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Associated impact of the COVID-19 induced lockdown on air quality of Kolkata Metropolitan Area (India)

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Abstract

As a pandemic, COVID 19 spread worldwide in early 2020. Primarily densely populated countries had remained vulnerable due to this biological hazard. Many people were forced to stay home owing to nature of the disease and no respite. A nationwide lockdown was implemented in India for 29 days (March 24th to April 21st) of 2020 during the wake of the COVID-19 pandemic. During the nationwide lockdown, industries, transport, and other commercial activities were suspended, except for necessary services. During the entire pandemic situation, an affirmative impact was observed as the air quality was reported to have improved worldwide. The complete economic lockdown to check COVID-19, brought unforeseen relief from severe condition of air quality. An apparent, reduction in level of PM2.5 and Air Quality Index (AQI) was experienced over Mumbai, Delhi, Kolkata, Hyderabad, and Chennai.

Present work explores the various metrics of air pollution in Kolkata, West Bengal, India (imposed as a result of containment measure for COVID-19). The polluting parameters (e.g., PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3, and NH_3) were chosen for seven monitoring stations (Ballygunge, Fort William, Victoria, Bidhannagar, Jadavpur, Rabindra Bharati, Rabindra Sarabar), which are spread across the metropolitan area of Kolkata. National Air Quality Index (NAQI) has been used to show pre-and during-lockdown air quality spatial patterns. The findings showed major changes in air quality throughout the lockdown period. The highest reduction in pollutants emission was observed for: PM_{10} (-60.82%), $PM_{2.5}$ (-45.05%) and NO_2 (-62.27%), followed by NH_3 (-32.12%) and SO_2 (-32.00%), CO (-47.46%), O_3 (15.10%). During the lockdown, the NAQI value was reduced by 52.93% in the study area.

Keywords: *air pollution, COVID-19, lockdown, National Air Quality Index, Kolkata Metropolitan Area*

Rezumat. Impactul asociat lockdown-ului generat de Covid-19 asupra calității aerului din zona metropolitană Calcutta

Pandemia de Covid-19 s-a răspândit la nivel mondial la începutul anului 2020, iar statele dens populate au rămas vulnerabile în fața acestui biohazard. Multe persoane au fost forțate să rămână acasă datorită modului de răspâdire a bolii. Prin urmare, un lockdown la nivel național a fost implementat în India pentru 29 de zile (24 martie – 21 aprilie 2020), la începutul pandemiei de COVID-19. În această perioadă, au fost suspendate toate activitățile industriale, de transport si comerciale, cu excepția serviciilor esențiale. Pe întreaga perioadă a pandemiei a fost observat un impact pozitiv asupra calității aerului la nivel mondial și național, perioada de lockdown generând o îmbunătățire a poluării aeriene severe. Aparent, o reduce a nivelului de PM 2.5 și a Indicelui de calitate a aerului afost înregistra și la Mumbay, Delhi, Kalcutta, Hyeabad și Chennai.

Lucrarea de față analizează diferiți parametri pentru poluarea aerului în Calcutta, Bengalul de Vest, India (ca urmare a măsurilor restrictive impuse de Covid-19). Parametrii de poluare (ex. PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3, NH_3) au fost aleși pentru 7 stații de monitorizare (Ballygunge, Fort William, Victoria, Bidhannagar, Jadavpur, Rabindra Bharati, Rabindra Sarabar) situate în zona metropolitană Calcutta. Indicele calității aerului la nivel național (NAQI) a fost utilizat pentru a arăta tiparele spațiale privind calitatea aerului în perioada înainte și în timpul lockdown-ului. Cea mai mare reducere la emisiile de poluanți a fost observată pentru PM_{10} (-60.82%), $PM_{2.5}$ (-45.05%) și NO_2 (-62.27%), urmat de NH_3 (-32.12%) și SO_2 (-32.00%), CO (-47.46%), O_3 (15.10%) și O_3 (-32.12%). De la începutul până la finalul lockdown-ului, valoarea NAQI s-a redus cu 52.93% în aria analizată.

Cuvinte-cheie: *poluarea aerului, Covid-19, lockdown, indicele calității aerului la nivel național, zona metropolitană Calcutta*

Introduction

The detrimental environmental impact is predominantly caused by air pollution, which is a serious global problem for both developing and developed countries. As per the report of WHO (2014b), the annual concentration level of PM_{10} is found maximum in Peshawar (Pakistan) (540 ug/m^3) followed by Rawalpindi (Pakistan) (448 ug/m^3), Mazar-e-Sharif (Afghanistan) (334 ug/m^3), and Gwalior (India) (329 ug/m^3). Globally, annual levels of PM10 increased by 6 percent during 2009 to 2012 in various cities of world (WHO, 2014b). It has been reported that, 193,000 people died in Europe in 2012 as a consequence of airborne particulate matter (Ortiz et al., 2017). Premature deaths occurred due to $PM_{2.5}$ exposure in 2012 in 40 European countries and the EU 28 e.g. Germany (59500 deaths), Poland (44600 deaths), France (43400 deaths), Italy (59500 deaths), United Kingdom (37800 deaths) etc. (EAA,

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2015). A new National Emissions reduction Commitments (NEC) Directive (2016/2284/EU) entered into force on 31 December 2016 replacing earlier legislation, (Directive 2001/81/EC). The new NEC Directive sets 2020 and 2030 emission reduction commitments for five main air pollutants (nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2), ammonia (NH_3) and fine particulate matter ($PM_{2.5}$) (EAA, 2017).

Urban areas are the hub of air pollution for its unabated growth of vehicles and industries. The megacities of Asia (Shanghai, Beijing, Delhi, Karachi (Pakistan), Tokyo, Mumbai etc. and Africa (Lagos, Cairo, Algiers, Casablanca etc.) will have a predicted 90% population increase by the end of 2050 (World Urbanization Prospect 2018 Revision). India faces the challenge of economic development along with ever-increasing population growth leading to the enhanced pollution level. Unprecedented rises by 15% have been noted in the domestic made vehicle sector (SIAM 2013). According to Amann et al. (2017), a rapid rise of 200% in the transportation sector is expected between the years 2015 and 2030, which will lead to an increase in the traffic population by 10.5%/year (MoSPI, 2015). The ever-increasing urbanization will lead to an increase in power generation by 11.1%/year (CEA 2015; 2016). In India industrial emissions lead to 51% of pollution, while vehicular emissions, crop burning, and festival fireworks are responsible for 27%, 17%, and 5% of pollution respectively (Indian Express, 2019). Thus, urbanization is an important catalyst of air pollution for Indian cities.

Air pollution is the leading contributor to premature deaths of 2 million Indians/year (Health Impact Institute, 2018 & WHO, 2021). According to the Census report of India 2011, 53 Indian megacities Mumbai, Delhi, Kolkata Bangalore etc. have been identified as hotspots of air pollution. The city of Kolkata in the West Bengal state of India is one of the hotspots of air pollution, which has been seriously affected by air pollution (Goyal, et al., 2003; Amann, 2017; Gulia, 2018; Kanawade, 2020). According to the World Health Organization (WHO), 140 million Indians are forced to breathe air that is more than ten times the WHO acceptable limit, resulting in premature deaths and poor public health effects such as severe lung illnesses, breathing issues, severe asthma, pneumonia, and so on (WHO, 2016; Heal, 2012; Dholakia, 2013). High air pollution is the reason for paramount public health desires (Heal, 2012; Dholakia, 2013; Rizwan, 2013).

Thus, air quality improvement and management are the primary concern of urbanization both in the developed and developing world. The extent of air pollution can be assessed through the statistical technique of 'Air Quality Index which is derived from various air quality measurements indices such as "Pollutant Standards Index (Ott and Hunt, 1976; USEPA 1994), Green Index (Green 1966), Penstock Air Quality Index (Fenstock 1969), Ontario Air Pollution Index (OAPI) (Shenfeld 1970), and Common Air Quality Index, (CAQI) (van den Elshout et al., 2008)". India initiated the National Air Quality Monitoring Program in 1984 and 2014 an index of air quality monitoring was developed as "National Air Quality Index (NAQI) by CPCB (Central Pollution Control Board)". Proper and timely monitoring of air pollution levels is indispensable for sustainable economic management and for policymakers to take suitable steps towards sustainable environmental goals.

Lockdown has a significant influence on air quality all across the world. Recent studies have revealed a link between improvements in air quality and partial or complete lockdowns, as well as the resulting decline in activities and emissions from sources such as road traffic and industrial operations. After the global lockdown, a considerable drop in NO_2 and other major pollutants are seen. The decrease in transportation emissions in cities is mostly accountable for this (Yaron 2020; Kerimray et al 2020). Delhi, India is used as the case study location in Mahato et al. (2020) investigation of air quality during lockdown conditions. According to the research, $PM_{2.5}$ and PM_{10} levels are now 50% lower than they were before to the lockdown. Using satellite and ground measurements, Ramesh P. and Chauhan (2020) provide a research to assess the quality of the air throughout India during the lockdown. Additionally in various other works the impact of COVID-19 on the air quality of various places of India has been studied (Singh et al 2020; Mahato et al 2020; Kumari et al 2021).

Recent data released by NASA (National Aeronautics and Space Administration, 2020) and ESA (European Space Agency, 2020) indicates that pollution in some of the epicenters of COVID-19 such as Wuhan, Italy, Spain and USA etc. has reduced up to 30%. In spite of pandemic, its indirect effect has played a positive role on nature by healing nature of pollution and thus can be termed as "Blessing in disguise". In India such kind of studies has been conducted in various cities. However the megacity of Kolkata lacks such work. Our work thus attempts to investigate COVID-19 lock down effect as a panacea of reduction of air pollution.

In this work, the authors have implemented the NAQI to assess the nature of air quality change in the Metropolitan area of Kolkata city during the nationwide 'lockdown owing to COVID-19'. Lockdown mechanisms were implemented in India in stages, in the first stage from "24^{th} March to 14^{th} April2020; second stage 15^{th} April to 3^{rd} May2020 and third stage 4^{th} May to 17^{th} May 2020". This unprecedented step forced to halt all the economic and commercial activities, thereby drastically reducing the urban air pollution level.

Study Area

Kolkata the capital city of the state of West Bengal, India is located at 22°57′26″ N and 88°36′39″ E on the eastern bank of Hooghly River. The city (Fig. 1) is spread on an area of 206.08 Km^2.The city of Kolkata has a tropical monsoonal climate having mean annual temperature of 25° C. The maximum temperature during summer touches up to 40° C while the minimum temperature is 10° C. The average annual rainfall is 1836.5 mm with the maximum rainfall occurring in August (328 mm). Throughout the year, winds in Kolkata blow at an average speed of 7 km/h. mostly southeast and southwest winds are blowing (Gupta et al 2008). 1428 W/m^2 is the average solar radiation measurement (Gupta et al 2006.) According to the Indian Metrological Department, the south-west and north-east monsoons have an impact on both the summer and winter climate. The city is located in the alluvial plain of the lower Ganga basin.

According to the 2011 census, the city's population is 4.5 million (inside city boundaries) and the Kolkata metropolitan area has a headcount of about 14.1 million people (Census of India, 2011). The density of population is 24000/Km^2 and the city is India's seventh most populous city. It is the cultural and educational center of India and is also home to the country's third-largest urban economy. Steel, heavy engineering, mining, minerals, cement, pharmaceuticals, food processing, agriculture, electronics, textiles, and jute are just a few of the sectors that have sprouted up in the capital. According to the International Association of Public transport (2013), Kolkata's public transportation system is considered to be the most progressive in India (Little, 2014). As a result of its increasing urbanization and industrialized activities, as well as its overcrowding, pollution is a serious concern in Kolkata. The pollution level (Table 1) of the city is seven times more than the limit set by WHO. The city is in the 25^{th} rank in terms of air pollution (WHO, 2016).

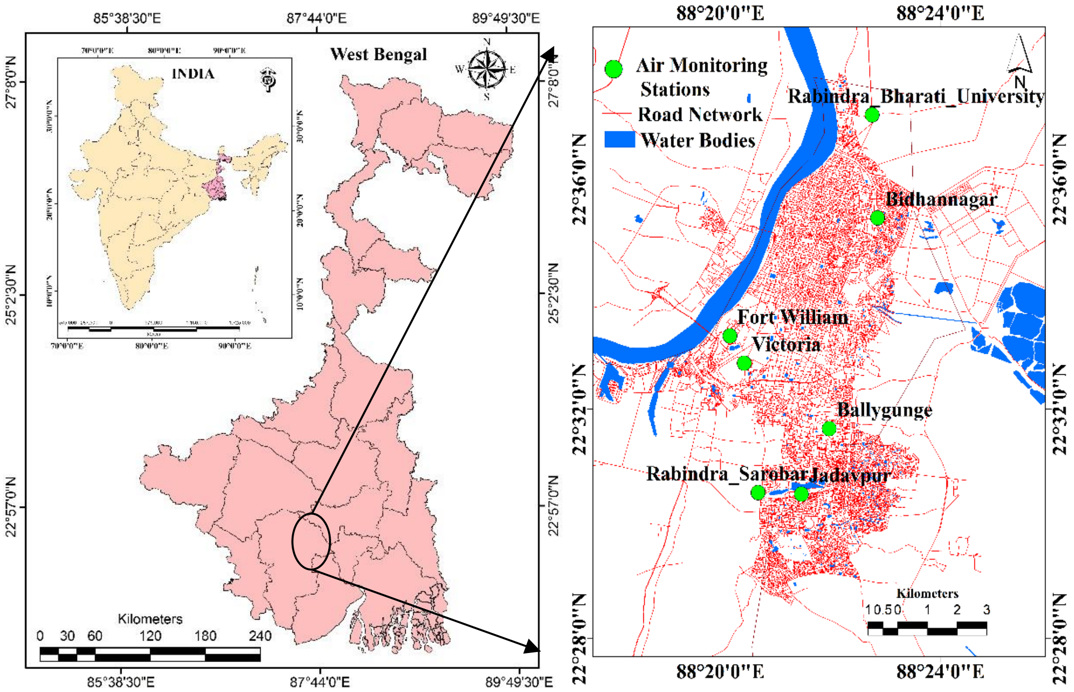

Fig. 1: Location of West Bengal state in eastern part of India (left side) and the study area (Kolkata city) in southern part of West Bengal (right side)

Materials and methods

Data from eight sites covering the whole megacity were used to determine the air quality status (CPCB, 2015) of Kolkata city throughout the lockdown period. The central pollution control board set the national standard of air pollutants given in Table 1. For the calculation of AQI the concentrations of air contaminants on a daily and hourly basis are necessary to be incorporated (Mahato et al., 2020). The Central Pollution Control Board collected Particulate Matters ($PM_{2.5}$ and PM_{10}), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Ozone (O_3), and Ammonia (NH_3). The Air

Quality Index (AQI) is computed using suspended contaminants and the number of individual pollutants, then processed into an index using a logical aggregation method (Ott, 1978). Five pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO) were used to create the AQ sub-index (Sharma, 2001). The detailed methodology is presented in Figure 2. Pune IITM has just developed a new indexing approach based on the O_3 sub-index (Beig et al., 2010).On a five-point scale, the IITM-AQI has classified air quality as very unhealthy, very poor, poor, moderate, and good. The updated Indian National Air Quality Standards of the Pollution Control Board (2015) took twelve factors into account while calculating air quality standards, including Particulate Matter (PM) larger than 2.5 microns ($PM_{2.5}$), Ammonia (NH_3), Particulate Matter (PM) larger than 10 microns (PM_{10}), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Benzo(a)Pyrene (BaP), Arsenic (As), Ozone (O_3), Lead (Pb), Benzene (C_6H_6), and Nickel (AQI). Only four of the twelve parameters have yearly norms, whereas the remaining eight have both short-term (1/8/24 hours) and annual standards (except for CO and O_3) (Table 1).

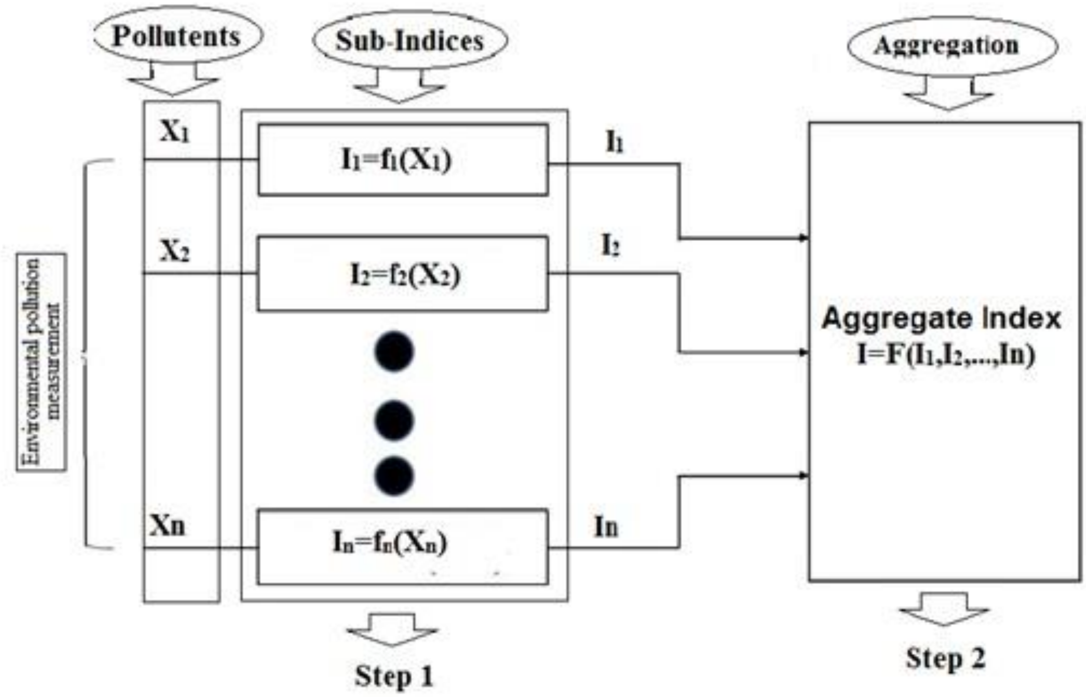

Fig. 2: Flow chart of the methodology

Table 1: Revised Indian National Air Quality Standards (INAQS)

Pollutants	**Time Weighted Average**	**Industrial, residential and other are**	**Economically sensitive area**
		The concentration of ambient air	
$PM_{2.5}$ (µg/m^3)	24 hrs	60	60
PM_{10} (µg/m^3)	24 hrs	100	100
SO_2 (µg/m^3)	24 hrs	80	80
NO_2 (µg/m^3)	24 hrs	80	80
O_3 (µg/m^3)	1 hrs	180	180
CO (mg/m^3)	8 hrs; 1 hrs	2; 4	2; 4
NH_3 (µg/m^3)	24 hrs	400	400

Source: CPCB (2015)

The current study studied the AQI levels during the lockdown period and correlated them to the levels before the lockdown. The parameters are chosen mostly based on the previously stated goals, the time duration, the consistency of monitoring data, and accessibility. Furthermore, six NAQI categories developed by the CPCB (2015) are used to present the projected health exposure, also known as Health Breakpoints, in the current scheme (Table 2).

Table 2: National AQI classes, health breakpoints for the seven pollutants and range, health impacts (Scale: 0-500)

AQI Class	Concentration Range						
	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (µg/m^3)	NO_2 (µg/m^3)	O_3 (µg/m^3)	CO (mg/m^3)	NH_3 (µg/m^3)
Good (0–50)	0–50	0–30	0–40	0–40	0–50	0–1	0–200
Satisfactory (51–100)	51–100	31–60	41–80	41–80	51–100	1.1 - 2	201–400
Moderately polluted (101– 200)	101–250	61–90	81–380	81–180	101–168	2.1–10	401–800
Poor (201–300)	251–350	91–120	381–800	181–280	169–208	10–17	801–1200
Very poor (301–400)	351–430	121–250	801–1600	281–400	209–748*	17–34	1200–1800
Severe (401–500)	>430	>250	>1600	>400	>748	>34	>1800

** CO in mg/m^3 and other pollutants 24 hourly average values for PM_{10}, $PM_{2.5}$, NO_2, SO_2, and NH_3 8-hourly values for CO and O_3.*

Source: CPCB (2015)

Results

Changing trend and concentrations of pollutants for the pre-lockdown and during lockdown period

A continuous trend of reduction in pollutants was recorded due to the commencement of lockdown. The changing character of major air pollutant components: $PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2, CO, and O_3 were monitored in two phases, during pre-lockdown (3rd March to 17th March) and during-lockdown (31st March to 21st April). Study shows that the pollution level of the city has witnessed a major reduction of pollution (Table 3).

A significant change in concentration of $PM_{2.5}$ and PM_{10} was recorded at Pre-Lockdown and during Lockdown. On 3rd March $PM_{2.5}$ and PM_{10} were computed very high and beyond the permissible level (181.71, 141.29), while with the commencement of lockdown the concentration of $PM_{2.5}$ and PM_{10} fell drastically (50.38, 55.83). It fell further to 23.67 and 30.57 on 21st April.

Table 3: Concentrations of major pollutants during the pre-lockdown and lockdown period and AQI

Air Pollutants (Average of 24 hours)	Pre-Lockdown			Commence-ment of Lock-down	During Lockdown				Change (%)
	3rdMar	10thMar	17thMar	24thMar	31stMar	07thApr	14thApr	21thApr	
$PM_{2.5}$	187.71	116.00	121.57	50.83	58.60	63.43	40.86	23.67	-60.82
PM_{10}	141.29	103.14	113.71	55.83	74.20	73.29	49.43	30.57	-45.05
NO_2	59.86	44.86	46.43	18.50	25.00	18.71	9.29	11.00	-62.27
NH_3	6.71	5.57	5.57	5.17	5.20	4.14	3.29	3.00	-32.12
SO_2	18.00	13.14	21.14	12.50	14.20	13.57	8.43	7.86	-32.00
CO	44.71	54.86	43.00	25.50	35.20	20.57	16.71	15.14	-47.86
O_3	37.71	25.71	22.14	21.17	32.00	30.43	25.86	34.57	15.10
AQI	187.71	118.57	126.00	51.14	59.00	74.57	49.43	44.57	-52.93

Source: Computed by authors

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Thus, the trend of average percentage was counted as -60.82% and -45.05%. NO_2 and NH_3 were beyond the standard permissible limit of WHO on 3rd March (59.86, 6.71). Rapid diminution was recorded from 24th March (Commencement of lockdown) and it reduced down to 11.00 and 3.00 on 21st April. In comparison between the two phases (Pre-Lockdown and during Lockdown), the highest and lowest changer in the concentration level of pollutants was NO_2 -62.27%, and NH_3 -32.12%. For SO_2 average concentration during pre-lockdown and lockdown was 17.52 and 11.02 respectively (Fig. 3). Only one parameter O_3 had no significant change during the whole surveyed period. The AQI as computed from the sub-indices indicated a positive change in air quality in Kolkata. During the phase of pre-lockdown, air quality was in the range of moderately polluted.

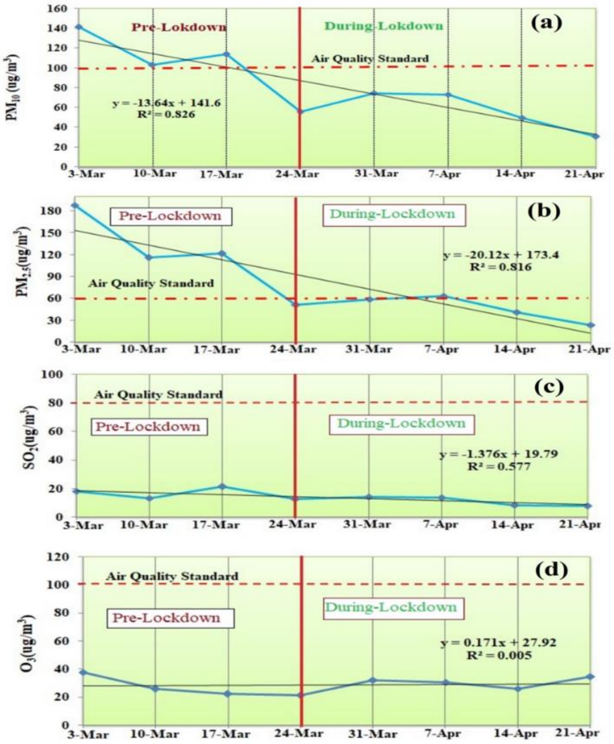


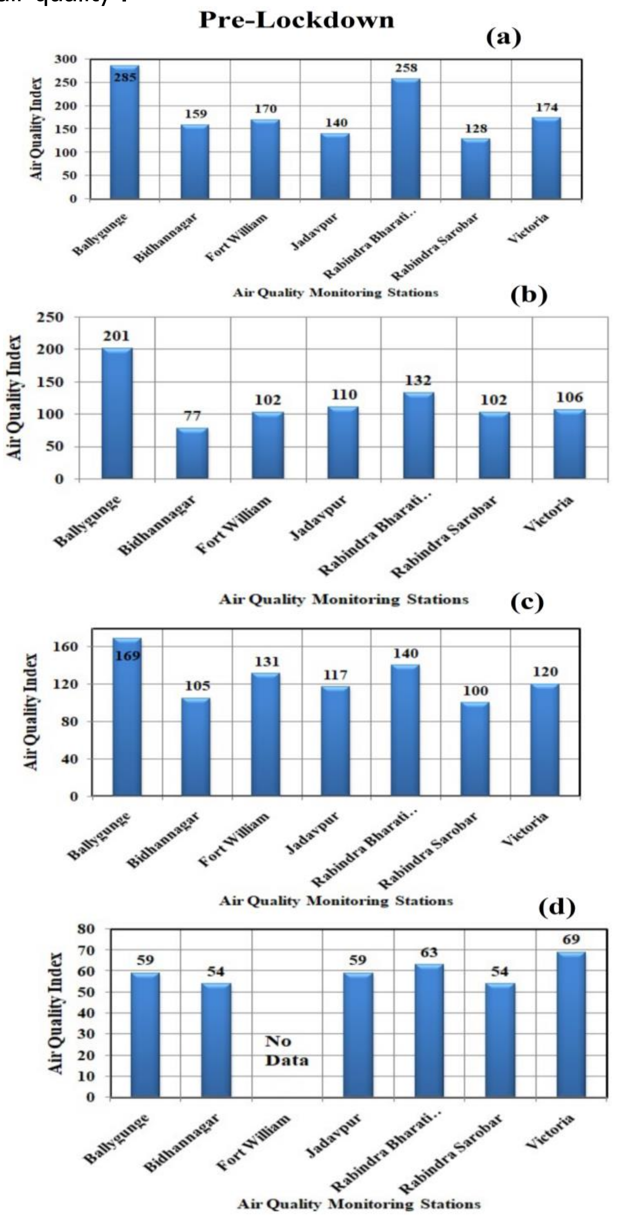
Fig. 3: Concentrations of pollutants for the pre-lockdown and during lockdown period – (a) PM_{10} (ug/m^3, 24 Hrs average), (b) $PM_{2.5}$ (ug/m^3, 24 Hrs average), (c) SO_2 (ug/m^3, 24 Hrs Average), (d) O_3 (ug/m^3, 8Hrs average)

A rapid change was assessed in AQI from the commencement of lockdown (AQI 51.14) On 31st March and 17th April, the level was satisfactory (AQI 59.00, 74.57 respectively).

By the end of 21st April, the air quality developed further and was categorized as 'good' (44.57).

Pre-lockdown and lockdown period spatial patterns of the National Air Quality Index (NAQI)

The spatial pattern of NAQI was counted at seven stations of the study area in two phases as stated earlier. During the pre-lockdown period at different considered times, the air quality index value was high. On 3rd March average air quality for the study area was "moderately polluted" (118.71). Of the seven stations, Ballygunge and Rabindra Bharati recorded "poor air quality" and the remaining stations came under "moderately poor" (Fig. 4). On 10th March average air quality was "moderately polluted" (118.57). At Ballygunge, air quality was recorded as "poor" (201), at Bidhannagar air quality was recorded as "satisfactory" (77) and the rest of the stations (Fort Willam, Jadavpur, Rabindra Bharati, Rabindra Sarabar, and Victoria) recorded "moderately polluted". On 17th March all the stations recorded "moderately polluted air quality".



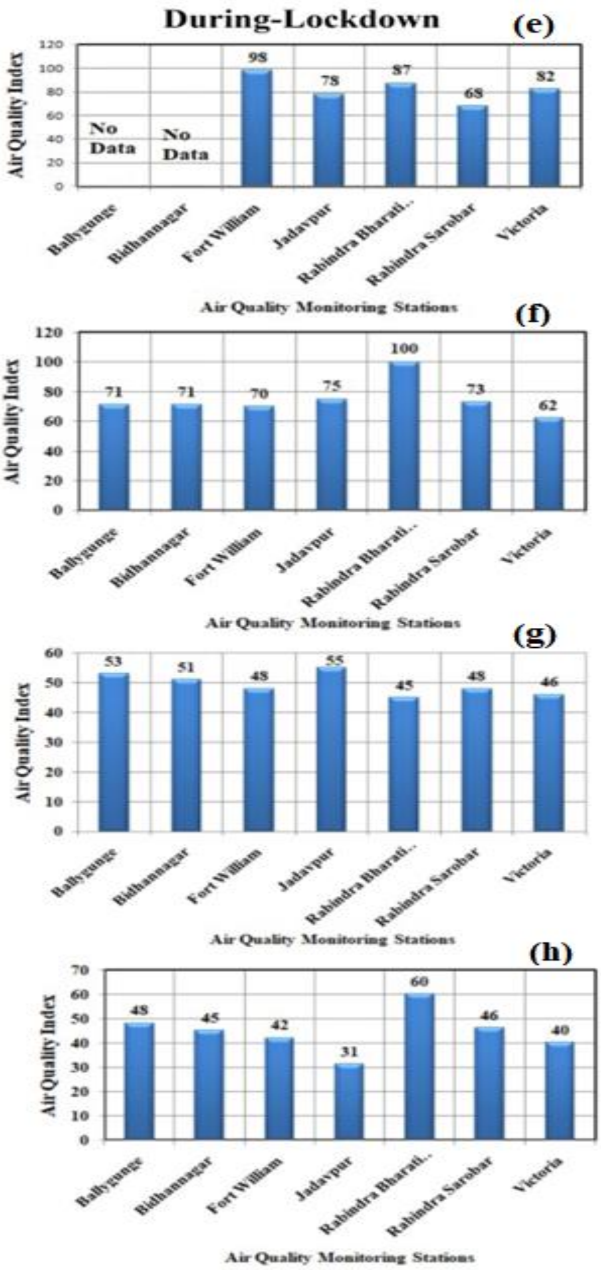


Fig. 4: Trend of air quality during pre (a, b, c, d) & post (e, f, g, h) lockdown period

A rapid change in air quality started from the day of lockdown commencement. A drastic change in AQI was computed on different dates during the lockdown period. On 31st March, 7th April, 14th April, and 21st April the average air quality was 82.60, 74.57, 49.42, and 44.57 respectively. The air quality could be categorized as "satisfactory" from 31st March to 7th April, while 14th April to 21st April was assigned as "good". The continuous development in air quality is the result of lockdown practice.

Co-relationships between air contaminants in the environment

Pearson's correlation coefficient is used to express the correlations between all air pollutant concentrations during the lockdown and before the lockdown (Table 4). The average $PM_{2.5}$ and PM_{10} concentrations over 24 hours are significantly associated with the daily average concentration of NO_2 (0.3974,0.972). NH_3 (0.868, 0.893) and CO (0.805,0.846). For SO_2 a strong correlation was detected with PM_{10} (0.857), NO2 (0.817), and NH_3 (0.8.16). An overall strong co-relation of the daily average concentration of NO_2 and NH_3 was found with all pollutants ($PM_{2.5}$, PM_{10}, SO_2, CO) except O_3. Daily 24 hrs average SO_2 and 8 hrs CO concentration was highly co-related with PM_{10}, NO_2, and NH_3. A less significant co-relation of SO_2 was recorded with $PM_{2.5}$ and CO (0.777, 0.688) and CO with SO_2 (0.688). There was no relation of O_3 concentration with the other pollutants ($PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2, CO).

Table 4: Correlation of concentration of pollutants

Pollutants	$PM_{2.5}$	PM_{10}	NO_2	NH_3	SO_2	CO	O_3
$PM_{2.5}$	1	0.979**	0.974**	0.868**	0.777*	0.805*	-0.420
PM_{10}	0.979**	1	0.972**	0.893**	0.857**	0.846**	-0.383
NO_2	0.974**	0.972**	1	0.898**	0.817*	0.897**	-0.458
NH_3	0.868**	0.893**	0.898**	1	0.816*	0.853**	-0.456
SO_2	0.777*	0.857**	0.817*	0.816*	1	0.688*	-0.252
CO	0.805*	0.846**	0.897**	0.853**	0.688*	1	-0.571
O_3	-0.420	-0.383	-0.458	-0.456	-0.252	-0.571	1

*Note: The correlations are expressed as Pearson's correlation coefficient, where, ** and ***denotes significant correlations at:**. Correlation is significant at the 0.01 level*. Correlation is significant at the 0.05 level*

Conclusions

Air pollution is a serious global problem. In India with its growing population and economic development air pollution is a major concern. The urban areas with high population concentration and industrial development are highly affected.

During the lockdown, data from eight stations spanning the whole megacity of Kolkata was used to evaluate the air quality state of the city.

The present research looked at AQI levels during the lockdown and compared them to levels prior to the lockdown. Herewith, for the lockdown and pre-lockdown periods we highlighted a positive effect of containment measure for COVID-19, indirectly on air pollution (e.g., the concentration of PM10, PM2.5, SO2, NO2, and CO) in Kolkata, West Bengal, India.

Since the start of lockdown, there has been a steady decrease in pollution levels. PM2.5, PM10, NO2, NH3, SO2, CO, and O3 were measured in two phases: before the lockdown (3rd March to 17th March) and during the lockdown (31st March to 21st April).There was rapid reduction in the concentration of all the major pollutants during the lockdown phase as compared to the pre lockdown phase. Only O3, did not alter significantly during the course of the study. The level of O3 was 37.71 as calculated on 3rd March, 2020 which came down slightly to 34.57 on 21st April,

2020. As a result of reduction of pollutants, there was substantive improvement in the AQI level.

On 3rd March average AQI for the study area was "moderately polluted" (187.71).However by the end of 21st April, the air quality developed further and was categorized as 'good' (44.57) indicating that the city's pollution level has decreased significantly.

Statistical analysis showed an overall strong co-relation of the daily average concentration of NO2 and NH3 with all pollutants (PM2.5, PM10, SO2, CO) except O3.Thus from the research work undertaken it can be said that the lockdown had a substantial positive effect in the air quality of an otherwise polluted megacity.

Author contribution

DDLS: Conceptualization-Original draft, program running. **JR**: Data curation& Data validation and Software. **BB**: Writing-review & editing, supervision. **AS**: Editing. **DP**: Writing

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