Assessment of Air Pollution before and during COVID-19 Pandemic Lockdown in Chhattisgarh State, India

H Rajput1 and S Barde2
1Research Scholar, MSIT, MATS University, Raipur (C.G), India
2Professor, MSIT, MATS University, Raipur (C.G), India
rajputhansa1991@gmail.com
v.snehabarde@gmail.com

Abstract. Air pollution is known to be the most common problem worldwide. Most cities have air pollution, and new pollutants are being added to the atmosphere, making it more toxic. Air quality prediction is a complex task because of the dynamics, volatility, and high temporal and spatial variability of pollutants and particles. Intending to control the expansion of COVID–19, the Indian government has announced a strict and total lockdown beginning March 25, 2020, in all countries, besides essentials. The goal of this research work is to find out the effect of lockdown on air quality in the four cities of Chhattisgarh state: Raipur, Bilaspur, Durg-Bhilai, and Korba. For that, we are using data from the official site of the Chhattisgarh Environment Conservation Board (CECB). The data is divided into two phases before the three months of lockdown (December 2019 to February 2020) and during the three months of lockdown (March to May 2020). We compared the data and performed a detailed analysis using SPSS software of the impact of COVID-19 on air quality and, as a result, found a major change in the Air Quality Index (AQI), geographical circulation levels, and concentration of various parameters: PM10, PM2.5, NO2, SO2, and CO.

Keywords: Air Pollution, IoT, Covid-19, Air Quality Index

1. Introduction
The new Corona-virus disease COVID–19 coming from SARS-CoV-2 Virus (Severe Acute Respiratory Syndrome Coronavirus-2) was foremost recognized in December 2019 in Wuhan, China [2, 3]. Next to March 2020, the disease had spread quickly to other countries, and a pandemic was proclaimed on March 12, 2020 (WHO 2020). COVID–19 had afflicted 110 million people worldwide as of February 18, 2021, and killed over 2.45 million people [2, 3, 4, 7].

India has imposed a national lockdown for several months, starting March 25, 2020, to stop the spread of COVID–19 infections. Except for required services, all transportation (roads, planes, railroads), schools, universities, industrial plants, hotels, restaurants, retail malls, and markets were closed during the lockdown (CPCB, 2020). The National Air Quality Index (NAQI) proclaimed by the Central Pollution Control Board (CPCB) poses various economic challenges. Nevertheless, it suggested a positive result. Several studies have reported the short-term and long-term changes in air quality, as well as the impact of COVID–19 dictated restrictions in Indian cities. Unlike most of the published work and research on Indian cities, the current study reports the findings on COVID-19 induced changes in air quality throughout both the lockdown and unlocking periods. In addition, we also report both periods have many changes and outcomes [1]. The improvement and enhancement...
inspired us to further investigate COVID–19 effects on air quality in four districts of Chhattisgarh State.

It is widely agreed, the growth of human population especially the rapid modernization, economic development, and co-modification of Chhattisgarh state resulted in a deterioration of the quality of air [11]. Chhattisgarh has been declared one of the most polluted states in the world (WHO, 2016). Air pollution was found to be less than or under the acceptable limits of air quality criteria set by the Central Pollution Control Board (CPCB, 2009) even in the most polluted cities. To better understand the effects of lockdown, some research has been done on air pollution. To understand the details of the air quality changes, we have divided the whole period into two stages: Before Lockdown and During Lockdown phase [8]. This research will assist us in evaluating the lockdown's impact on the targeted five pollutants (PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$, and CO). All industrial, vehicle and commercial activities were prohibited during the lockdown period. As a result, this is a perfect situation in which to investigate their direct impact on pollution reduction and their role in raising air pollution [10].

2. Research study area

The research area encompasses Chhattisgarh state, which includes four cities, namely Raipur, Bilaspur, Durg-Bhilai, and Korba (Figure 1). These cities are among Chhattisgarh's most developed and densely populated. They are also experiencing rapid urbanisation and industrialization, as well as increased socio-economic activity. However, the problem of air pollution is increasing due to rapid development. As a result, cities are facing serious air pollution problems and challenges, thus Chhattisgarh state has been named one of the most polluted states in the country.

![Figure 1](source:WHO Report 2014–2018 b) in map black circles showing study area of Chhattisgarh state (Source: infoandopinion.com).

Raipur

Raipur city is jammed in the middle of 2 industrial buildings on its east and west edges (extended at distances of about 20–30 km) in the company of a few notable industries, namely Century Cement Factory, Monnet Sponge Iron and Power Plant, Bhilai Steel Plant, Larson & Toubro Cement Plant, Jamul Cement Factory, Woolworth Textile Plant and others. Within 30 kilometers of the circle, there are numerous agro forestry plants, electrical product manufacturing factories, fertilizer plants, and oil extraction plants. This massive coal-burning industry generates a lot of fly ash. The air distribution method has an impact on the local environment and the surrounding area [12, 13].
Figure 2. a) Waste product of chemical factory have been thrown in open field in Lalpur area of Raipur b) Carbon spread in all over the city in the form of smoke c) Heavy traffic in many areas of the city (Source: oneindia.com)

Bilaspur

In the case of pollution in the country, Justice Bilaspur has now come to the top. Bilaspur is also known as the center of India's power generation hub, among other industries. Comparable to Raipur, Bilaspur has witnessed numerous changes since the creation of the state. Alike another city in Chhattisgarh, Bilaspur city is also home to many coal and iron factories. Iron and Steel production is a result of speedy development, which has resulted in environmental issues due to the massive amount of waste produced and its management implications. The steel industry is the largest consumer of energy and natural resources, emits massive amounts of air pollutants, and consequently causes substantial local and worldwide environmental challenges.

Figure 3. a) Smoke billows out of a cement plant at Barmana in Bilaspur (Source: tribune.com) b) A toxic haze has blanketed the streets of Bilaspur since morning time c) Dust from construction work.

Durg-Bhilai

The Durg-Bhilai city area in Chhattisgarh state is home to the state's new administrative capital, which is connected by an expressway that serves as an industrial corridor and is situated between the edge of the Mahanadi River in the North and Deccan Plateau in the South Chota Nagpur. Raipur, Durg-Bhilai (RDB) is the largest steel manufacturing hub, with many foundries, metal-alloy factories, steel casting, and rolling work, iron and sponge factories, cement production, and formalin manufacturing hub in India. India's largest and most productive integrated steel plant is the Bhilai Steel Plant [12, 13].

Figure 4. a) Alarming levels of air emissions b) Open Waste Burning c) Smog and dust.

Korba

Korba, placed inside the northern 1/2 of Chhattisgarh, quarters to many coal-floor thermal power plants, inclusive of National Thermal Power Corporation (NTPC) and Chhattisgarh State Electricity Board (CSEB). Korba has 14 thermal power plants with a turn-out of 8,625 MW accounting for 17.26 percent of the country's total coal production. Annually, the Korba plant produces over 1 lakh metric tons of fly ash. These power plants produce 6090 (MW) of electricity and supply electricity to Korba
and its surrounding areas. This is one of the reasons to make the city a pollution hub. Coal transportation in open trucks is frequent in Korba, which contributes to poor air and water pollution. Korba is one of the most severely contaminated locations in the country, according to the Central Pollution Control Board's (CPCB) Comprehensive Environmental Pollution Index [12].

![Figure 5.](https://example.com/figure5.png)  
Figure 5. a) In Korba, Transportation of coal in open trucks is very common (Source: Mayank Aggarwal/Mongabay-India) b) Coal mines that are just a few minutes away from the main Korba city (Source: Mayank Aggarwal/Mongabay-India) c) Black Dust in local area and on the roadside is a daily occurrence.

3. Data collection

The data on air pollutants were collected from the official site of the Chhattisgarh Environment Conservation Board (CECB). CECB's headquarters are in Raipur, with few regional offices in significant cities like Raipur, Bilaspur, Durg-Bhilai, and Korba. The board recently promoted Raipur Laboratory to Central Laboratory and Research & Development Center. Each laboratory has high-precision laboratory equipment for examining and measuring a wide range of environmental samples. The data is divided into two phases: before lockdown (December 2019 to February 2020) and during lockdown (March to May 2020). Data were obtained for four cities from 15 monitoring stations: 6 from Raipur, 1 from Bilaspur, 4 from Durg-Bhilai, and 4 from Korba, respectively.

CECB maintains an air pollution monitoring system in Chhattisgarh, together with those used in this study, through an air quality monitoring network called the Ambient Air Quality Monitoring System (AAQMS). Intending to completely understand the influences of procedures made during the phase of lockdown on air quality, this study took into 5 most relevant pollutants were, and these air pollutants incorporate particulate matter (PM$_{10}$ and PM$_{2.5}$), nitrogen dioxide (NO$_2$), sulfur dioxide (SO$_2$), and carbon mono-oxide (CO).

4. Result Analysis

The air quality in Chhattisgarh state is being investigated in four major districts. The real-time data set were divided into two phases, i.e. before three months of lockdown and during three months of lockdown. For identifying the variation among different parameters, SPSS software is used as a tool for the calculation of pollutants (minimum, maximum, mean, and standard deviation) shown in below tables, for plotting graphs the ROC curve is used. The phase-wise variations of the pollutants for four cities are shown below.

| Parameter     | N  | Minimum | Maximum | Mean  | Std. Dev. |
|---------------|----|---------|---------|-------|-----------|
| PM$_{10}$ (µg/m$^3$) | 55 | 45.00   | 92.00   | 67.4436 | 25.04423  |
| PM$_{2.5}$ (µg/m$^3$) | 55 | 40.37   | 90.54   | 63.7476 | 14.80779  |
| NO$_2$ (µg/m$^3$)     | 55 | 10.41   | 33.96   | 27.2200 | 4.69800   |
| SO$_2$ (µg/m$^3$)     | 55 | 8.59    | 23.59   | 19.1773 | 4.16274   |
| CO (mg/m$^3$)         | 55 | 10.59   | 23.59   | 11.4927 | 5.84078   |

Valid N (listwise) | 55 |
Figure 6. a) ROC curve: Mean and standard deviation of PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO (pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$) levels in Raipur before lockdown.

Table 1. b) Raipur: Descriptive Statistics during the Lockdown (March to May 2020).

| Parameters   | N  | Minimum | Maximum | Mean   | Std. Deviation |
|--------------|----|---------|---------|--------|----------------|
| PM$_{10}$ (µg/m$^3$) | 47 | 30.50   | 61.35   | 46.1540| 5.37943        |
| PM$_{2.5}$ (µg/m$^3$) | 47 | 30.50   | 61.35   | 45.2679| 5.55641        |
| NO$_2$ (µg/m$^3$)    | 47 | 7.50    | 28.63   | 25.3636| 3.86007        |
| SO$_2$ (µg/m$^3$)    | 47 | 4.75    | 17.63   | 7.0919 | 1.96676        |
| CO (mg/m$^3$)        | 47 | 4.30    | 17.45   | 7.2577 | 1.77024        |
| Valid N (listwise)   | 47 |         |         |        |                |

Figure 6. b) ROC curve: Mean and standard deviation of PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO (pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$) levels in Raipur during lockdown.
### Table 2.a) Bilaspur: Descriptive Statistics before Lockdown (December 2019 to February 2020).

| Parameters     | N  | Minimum | Maximum | Mean   | Std. Deviation |
|----------------|----|---------|---------|--------|----------------|
| PM$_{10}$ (µg/m$^3$) | 25 | 48.50   | 63.50   | 56.9160 | 4.04925        |
| PM$_{2.5}$ (µg/m$^3$) | 25 | 48.50   | 63.50   | 57.3240 | 3.90099        |
| NO$_2$ (µg/m$^3$)   | 25 | 10.50   | 13.30   | 12.1600 | .68860         |
| SO$_2$ (µg/m$^3$)   | 25 | 3.50    | 6.80    | 5.4200  | .78049         |
| CO (mg/m$^3$)       | 25 | 3.50    | 6.80    | 67      | .64420         |
| Valid N (listwise) | 25 |         |         |         |                |

### Table 2.b) Bilaspur: Descriptive Statistics during the Lockdown (March to May 2020).

| Parameters     | N  | Minimum | Maximum | Mean   | Std. Deviation |
|----------------|----|---------|---------|--------|----------------|
| PM$_{10}$ (µg/m$^3$) | 12 | 33.70   | 63.00   | 55.0333 | 7.27728        |
| PM$_{2.5}$ (µg/m$^3$) | 12 | 33.70   | 63.00   | 55.9167 | 7.62935        |
| NO$_2$ (µg/m$^3$)   | 12 | 11.20   | 17.00   | 14.3750 | 2.00097        |
| SO$_2$ (µg/m$^3$)   | 12 | 3.30    | 8.00    | 6.1333  | 1.63892        |
| CO (mg/m$^3$)       | 12 | 3.30    | 17.00   | 11.9833 | 5.45324        |
| Valid N (listwise) | 12 |         |         |         |                |

**Figure 7.** a) ROC curve: Mean and standard deviation of PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO (pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$) levels in Bilaspur before lockdown.
Figure 7.b) ROC curve: Mean and standard deviation of PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO (pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$) levels in Bilaspur during the lockdown.

Table 3.a) Durg-Bhilai: Descriptive Statistics before Lockdown (December to February 2020).

| Parameters     | N  | Minimum | Maximum | Mean   | Std. Deviation |
|----------------|----|---------|---------|--------|----------------|
| PM$_{10}$ (µg/m$^3$) | 74 | .00     | 92.00   | 68.4332| 22.64548       |
| PM$_{2.5}$ (µg/m$^3$) | 74 | .00     | 90.54   | 62.6682| 14.73104       |
| NO$_2$ (µg/m$^3$)   | 74 | 10.41   | 23.96   | 17.1692| 4.73712        |
| SO$_2$ (µg/m$^3$)   | 74 | 4.59    | 23.59   | 9.1984 | 4.14219        |
| CO (mg/m$^3$)       | 4.59| 23.59  | 11.0930 | 5.70610| 4.59           |

Valid N (listwise) 74

Figure 8.a) ROC curve: Mean and standard deviation of PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO (pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$) levels in Durg-Bhilai before lockdown.
Table 3. b) Durg-Bhilai: Descriptive Statistics during the Lockdown (March to May 2020).

| Parameters     | N  | Minimum | Maximum | Mean    | Std. Deviation |
|----------------|----|---------|---------|---------|----------------|
| PM$_{10}$ (µg/m$^3$) | 52 | 8.75    | 83.46   | 50.5704 | 15.66342       |
| PM$_{2.5}$ (µg/m$^3$) | 52 | 6.25    | 75.66   | 43.3710 | 15.98413       |
| NO$_2$ (µg/m$^3$)   | 52 | 6.66    | 47.94   | 11.5571 | 7.23068        |
| SO$_2$ (µg/m$^3$)   | 52 | 4.16    | 46.75   | 7.1708  | 5.93203        |
| CO (mg/m$^3$)       | 52 | 4.38    | 22.50   | 10.2719 | 5.21595        |
| Valid N (listwise)  | 52 |         |         |         |                |

Figure 8. b) ROC curve: Mean and standard deviation of PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO (pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$) levels in Durg-Bhilai during the lockdown.

Table 4. a) Korba: Descriptive Statistics before Lockdown (December to February 2020).

| Parameters     | N  | Minimum | Maximum | Mean    | Std. Deviation |
|----------------|----|---------|---------|---------|----------------|
| PM$_{10}$ (µg/m$^3$) | 51 | 41.00   | 66.00   | 56.3137 | 5.90081        |
| PM$_{2.5}$ (µg/m$^3$) | 51 | 41.00   | 66.00   | 56.9608 | 5.57480        |
| NO$_2$ (µg/m$^3$)   | 51 | 22.00   | 25.00   | 22.8039 | .82510         |
| SO$_2$ (µg/m$^3$)   | 51 | 10.00   | 14.00   | 10.6275 | .74728         |
| CO (mg/m$^3$)       | 51 | 22.00   | 25.00   | 22.6275 | .77358         |
| Valid N (listwise)  | 51 |         |         |         |                |
Figure 9.a) ROC curve: Mean and standard deviation of PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO (pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$) levels in Korba before lockdown.

Table 4.b) Korba: Descriptive Statistics during the Lockdown (March to May 2020).

| Parameters   | N   | Minimum | Maximum | Mean      | Std. Deviation |
|--------------|-----|---------|---------|-----------|----------------|
| PM$_{10}$ (µg/m$^3$) | 38  | 32.00   | 68.00   | 45.9737   | 10.07938       |
| PM$_{2.5}$ (µg/m$^3$) | 38  | 17.00   | 56.00   | 39.1316   | 10.04092       |
| NO$_2$ (µg/m$^3$)   | 38  | 20.00   | 23.00   | 21.5526   | 1.03185        |
| SO$_2$ (µg/m$^3$)   | 38  | 6.00    | 12.00   | 9.2105    | 1.21161        |
| CO (mg/m$^3$)       | 38  | 20.00   | 24.00   | 21.8684   | 1.09473        |
| Valid N (listwise)  | 38  |         |         |           |                |

Figure 9.b) ROC curve: Mean and standard deviation of PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO (pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$) levels in Korba during the lockdown.
Before lockdown phase, the combined data of four cities are shown in (Table 5 and Figure 10) which depict the mean and standard deviation of pollutants (PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO). Before lockdown, the PM$_{10}$ mean value was highest (74.26) in Raipur and minimum (56.91) in Bilaspur, PM$_{2.5}$ mean value was highest (65.1) in Raipur and minimum (23.58) in Korba, NO$_2$ mean value was highest (28.79) in Raipur and lowest in Bilaspur (12.16), SO$_2$ was highest (24.41) in Korba and lowest (5.42) in Bilaspur and CO was highest (24.47) in Korba and lowest (5.5) in Bilaspur.

**Table 5.** Before lockdown phase (December 2019 to February 2020): Mean and Standard Deviation of four cities (all pollutants are in units of µg/m$^3$ and CO is expressed in units of mg/m$^3$).

| City     | Parameter | Raipur | Bilaspur | Durg-Bhilai | Korba |
|----------|-----------|--------|----------|-------------|-------|
|          | Before Lockdown |        | Before Lockdown | Before Lockdown | Before Lockdown |
|          | Mean | Std.Dev | Mean | Std.Dev | Mean | Std.Dev | Mean | Std.Dev |
| PM$_{10}$(µg/m$^3$) | 74.26 | 7.72 | 56.91 | 4.04925 | 67.44 | 25.04 | 66.38 | 19.04 |
| PM$_{2.5}$(µg/m$^3$) | 65.1 | 8.43 | 57.32 | 3.90099 | 63.75 | 14.8 | 23.58 | 7.90 |
| NO$_2$(µg/m$^3$) | 28.79 | 9.86 | 12.16 | 0.6886 | 17.22 | 4.69 | 24.67 | 4.45 |
| SO$_2$(µg/m$^3$) | 18.52 | 3.1 | 5.42 | 0.78049 | 9.18 | 4.16 | 24.41 | 5.34 |
| CO(mg/m$^3$) | 23.89 | 8.52 | 5.5 | 0.6442 | 11.49 | 5.84 | 24.47 | 3.39 |

**Figure 10.** Variation of air pollutants of four cities: Before Lockdown.
During the lockdown, the percentage fluctuation of the mean and standard deviation of pollutants in four cities is shown in (Table 6 and Figure 11). From the table, it can be observed that the PM$_{10}$ mean value was highest (56.31) in Korba and lowest (46.15) in Raipur. PM$_{2.5}$ mean value was highest (56.96) in Korba and lowest (43.37) in Durg – Bhilai. NO$_2$ mean value was highest (25.36) in Raipur and lowest (11.56) in Durg – Bhilai. SO$_2$ mean value was highest (14.09) in Raipur and lowest (6.13) in Bilaspur. CO mean value was highest (22.63) in Korba and lowest (10.27) in Durg – Bhilai.

**Table 6.** During lockdown phase (March to May 2020): Mean and Standard Deviation of four cities (all pollutants are in units of $\mu g/m^3$ and CO is expressed in units of mg/m$^3$).

| City          | Raipur         | Bilaspur       | Durg-Bhilai   | Korba         |
|---------------|----------------|----------------|---------------|---------------|
| **Parameters**| **Mean** | **std.Dev** | **Mean** | **std.Dev** | **Mean** | **std.Dev** | **Mean** | **std.Dev** |
| PM$_{10}$($\mu g/m^3$) | 46.15 | 5.37 | 55.03 | 7.27 | 50.47 | 15.66 | 56.31 | 5.9 |
| PM$_{2.5}$($\mu g/m^3$) | 45.26 | 5.55 | 55.92 | 7.26 | 43.37 | 15.98 | 56.96 | 5.57 |
| NO$_2$($\mu g/m^3$) | 25.36 | 3.86 | 14.38 | 2 | 11.56 | 7.23 | 22.8 | 0.82 |
| SO$_2$($\mu g/m^3$) | 14.09 | 1.96 | 6.13 | 1.63 | 7.17 | 5.93 | 10.63 | 0.74 |
| CO(mg/m$^3$) | 14.25 | 1.77 | 11.98 | 5.45 | 10.27 | 5.21 | 22.63 | 0.77 |

**Figure 11.** Variation of air pollutants of four cities: During Lockdown.
5. Conclusion

The impact of pollution improvements due to decreased anthropogenic interference during the COVID-19 epidemics in Chhattisgarh was investigated in this study. The study looked at the impact of COVID-19 on air quality in four main cities in Chhattisgarh. These cities have been rated as seriously polluted in Chhattisgarh state in recent decades. The current study, on the other hand, revealed a significant reduction in air pollution. We collected the data and separated it into two phases before three months of lockdown and during three months lockdown period. According to the acquired results, it was found that the concentration of all taken pollutants reduced dramatically due to several restrictive measures adopted by government authorities during the lockdown period. These reductions in pollutants are depicted in (Table 7 and Figure 11). Through these stages, a notable reduction in PM$_{10}$ (41.81%) was observed, similarly PM$_{2.5}$ decreased by 37.08%, NO$_2$ decreased by 7.30%, SO$_2$ decreased by 3.43% and CO decreased by 5.53%.

As a result of several strict measures implemented during the lockdown, such as limiting public and private transportation, halting industrial and commercial activity, and so on, the concentration of several pollutants (PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$, CO) decreased dramatically, and this remarkable decline in the concentration of several pollutants can be seen. This demonstrates that there is ample scope to maintain ambient air quality with proper implementation of regulations, norms, and standards.

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