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Assessment of interrelationship between meteorology, air quality and COVID 19 cases in Gujarat state

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ABSTRACT

In the present study, pollutants levels from March 1, 2020, to August 30, 2020, were compared with similar periods of 2019 to assess the impact of lockdown due to COVID 19 on the quality of air in 3 different cities of Gujarat, India named Ahmedabad, Gandhinagar, and Valsad. Data was collected from AccuWeather and Central Pollution Control Board website for study period. Data was analyzed by comparing air quality taking 2019 as reference and correlation matrix were developed for study sites. Lockdown resulted from COVID-19 has shown decline trends in pollutant concentration resulting in improved air quality in the study area. In the first city Ahmedabad, Gujarat an air pollutant parameter such as CO, PM_{2.5}, PM₁₀, NO₂, and SO₂ were reduced by 54%, 181%, 70%, 33%, and 103% respectively. Almost similar trends were observed in the rest of the two cities also i.e., Gandhinagar and Valsad. NO₂ level got reduced by a factor of 100% which can be associated with ban on vehicular movement. Correlation between the air pollutant and metrological variables with COVID-19 variables were also studied by developing correlation matrix. In Gandhinagar, a strong correlation was observed between carbon monoxide, and PM₁₀ with COVID-19, a moderate correlation between NO₂, and SO₂ with the COVID-19 variables, a weak correlation was found between temperature and COVID-19, and no correlation is found between wind speed and COVID-19 variables.

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1. Introduction

An infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) later called Coronavirus disease 2019 (COVID-19) on January 30, 2020 trace back its origin to China, Wuhan district to December 2019 [1,13]. The current ongoing threat to global health that affects the respiratory system of humans declared by the WHO as a Global health emergency for the international community and on March 11, 2020, the organization declared it as a global pandemic [2,3,15]. The spread and transmission of the virus is through a close contact with an infected person through droplet of aerosol during coughing or sneezing [16]. The rapid spread of the virus was so fast that the total confirmed case rises from 83,441 in May 7, 2020 to 157,283,915 by May 7, 2021 world wide and 3.27 million people lost their life because of the virus according to the WHO report [15].

As of May 7, 2021, India reports 21.87 million total cases and 594,135 deaths due to this virus (WHO report). The first case in January 30, 2020 from Thrissur district of Kerala state, where a student comes back from the origin of the virus, Wuhan, China. According to the website called corona India tracker the total number of people affected in Gujarat as of May 7, 2021, was 646,000 total cases and 8035 death was recorded [12]. As a result of this the government of Gujarat put the state under lockdown from March 19, 2020, similarly many state governments put their state under lockdown, due to this Indian government forced to put a nationwide lockdown from March 25, 2020 [4,12].

During phase one lockdown in India nearly all services and factories were suspended which lasted up to April 14, 2020 [19]. And the second phase of the lockdown which was extended up to May 3, 2020 areas were classified as a red orange and green zone based on the spread of the virus as highly, moderate and less respectively [19,20]. Third and fourth phases of lockdown were more relaxed than the previous one but still some restrictions were put down. But Residents were encouraged to stay at home and to keep up

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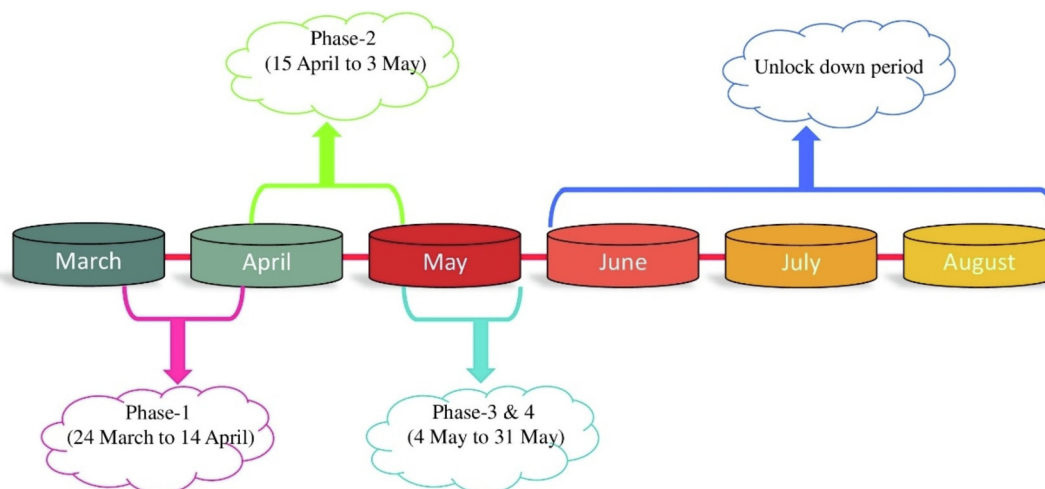


Fig. 1. Different phases of lockdown in Gujarat in 2020.

with social separating [5,21]. Fig. 1 shows various periods of Lockdown in Gujarat state.

Some of the activities that were banned during the pandemic periods are social gathering, education including schools and universities, sport activities, all domestic and international air travels, all passenger movement by train, buses and public transport, taxis, industrial activities etc. Such Economic development activities and movement of people are the major factor that contribute to global environmental pollution because fuel combustion directly releases Greenhouse Gas (GHG) emissions into the atmosphere. Which directly or indirectly responsible for the release of air pollutant to the atmosphere [14,23]. Air pollution is the presence of foreign matter (chemicals gases like NO₂, SO₂, and CO, particles like PM_{2.5}, PM₁₀, and dust, or biological molecules like viruses and bacteria's) to the atmosphere or environment that can harm human health, animals, plants and other non-living things including water bodies and buildings. [24]

Air pollutants can be manmade or naturally occurring but due to the rapid increase of industries and activities of humans in our world, theirs is the release of air pollutants [6,10,25]. According to the report from IQAir in 2019, 13 cites from India present on top 20 most polluted cities in the world list on the annual average concentration of PM_{2.5} [6] and Ahmedabad the largest city in Gujarat ranked 69 With PM_{2.5} Annual Average 59 µg/m³ in 2019 [11]. Which exceed the WHO limit which is 35 µg/m³ [22]. Air pollution sources in India are thermal power plants, biomass burning, and vehicles in cities. A report from the world health organization in 2014, Indian cities have the dirtiest atmosphere out of 1600 cities in the world, based on the report the capital city Delhi has six times higher the world health organization's safe limit for particulate matter diameter less than 2.5 µm [7,10].

The objectives of this study are to analyse the impact of the COVID-19 lockdown on the quality air such as concentration NO₂, SO₂, CO, PM_{2.5}, PM₁₀ in three cities of Gujarat, India and to find a correlation between COVID-19, air pollutants, and metrological parameters for Gujarat state, India.

2. Methods and materials

The study was conducted in Gujarat state, one of the states in India which are found on the western coast. The geographical location of Gujarat on a map is 22.2587° N, 71.1924° E [8]. Specifically, the study had focused on 3 major industrial and important cities of Gujarat state i.e., Ahmedabad, Gandhinagar, and Valsad. Table 1 is

having detailed information about the study area including area, elevation, average temperature, and population. In this study, an analysis was carried out for variables like air quality parameters and COVID-19 statistics. The study period was kept from the first of March 2020 to the end of August 2020 to understand more about the changes in quality of air due to lockdown imposed due to COVID-19. As a reference, air quality data for 2019 was used for the comparison.

2.1. Data collection

The daily average air pollutant concentration such as NO₂, PM_{2.5}, PM₁₀, SO₂, and CO was generated from the official website of the Central Pollution Control Board (CPCB) at https://app.cpcbcr.com/AQI_India/, which was established in 1974. The daily average Metrological data such as air temperature and wind speed for the three study areas were generated from the website <https://www.accuweather.com/en/in>. For COVID-19 data (new case, recovery, and deaths), The Database of National Center for Disease Control (NCDC) was used, which is controlled by the Ministry of Health and Family Welfare (MoHFW) - Government of India (<https://ncdc.gov.in/dashboard.php>). NCDC was established in 1963, with the main objective to provide support to research in epidemiology and control of communicable diseases [18]. Fig. 2 shows portals of AccuWeather and CPCB.

2.2. Data analysis

- I. A Change in the quality if air during the Lockdown Period in 2020 and during 2019 was studied. The data set has been distributed into reference year (2019), and the year of (2020) for comparison. Equation (1) were used to calculate the percentage change.

$$c = \frac{Yc - Yp}{Yc} * 100 \tag{1}$$

Where **C**- Percentage change, **Yc** -Average pollutant concentration in 2020, **Yp**- Average pollutant concentration in 2019

- II. A correlation matrix was developed using Microsoft Excel software to analyze the degree of two variables affects each other. This study divides the matrix table into 5 categories denoted by colors red denotes a very strong correlation, yellow denotes a strong correlation, brown represents a moderate correlation, green represents a weak correlation, and

Table 1
Basic details about Study Area.

City	Area (km ²)	Elevation	Average Temperature	Population (as of 2011 Census)	Remark
Ahmedabad	464	53 m	29 °C	55,70,000	Metro City
Gandhinagar	326	81 m	28 °C	2,92,000	Capital City
Valsad	2947	13 m	36 °C	17,10,000	Industrial City

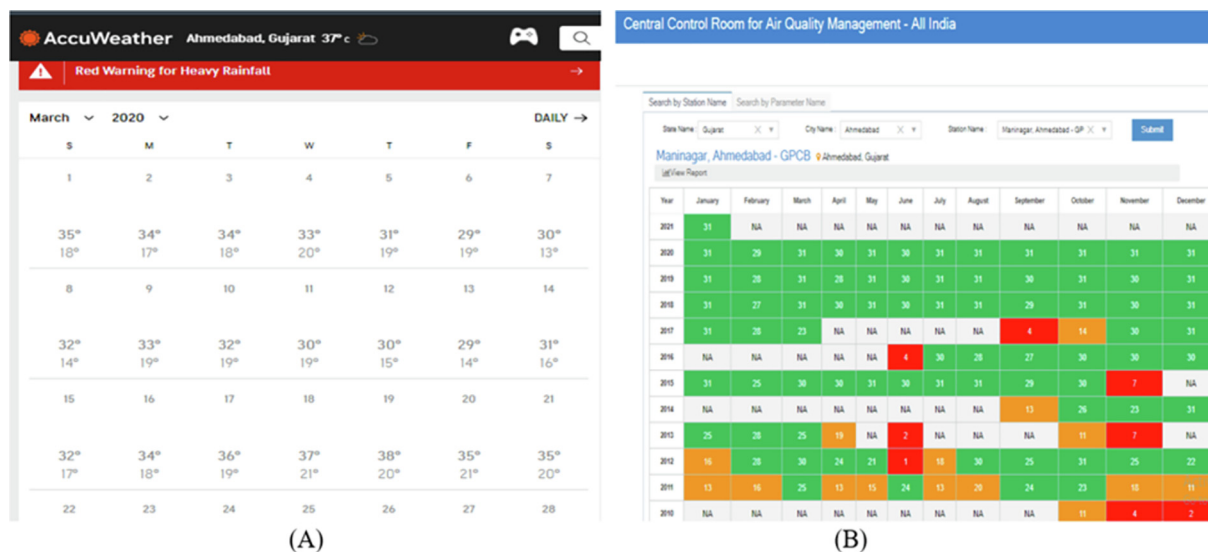


Fig. 2. Snapshots of portal of AccuWeather (A) and Central Pollution Control Board (B) [26,27].

blue represents no correlation, which is a tool to measure and analyse the degree of the extent to which two variables fluctuate regarding each other [9,17]. Two variables are said to be correlated to study the change in one variable that affects a change in the other variable

3. Results and discussion

3.1. Impact of lockdown on the quality of ambient air

The lockdown due to COVID-19 made a significant impact on the overall ambient air quality of the state and the concentration of the major criteria air pollutants. According to the data gathered from the central pollution board a significant enhancement on the quality of ambient air in Ahmedabad, Gandhinagar, and Valsad districts are observed. As shown in Fig. 3(a), during the lockdown period that starts from March, the air pollutant parameters such as CO, NO₂, PM_{2.5}, PM₁₀, and SO₂ were reduced by 54%, 181%, 70%, 33%, and 103% respectively in the city of Ahmedabad, Gujarat. Fig. 3 (b) shows, during the lockdown period that starts from March the air pollutant parameters such as NO₂, PM_{2.5}, PM₁₀, and SO₂ reduced by 112%, 55%, 72%, and 15% respectively in the capital city of Gujarat, Gandhinagar. But an increase in the concentration of CO observed by 19%. During the lockdown period that starts from March the air pollutant parameters such as NO₂, PM_{2.5}, PM₁₀, and Sulfur dioxide reduced by 171%, 62%, 73%, 85%, respectively in the district of Valsad, Gujarat as shown in Fig. 3(c). But it shows an increase in the concentration of carbon monoxide by 40%.

3.2. Correlation between air pollutants, meteorological variables, COVID-19 cases

Tables 2–4 are for cities of Ahmedabad, Gandhinagar and Valsad respectively, representing the correlation between different air

pollutant variables such as Carbon Monoxide (mg/m³), Nitrogen Dioxide (µg/m³), Sulfur Dioxide (µg/m³), Particulate Matter (µg/m³) (PM_{2.5} and PM₁₀) with COVID-19 variables such as new case, death, and recovery also with Air Temperature (°C) and Wind Speed (m/s). Major air pollutants concentration during COVID 19 were also compared with the concentration of same pollutants before COVID 19 (i.e. 2019) (Figs. 4–6).

As shown from the table there is a very strong positive correlation between confirmed new cases with recovery, confirmed new case with death, and also recover with death due to COVID-19 which is marked by red in the table, that means an increase in confirmed new cases there will be increase recovery and death rate. Carbon Monoxide (mg/m³) has a strong positive correlation (marked by yellow) with a confirmed new case with a coefficient of 0.63. That means an increase in the concentration of carbon monoxide in the air, there will be an increase in the number of new confirmed cases. Also, carbon monoxide has a moderate positive correlation, (marked by brown) with recovery and number of deceases.

Particulate matter (PM_{2.5}) has a weak negative correlation (marked by green) with confirmed new cases, recovery rate, and the number of deceases. Based on this result showed in the table an increase in the concentration of particulate matter (PM_{2.5}) will decrease the variables in the COVID-19 (new cases, recovery rate, and the number of death) side. The table also shows there is almost no correlation (marked by blue) between particulate matter (PM₁₀) with the COVID-19 new case, recovery cases, or death in Ahmedabad.

Nitrogen dioxide has a weak positive (marked by blue) correlation that means an increase in the concentration of nitrogen dioxide will also affect the COVID-19 variables slightly. Sulfur dioxide also has a weak negative correlation with all the COVID-19 variables. The temperature has a week positive correlation (marked by green) with recovery rate but no correlation with new cases

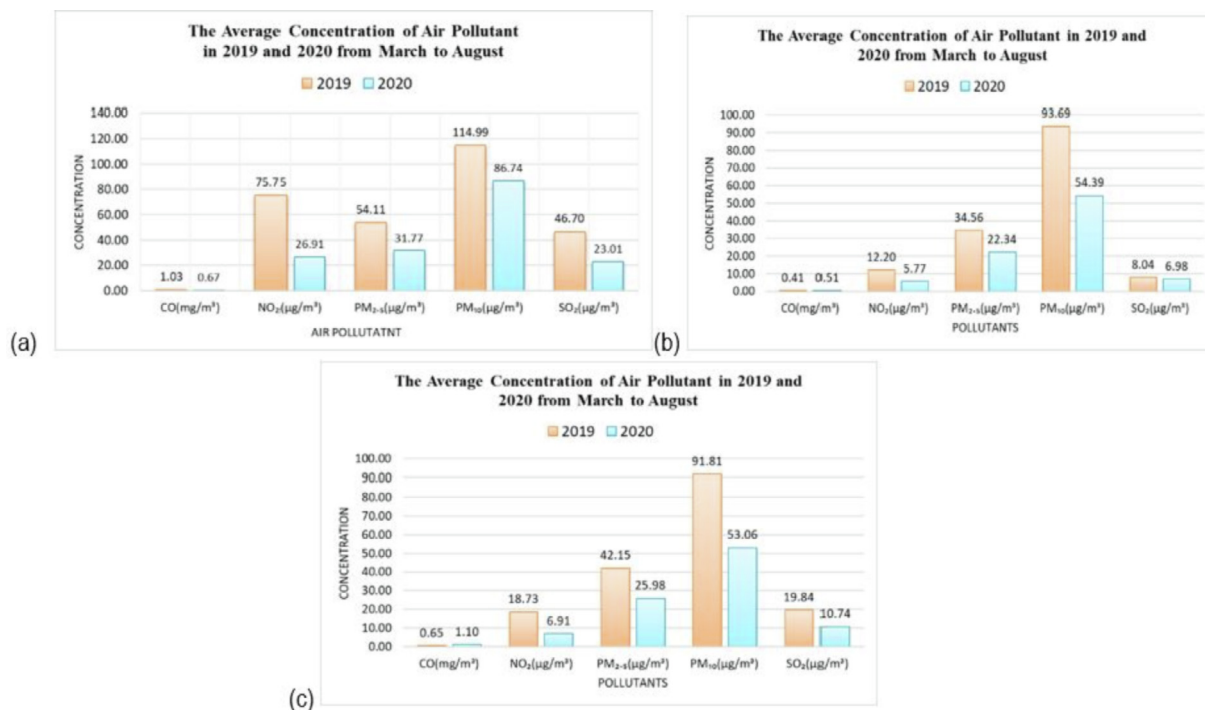


Fig. 3. Average concentration of pollutants in 2019 and 2020 for 3 major cities (a) Ahmedabad, (b) Gandhinagar, and (c) Valsad.

Table 2
Correlation between air pollutant and COVID-19 variables in Ahmedabad.

	New case	Recovered	Deceased	CO (mg/m ³)	NO ₂ (µg/m ³)	PM _{2.5} (µg/m ³)	PM ₁₀ (µg/m ³)	SO ₂ (µg/m ³)	T (°C)	WS (m/s)
Confirmed	1.00									
Recovered	0.99	1.00								
Deceased	0.99	0.97	1.00							
CO (mg/m ³)	0.63	0.49	0.53	1.00						
NO ₂ (µg/m ³)	0.15	0.28	0.18	0.14	1.00					
PM _{2.5} (µg/m ³)	-0.23	-0.19	-0.29	-0.19	0.45	1.00				
PM ₁₀ (µg/m ³)	-0.12	-0.15	-0.16	-0.02	0.21	0.48	1.00			
SO ₂ (µg/m ³)	-0.28	-0.27	-0.33	-0.18	0.12	0.27	0.18	1.00		
T (°C)	-0.18	-0.31	-0.11	-0.07	-0.51	-0.25	-0.02	-0.18	1.00	
WS (m/s)	0.22	0.14	0.13	-0.01	-0.27	-0.16	-0.05	0.02	0.02	1.00

Red denotes a very strong correlation (±0.8 to 1), yellow denotes a strong correlation (±0.6 to 0.8), brown represent a moderate correlation (±0.4 to 0.6), green represent a weak correlation (±0.2 to 0.4), and blue represents no correlation (±0 to 0.2).

and recovery cases. Like temperature, wind speed shows a weak positive correlation (marked by green) with the number of new cases but no correlation with recovery in death rate.

Carbon monoxide (CO) has a strong positive correlation (marked with yellow) with covid-19 new cases and recovery rate, and a very strong positive correlation with the number of death

Table 3
Correlation between air pollutant and COVID-19 variables in Gandhinagar.

	New case	Recovered	Deceased	CO (mg/m ³)	NO ₂ (µg/m ³)	PM _{2.5} (µg/m ³)	PM ₁₀ (µg/m ³)	SO ₂ (µg/m ³)	T (°C)	WS (m/s)	
Confirmed	1.00										
Recovered	1.00	1.00									
Deceased	0.96	0.93	1.00								
CO (mg/m ³)	0.72	0.68	0.83	1.00							
NO ₂ (µg/m ³)	0.50	0.55	0.34	-0.22	1.00						
PM _{2.5} (µg/m ³)	-	0.52	-0.50	0.52	0.44	-0.10	1.00				
PM ₁₀ (µg/m ³)	-	0.65	-0.62	0.68	0.66	-0.24	0.80	1.00			
SO ₂ (µg/m ³)	-	0.43	-0.41	0.50	0.22	0.09	0.25	0.17	1.00		
T (°C)	-	0.37	-0.43	0.26	0.26	-0.66	0.11	0.31	-0.21	1.00	
WS(m/s)	-	0.01	-0.03	0.03	-0.13	0.03	-0.13	-0.13	0.06	0.02	1.00

Red denotes a very strong correlation (±0.8 to 1), yellow denotes a strong correlation (±0.6 to 0.8), brown represent a moderate correlation (±0.4 to 0.6), green represent a weak correlation (±0.2 to 0.4), and blue represents no correlation (±0 to 0.2).

Table 4
Correlation between air pollutant and COVID-19 variables in Valsad.

	New case	Recovered	Deceased	CO (mg/m ³)	NO ₂ (µg/m ³)	PM _{2.5} (µg/m ³)	PM ₁₀ (µg/m ³)	SO ₂ (µg/m ³)	T (°C)	WS (m/s)
Confirmed	1.00									
Recovered	0.98	1.00								
Deceased	0.95	0.91	1.00							
CO (mg/m ³)	0.22	0.03	0.19	1.00						
NO ₂ (µg/m ³)	-0.39	-0.33	-0.53	0.09	1.00					
PM _{2.5} (µg/m ³)	-0.48	-0.41	-0.63	0.20	0.70	1.00				
PM ₁₀ (µg/m ³)	-0.44	-0.36	-0.61	0.10	0.72	0.94	1.00			
SO ₂ (µg/m ³)	-0.55	-0.44	-0.62	-0.31	0.26	0.37	0.42	1.00		
T (°C)	-0.50	-0.52	-0.37	-0.19	-0.03	-0.10	-0.15	0.20	1.00	
WS(m/s)	-0.20	-0.14	-0.21	-0.30	0.08	0.07	0.14	0.13	-0.09	1.00

Red denotes a very strong correlation (±0.8 to 1), yellow denotes a strong correlation (±0.6 to 0.8), brown represent a moderate correlation (±0.4 to 0.6), green represent a weak correlation (±0.2 to 0.4), and blue represents no correlation (±0 to 0.2).

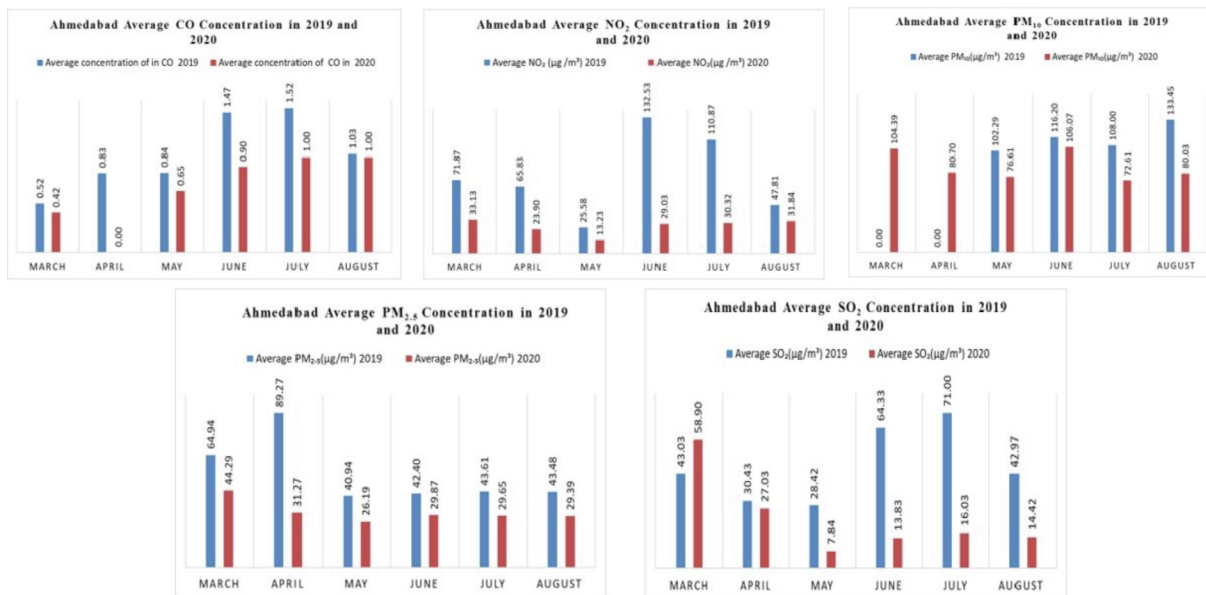


Fig. 4. Average air pollutant concentration in 2019 and 2020 in Ahmedabad city.

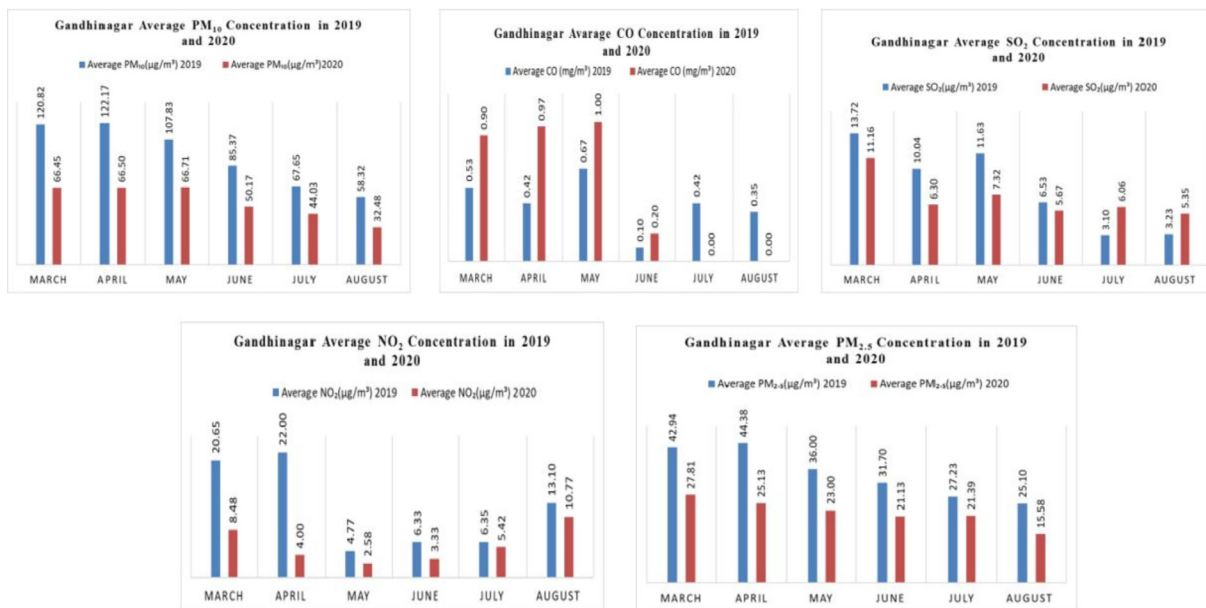


Fig. 5. Average air pollutant concentration in 2019 and 2020 in Gandhinagar city.

(marked with red) due to covid-19 an increase in the concentration of carbon monoxide will directly relate with an increase the new number of cases, number death and the number of recovers.

Nitrogen dioxide (NO₂) have a moderate relation with COVID-19 variables (marked with brown) in the table and also have a weak correlation with the number of deaths, the same way sulfur dioxide (SO₂) and particulate matter (PM_{2.5}) have a moderate negative correlation with COVID-19 variables (marked with brown) that means an increase in these air pollutants will decrease the variables in the covid-19 side. A negative strong correlation between Particulate matter (PM₁₀) and new cases, recovery case, death was observed. Also, a moderate correlation between temperature and recovery case as well as weak correlation between tem-

perature and new case and death observed. And no correlation is found with wind speed and COVID-19 cases

As always there is a strong correlation between confirmed cases, recovery rate, and the number of deaths. When we come to the correlation between the air pollutant variable and the COVID-19 variable. A weak PM correlation was observed between carbon monoxide and new COVID-19 cases, marked by green. And almost no correlation with recovery rate and the number of death due to COVID-19 in the district of Valsad.

Nitrogen dioxide has a weak negative correlation denoted by green with new COVID-19 cases, recovery cases and a moderate negative correlation with the number of deaths. Particulate matter (PM_{2.5}, PM₁₀) has a moderate negative correlation with new con-

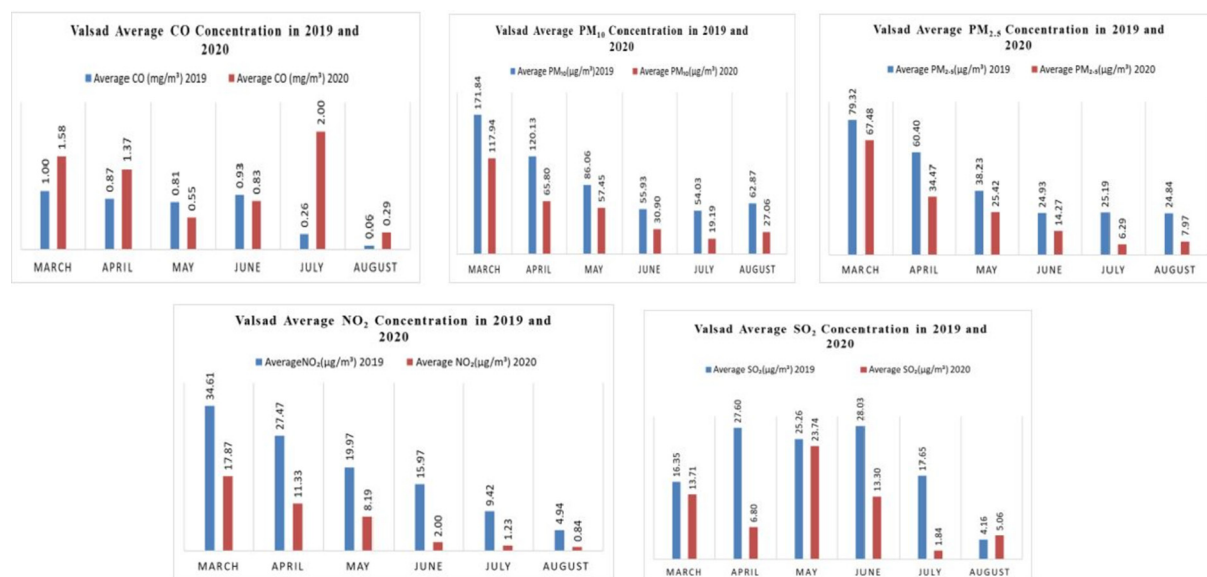


Fig. 6. Average air pollutant concentration in 2019 and 2020 in Valsad city.

firmed cases and recovery rate but particulate matter (PM_{2.5}, PM₁₀) has a strong negative correlation denoted by yellow with the number of deaths.

A moderate correlation ship between sulfur dioxide concentration and new confirmed cases, and recovery were observed. But it has a strong negative correlation represented by yellow with the number of deaths that means when the concentration of the air pollutant increases the number of deaths is decreasing. Temperature also has a moderate correlation with new cases and recovery rate but a weak correlation was observed with the number of deaths. Wind speed almost does not correlate with the transmission of COVID-19 in Valsad district.

4. Conclusion

Results showed that the lockdown due to COVID-19 enhanced the quality of ambient air in the three cities of Gujarat. The enhancement in the quality of air can be correlated with the prohibited activities put by the government in the name of lockdown including ban of all domestic and international air travel for passengers, metros rail service, buses for public transport, inter-district or state movement, education, training, social gathering, and closure of industries that produce non-essential goods. But agricultural activity is not on the list of prohibited activities so it led to the release of carbon monoxide which shows an increase in two of the three cities.

Correlation between the air pollutant and metrological variables with COVID-19 variables was also studied along with development of correlation matrix for three cities. NO₂ level got reduced by a factor of more than 100% for all 3 cities which can be linked with ban on vehicular movement and industrial activity. CO was found to be having strong correlation with number of COVID cases and recovery rate. The lockdown and restrictions put down by different governments and states to governor the spread and transmission of COVID-19 has indirectly helped our environment to recover by reducing the number of air pollutants released to the environment.

CRedit authorship contribution statement

Tewodros Adane Simret: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization, Validation.

Abhishek Gupta: Supervision, Formal analysis, Project administration, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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