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RESEARCH ARTICLE

The Impact of COVID-19 Strict Lockdown on the Air Quality of Smart Cities of Rajasthan, India

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Abstract:

Aim:

The main focus of this study is to evaluate the air quality by comparing the concentration of particulate matter $PM_{2.5}$, PM_{10}, NO_2, CO, SO_2, and ozone of smart cities of Rajasthan before the lockdown and during the period of lockdown.

Background:

In India, the first case of the COVID-19 was reported on January 30th, 2020. Indian government declared strict lockdown, *i.e.*, public health emergency in India on March 24th, 2020, which is implemented from March 25th, 2020, to April 14th, 2020, for 21 days.

Objective:

The objective of this study is to evaluate the air quality by comparing the levels of all parameters of air pollution during the COVID-19 lockdown period with values registered in the pre-lockdown period.

Methods:

Data were obtained from four automatic monitoring stations under the control of the Central Pollution Control Board, New Delhi (https://www.cpcb.nic.in/). Data regarding all the parameters were recorded as 24 hours average period.

Results:

CO levels showed the highest significant reduction in Udaipur (50.76%) followed by Jaipur (19.96%), Ajmer (17.11%), and Kota (5.51%) due to the ban on transport and driving. The levels of $PM_{2.5}$, PM_{10}, NO_2, and SO_2 were also decreased substantially for each smart city. Ozone concentrations were recorded greater than before due to decreased nitrogen oxides levels.

Conclusion:

This study can be useful considering our present role in environmental restoration or environmental destruction. It will also be helpful in updating our present plan toward the assurance and conservation of nature.

Keywords: COVID-19, Sulfur dioxide, PM, Ozone, Public health, Lockdown.

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1. INTRODUCTION

On December 8th, 2019, the novel SARS-CoV-2 coronavirus first reported in Wuhan, China. It causes COVID-19 disease, which spreads across the world. On January 9th, 2020, coronavirus was discovered as a novel infectious agent of COVID-19 [1, 2]. It is a communicable disease that spreads very quickly from one person to another. To date, all over the world, the total reported cases are estimated to be 4,628,821, and 308,654 people died because of this pandemic. All world governmental bodies are worried about this crisis because its cure has not been discovered yet. Currently, prevention is the

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only way to avoid infection. For this, many countries announced the complete lockdown to prevent the spread of infection and succeeded. The Indian government also imposed total fives lockdown with various rules and regulations. Out of five lockdowns, the first lockdown implemented from March 25th, 2020, to April 14th, 2020, for 21 days was very strict; there were strict restrictions on most of the activities, like the transportation, market, industries, *etc*.

Rajasthan also implemented all rules and regulations of this lockdown. We know that industries and transportation are major sources of pollutants, like particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3), which are directly impacting the air quality. It is a major concern of health risk and cause of large premature mortality [3, 4]. In research, it has been found that the air quality parameters of the most polluted cities (Delhi, Lucknow, Kolkata, Patna, and Bihar) and the least polluted cities (Amaravati, Panchkula, Shillong, and Chennai) of India have been changed during the lockdown period. The information regarding air quality parameters of the most and least polluted cities is provided in Table **1** [5]. In India, Rajasthan is also a very growing state with a lot of industrial development, power plants, and transportation. According to the WHO Global Air Pollution Database 2018, all four smart cities, *i.e.,* Jaipur, Udaipur, Ajmer, and Kota, are listed in the polluted cities of the world. The major pollutants include CO, which is mainly introduced into the air by the burning of fossil fuels and vehicles exhaust, SO_2 from petroleum refineries and thermal power plants, NO_2 from thermal power plants and vehicle exhausts, ozone from industrial release and vehicle exhaust, and particulate matter consists of solid in the air in the form of dust, smoke, and vapour.

Recently, researchers have reported that the lockdown period dealt with social distancing and decreasing vehicle transport, significantly improving air quality. Tobias *et al*. [6] reported that NO_2 and particulate matter (PM_{10}) were reduced by 51% and 31%, respectively, in Barcelona (Spain) during the lockdown. Nakada and Urban [7] analyzed that concentrations of CO, NO, and NO_2 decreased by 64.8%, 77.3%, and 54.3%, respectively, during the partial lockdown in the Sao Paulo state of Brazil. Dantas *et al*. [8] also reported a significant reduction in NO_2, CO, and PM_{10} levels during the COVID-19 partial lockdown in Rio de Janeiro, Brazil. It has been estimated that long-term or wide exposure to air pollution is correlated with respiratory diseases, such as bronchitis, aggravated asthma, respiratory allergies, heart disease, stroke, and death [9 - 11]. Particulate matters ($PM_{2.5}$ and PM_{10}) are considered as one of the most health risk factors and cause millions (~ 9%) of deaths around the world annually [11]. A higher concentration of NO_2 emitted from transportation and fuel combustion (outdoor anthropogenic sources) is another most important air pollutant that causes toxicity to human respiratory systems [12, 13]. A higher concentration of NO_2 causes severe illnesses, like cytokine-mediated lungs inflammation, diabetes, hypertension, cardiovascular diseases, and even death [11, 14]. Polluted air is associated with more SARS fatality and influenza [15, 16]. *In situ* study declared that SARS-CoV-2 shows stability in ambient aerosols, which can be considered a source of COVID-19 transmission [17]. Atmospheric aerosol works as a cofactor that can alter immune defence response system pathways and causes severe pneumonia [16, 18 - 20].

Table 1. Comparison of average air quality parameters before and during lockdown phase among (A) Major polluted cities and (B) Least polluted cities of India [5].

(A)								
	Delhi, Delhi		Lucknow, Uttar Pradesh		Kolkata, West Bengal		Patna, Bihar	
Air quality Parameters	Before Lockdown	During Lockdown	Before Lockdown	During Lockdown	Before Lockdown	During Lockdown	Before Lockdown	During Lockdown
$PM_{2.5}$	151.8	54.8	245	186.66	137.7	63.9	117.5	29.4
PM_{10}	166.0	71.9	NA	NA	109.5	72.0	226	NA
NO_2	60.6	21.9	37	19.33	28.1	9.6	67.5	60
CO	91.4	61.3	61.66	46.66	23.5	16.8	45	29
SO_2	13.4	12.0	5.66	5.66	10.7	8.2	9	7
Ozone	30.1	45.4	35	31.66	40.2	42.8	71	70

(B)								
	Amaravati, Andhra Pradesh		Panchkula, Haryana		Shillong, Meghalaya		Chennai, Tamil Nadu	
Air quality Parameters	Before Lockdown	During Lockdown	Before Lockdown	During Lockdown	Before Lockdown	During Lockdown	Before Lockdown	During Lockdown
$PM_{2.5}$	40.5	29	32	23.33	59	74.5	38.5	25.33
PM_{10}	42	36.66	NA	NA	50	66	NA	NA
NO_2	11.5	5.3	21.5	22.66	3.5	3	4	2
CO	25.5	10.66	2	21.33	16	14.5	16	38.66
SO_2	26	23	14	9.33	6	9	7.5	8.66
Ozone	29	20.66	56	35	52.5	11.5	52.5	24.33

In India, indoor air pollution is also causing serious public health issues because most households depend on the use of solid fuel. The long periods of lockdown to control COVID-19 in India causes adverse health effects through household air pollution [21]. In this study, we have selected four major cities of Rajasthan, *i.e.*, Jaipur, Ajmer, Udaipur, and Kota. The details of the selected cities are provided in Table **2** [22]. The main goal of this study is to analyze the impact of strict lockdown amid COVID19 on the air quality of the smart cities of Rajasthan, India, by comparing the particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide, and ozone concentrations determined during the strict lockdown with values obtained before and during the lockdown.

2. MATERIAL AND METHODS

2.1. Studied Area

Rajasthan is the largest state by area in India. It covers an area of 342,239 square kilometers (132,139 sq mi) or 10.4% of the total geographical area of India. It is located on the western side of the country, situated between 23 30' and 30 11' North latitude and 69 29' and 78 17' East longitude. In this study, we have selected four smart cities, *i.e.,* Jaipur, Udaipur, Ajmer, and Kota, as shown in Fig. (**1**), and their geographical locations, coordinates, and monitoring station are shown in Table **2** [22].

Jaipur, a smart city, is situated in the East-central part of the state. It is the capital and largest city of Rajasthan. Udaipur, Ajmer, Kota are also important cities of Rajasthan. Udaipur is located in the southern region of Rajasthan. Ajmer is situated in the center or heart of Rajasthan, and the Kota is situated at the center of the southeastern region of Rajasthan. The main characteristics are briefly described in Table **2** [22].

2.2. Experimental Data and Analysis

In this study, we have selected a total of four parameters, *i.e.,* $PM_{2.5}$, NO_2, SO_2, CO, and ozone concentration, to assess the air quality of smart cities of Rajasthan. These data were obtained from four automatic monitoring stations, *i.e.,* Adarsh Nagar, Jaipur – RSPCB, Ashok Nagar, Udaipur – RSPCB, Civil Lines, Ajmer – RSPCB and Shrinath Puram, Kota – RSPCB under the control of Central Pollution Control Board, New Delhi (https://www.cpcb.nic.in/). Data of all parameters were recorded as 24 hours average period, and the air quality of these cities was compared with the standard air quality index (AQI) before and during the lockdown (Table **3**) [5]. Experimental data obtained by each monitoring station were analyzed using standard statistical techniques. Comparisons of each parameter, *i.e.,* obtained during the lockdown and before the lockdown, were made by graphical representation. This study also included the data regarding total COVID-19 cases and death (mortality) registered in India in pre- and during the lockdown period (Table **4**) [23].

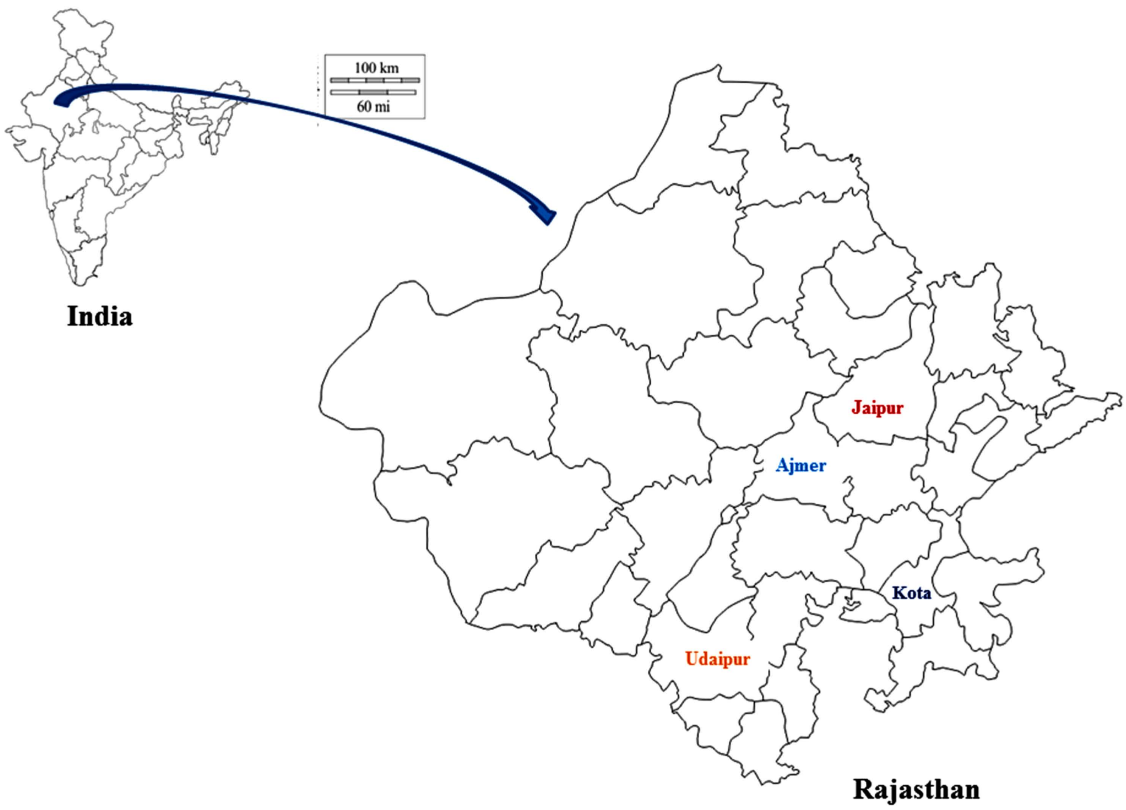

Fig. (1). Geographical status of the studied smart cities of Rajasthan situated in India.

Table 2. Description of the studied smart cities of Rajasthan, India [22].

S. No.	Smart city	Coordinates	Area (km^2)	City Population	The Monitoring Station
1.	Jaipur	26.9124°N, 75.7873° E	484.6	3,046,163	Adarsh Nagar, Jaipur - RSPCB
2.	Udaipur	24.5854°N, 73.7125° E	37	451,100	Ashok Nagar, Udaipur - RSPCB
3.	Ajmer	26.4499°N, 74.6399° E	55.76	542,321	Civil Lines, Ajmer - RSPCB
4.	Kota	25.2138°N, 75.8648° E	527	1,001,694	Shrinath Puram, Kota - RSPCB

Table 3. (A) Standard AQI and (B) AQI registered in smart cities of Rajasthan in pre and during lockdown period [5].

(A)		
AQI	**Remark (Air Pollution Level)**	**Possible Health Impacts**
0-50	Good	Minimal impact
51-100	Satisfactory	Minor breathing discomfort to sensitive people
101-200	Moderate	Breathing discomfort to the people with lungs, asthma, and heart diseases
201-300	Poor	Breathing discomfort to most people on prolonged exposure
301-400	Very Poor	Respiratory illness on prolonged exposure
401-500	Severe	Affects healthy people and seriously impacts those with existing diseases

(B)			
S. No.	**Smart City**	**Air Quality Index (AQI)**	
		Pre-Lockdown Period	**During Lockdown Period**
1.	Jaipur	91.00	66.33
2.	Udaipur	81.00	53.33
3.	Ajmer	102.50	58.00
4.	Kota	95.00	73.67

Table 4. COVID-19 cases and mortality registered in India in pre- and during lockdown period [23].

Duration	Date	Cases	Mortality	Percent (%)	Average Percent (%)
Pre-Lockdown Period	March 1	3	0	0	1.81
	March 5	30	0	0	
	March 10	62	0	0	
	March 15	114	2	1.75	
	March 20	249	5	2.00	
	March 24	536	11		
During Lockdown Period	March 25	657	13	1.97	2.70
	March 30	1251	33	2.63	
	April 1	4289	59	1.37	
	April 5	4778	119	2.49	
	April 10	7600	250	3.28	
	April 14	11887	349	2.94	

3. RESULTS AND DISCUSSION

Changes in concentrations of major pollutants during the pre-lockdown and during-lockdown period are depicted in Fig. (**2**). Indian government declared a strict lockdown in India on March 24th, 2020, which was implemented from March 25th, 2020, to April 14th, 2020. During this period, *i.e.,* 21 days, all four smart cities of Rajasthan observed substantial diminution of the pollutants. The present article assessed air quality during the strict lockdown (March 25th, 2020 to April 14th, 2020). Results showed the highest reduction in $PM_{2.5}$ found in Ajmer (53.07%), followed by Jaipur (38.32%), Kota (28.39%), and Udaipur (15.37%), respectively. PM_{10} was also found to be reduced in Ajmer (45.56%), followed by Jaipur (36.18%), Udaipur (29.40%), and Kota (19.69%), respectively. Whereas, concerning NO_2, the highest reduction was found in Udaipur (66.07%), followed by Jaipur (62.90%), Kota (56.83%), and Ajmer (54.36%), respectively. In the case of SO_2, the highest reduction was found in Udaipur (28.70%), and the lowest was found in Jaipur (11.71%).

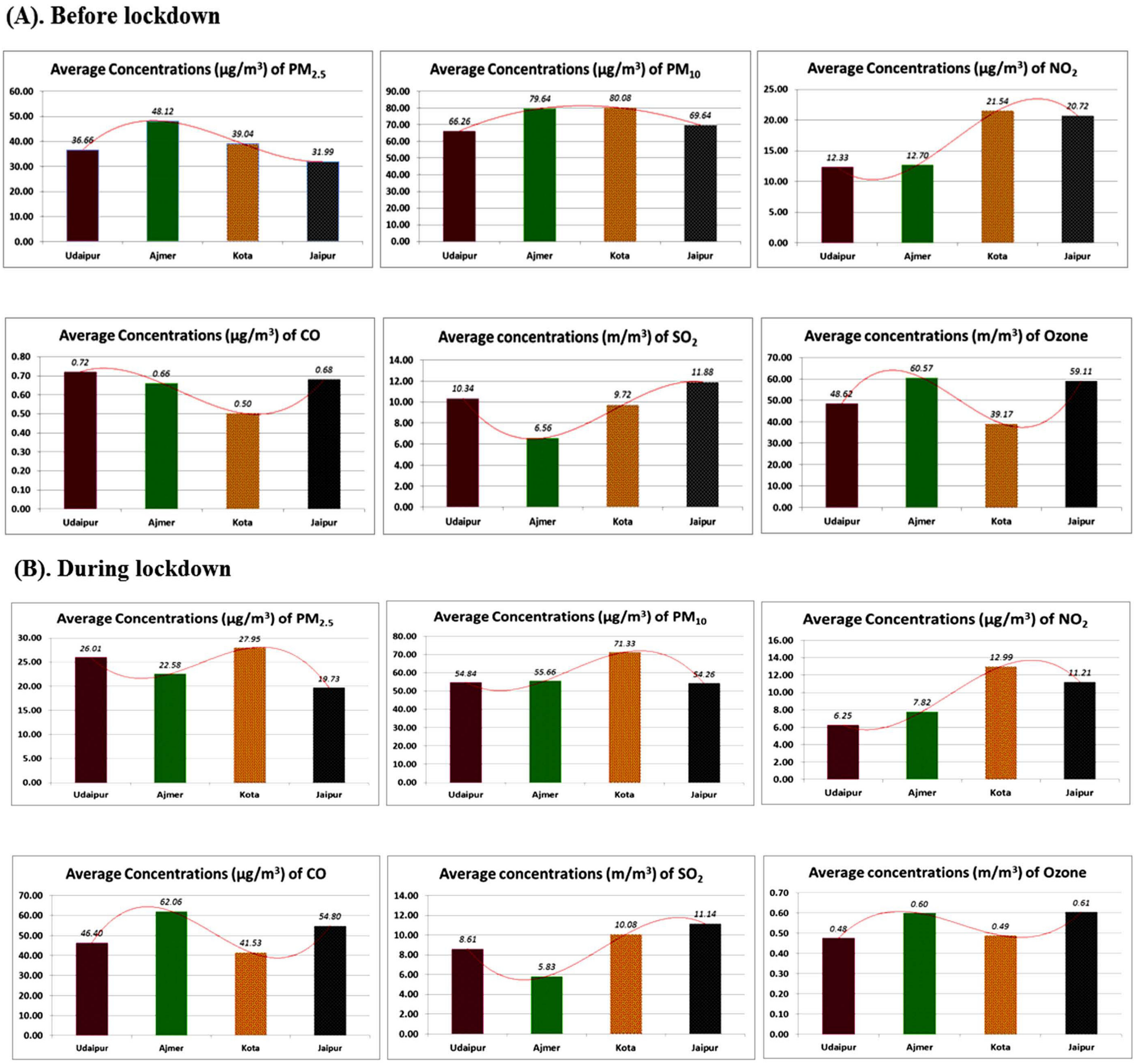

Fig. (2 A,B). Comparative analysis of different air quality parameters ($PM_{2.5}$, PM_{10}, NO_2, CO, SO_2, and ozone) of smart cities of Rajasthan, *i.e.,* Jaipur, Udaipur, Ajmer, and Kota before and during the period of lockdown.

However, increasing O_3 concentration was recorded at 12.82% in Kota and 6.08% in Ajmer, but Udaipur and Jaipur showed negative results -6.08 and -13.59%, respectively. Overall the result concluded that the air quality index of the cities was found more satisfactory during the lockdown period than the pre-lockdown period by comparing with standard AQI. In India, a high number of people were infected due to coronavirus. During the pre-lockdown (from March 1st to 24th, 2020), a total of 994 active cases and 18 deaths were registered. During the lockdown period (March 25th, 2020, to April 14th, 2020), a total of 30462 active cases and 823 deaths were registered. It was reported that active cases were increased during lockdown conditions (Table **4**). The average death rate percentage was found to be 1.81% during the pre-lockdown and 2.70% during the lockdown phase. The relationship between active cases and deaths may specify the severity of any pandemic.

It has been investigated that meteorological conditions, such as air, temperature, wind direction, and wind speed, are known to greatly impact urban air pollutant's level *via* some physical and chemical processes, like accumulation or dispersion and multiphase reactions of aerosol formation and growth [24]. Therefore, it is reasonable to suppose that changes in urban air pollutant concentrations during the COVID-19 lockdown may partially depend on meteorological conditions during that period [25]. Movements of air affect the fate of air pollutants. Concentrations of pollutants build up by non-dispersion of air pollutants due to calm air. However, when strong, turbulent winds blow, the concentration of air pollutants decreases. To estimate air quality, some important factors need to be measured, which can help in understanding the chemical reactions which occur in atmospheres, such as wind speed and direction, temperature, humidity, rainfall, and solar radiation [26].

In India, Rajasthan is also a growing state with the establishment of various kinds of industries and high pressure of transportation. Moreover, WHO also listed all four smart cities, *i.e.,* Jaipur, Udaipur, Ajmer, and Kota, as the most polluted cities of the world based on the global air pollution database. The air quality of all these smart cities was measured by the data provided by the four automatic monitoring stations. The impact of lockdown on air quality in different parts of the world indicated how human beings drastically affect the environment. Therefore, the results of the present article will possibly help us in rethinking the kind of future we are establishing. The article may also help explain how industries and transportation negatively affect the environment and how we can restore the environment and provide a good quality ecosystem to future generations. Currently, on the one hand, the outrageous viruses have affected our lives, and on the other hand, the process of environmental restoration is also going on. Hence, global concern for air pollution has led to drawing significant attention towards analyzing air pollution during the pandemic. In the metropolitan area of São Paulo (2100 km^2), the NO_2 concentration reduction is visualized by satellite measurements [5, 27, 28]. However, Sharma *et al*. [29] reported an increase of 17% in O_3 concentration in India. In China, about 25% carbon and 30% NO_2 emission have been reduced during the period of lockdown [30 - 33]. Overall, pollutant concentrations decreased in all analyzed areas.

CONCLUSION

This study can be helpful in evaluating our present role in environmental restoration or environmental destruction. It will also be helpful in updating the present plan toward the assurance and conservation of nature. The main focus of this study is to evaluate the air quality by comparing the concentration of particulate matter $PM_{2.5}$, PM_{10}, NO_2, CO, SO_2, and ozone in smart cities of Rajasthan, *i.e*., Jaipur, Udaipur, Ajmer, and Kota before and during the period of lockdown. CO levels showed the highest significant reduction in Udaipur (50.76%), followed by Jaipur (19.96%), Ajmer (17.11%), and Kota (5.51%), due to the ban on transport and driving. The levels of $PM_{2.5}$, PM_{10}, NO_2, and SO_2 were also found to be substantially decreased for each smart city.

Ozone concentration was recorded greater than before lockdown due to decreased nitrogen oxides level. Although, more specific studies are required to explore the interactions between SARS-CoV-2 and air pollutants to understand their impacts on human health. Future studies should be investigated to examine the role of indoor air pollution (biomass and tobacco smoke) during COVID-19. Biology and atmospheric chemistry should be implicated in a more holistic way to the disease management and mitigation to address the current pandemic condition and future viral epidemics. We should not ignore our surrounding environment, which is causing not only chronic diseases but also severe infectious diseases. To establish a healthy future, we need to reduce air pollution from all sources, such as road traffic and heat generation, by strengthening public health policies.

LIST OF ABBREVIATIONS

PM	=	Particulate Matter
NO_2	=	Nitrogen Dioxide
SO_2	=	Sulfur Dioxide
CO	=	Carbon Monoxide
NO	=	Nitric Oxide
WHO	=	World Health Organization
AQI	=	Air Quality Index

AUTHORS' CONTRIBUTION

TSB, MM, and PKT contributed to the study concept and design. PKT, TSB, and MM participated in data collection. Data analysis was performed by PKV and MM. TSB, PS, and MM contributed to the writing of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used in the studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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