Impact of Lockdown on Air Quality in the Most Polluted Cities of India

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Abstract

Background: COVID-19 has become a global pandemic, prompting lockdowns in practically every country. To prevent the spread of the disease, India has enforced a rigorous nationwide lockdown that commenced in March 2020. The lockdown imposed amid the pandemic ensured that most commercial activities and vehicle transportation ceased, resulting in a significant reduction in air pollution levels. **Material and Methods:** The value of air pollutants PM10, PM2.5, NO_2, and SO_2 from January to May 2020 was obtained from the Indian Central Pollution Control Board. Before lockdown and during lockdown, relative fluctuations in ambient concentrations of four air contaminants were investigated. The Box–Jenkins approach was used to estimate future air pollution data points using time series data analysis. **Results:** The PM10 level reduced by 61%, 30%, 68%, 37%, and 43% in the selected cities, respectively. Comparison of other pollutant concentrations before and after the lockdown also found a reduction in ambient pollutant concentrations, resulting in improved air quality. Inference of predicted model values to observed values revealed a significant increase in the concentrations of all pollutants. The percentage increases in AQI_{mean} from predicted to observed values were 206% in Ghaziabad, 148% in Delhi, 59% in Hyderabad, and 160% in Cochin. **Conclusion:** The strict lockdown has resulted in a significant drop in air pollutant levels. Upgrading present technologies could help keep pollution to a minimum of 37% under control. The findings would prompt the government to consider how to strictly reduce vehicle and industrial pollution to improve air quality and maintain improved public health.

Keywords: Air pollutants, air quality indices, COVID-19, India, particulate matters

Introduction

Air pollution can be a complex mixture of gases, water vapor, particulate contaminants, and aerosols that have been expelled by human development and other natural/anthropogenic activities. Air pollution has been increasingly posing a threat to public health. It prompted the nation to take steps at various levels to come up with practical measures to minimize the damage. Science and technology plays an essential role in these efforts to reduce air pollution.[1] Different researchers, including government and non-governmental organizations, are trying to reduce the effects of air pollution by creating pollution-reducing devices and mechanisms.

Several countries around the world have been on lockdown as a result of a dramatic surge in the number of positive cases and deaths linked to COVID-19. As a result of the series of lockdowns, industrial activity, transportation by all modes, and virtually all other polluting activities have decreased considerably.[2] Almost every country experienced a significant reduction in automobile traffic and industrial activity, with the result being the cleanest and finest air quality in recent history. Lockdown events, however, factoring for meteorological changes lowered air pollutants, including weighted nitrogen dioxide and particulate matter levels, by nearly 60%, 31%, and 34%, respectively, with mixed impacts on ozone.[3] The decrease in NO_2 could be due to a decline in transportation sector emissions. The lockdown imposed in the aftermath of the

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COVID-19 pandemic ensured that most commercial activities ceased, resulting in a drastic reduction in air pollution levels.[4]

Although major air pollutants such as PM10, PM2.5, carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ammonia (NH_3) showed significant reductions in concentrations during the lockdown period, and ozone (O_3) levels climbed in many places of the world.[5] The drop in PM2.5, CO, and NO_2 could also be due to reduced traffic and restricted industrial operations during the lockdown.[6] A study conducted in Delhi and Kolkata provides evidence of the reduction of PM10, PM2.5, NO_2, and CO concentrations, and the air quality in Delhi has improved by a maximum of 60%.[2,7] Therefore, it is proposed to model the optimal emission of pollutants by utilizing the pollutant emission data during the lockdown.

An air quality standard is a description of an enforceable level of air quality set by a regulatory authority. This paper focused on four parameters from the new Indian National Air Quality Standards (INAQS). According to the World Health Organization (WHO) database, India has 13 of the world's 20 most polluted cities[3] As per the World Air Quality Report, 2019, Ghaziabad and Delhi are the most polluted cities in India, whereas Kolkata and Hyderabad are among India's 10 most populated cities. This paper has considered Ghaziabad, Delhi, Kolkata, Hyderabad, and Cochin for the comparison of the impact of lockdown on air quality. Kerala, which is less polluted than the rest of the states, and the city of Cochin were chosen to learn more about the pollution trend in such areas.[8] The paper also tries to propose a control guideline for the emission of air pollutants in the upcoming period after lockdowns.

Materials and Methods

The secondary data were obtained from the Central Pollution Control Board through their website https://app.cpcbccr.com from January 2020 to May 2020. The 24-h average of each pollutant was used to compute the corresponding per-day levels. The data included the value of air pollutants PM_{10} (particulate matter less than 10 μm in diameter), $PM_{2.5}$ (particulate matter less than 2.5 μm in diameter), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). The Indian cities in the first 10 ranking of the World Air Quality Report, 2019, were taken into consideration except for Cochin. Cochin has been selected to know the trend in Kerala, which is lesser in pollution compared to others.

The monitoring of ambient air quality was carried out using different air quality indices (AQI). AQI can be defined as an overall value that converts weighted concentrations of individual air pollution-related parameters (particulate matter, SO_2, NO_2, etc.) into a single number or set of numbers.[2] This toxicity of the air was evaluated by classifying the AQIs based on a predefined criterion[9] [Table 1]. The table defines the guideline values for each pollutant.

Several types of AQIs with varying purposes and scopes have been developed in the recent past. Four different methods of estimating the AQI based on average pollutant concentration were used to compare the prevailing ambient air quality in the study regions. The study is performed in two compartments: before lockdown and during the lockdown. The time series method and its predicted value are then compared with the real-time values to ensure that the model is capable of predicting concentrations of different pollutants.

Four air quality approaches were illustrated in this study to estimate AQIs for two time periods for each city individually.

Method 1(AQI_{mean}): Ambient AQI was estimated by taking the arithmetic mean of the sum of the ratios of the four pollutants to their standard air quality values and was multiplied by 100. The air quality rating of each pollutant was estimated for AQI using the formula:

$$Q = \left(\frac{C}{Cs}\right) *100 \qquad (1)$$

where C is the observed value of the air quality pollutants and Cs is the CPCB standard for the given area (B, 2020a).

Method 2 (AQI_{gm})**:** Ambient AQI was estimated by taking the geometric mean of the AQIs provided by individual components (as in method 1) and was multiplied by 100. This measure is also compared with the quality scale provided by CPCB.

Method 3 (ORNAQI)**:** The Oak Ridge National Air Quality Index (ORNAQI), developed by the Oak Ridge National Laboratory (ORNL), USA, was estimated using the mathematical formula

$$AQI = \left[39.02 \sum \frac{Xi}{Xs}\right]^{0.967} \qquad (2)$$

where X_i is the value of individual air quality parameters and X_s is the prescribed standard value for that parameters.[10] AQI measured by this method was then compared with relative ORAQI values.

Method 4 (AQI_{WeiAv})**:** This AQI was obtained by combining qualitative measures with the qualitative concept of the environment. The individual AQI is estimated as:

Table 1: Air quality ranges for AQIs

AQI (CPCB 2015)	ORNAQI	$AQI_{Wei Av}$
0-50	0≥ AQI ≤25	0.0≥ AQI ≤0.5
Good	Clean air	Acceptable
51-100	26≥ AQI ≤50	0.51≥ AQI ≤1.0
Satisfactory	Light air pollution	Unacceptable
101-200	51≥ AQI ≤75	1.01≥ AQI ≤2.0
Moderately polluted	Moderate	Alert
201-300	76≥ AQI ≤100	AQI ≥2.01
Poor	Heavy air pollution	Significantly harmful
301-400	AQI >101	
Very poor	Severe air pollution	
>401		
Severe		

$$Q = \frac{W * C}{Cs} \quad (3)$$

where W is the weightage of the pollutant, C is the observed value of the pollutant, and Cs is the CPCB standard of pollutant for the given area. Here, all individuals are given equal weight (W = 1) and the total index is obtained as:

$$AQI = \sqrt{\left(\frac{1}{N}\right)\Sigma_{i=1}^{N} Q_i^2} \quad (4)$$

where N is the number of air quality variables.[2]

A higher index value indicates higher levels of air pollution and, consequently, higher health risks. Forecasting of future data points of air pollutants 10 days posterior to the date was performed by the Box–Jenkins approach to time series Analysis.[11] The autoregressive integrated moving average model (ARIMA) was obtained by combining the autoregressive (AR) model and the moving average (MA) model.[10] The stationarity of data was evaluated using the Augmented Dicky Fuller test.[12] The time-series data after differencing is said to follow ARIMA (p, d, q), where parameters p is the lag order, d is the number of differencing and q is the order of moving average.[13]

By considering d = 1, we can obtain ARIMA (p, 1, q) with $\Delta_d y_t = W_t$ or $W_t = y_t - y_{t-1}$. Then,

$$W_t = \phi_1 W_{t-1} + \phi_2 W_{t-2} + \ldots + \phi_p W_{t-p} + €_t - \theta_1 €_{t-1} - \theta_2 €_{t-2} - \ldots - \theta_q €_{t-q}. \quad (5)$$

The data were analyzed using R version 4.0.0. A paired *t*-test was used to test the significant difference between two time periods (pre- and during lockdown) The Pearson correlation coefficient was used to identify the correlation between the individual air pollutants in the selected geographic areas. The level of $P > 0.05$ was considered significant.

Results

The CPCB data were used to calculate the average concentrations of ambient air pollutants PM10, PM2.5, SO_2, and NO_2, as well as the corresponding air pollution index. Some of the main AQIs were estimated for these periods before and during the lockdown. Table 2 shows the variations in air pollutant concentrations before and during lockdown periods. The reductions in the average concentrations of air pollutants in μgm/m³ (PM_{10}, $PM_{2.5}$, SO_2, NO_2) were observed in Hyderabad (before: 99.33, 44.05, 27.92, and 9.52°, during: 62.04, 28.68, 16.92, and 8.41) and Cochin (before: 102.98, 16.51, 22.15, and 8.74°, during: 58.01, 9.82, 6.16 and 5.53) before and during lockdowns. Before the lockdown, pollutant concentrations were greater in Ghaziabad than in other cities, but during the lockdown, this highest position was switched to second, with Delhi being the city with the highest pollutant concentrations.

Variations in different AQI estimated for all five cities before and during the lockdown in India are shown in Table 3 and Figure 1.

In AQI_{mean}: Before the lockdown, the air in Ghaziabad, Delhi, Kolkata, Hyderabad, and Cochin was moderately polluted, satisfactory, satisfactory, and good, respectively, but at the time of the lockdown, there had been a noticeable change in Ghaziabad (satisfactory), Kolkata (good), and Hyderabad (good).

In AQI_{gm}: There was a drastic change in Ghaziabad, Delhi, and Kolkata from satisfactory to good air quality, whereas Hyderabad and Cochin already had good air quality with a reduction in the quantity of AQI values before and during the lockdown.

In ORNAQI: The quality of air in Ghaziabad has changed from severe to moderate air pollution, Delhi-severe to heavy air pollution, Kolkata-severe to light air pollution, Hyderabad and Cochin-moderate to light air pollution before and during the lockdown. But none of the cities fell under clean air range during the lockdown.

In AQI_{WeiAv}: The air quality in Ghaziabad and Delhi was at an alert level before the lockdown, which was changed to an unacceptable level during the lockdown. Similarly, Kolkata was at an alert level and has changed to an acceptable level during the lockdown. Hyderabad and Cochin were also changed from unacceptable to acceptable levels.

Table 2: Variation in the concentrations of pollutants in the selected cities of India

City	Time period	Average concentration of pollutants			
		PM_{10}	$PM_{2.5}$	NO_2	SO_2
Ghaziabad	Before lockdown	196.10	108.48	53.78	17.94
	During lockdown	101.82	41.26	20.49	17.54
Delhi	Before lockdown	178.80	107.70	41.45	15.90
	During lockdown	124.82	49.57	27.74	13.81
Kolkata	Before lockdown	181.201	96.17	36.50	9.07
	During lockdown	59.36	25.38	6.12	4.56
Hyderabad	Before lockdown	99.33	44.05	27.91	9.52
	During lockdown	62.04	28.68	16.92	8.41
Cochin	Before lockdown	102.98	16.51	22.15	8.74
	During lockdown	58.01	9.82	6.16	5.53

Table 3: AQI values of the selected cities of India

City	Time Period	AQI			
		AQI_{mean}	AQI_{gm}	ORNAQI	AQI_{WeiAv}
Ghaziabad	Before lockdown	115.43	82.22	174.45	1.39
	During lockdown	52.94	43.29	82.07	0.63
Delhi	Before lockdown	99.08	56.72	130.52	1.27
	During lockdown	60.30	40.23	80.85	0.76
Kolkata	Before lockdown	177.73	60.61	130.88	1.23
	During lockdown	45.39	17.39	39.49	0.37
Hyderabad	Before lockdown	54.88	40.55	73.87	0.64
	During lockdown	35.40	27.72	48.38	0.41
Cochin	Before lockdown	42.28	26.91	57.29	0.57
	During lockdown	22.25	14.64	30.88	0.30

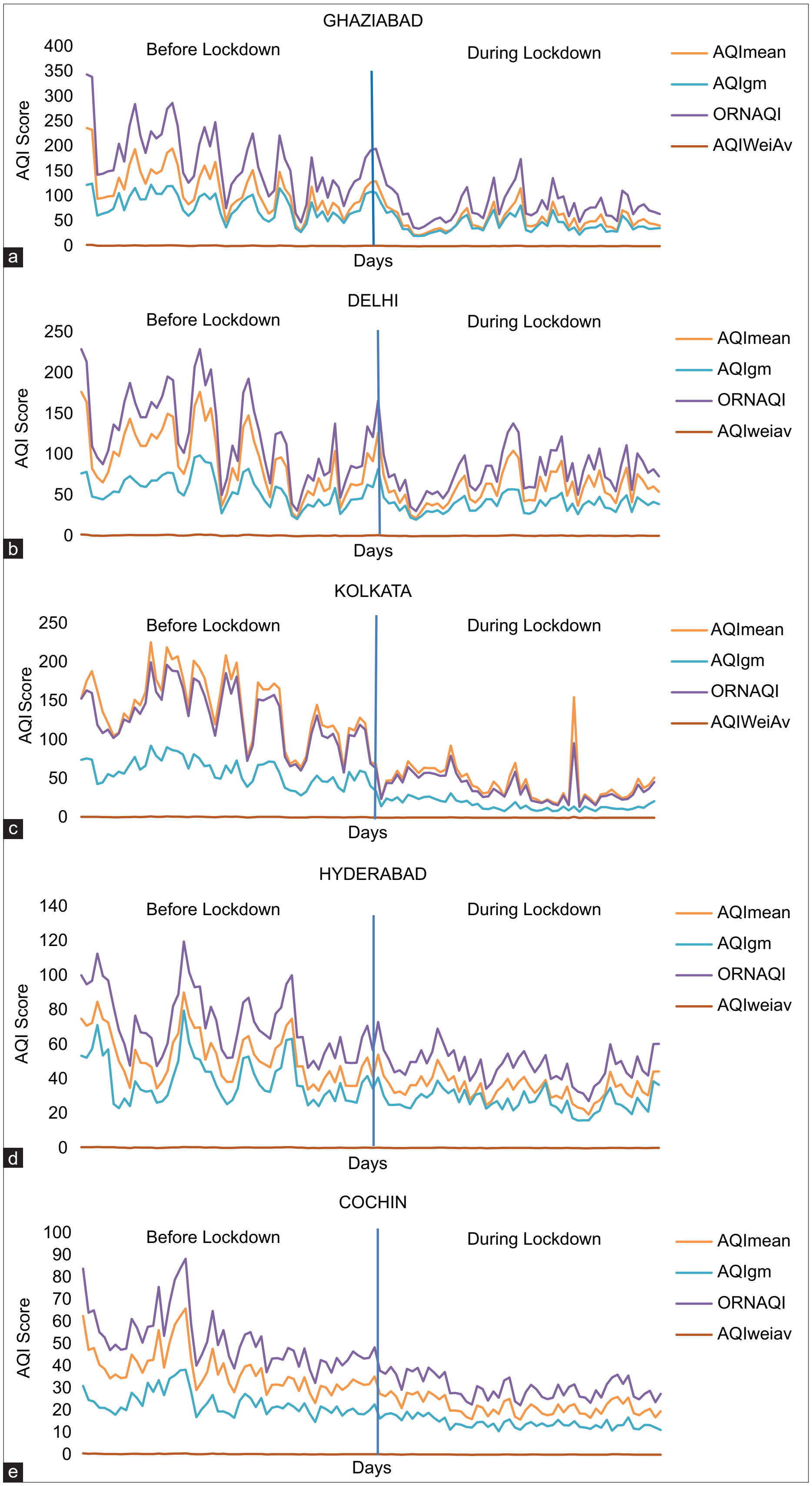

Figure 1: Variation in air quality before and during the lockdown in various Indian cities (a) Ghaziabad (b) Delhi (c) Kolkata (d) Hyderabad (e) Cochin

Table 4 shows the statistically significant difference in mean concentrations of ambient air pollutants in these cities over the comparison period. Except for the difference in SO_2 concentration at Ghaziabad and Delhi, the difference in the mean values of all parameters between the two time periods (before and after lockdown) was statistically significant ($P > 0.05$). The Pearson coefficient of correlation for cities during study periods is shown in Table 5. This shows that before the lockdown, cities had a positive correlation between the parameters PM_{10}, $PM_{2.5}$, SO_2, and NO_2, except for Cochin. During the pre-lockdown period, Ghaziabad, Delhi, and Kolkata showed a higher correlation between PM_{10} and $PM_{2.5}$. For Ghaziabad and Delhi, there was the least correlation between SO_2 and PM_{10} during both periods. However, in Delhi, during the lockdown period, the higher correlation remained the same, but the lowest correlation was between the pollutants NO_2 and PM_{10}. It should be noted that the deviation in the SO_2 level of Ghaziabad was not significant. Although in Hyderabad, there was a higher correlation between PM_{10} and SO_2 and a lower correlation between NO_2 and $PM_{2.5}$ before the lockdown and during the lockdown, there existed a higher correlation between NO_2 and SO_2 and a lower correlation between PM_{10} and NO_2. In the case of Cochin, the correlation between the pollutants was very weak, and the pollutants NO_2 and PM_{10} showed a negative correlation in the pre-lockdown period. During the lockdown, a negative correlation existed between SO_2 and PM_{10}. The results from the correlation coefficient stated that the strength of the correlation between the pollutants was reduced during the lockdown period.

It is shown that average PM_{10} levels are reduced by 61%, 30%, 68%, 37%, and 43%, respectively, in Ghaziabad, Delhi, Kolkata, Hyderabad, and Cochin. Similarly, in the case of $PM_{2.5}$, the average concentrations are reduced at a rate of 61%, 53%, 73%, 34%, and 40%, respectively. At Ghaziabad, Delhi, Kolkata, Hyderabad, and Cochin, NO_2 is reduced at 61%, 33%, 83%,

Table 4: Results of paired *t*-test for the mean difference in pollutants of the selected cities of India

City	Pollutants											
	PM_{10}			$PM_{2.5}$			NO_2			SO_2		
	Mean difference	95% CI	*P*	Mean difference	95% CI	*P*	Mean difference	95% CI	*P*	Mean difference	95% CI	*P*
Ghaziabad	94.28	69.96, 118.62	<0.01	67.55	50.04, 82.22	<0.01	33.29	27.10, 37.29	<0.01	00.36	-3.91, 2.78	0.73
Delhi	48.99	24.33, 73.65	<0.01	51.06	36.77, 65.35	<0.01	15.89	12.30, 19.47	<0.01	03.64	-2.88, 0.16	0.08
Kolkata	121.65	104.17, 139.12	<0.01	70.79	61.18, 180.40	<0.01	30.38	28.17, 35.68	<0.01	4.50	3.33, 5.67	<0.01
Hyderabad	37.50	29.734, 45.27	<0.01	13.14	9.11, 17.18	<0.01	14.56	8.41, 13.12	<0.01	01.35	0.88, 3.59	0.02
Cochin	38.29	32.38, 44.21	<0.01	06.76	2.17, 11.35	0.004	10.98	7.76, 14.20	<0.01	0.64	0.30, 0.98	<0.01

Table 5: Correlation between the pollutants PM_{10}, $PM_{2.5}$, SO_2, and NO_2 in the selected cities of India

City	Correlation between individual pollutants								
	Pollutant	Before lockdown				After lockdown			
		PM_{10}	$PM_{2 \cdot 5}$	NO_2	SO_2	PM_{10}	$PM_{2 \cdot 5}$	NO_2	SO_2
Ghaziabad	PM_{10}	1.000	0.957	0.725	0.153	1.000	0.895	0.709	0.418
	$PM_{2 \cdot 5}$	0.957	1.000	0.669	0.618	0.895	1.000	0.720	0.532
	NO_2	0.725	0.669	1.000	0.288	0.709	0.720	1.000	0.390
	SO_2	0.153	0.618	0.288	1.000	0.418	0.532	0.390	1.000
New Delhi	PM_{10}	1.000	0.941	0.614	0.382	1.000	0.836	0.304	0.793
	$PM_{2 \cdot 5}$	0.941	1.000	0.461	0.215	0.836	1.000	0.536	0.710
	NO_2	0.614	0.461	1.000	0.487	0.304	0.536	1.000	0.319
	SO_2	0.382	0.215	0.487	1.000	0.793	0.710	0.319	1.000
Kolkata	PM_{10}	1.000	0.747	0.558	0.089	1.000	0.375	0.236	0.230
	$PM_{2 \cdot 5}$	0.747	1.000	0.604	0.465	0.375	1.000	0.524	0.559
	NO_2	0.558	0.604	1.000	0.100	0.236	0.524	1.000	0.695
	SO_2	0.089	0.129	0.100	1.000	0.230	0.559	0.695	1.000
Hyderabad	PM_{10}	1.000	0.465	0.647	0.785	1.000	0.349	0.190	0.608
	$PM_{2 \cdot 5}$	0.615	1.000	0.494	0.652	0.349	1.000	0.293	0.269
	NO_2	0.647	0.494	1.000	0.777	0.190	0.293	1.000	0.723
	SO_2	0.785	0.652	0.777	1.000	0.608	0.269	0.723	1.000
Cochin	PM_{10}	1.000	0.007	-0.118	0.006	1.000	0.244	0.255	-0.123
	$PM_{2 \cdot 5}$	0.007	1.000	0.160	0.338	0.244	1.000	0.796	0.175
	NO_2	-0.118	0.160	1.000	0.155	0.255	0.796	1.000	0.165
	SO_2	0.006	0.338	0.155	1.000	-0.123	0.175	0.165	1.000

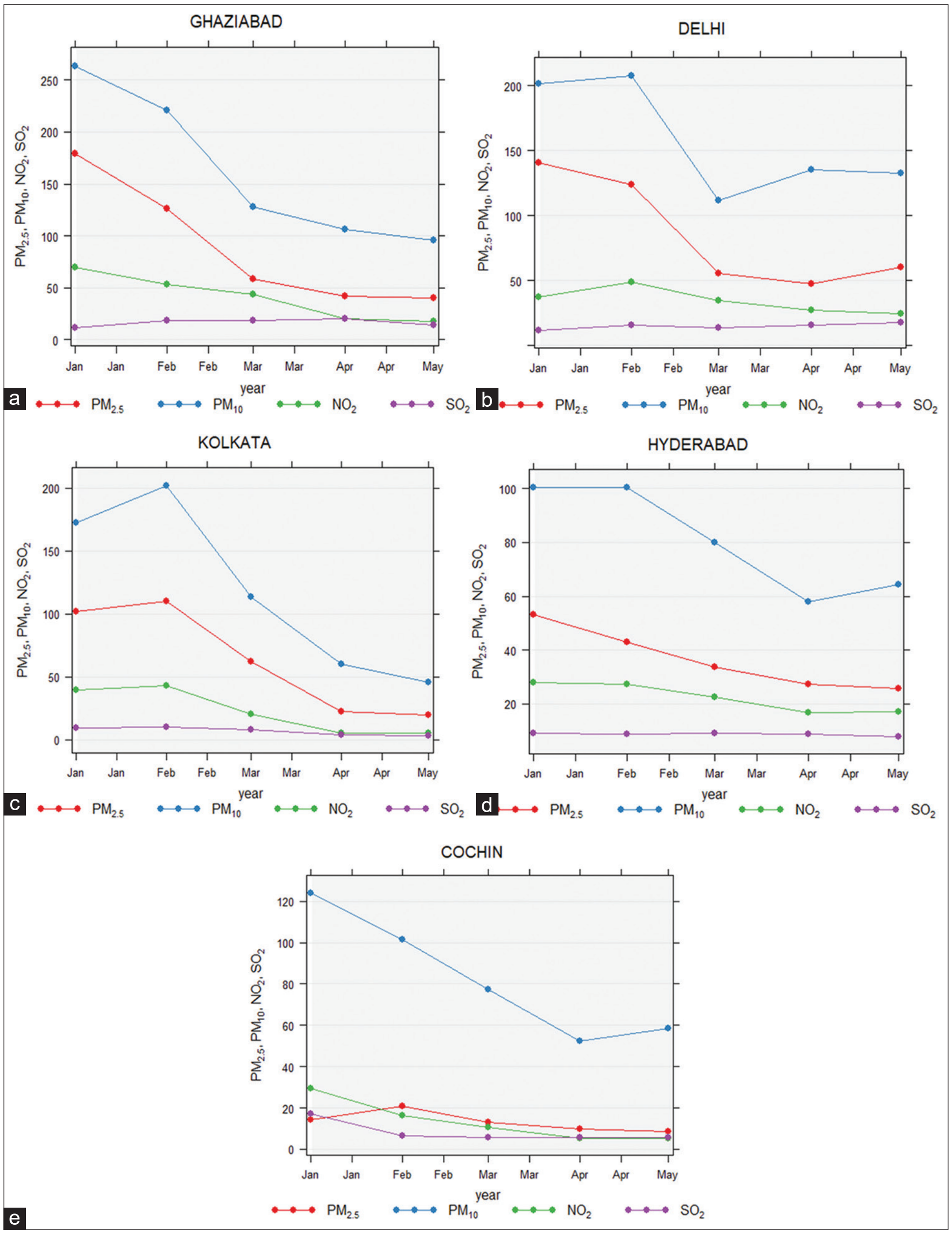

Figure 2: Trend in the variations in pollutant concentrations before and during the lockdown in various Indian cities (a) Ghaziabad (b) Delhi (c) Kolkata (d) Hyderabad (e) Cochin

39%, and 72% respectively. The decrease in the concentrations of SO_2 is very low when compared to other pollutants. SO_2 undergoes a decline of 2% at Ghaziabad, 13% at Delhi, 49% at Kolkata, 11% at Hyderabad, and 36% at Cochin. Figure 2 represents the trend in the variations in polluted concentrations before and during the lockdown in various Indian cities.

The ARIMA model for all orders of p, d, and q was built, and chosen the best model, which has the least AIC value. Table 6 shows the selected ARIMA models with predicted values of the air pollutants and AQI_{mean}, for the 10^{th} day after 12^{th} May 2020 (May 22, 2020). Inference of predicted model values to observed values revealed a significant increase in the concentrations of all pollutants (excluding PM_{10} in Kolkata). Based on the predicted AQI_{mean}, the air quality in Ghaziabad and Delhi on May 22, 2020, was satisfactory, whereas Kolkata, Hyderabad, and Cochin were in the good air quality range. Observed values inferred that Ghaziabad and Delhi were in a moderately polluted range, Hyderabad was satisfactory, whereas Kolkata and Cochin remained good. The percentage increases in the AQI_{mean} from predicted to observed value were 206% in Ghaziabad, 148% in Delhi, 59% in Hyderabad, and 160% in Cochin, whereas in Kolkata AQI_{mean} predicted and observed values were 28.

Discussion

The current study shows that the COVID-19 pandemic-related

Table 6: Selected ARIMA model, forecasted values and % change of pollutants (PM_{10}, $PM_{2.5}$, SO_2, and NO_2) and AQI_{mean} with observed value

City	PM_{10}			$PM_{2.5}$		
	Selected ARIMA	Predicted Value	Observed (% change)	Selected ARIMA	Predicted Value	Observed (% change)
Ghaziabad	(3,1,1)	95	201 (112)	(2,1,1)	40	194 (385)
Delhi	(2,1,1)	124	158 (27)	(2,1,2)	55	222 (304)
Kolkata	(2,1,2)	55	42 (-24)	(0,1,3)	27	32 (19)
Hyderabad	(3,1,3)	81	120 (48)	(3,1,3)	28	53 (89)
Cochin	(2,1,3)	10	22 (120)	(1,1,2)	10	20 (100)

City	NO_2			SO_2			AQI_{mean}	
	Selected ARIMA	Predicted Value	Observed (% change)	Selected ARIMA	Predicted Value	Observed (% change)	Predicted Value	Observed (% change)
Ghaziabad	(0,1,3)	19	85 (347)	(3,1,3)	14	31 (121)	51	156 (206)
Delhi	(2,1,1)	23	57 (148)	(3,1,1)	18	61 (239)	62	154 (148)
Kolkata	(3,1,2)	6	11 (83)	(1,1,2)	3	4 (33)	28	28 (0)
Hyderabad	(3,1,3)	23	38 (65)	(1,1,1)	9	16 (78)	44	70 (59)
Cochin	(0,1,3)	5	26 (420)	(2,1,3)	4	15 (275)	10	26 (160)

lockdown has a direct impact on improving ambient air quality in Indian cities, as indicated by significant reductions in most air pollutants, particularly PM_{10}, $PM_{2.5}$, $SO_{2,}$ and NO_2. These reduced levels of AQI are within the allowed limits set by the Indian National Pollution Control Agency, namely the Central Pollution Control Board (CPCB) regulations [Table 1].

Before the lockdown began, Ghaziabad and Kolkata were the most polluted cities on the list. However, when the lockdown began, both cities experienced sudden changes in air quality compared to other cities. Among five of the selected cities, Cochin remained the least polluted in both periods. With the implementation of the lockdown, air pollution levels in India's most polluted cities met the CPCB ambient air quality criteria (Organization., 2016). The reasons for this reduction were the strict implementation of laws and regulations such as prohibiting all outdoor activities, closing transportation sectors, closing industries, markets, workplaces, offices, schools, colleges, and any other institutional areas framed to combat the disease outbreak in hotspot regions.[14]

To combat the spread of the coronavirus pandemic, a 21-day lockdown was imposed across the country from March 25, 2020. Except for critical services, all industries have been shut down and the government has implemented very strict restrictions, which were reflected in the concentration decline of air pollutants. With very few relaxations, the Government of India and the Ministry of Home Affairs (MHA) extended the lockdown duration to 2 weeks beyond May 4 on May 1.[15] The current study considered, predicting concentrations of different pollutants and AQI_{mean}, indicating the upcoming changes in the air quality as a result of lockdown measures. The concentration of pollutants and AQI during the pre-lockdown period were found to be at a very high level, whereas the concentration drastically changed to an almost acceptable level during the strict lockdown. The pre-lockdown period, which lasted until March 24, 2020, was the first. Following the first lockdown, three additional lockdown stages followed in quick succession (LD 2: April 15–May 3, 2020, LD 3: May 4–May 17, 2020, LD 4: May 18–May 31, 2020).[16] The National Disaster Management Authority announced on May 17 that the lockdown would be prolonged for another 2 weeks, with other additional relaxations in transportation and opening of shops. If a strict lockdown scenario existed until May 22, 2020, the air quality would be similar to the study's predicted values, but the additional relaxations, which were given two times after May 11, 2020, resulted in an increase in the observed concentrations and AQI_{mean} (except Kolkata) of pollutants compared to the predicted values on May 22, 2020. Due to the sharp increase in COVID-19 instances, the West Bengal government enforced near-complete lockdown regulations throughout the state, allowing only emergency movement of persons and vehicles. As a result of the decrease in contaminants, the AQI_{mean} predicted and observed were the same. Thus, the COVID-19 pandemic lockdown gave awareness to all governments throughout the world about the importance of restoring environmental quality and natural ecosystem stability.[17]

Predicting air quality is a useful strategy for air pollution management that the local government and municipality might employ in the future. It is beneficial to act quickly before the situation worsens in the long run. Thus, the study clearly shows that improved model performance is critical for accurate forecasting of air quality.

Conclusion

Air quality was significantly improved when the lockdown was imposed in Ghaziabad, Delhi, Kolkata, Hyderabad, and Cochin. A markable reduction was observed in the ambient concentration of PM_{10}, $PM_{2.5}$, $SO_{2,}$ and NO_2 pollutants during the lockdown days of 2020. These current environmental gains are quite short, and this short-term improvement in air quality during lockdown can provide a promising signal to the governments and policymakers to improve the quality of air through a planned strict restriction on pollution sources. For a period of time, the government can consider a lockdown at the hotspot pollution areas to manage the level of pollution with low economic loss. A further increase in the concentration of air pollutants can be handled if proper measures are taken at the right time.

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Conflicts of interest

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