Impact of COVID-19 induced lockdown on air quality of Kolkata Metropolitan area, India

David DurjoyLal Soren[*], Jagabandhu Roy[**], Brototi Biswas[*], Ratnaprabha Jadhav[***], Ashutosh Singh[****],Dipak Prasad[*****]

[*] Department of Geography & RM, Mizoram (Central) University, India.

[**]Department of Geography, University of GourBanga, India.

[***]Department of Geography, SNDT Women's University, India

[****]Department of Geography, Mizoram University, PachhungaUniversity College Campus, India

[*****]Department of Geography, D.D.U. Gorakhpur University, India

Corresponding Author:*:brototibiswas@gmail.com*

Abstract

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.The amount of pollution in cities across the country decreased dramatically in just a few days as a result of the imposed limits, prompting lockdown debates as a viable alternative to be implemented to combat pollution. This work finally emphasized a scientific look in the context of air quality throughout the lockdown time to the Indian metropolitan area of Kolkata. The air quality data of polluting parameters such as PM10, PM2.5, SO_2, NO_2, CO, O_3, and NH_3 for seven monitoring stations of the city of Kolkata has been used, namely Bullygaunge, Fort William, Victoria, Bidhannagr, Jadavpur, RabindraBharati, RabindraSarabor, spread across the metropolitan area of Kolkata, we used the "National Air Quality Index (NAQI)" 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 was observed in pollutants of PM10 (-60.82 percent), PM2.5 (-45.05 percent) and NO_2 (-62.27), followed by NH_3 (-32.12 percent) and SO_2 (-32.00 percent), CO (-47.46 percent), O_3 (15.10 percent) and O_3 (-32.12 percent). During the lockdown, the NAQI value was reduced from pre-lockdown to the end of the lockdown at-52.93 percent due to the lockdown effect in the study area. Overall, the study is focused on the planners and government agencies for suitable measures for controlling and attenuating the pollutant components of air quality.

Keywords: National Air Quality Index, COVID-19, Kolkata Metropolitan Area, Lockdown.

I. Introduction

The detrimental environmental impact is predominantly caused by air pollution, which is a serious global problem for both developing and developed countries. For example, 193,000 people died in Europe in 2012 as a consequence of airborne particulate matter [1]. Urban areas are the hub of air pollution for its unabated growth of vehicles and industries. The megacities of Asia and Africa will have a predicted 90% population increase by the end of 2050 (World Urbanization Prospect 2018 Revision). Countries like India face 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 [2]. According to Amann et al. [3] 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 [4]. The ever-increasing urbanization will lead to an increase in power generation by 11.1%/year [5-6]. 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. Thus, urbanization is an important catalyst of air pollution for Indian cities.

Air pollution is the leading contributor towards premature deaths of 2million Indians/year (https://en.wikipedia.org/wiki/Air_pollution_in_India). According to the Census report of India 2011, 53 Indian megacities 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 [7-8]. According to the World Health Organization, 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 [9-11]. High air pollution is the reason for paramount public health desires [10-12].

Thus, air quality improvement and management are the primary concern of urbanization in recent times. 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 [13-14], Green Index [15], Ontario Air Pollution Index (OAPI) [16], and Common Air Quality Index, (CAQI) [17]. 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)". The present study has implemented the National Air Quality Index 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 "24th March to 14th April2020; second stage 15th April to 3rd May2020 and third stage 4th May to 17th May 2020". This unprecedented step forced to halt all the economic and commercial activities, thereby drastically reducing the urban air pollution level. Proper and timely monitoring of air pollution levels is indispensable for sustainable economic management. In the present research work, the researchers have analyzed the air pollution level of Kolkata city of West Bengal during the lockdown period in an attempt for policymakers to take suitable steps towards sustainable environmental goals.

II. Materials and Methodology

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 square kilometers. 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. The density of population is 24000/ square kilometers 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 ranks among the top six

Indian cities in terms of the public transport system. As a result of its increasing urbanization and industrialized activities, as well as its overcrowding, pollution is a serious concern in Kolkata. According to the State pollution control board, the pollution level of the city is seven times more than the limit set by WHO.

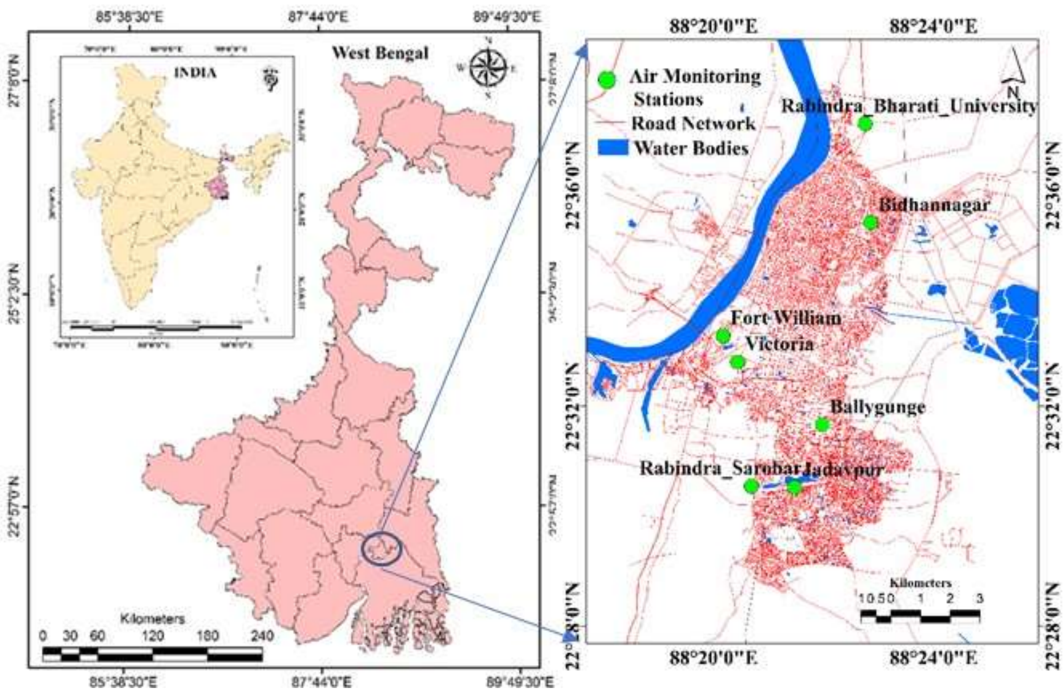

Figure 1: study area

Data sources and Methods

Data from eight sites covering the whole megacity were used to determine the air quality status of Kolkata city throughout the lockdown period. The concentrations of seven air contaminants on a daily and hourly basis: - The Central Pollution Control Board collected Particulate Matters (PM2.5 and PM10), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Ozone (O_3), and Ammonia (NH3). 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 [18]. Five pollutants (PM10, PM2.5, SO_2, NO_2, and CO) were used to create the AQ sub-index [19]. The detailed methodology is presented in Fig 2. Pune IITM has just developed a new indexing approach based on the O_3 sub-index [20]. 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 [21] took twelve factors into account while calculating air quality standards, including Particulate Matter (PM) larger than 2.5 microns (PM2.5), Ammonia (NH3), Particulate Matter (PM) larger than 10 microns (PM10), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Benzo(a)Pyrene (BaP), Arsenic (As), Ozone (O_3), Lead (Pb), Benzene (C6H6), 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).

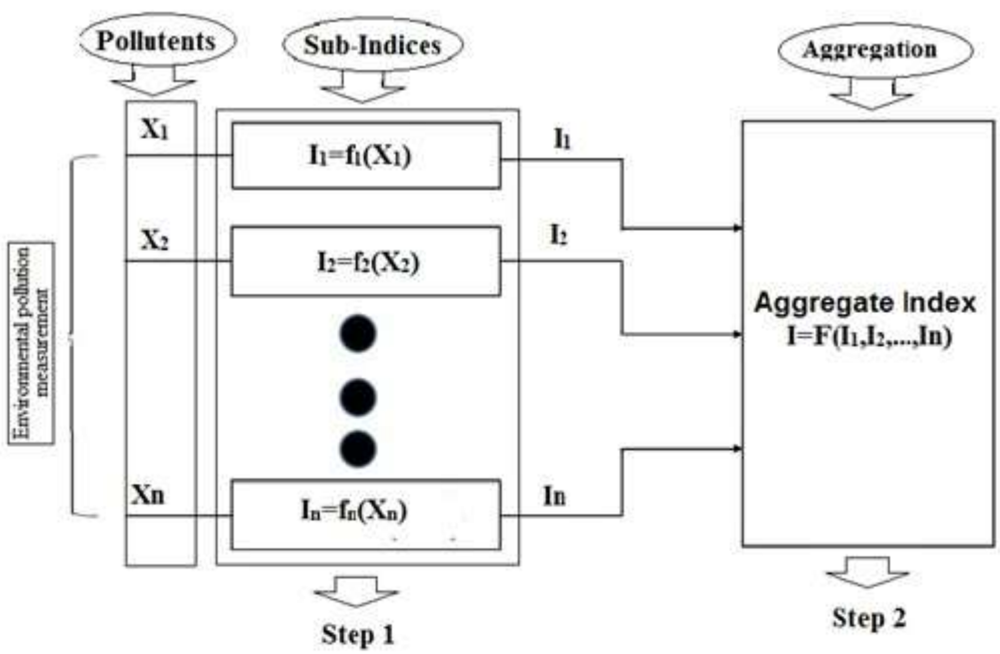

Figure 2: Flow chart of the methodology

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_{10} ($\mu g/m^3$)	24 hrs	100	100

$PM_{2.5}$ ($\mu g/m^3$)	24 hrs	60	60
SO_2 ($\mu g/m^3$)	24 hrs	80	80
NO_2 ($\mu g/m^3$)	24 hrs	80	80
O_3 ($\mu g/m^3$)	1 hrs	180	180
CO (mg/m^3)	8 hrs 1 hrs	2 4	2 4
NH_3 ($\mu g/m^3$)	24 hrs	400	400

Source: CPCB 2015

The current study studied at 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 National Air Quality Index (NAQI) categories developed by the Central Pollution Control Board [21] (Table 2) are used to present the projected health exposure, also known as Health Breakpoints, in the current scheme.

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

AQI Class	Concentration Range						
	PM_{10}	$PM_{2.5}$	SO_2	NO_2	O_3	CO	NH_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/m3 and other pollutants 24 hourly average values for PM10, PM2.5, NO2, SO2, and NH3 8-hourly values for CO and O3.

III. Results and Discussions:

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).

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

Air Pollutants (Average of 24 hours)	Pre-Lockdown			Commencement Of Lockdown	During Lockdown				change in Percentage
	3rdMar	10thMar	17thMar	24thMar	31stMar	07thApr	14thApr	21stApr	
$PM_{2.5}$	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

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. 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 to11.00 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 NO2 -62.27%, and NH3 -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.

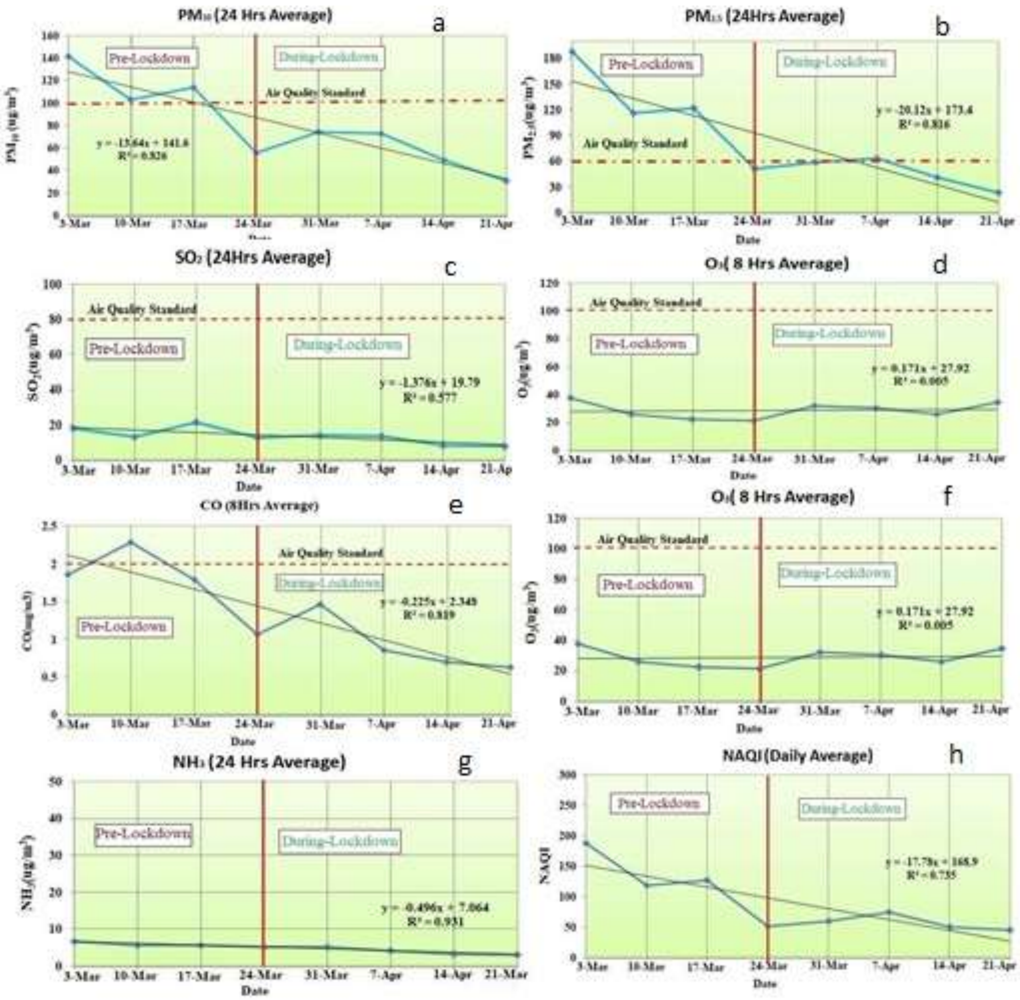

Figure 3: Concentrations of pollutants for the pre-lockdown and during lockdown period (a, b, c, d, e, f, g); Daly air quality (h).

A rapid change was assessed from the commencement of lockdown (51.14). On 31st March and 17th April, the level was satisfactory (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, RabindraBharati, RabindraSarabar, and Victoria) recorded "moderately polluted". On 17th March all the stations recorded "moderately polluted air quality".

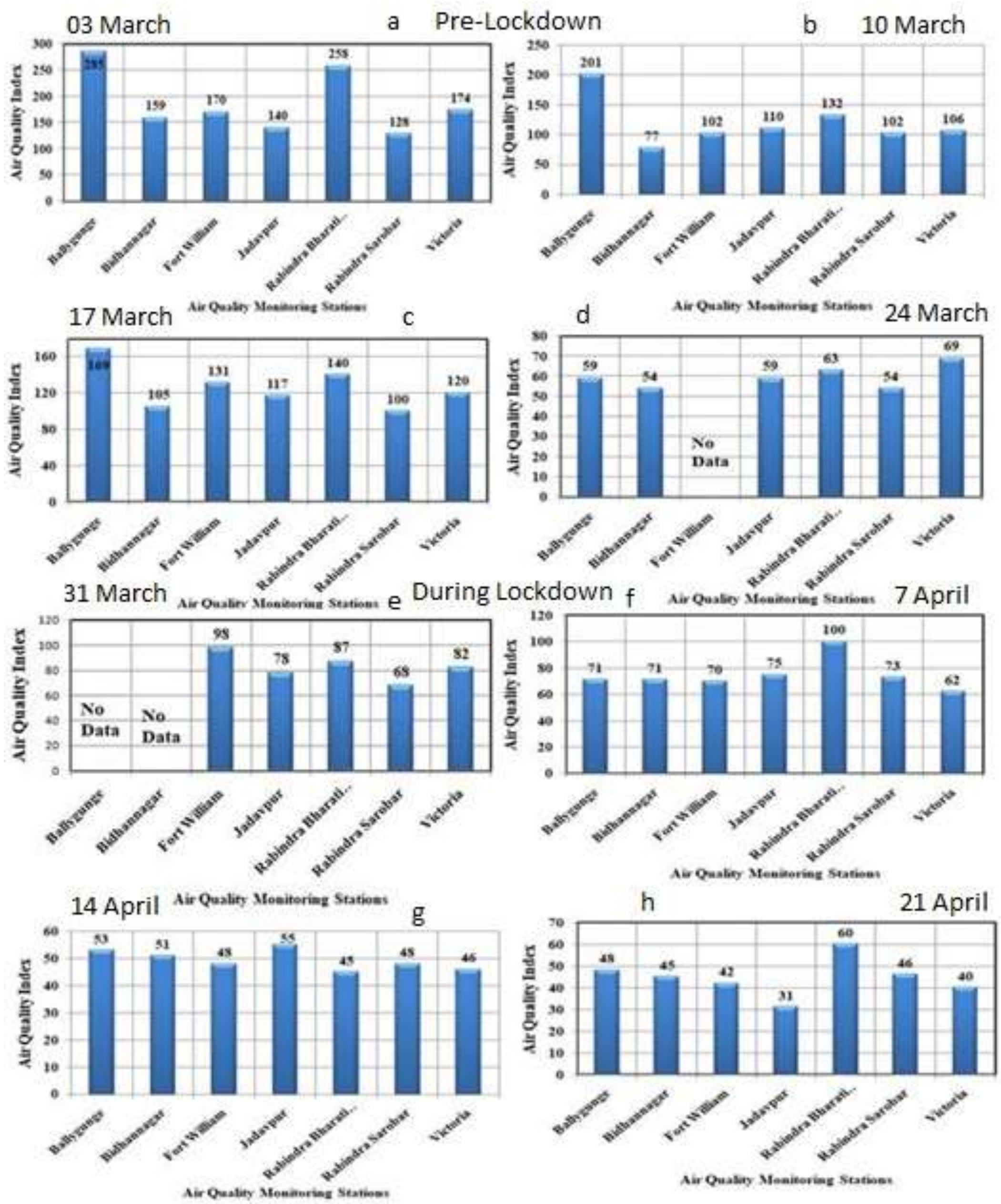

Figure 4: Trend of air quality during pre (a, b, c, d) & post (e, f, g, h) lockdown period

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 cure 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 PM2.5 and PM10 concentrations over 24 hours are significantly associated with the daily average concentration of NO_2 (.3974,.972). NH_3 (.868,.893) and CO (.805,.846). For SO_2 a strong correlation was detected with PM10 (.857), NO_2 (.817), and NH_3 (.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 (.777, .688) and CO with SO_2 (.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	.979**	.974**	.868**	.777*	.805*	-0.420
PM_{10}	.979**	1	.972**	.893**	.857**	.846**	-0.383
NO_2	.974**	.972**	1	.898**	.817*	.897**	-0.458
NH_3	.868**	.893**	.898**	1	.816*	.853**	-0.456
SO_2	.777*	.857**	.817*	.816*	1	.688*	-0.252
CO	.805*	.846**	.897**	.853**	.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

IV. 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 and pre-lockdown periods, this article explores the various metrics of air pollution in Kolkata, West Bengal, India (imposed as a result of containment measure for COVID-19). A positive effect highlighted that COVID-19 indirectly affects the concentration of PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO. The high concentration of these gases is one of the greatest environmental problems. The concentration of all pollutants was positively associated with each other (except O_3) in co-relation. The trend analysis of average air quality in pre-lockdown and during the lockdown phase continuously improved from "moderate pollutants" to "good for health". As a result of the lockdown practice, there was a substantial shift in air quality. The result of the study can help policymakers the implementation of proper steps towards sustainable environmental management in the future.

Declaration

Ethics approval

Not applicable

Authors' contributions

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

Funding

Not Applicable

Competing interests

The authors declare no competing interests.

Data availability

The manuscript and data are the authors' original work, and the manuscript has not received prior publication and is not under consideration for publication elsewhere. The manuscript now submitted is not a copied or plagiarized version of some other published work.

Acknowledgments

Not applicable

References

1. C. Ortiz, C. Linares, R. Carmona, and J. Díaz, "Evaluation of short-term mortality attributable to particulate matter pollution in Spain," *Environ. Pollut.*, vol. 224, pp. 541–551, 2017. https://doi.org/10.1016/j.envpol.2017.02.037
2. SIAM, "Vehicle Sales and Projections. Society of Indian Automobile Manufacturing," Government of India, New Delhi, India. 2013.
3. M. Amann, P. Purohit, A. Bhanarkar, I. Bertok, J. Borken-Kleefeld, J. Cofala,. . . G. Kiesewetter, "Managing future air quality in megacities: A case study for Delhi," *Atmos. Environ.*, 2017. doi:10.1016/j.atmosenv.2017.04.041.
4. Ministry of Statistics and Programme Implementation (MOSPI), "Statistics Related to Climate Change—India, "2015.
5. CEA, "Growth of Electricity Sector in India from 1947-2015. Central Electricity Authority (CEA), Ministry of Power, Govt of India, New Delhi," 2015.
6. CEA, "All India Installed Capacity (In MW) of Power Stations as on 31.08.2016. Central Electricity Authority (CEA), New Delhi," 2016.

7. A. Goyal and P. "Santa-Clara, Idiosyncratic Risk Matters!", *The journal of finance*, 2003. doi:https://doi.org/10.1111/1540-6261.00555.
8. V.P. Kanawade, A.K. Srivastava, K. Ram, E. Asmi, V. Vakkari, V.K. Soni, V. Varaprasad and C. Sarangi, "What caused severe air pollution episode of November 2016 in New Delhi?,".*Atmos. Environ.,* vol. 222, p.117125, 2020.
9. WHO, "WHO Global Urban Ambient Air Pollution Database (Update 2016)," 2016.
10. M. Heal, P. Kumar and R. Harrison, "Particles, Air Quality,Policy and Health," *Chemical Society reviews*, 2012. doi:41. 6606-30. 10.1039/c2cs35076a
11. H. Dholakia, P. Purohit, S. Rao, and A. Garg, "Impact of current policies on future air quality and health outcomes in Delhi, India," *Atmos. Environ.*, 2013. doi:75. 241-248. 10.1016/j.atmosenv.2013.04.052,.
12. S.A. Rizwan, B. Nongkynrih, and S.K. Gupta, "Air pollution in Delhi: its magnitude and effects on health," *Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine*, vol. 38(1), pp. 4 , 2013.
13. W. Ott and W. Hunt, "Airpollution," *Journal of Air Pollution Control Association,* vol. 26, pp. 10501054, 1976.
14. U.S. Environmental Protection Agency, (USEPA) "Measuring air quality: the pollutant standards index. Environmental Protection Agency 451: K-94-001 Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park," 1994.
15. J. Green, F. Ludlam and J. McIlveen, "Isentropic relative-flow analysis and the parcel theory," *Quaternary journal of royal meteorological science*, 1966. doi:https://doi.org/10.1002/qj.49709239204.
16. L. Shenfeld, "Ontario's Air Pollution Index and Alert System," *Journal of the Air Pollution Control Association*, vol. 20(9), pp. 612-612, 1970.
17. S. Van den Elshout, K. Léger, and , F. Nussio, "Comparing urban air quality in Europe in real time: A review of existing air quality indices and the proposal of a common alternative," *Environ. Internat.*, vol. 34(5), pp.720-726, 2008.
18. W.R. Ott, "Environmental Indices: Theory and Practice (Ann Arbor Science, Ann Arbor, MI)," 1978.

19. S. Sharma, M. Zhang, J. Gao, H. Zhang, and S.H. Kota, "Effect of restricted emissions during COVID-19 on air quality in India," *Sci. Total Environ.*, vol. 728, pp.138878. 2020.
20. G. Beig, S.D. Ghude, and A. Deshpande, "Scientific evaluation of air quality standards and defining air quality index for India. Indian Institute of Tropical Meteorology," 2010.
21. Central Pollution Control Board (CPCB), "Ambient Air Quality Data at Various Locations in the Country [WWW Document]. http://www.cpcb.gov.in/CAAQM/frmUserAvgReportCriteria.aspx (Accessed 10 March 2016)" 2016.