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Impact of SARS-CoV-2 Pandemic Lockdown on Air Quality Using Satellite Imagery with Ground Station Monitoring Data in Most Polluted City Kolkata, India

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Abstract

Immediate lockdown (March 24–May 31, 2020) of industrial activity and traffic flows has been announced by the government of India across the country after the declaration of World Health Organization that the Novel Coronavirus (SARS-CoV-2) outbreak is pandemic. In this study, we tried to estimate the air quality improvement during the pre-lockdown period (January 1–March 23, 2020) by comparing the lockdown period (March 24–May 31, 2020). From the results, we found the highest reduction in the concentration of NO_2 (81.98%) during the lockdown period. The average concentration of NO_2 was 51.57 μg/m^3 during pre-lockdown has changed to 9.29 μg/m^3. The average $PM_{2.5}$ concentration was 80.09 μg/m^3 during the pre-lockdown period has reduced to 20.24 μg/m^3 with 74.72% of reduction during the lockdown period. From the overall analysis of various parameters, we observed significant improvement with the range of 73.27–78.26% in $PM_{2.5}$, 69.01–82.55% in PM_{10}, 72.12–87.62% in NO_2, 18.61–63.19% in SO_2 and 47.16–72.11% in CO with the highest improvements in Ballygunge, Rabindra Bharati University, Ballygunge, Bidhannagar, Rabindra Sarobar and Rabindra Bharati University, respectively, with an overall average reduction in air pollutants of 53.61%. Reduction in the concentration of $PM_{2.5}$, PM_{10}, CO, NO_2 and SO_2 is mainly due to the closure of on-road vehicle emission, industrial activities, shut down of malls, shops etc. This reduced level of air pollutants may help in the modification of all the environmental policies for better air quality in future.

Keywords Air pollution · SARS-CoV-2 · NO_2 · $PM_{2.5}$ · PM_{10}

1 Introduction

On 29th December 2019, at Wuhan city, the capital of Hubei Province in China a new infectious disease (COVID-19) was first identified (Huang et al. 2020; Zhou et al. 2020a, b) and then it spread all over the world. More than 11,635,939 confirmed cases of COVID-19, including 539,026 deaths, reported to the World Health Organization (WHO). In the USA, the number of confirmed cases is more than 2 million and death cases are about 1,29,963. The other worst-affected countries such as Brazil (1,623,284 cases with 65,487 deaths), Russia (694,230 cases with 10,494 deaths), UK (285,772 cases with 44,236 deaths), Italy (241,819 cases with 34,869 deaths), France (159,568 cases with 29,831), Spain (251,789 cases with 28,388 deaths) and Mexico (261,750 cases with 31,119 deaths) have reported to WHO. The first case reported in India on January 30, 2020, and after that immediate lockdown has been announced by the Government of India throughout the entire nation on March 24, 2020, to maintain social distancing and restriction on the industrial activities, the closure of hotels, gym, universities, schools, malls, shopping malls also the restrictions in transport activities until May 31, 2020, to restrict the spread of the infectious virus. The total number of positive cases in India has increased to 6,731,665 and number of deaths rises to 19,268 (Ministry of Health and Family Welfare, Government of India) as on July 5, 2020. Maharashtra has found the highest number of positive cases (20,064 confirmed cases with 8671 deaths) followed by Tamil Nadu (107,001 confirmed cases with 1450 deaths). Other states like Delhi recorded 97,200 confirmed cases with 3004 deaths, Gujarat 35,312 confirmed cases with 1925 deaths, Uttar Pradesh

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26,554 with 773 deaths, Telangana 22,312 with 736 deaths, Karnataka 21,549 with 335 deaths and West Bengal 21,231 with 736 deaths.

Recently some of the research related to the improvement in air quality during lockdown period has been done by various researchers which were mainly related to the closure of industrial activities with a reduction in vehicle movements, such as Selvam et al. (2020) used the Central Pollution Control Board data of air pollution data ($PM_{2.5}$, PM_{10}, NO_2, SO_2 and CO) of Gujrat state of pre-lockdown and lockdown period and compared both air quality to analyse the changes in air quality and found that the concentrations of $PM_{2.5}$, PM_{10}, and NO_2 were reduced by 38–78%, 32–80% and 30–84%, respectively. The National Air Quality data used by Mahato et al. (2020) from 34 different monitoring station of Delhi and observed reduction in $PM_{2.5}$, PM_{10}, NO_2, SO_2, CO and NH_3 concentrations of 40–52% when compared the air quality data to a month before the lockdown. Tobías et al. (2020) observed an average reduction of 51% nitrogen dioxide (NO_2) and 31% in particulate matter (PM_{10}) of Barcelona in Spain when compared the air quality data in the same period over the last 4 years.

The process of urbanization witnessing all over the world but these growths are mostly concentrated in the developing countries of the world. $PM_{2.5}$ constituted 70–80% more than PM_{10} in residential areas and the major source is coal combustion activity throughout the entire community (Johann et al. 2001) and the main source of PM_{10} is motor vehicles (Anon 1995). It is also reported by the UK that the $PM_{2.5}$ comprises about 80% of PM_{10} during the month of winter, whereas it is 50% during summer months (Harrison et al. 1997). A large number of vehicular emission (40–80%) in developing countries creating the situation of air quality crisis in cities and it is the source emission of CO, toxicants and particulates (Davis 1998).

Kolkata, a major megacity in India which is overcrowded (more than 16 million of the population) and highly congested road network with a large number of vehicles. The city growth already overwhelmed with rapidly unplanned urban development. Unplanned urbanization, highly congested roads with uncontrolled vehicle density, low turnover of the old vehicle with badly cared road spaced and same time high population growth degrade the air quality. Kolkata is in serious air pollution problem out of all the major cities in India. All air pollutants (SPM, RPM, SO_2, NOx, Pb) are present in higher concentration level above the permissible limit. Leaded petrol usage is high in Kolkata than in other cities (Neelam 1993). There various factors which cause air pollution in Kolkata such as the abundance of vehicles, thermal power plants operating around the Kolkata and some small-scale industries (Mukherjee and Mukherjee, 2013; Ghose 2013). It is the third most the densely populated

metropolitan area with 14.1 million people in the country. A study of air quality data of four metropolitan areas in India indicates the higher level of pollution in Kolkata as compared to the Mumbai and Chennai and it is very close to Delhi. This research assessed the air quality changes during pre-lockdown and lockdown period by comparing the various air quality parameters ($PM_{2.5}$, PM_{10}, SO_4, CO, NO_2 and O_3) from seven air quality monitoring stations within Kolkata (Fig. 1) and tried to correlate the average percentage of reduction of air pollutants ($PM_{2.5}$, PM_{10}, NO_2, O_3, SO_2 and CO) zonewise (industrial, commercial and residential regions) to get the spatial information about the reduction of air pollutants.

2 Materials and Methods

The geospatial data of seven air quality monitoring stations at different locations in Kolkata of the CPCB (Central Pollution Control Board) data has used to evaluate the changes in air quality in different locations. In 1984, Central Pollution Control Board initiated National Ambient Air Quality Monitoring (NAAQM) at national level which was later named as The National Ambient Air Quality Monitoring Program (NAMP) to regularly monitor the ambient air quality of selected urban cities and industrial towns of the country. Under the guidance of NAMP West Bengal Pollution Control Board regularly monitor the ambient air quality of major urban town and industrial areas of the state. We have divided the seven-air quality monitoring station into three different regions of residential, commercial and industrial (Table 1). Six air quality parameters such as $PM_{2.5}$ and PM_{10}, Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), Carbon monoxide (CO) and Ozone (O_3) were used to evaluate the overall air quality of the study area. The hourly emission level of the above-mentioned pollution parameters has been obtained on daily basis from the CPCB website. Daywise data from January to May 2019 and January to May 2020 were used for the evaluation of the different parameters of air quality. Daily data were separated in terms of pre-lockdown (January 1, 2020–March 23, 2020) and lockdown period (April–May 2020). Each station data of air pollutants averaged separately for pre-lockdown and lockdown period to evaluate the percentage of changes. The mean value of air pollutant of each station used to show the geospatial distribution and variation in pre-lockdown and lockdown period of the different air pollutants in the study area. Also, we averaged all air pollutants from January to May 2019 and for the same months in 2020 to compare the mean concentration and also the percentage of reduction in the year 2019. The study area covers a total of 186.57 km^2. We used the Tropospheric monitoring instrument of Sentinel-5 product (S5p/TROPOMI)
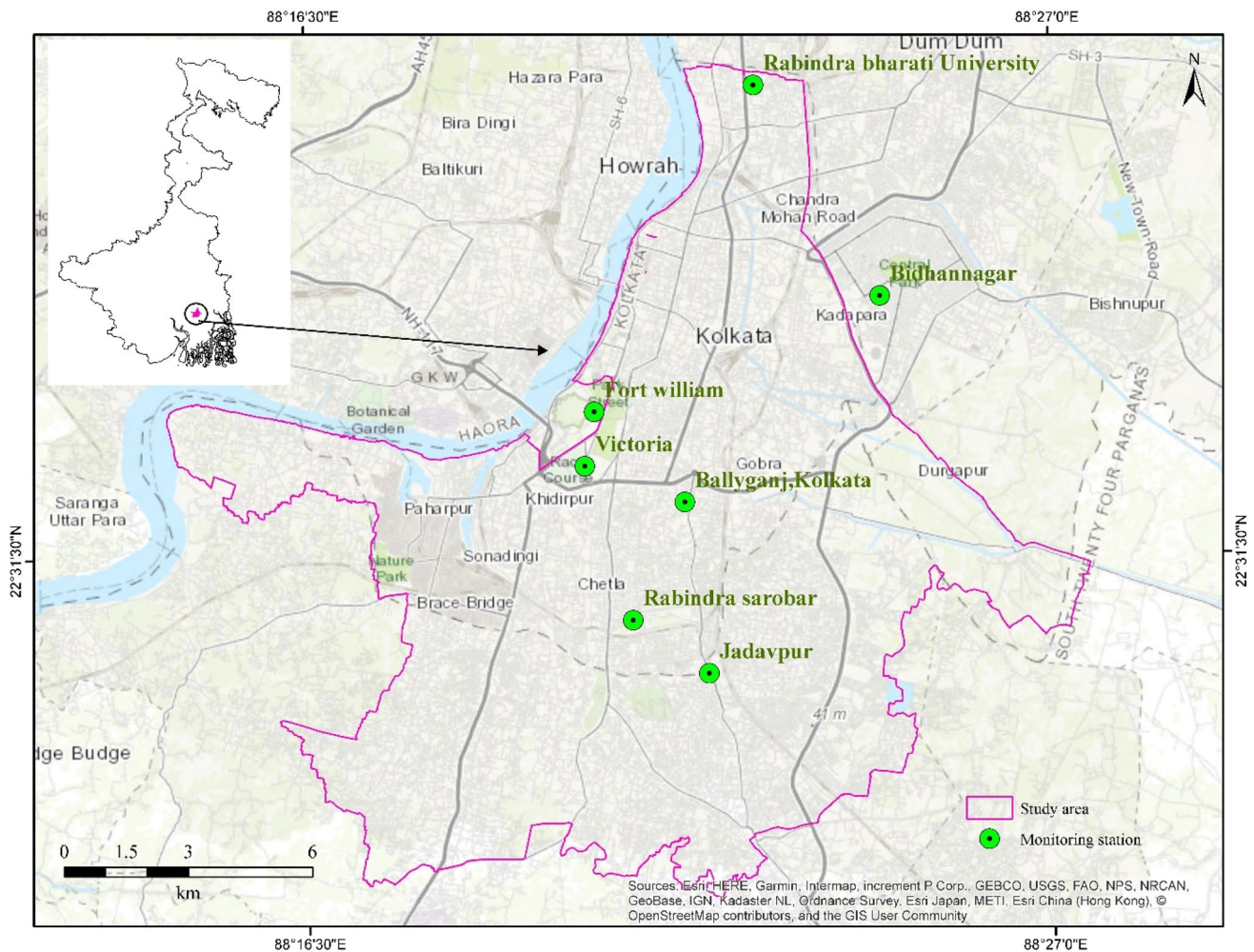
Fig. 1 Study area with air quality monitoring station

Table 1 Details description of the sample location

Sl. no	Sampling site name	Category	Latitude	Longitude
1	Bidhannagar	Residential	22.58157048	88.41002457
2	Jadavpur	Residential	22.49929	88.36917
3	Robindra Sarobar	Residential	22.51106	88.35142
4	Fort William	Commercial	22.55664	88.342674
5	Victoria	Commercial	22.5448082	88.3403691
6	Ballygunge	Industrial	22.5367507	88.3638022
7	Rabindra Bharati University	Industrial	22.627847	88.380669

Sampling location category wise

established by European Space Agency (ESA) to measure the Nitrogen dioxide (NO_2) data (mol/m^2) for pre-lockdown and lockdown period, respectively.

3 Results and Discussion

3.1 Concentration of Air Pollutants

In Bidhannagar, the mean concentration of all air pollutants reduced during the lockdown period. The mean
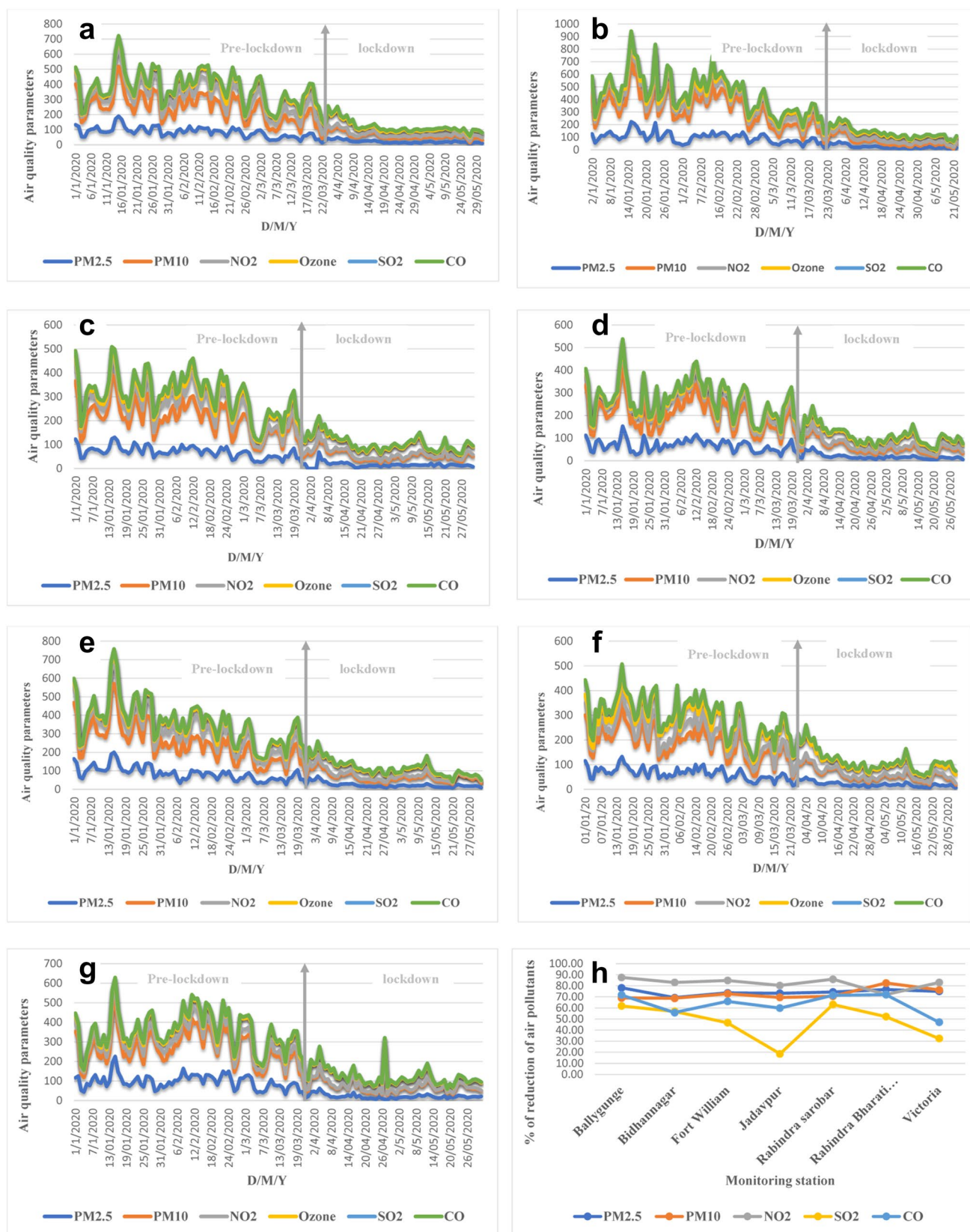
◀**Fig. 2** Daily average concentrations of air pollutants ($PM_{2.5}$ in $\mu g/m^3$, PM_{10} in $\mu g/m^3$, CO in $\mu g/m^3$, SO_2 in $\mu g/m^3$ and O_3 in $\mu g/m^3$) during pre-lockdown and lockdown periods in seven different monitoring station of Kolkata, India. **a** Victoria (Commercial region), **b** Rabindra Bharati University (Industrial region), **c** Rabindra Sarobar (Residential region), **d** Jadavpur (Residential region), **e** Fort William (Commercial region), **f** Bidhannagar (Residential region), **g** Ballygunge (Industrial region), **h** Average percentage of reduction in air pollutants station wise

concentration of $PM_{2.5}$, PM_{10}, SO_2, and CO reduced by 69.31%, 68.71%, and 56.96% (Fig. 2f, h and Table 3), respectively, during the lockdown period. The mean concentration of O_3 reduced by 24.49% during the lockdown period. Whereas in Jadavpur, the average concentration of $PM_{2.5}$ and PM_{10} during pre-lockdown was 66.50 $\mu g/m^3$ and 135.18 $\mu g/m^3$, respectively, which has reduced to 73.27% and 69.59% (Tables 2 and 3) during the lockdown period. Other air pollutants such as SO_2 and CO reduced to 18.61% and 59.93% (Fig. 2d, h), respectively, during the lockdown period. During the lockdown period, the average concentration of O_3 increased by 137.99% due to low consumption of O_3 which consequently leads to less emission of NO_2 from the various anthropogenic sources (Andrade et al. 2017; Tobias et al. 2020). The O_3 concentration above 200 $\mu g/m^3$ or 0.2 mg/m^3 is very harmful in the lower atmosphere for human health and the environment as well. During the lockdown period, the average concentration of O_3 has increased from 39.09 $\mu g/m^3$ (pre-lockdown) to 40.71 $\mu g/m^3$ due to less emission of NO_2 from the various anthropogenic sources. Reduction in NO_2 is mainly due to stop in vehicle flow and industrial activities during the lockdown period. In Robindra Sarobar, the mean concentration of $PM_{2.5}$, PM_{10} reduced by 74.48% and 70.57% (Table 3). Whereas average concentration of SO_2 and CO reduced by 63.19% and 71.50% (Table 3 and Fig. 2c, h), respectively, during lockdown period due to the stop in vehicle movements, closure of industrial activities. Whereas the mean concentration of O_3 increased by 12.78% during the lockdown period due to less emission of NO_2 from the different anthropogenic sources.

The mean concentration of $PM_{2.5}$, PM_{10}, O_3, SO_2 and CO of Fort William decreased by 73.66%, 72.82%, 7.57%, 46.73% and 65.98% (Table 3 and Fig. 2e, h), respectively, whereas in Victoria these concentrations reduced by 75.09%, 76.32%, 17.36%, 32.48% and 47.16% (Table 3 and Fig. 2a, h), respectively, during lockdown period. Reduction in PM_{10} concentration may be due to the shutdown of pharmaceutical, auto parts manufacturing and textile industries. The rate of decrease in SO_2 (46.73%) (Table 3) must be due to restrictions industrial and transport activities. The decrease in the concentration of $PM_{2.5}$, PM_{10}, CO pollutants mainly because of the closure of vehicle flows, constructional works.

Air pollutants concentration in Ballygunge mainly contributes to the transportation sectors and power plant. The concentration of air pollutants has reduced drastically during lockdown periods. The mean of $PM_{2.5}$ and PM_{10} concentration reduced by 78.26% and 69.01% (Table 3 and Fig. 2g, h), whereas the mean concentration of SO_2 and CO reduced by 61.82% and 71.77% (Table 3), respectively. The average concentration of O_3 during the pre-lockdown period was 42.84 $\mu g/m^3$ has reduced to 42.81 $\mu g/m^3$ of 0.07% of reduction during the lockdown.

The average concentration in Rabindra Bharati University of $PM_{2.5}$, PM_{10}, SO_2 and CO decreased by 76.68%, 82.55%, 58.18 and 72.11% (Fig. 2b, h), respectively, during lockdown period, whereas the mean concentration of O_3 increased by 30.82% in the region. The reduction in the concentration of SO_2 may be due to the shutdown of large, medium and small-scale industries, which are the major sources of SO_2 (He et al. 2020; Sharma et al. 2020) during the lockdown period.

3.2 Air Pollutant Comparison Between 2019 and 2020

We compared the data of January–May, 2020 with January—May, 2019 to calculate the effect of lockdown on the long-term changes in air quality (Table 4). $PM_{2.5}$ and PM_{10} concentration monitoring station maintained by CPCB provided data for the same time interval for two consecutive years. The average concentration of $PM_{2.5}$ decreased by 42.25% and mean concentration of PM_{10} decreased by 33.29% (Table 4) in 2020. Highest reduction observed in the concentration of NO_2 which is reduced by 45.25%, whereas the mean concentration of CO was decreased by 15.47%. The source of NO_2 and CO is especially from the road traffic by combustion of diesel and from gasoline transport vehicles, power plants and manufacturing industries in the city areas. The sudden stop of traffic flows during the lockdown led to decrease in the NO_2 concentration. The partial shutdown of the industries and transport sectors reduced the SO_2 concentration by 3.54% in 2020. At last, the O_3 concentration levels amplified by 31.72% in 2020 (Table 4). This is mainly due to less consumption of $O_{3\ and}$ the reduction in emission of NO_2 from the various anthropogenic sources (Andrade et al. 2017; Tobias et al. 2020). The warmer temperature and higher insolation of March to May months might have increased the levels of O_3. Results suggest that the lockdown reduced almost all the air pollutants and helped in improving the air quality. This can be considered as an alternative measure to decrease the air pollution level.

Table 2 (a) Average air pollutant concentration during Pre-lockdown period in Kolkata (Jan–March, 2020). (b) Air quality during Lockdown period in Kolkata (April–May, 2020)

(a) Station name	Air quality parameters (Pre-lockdown)					
	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	CO ($\mu g/m^3$)
Ballygunge	95.50	169.81	36.52	42.84	9.05	0.94
Bidhannagar	64.58	122.41	33.78	55.73	21.62	0.80
Fort William	85.61	160.53	66.56	38.78	10.44	0.99
Jadavpur	66.50	135.18	43.38	15.56	8.51	1.08
Rabindra Sarobar	68.22	137.99	47.49	35.73	14.86	0.88
Rabindra Bharati university	96.89	227.78	63.39	34.68	21.61	0.77
Victoria	83.32	160.53	69.87	50.31	11.93	1.27
(b) Station name	Air quality parameters during Lockdown					
	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	CO ($\mu g/m^3$)
Ballygunge	20.77	52.62	4.52	42.81	3.46	0.27
Bidhannagar	19.82	38.30	5.72	42.08	9.30	0.36
Fort William	22.55	43.63	10.09	35.84	5.56	0.34
Jadavpur	17.78	41.11	8.52	37.04	6.92	0.43
Rabindra Sarobar	17.41	40.61	6.65	40.29	5.47	0.25
Rabindra Bharati university	22.60	39.75	17.67	45.37	10.33	0.21
Victoria	20.76	38.01	11.83	41.57	8.05	0.67

Table 3 Percentage change in the mean concentration of air pollutants during pre-lockdown and lockdown period

Percentage of change between pre-lockdown and lockdown period air quality						
Station name	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	CO ($\mu g/m^3$)
Ballygunge	− 78.26	− 69.01	− 87.62	− 0.07	− 61.82	− 71.77
Bidhannagar	− 69.31	− 68.71	− 83.07	− 24.49	− 56.96	− 55.81
Fort William	− 73.66	− 72.82	− 84.85	− 7.57	− 46.73	− 65.98
Jadavpur	− 73.27	− 69.59	− 80.35	137.99	− 18.61	− 59.93
Rabindra sarobar	− 74.48	− 70.57	− 85.99	12.78	− 63.19	− 71.50
Rabindra Bharati university	− 76.68	− 82.55	− 72.12	30.82	− 52.18	− 72.11
Victoria	− 75.09	− 76.32	− 83.07	− 17.36	− 32.48	− 47.16

Table 4 Average variation between different air pollutants between 2019 (Jan–May) and 2020 (Jan–May)

Difference between the average concentration between 2019 (Jan–May) and 2020 (Jan–May)			
Air pollutants	2019 (Jan–May)	2020 (Jan–May)	Percentage of change between 2019–2020 (Jan–May)
$PM_{2.5}$	97.32	55.86	− 42.60
PM_{10}	167.94	112.02	− 33.29
NO_2	62.89	34.43	− 45.25
O_3	30.14	39.7	31.72
SO2	11.58	11.17	− 3.54
CO	0.84	0.71	− 15.47

Variations and Percentage changes in air pollutants estimated between the pre-lockdown and lockdown periods of 2020 are compared with the same interval of 2019. ($PM_{2.5}$ in $\mu g/m^3$, PM_{10} in $\mu g/m^3$, CO in $\mu g/m^3$, NO_2 in $\mu g/m^3$, SO_2 in $\mu g/m^3$ and O_3 in $\mu g/m^3$)

3.3 Spatial Distribution of Air Pollutants

From the daily data of air pollutants, the average concentration of all air pollutants during pre-lockdown and lockdown period of all the monitoring station has been calculated. We have calculated separately the average concentration of air pollutants during the pre-lockdown and lockdown period in different ground monitoring station in Kolkata. Using the latitude and longitude value of all the monitoring station the average value of all the different air pollutants has been assigned to calculate the air pollutants distribution over the study area using the software ArcGIS 10.5 version. After assigning all the average value of different pollutants ($PM_{2.5}$, PM_{10}, SO_2, CO and O_3) to all monitoring station, interpolation map (Fig. 3a, b) has been created using Inverse Distance Weighted (IDW) tool in ArcGIS (Hossain et al. 2010). Interpolation map of all the air pollutants is shown in Figs. 3 and 4. From the analysis of interpolation, it is found that the almost all the air pollutant parameters concentration level decreased in Kolkata except the O_3 concentration in Industrial region. The overall average concentration of $PM_{2.5}$ over the study area reduced by 74.87%, whereas the average concentration of PM_{10} reduced by 72.47% during the lockdown period. The mean SO_2 concentration also reduced by 82.36% in the overall study area. Using the interpolation techniques, it made it possible to calculate the mean value of each air pollutants in the whole study area and also to show the spatial variation over the study area.

3.4 Trend Analysis of NO2 Using S5p/TROPOMI

The average concentration of tropospheric NO_2 evaluated (mol/m^2) using S5p/TROPOMI of level 2 product during pre-lockdown and lockdown both period and we compared the satellite data with the ground data for validation. We processed the satellite data using Google Earth Engine (GEE) to evaluate the concentration level from satellite imagery. We have calculated the mean value of two different period data during pre-lockdown and lockdown period (Fig. 4a, b). From the analysis, we found that the overall NO_2 concentration decreased during the lockdown period when compared to pre-lockdown image data. We achieved an accuracy level of 64% of the overall NO_2 concentration in the study area. However, the percentage of accuracy level is different from place to place. We extracted the mean pixel value of each air quality monitoring station to get the proper spatial data from the imagery. When we extracted the mean values of a particular region and compared with the ground data the accuracy level has improved. The highest accuracy observed in the residential region with 78.12%, whereas it is 75.03% in the commercial region and less accuracy found in the industrial region with 72.47%. From the satellite imagery, we found the average rate of decrease of NO_2 is highest

in commercial regions (63.03%), whereas it is reduced by 56.25% in the residential region and very less reduction of NO_2 observed in the industrial region (39.86%). The concentration of NO_2 measurement form satellite imagery gives a detail spatial picture of the study area. It is very useful in the regions, where ground monitoring stations are not available.

3.5 Discussion

The worldwide human deaths are legitimately connected with respiratory ailments (26%), incessant obstructive pulmonary infection (25%), Ischaemic heart and stroke (17%) due to the risk of extreme air contamination (WHO 2020). As indicated by the United Nations Environment Program, 1.1 billion world population have been compelled to breathe in poisonous air (UNEP 2002). The major sources of air pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO) in Kolkata are heavy traffic flows, dust emissions from outdated, unwell maintained vehicles, various industries, power plants, activities of construction work, eateries which degrades the air quality standard in and around the Kolkata city.

Higher PM_{10} and $PM_{2.5}$ values have observed during the pre-lockdown period in industrial sites than any other sites, this may be because of resuspension of road dust, vehicular traffic, soil dust, construction activities and local industrial emissions. Moreover, the major source of $PM_{2.5}$ and PM_{10} are mostly released from gaseous emission of vehicles, combustion of coal, industrial chimneys and burning of municipal wastes. In general, the principal sources of NO_2 are power plants, lighting and transport sectors (Sharma et al. 2020; He et al. 2020). The other sources of NO_2 are automobile exhaust and different industrial pollutants in Kolkata (Samanta et al. 1998). At present as the country passing through lockdown situation which imposes strict quarantine rules upon residents, as a result, transportation and industrial activities are paused. Railways, airways, waterways and roadways are stopped which reduces the concentration of CO and NO_2 during the lockdown period in Kolkata. The mean concentration of SO_2 in the industrial site such as Ballygunge and Rabindra Bharati University was reduced during lockdown period due to the shutdown of industries. The residential sites such as Jadavpur, Bidhannagar and Robindra Sarobar, the mean concentration of $PM_{2.5}$, PM_{10}, NO_2, SO_2 and CO reduced drastically due to the closure of heavy traffic and vehicle movements, constructional activities, activities of eateries. The mean concentration of O_3 reduced in residential and commercial regions, whereas increased in industrial areas during the lockdown in 2020. It is also noticed that the concentration of O_3 increased (31.72%) when compared to the average concentration of 2020 with 2019 of January to May of both the years. The increase of O_3 is mainly due to the less consumption of O_3 and less
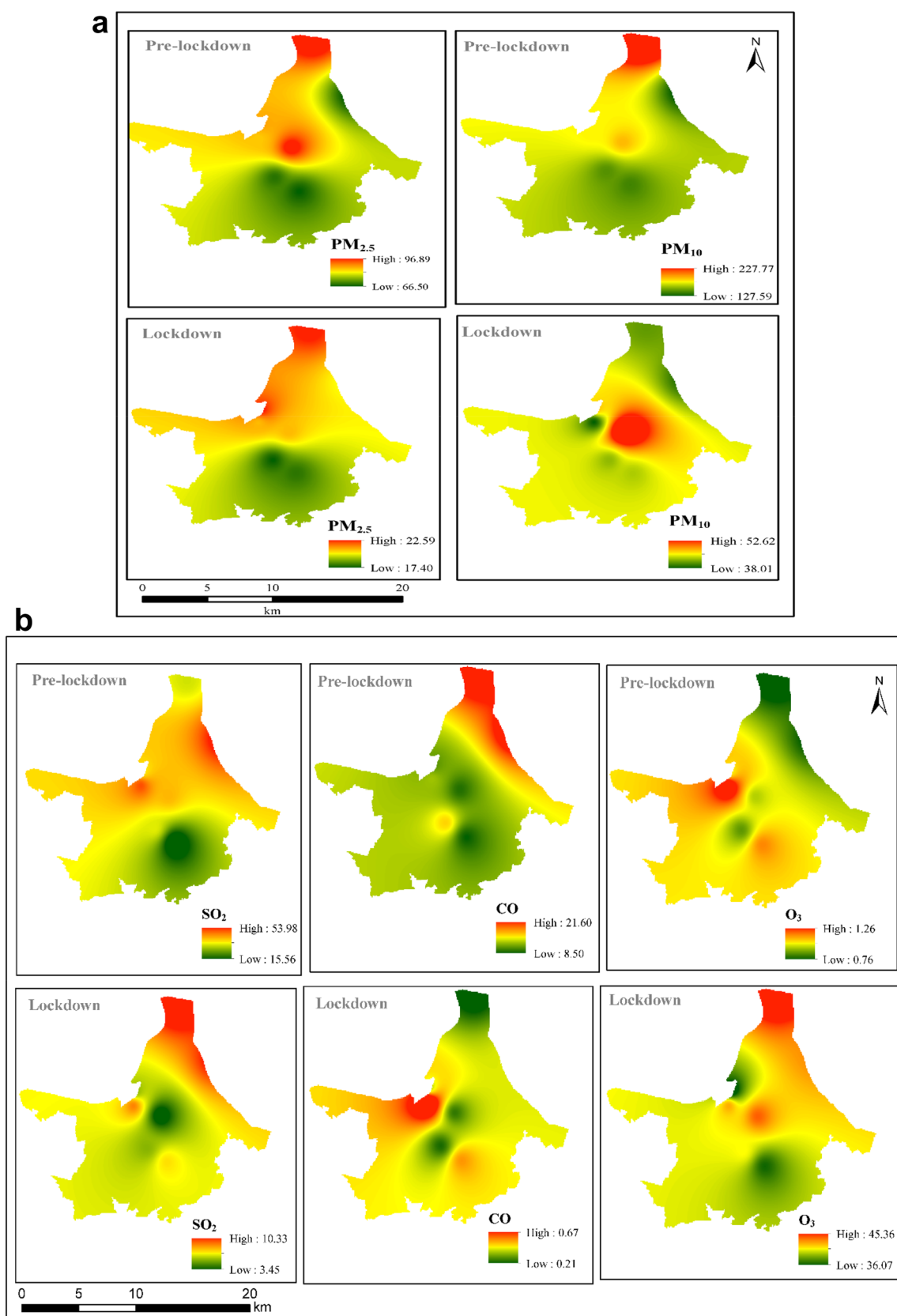
Fig. 3 **a** Spatial distribution of mean concentration of air pollutants during pre-lockdown and lockdown period ($PM_{2.5}$, PM_{10}). **b** Spatial distribution of mean concentration of air pollutants during pre-lockdown and lockdown period (SO_2, CO and O_3)
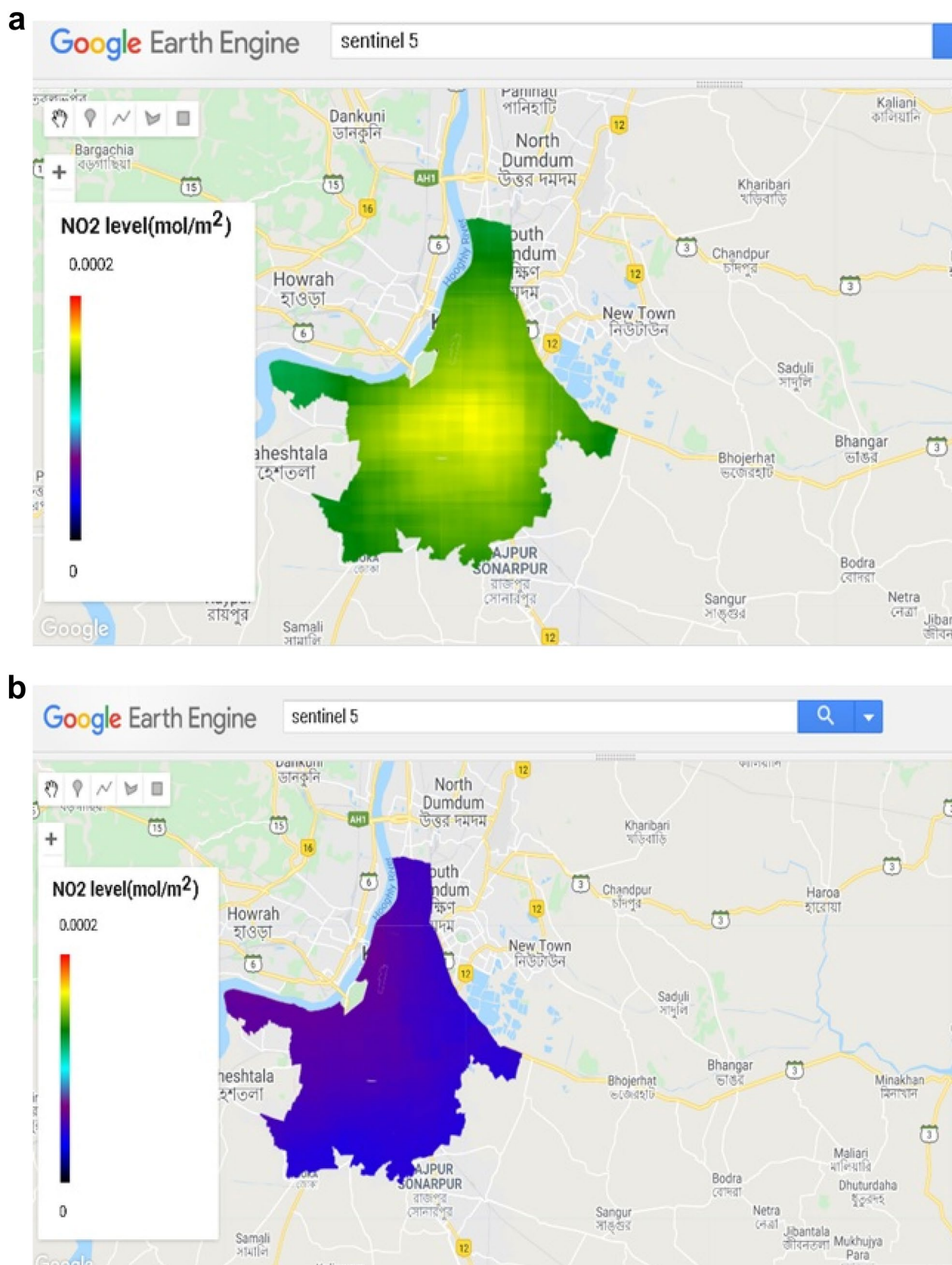
Fig. 4 Average concentration of tropospheric NO₂ measured by the S5p/TROPOMI-ESA in Kolkata, India. **a** Pre-lockdown and **b** lockdown periods

emission of NO_2 as well (Andrade et al. 2017; Tobias et al. 2020). However, it should be considered that the lockdown situation helps in the improvement of air quality and it can be an alternative measure of improving the air quality.

4 Conclusions

This study assessed the changes taken place during the lockdown (March 24, 2020–May 31, 2020) by comparing the various air pollutants concentration during pre-lockdown (January 1, 2020–March 23, 2020) period. Due to the shutdown of all industries and Vehicle movements during lockdown period improvement in various air pollutants has observed with a significant difference between various regions of industrial, commercial and residential zones in Kolkata. Various air pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2 and CO) data records from various air quality monitoring stations showed a drastic reduction in air pollutants during the lockdown period. The most significant reduction in NO_2 (83.96%) observed in commercial regions (Victoria and Fort William), whereas significant reduction also observed in $PM_{2.5}$ and PM_{10} (77.47% and 75.48%) in industrial regions (Ballygunge and Rabindra Bharati University) which is must be due to the shutdown of industries and commercial sectors and reduce vehicle movements. In residential regions (Bidhannagar, Jadavpur and Robindra Sarobar) the highest reduction has observed in NO_2 (83.14%) followed by $PM_{2.5}$ (72.35%), PM_{10} (69.62) and CO (62.41%) during lockdown period. With a short period of lockdown, the average concentration of all air pollutants reduced by 53.61% which is very significant improvements in air quality in Kolkata. This improvements in all air pollutants may help all the environmental planners in the modification of their existing plan and policies.

Compliance with Ethical Standards

Conflict of interest This is to certify that the reported work in the paper entitled "Spatio-temporal changes in air pollutants level during SARS-CoV-2 pandemic lockdown: a case study of most polluted city Kolkata, India." submitted for publication is an original one and has not been submitted for publication elsewhere. I/we further certify that proper citations to the previously reported work have been given and no data/table/figure has been quoted verbatim from other publications without giving due acknowledgement and without the permission of the author(s). The consent of all the authors of this paper has been obtained for submitting the paper to the 'Aerosol Science and Engineering'.

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