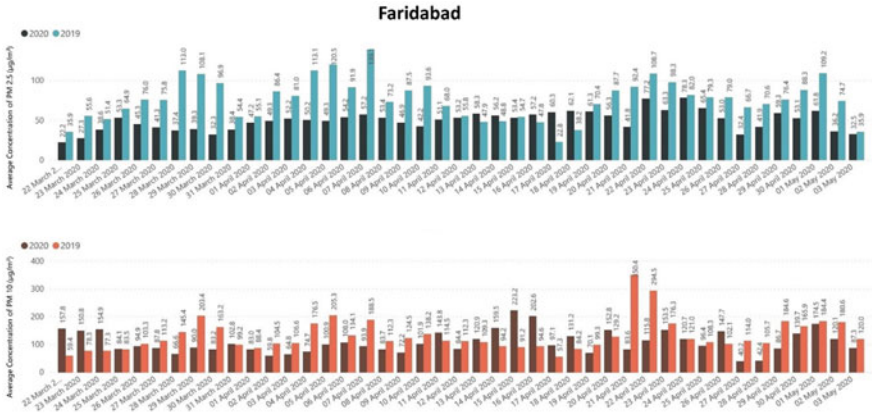

Fig. 12 $PM_{2.5}$ and PM_{10} emissions in Faridabad, India before and after lockdown

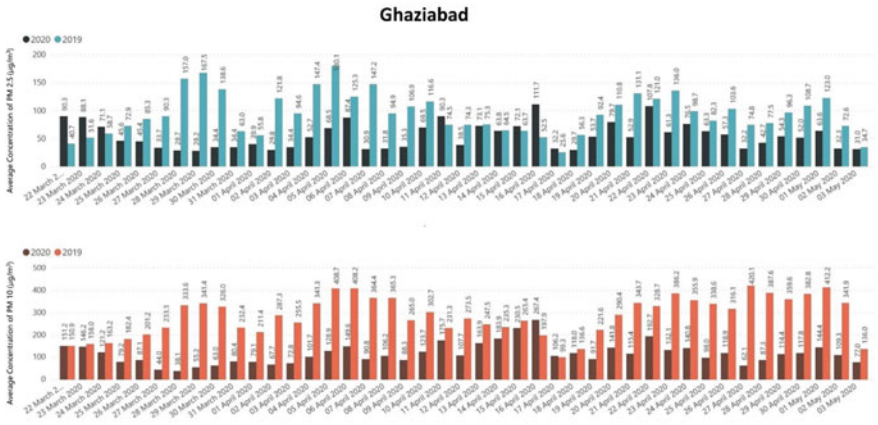

Fig. 13 $PM_{2.5}$ and PM_{10} emissions in Ghaziabad, India before and after lockdown

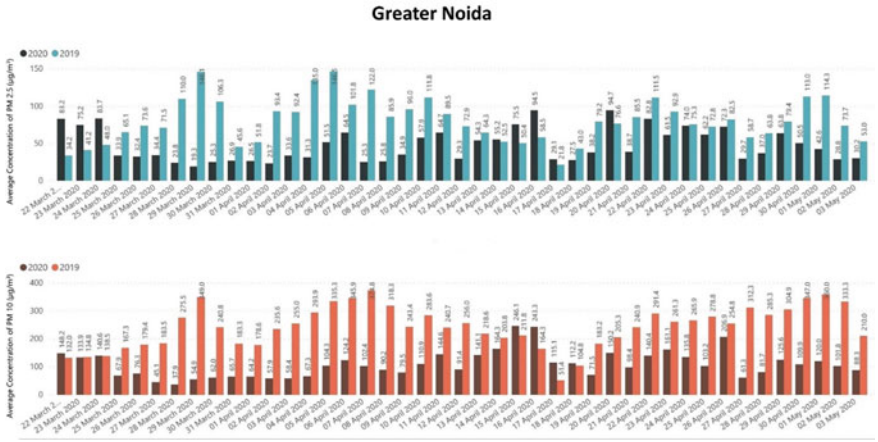

Fig. 14 $PM_{2.5}$ and PM_{10} emissions in Greater Noida, India before and after lockdown

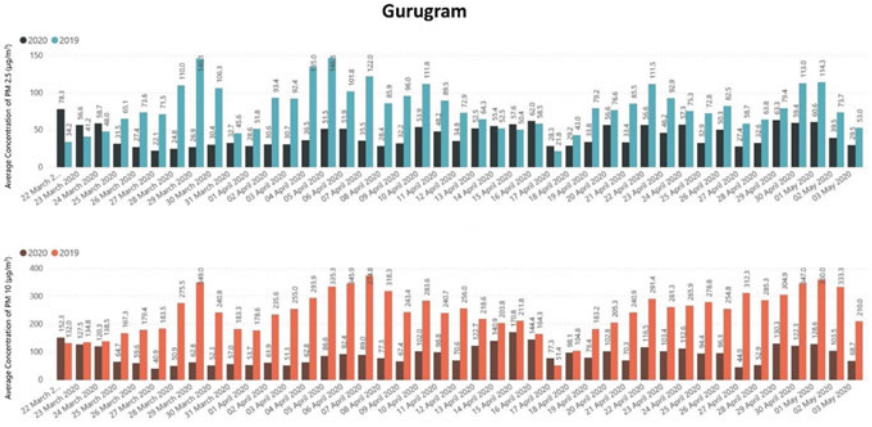

Fig. 15 $PM_{2.5}$ and PM_{10} emissions in Gurugram, India before and after lockdown

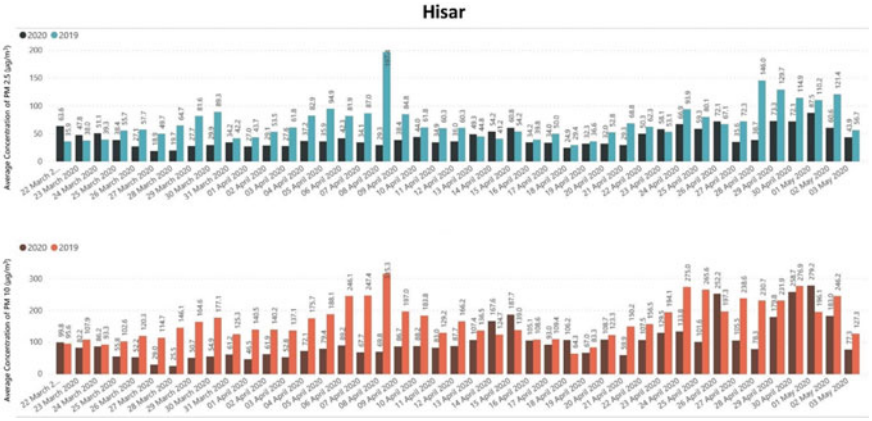

Fig. 16 $PM_{2.5}$ and PM_{10} emissions in Hisar, India before and after lockdown

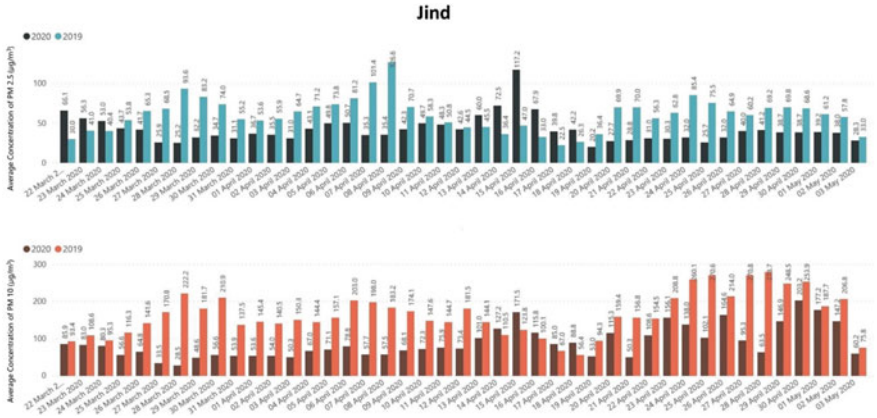

Fig. 17 $PM_{2.5}$ and PM_{10} emissions in Jind, India before and after lockdown

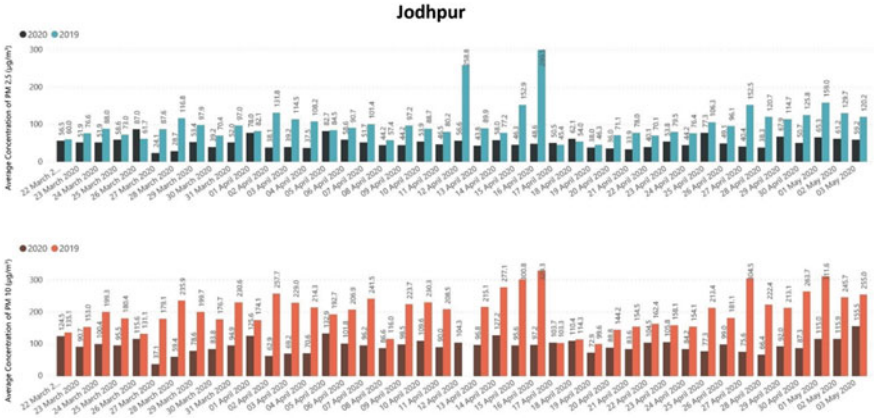

Fig. 18 $PM_{2.5}$ and PM_{10} emissions in Jodhpur, India before and after lockdown

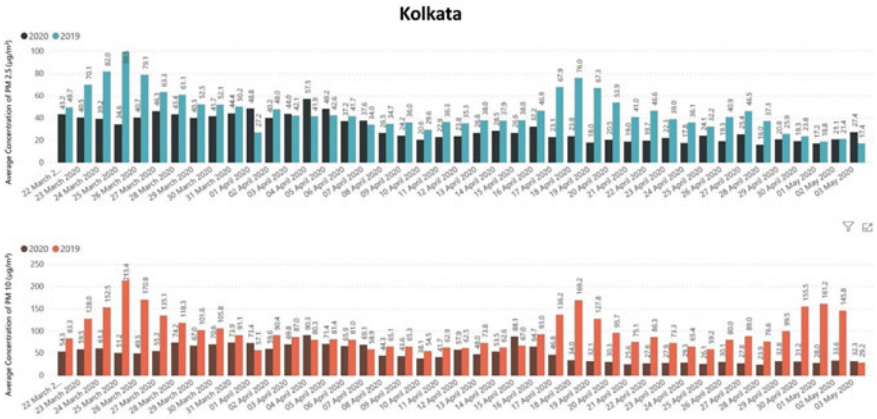

Fig. 19 $PM_{2.5}$ and PM_{10} emissions in Kolkata, India before and after lockdown

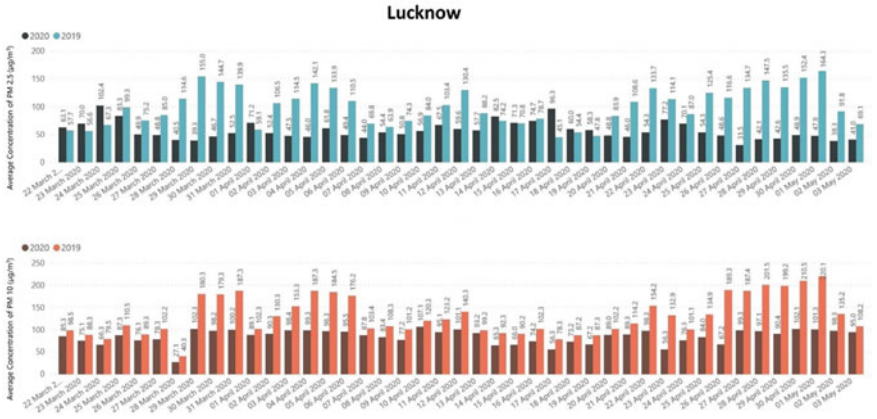

Fig. 20 $PM_{2.5}$ and PM_{10} emissions in Lucknow, India before and after lockdown

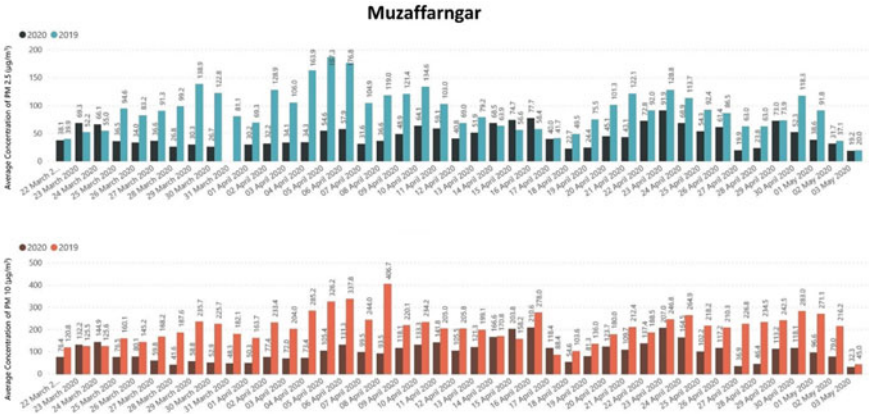

Fig. 21 $PM_{2.5}$ and PM_{10} emissions in Muzaffarnagar, India before and after lockdown

Fig. 22 $PM_{2.5}$ and PM_{10} emissions in Muzaffarpur, India before and after lockdown

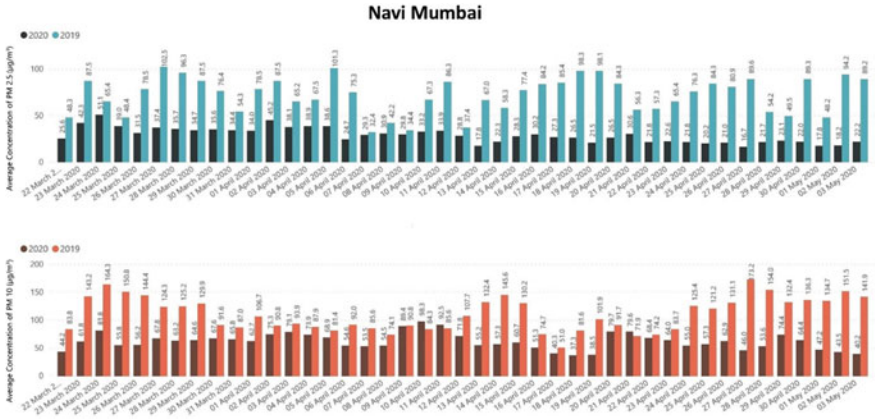

Fig. 23 $PM_{2.5}$ and PM_{10} emissions in Navi Mumbai, India before and after lockdown

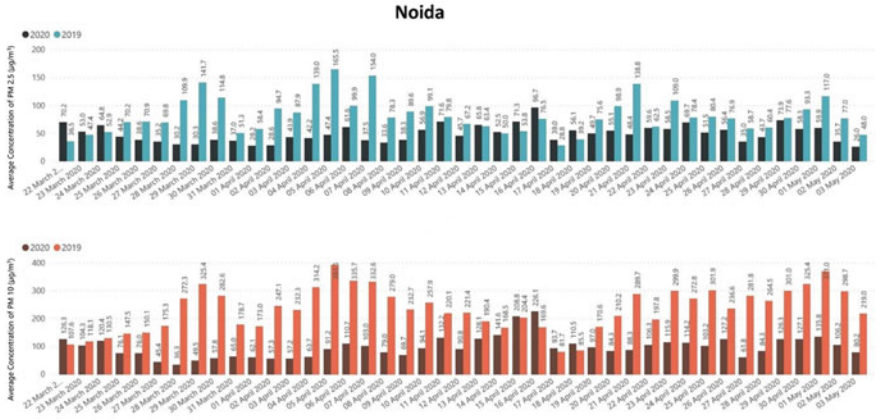

Fig. 24 $PM_{2.5}$ and PM_{10} emissions in Noida, India before and after lockdown

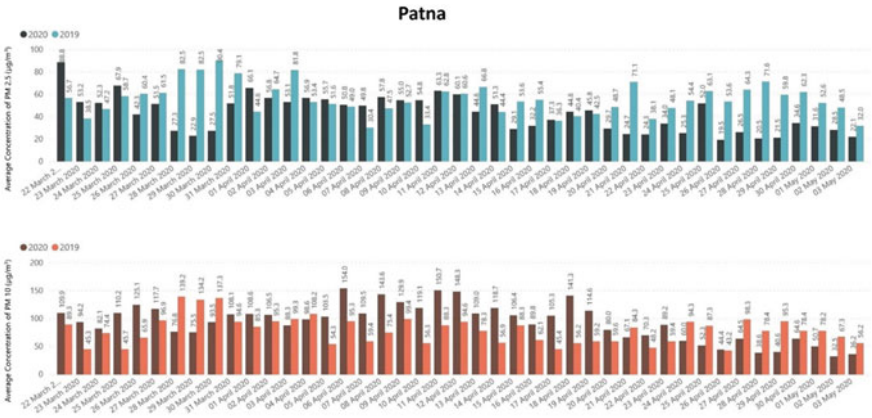

Fig. 25 $PM_{2.5}$ and PM_{10} emissions in Patna, India before and after lockdown

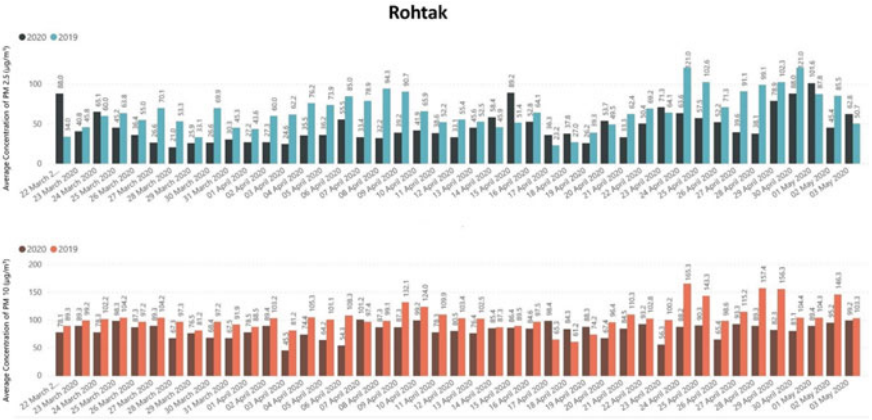

Fig. 26 $PM_{2.5}$ and PM_{10} emissions in Rohtak, India before and after lockdown

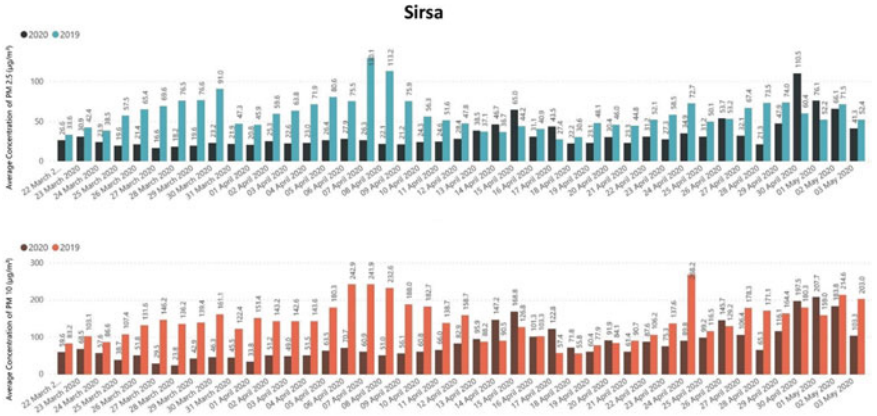

Fig. 27 $PM_{2.5}$ and PM_{10} emissions in Sirsa, India before and after lockdown

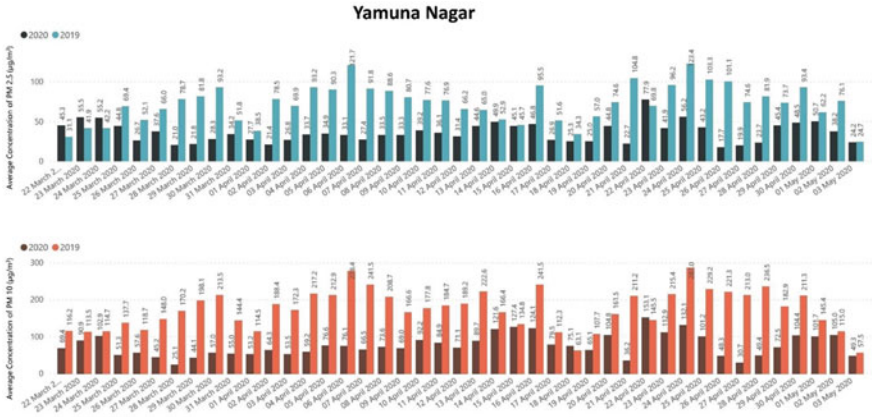

Fig. 28 $PM_{2.5}$ and PM_{10} emissions in Yamuna Nagar, India before and after lockdown

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