Air quality assessment of Jaipur city Rajasthan after the COVID-19 lockdown

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Abstract In the whole world, most of the air polluted cities were normalized during the COVID-19 lockdown but after the lockdown, the air pollution is continuously increasing day by day. In the present study, we assessed the air quality at the selected sites of Jaipur city after the COVID-19 lockdown from October 2020 to February 2021 to quantify the enhancement in air pollution. The obtained data was processed using air quality index (AQI), principal component analysis (PCA) and pearson correlation matrix (PCM). The obtained data were also compared with National Ambient Air Quality Standards (NAAQS). Values of particulate matter (PM$_{10}$, PM$_{2.5}$) were found beyond the limits of NAAQS (100 µg/m$^3$, 60 µg/m$^3$) while the values of gaseous pollutant such as SO$_2$, NO$_2$, and CO was found below the limits of NAAQS (80 µg/m$^3$, 80 µg/m$^3$, 4.0 mg/m$^3$). Based on AQI, air quality of site 1 (114.80) and site 2 (110.48) was found severely polluted while air quality of site 3 (70.47) was found moderately polluted. Based on PCA, the highest loading factor was declared to PM$_{10}$ and the lowest loading factor was SO$_2$. The study concludes that by adopting the control measures of particulate matter and periodical transport lock down, air pollution can be minimised.

Keywords AQI · COVID-19 · Jaipur city · NAAQS · Particulate matter · PCA · Urbanisation

1 Introduction

Air pollution is one of the serious environmental concerns of both developed and developing countries due to its direct impact on the health of the human population. According to a report (2021), 22 Indian cities are in the top 30 most polluted cities of the world and they are Ghaziabad, Bulandshahar, Bisrakh Jalalpur, Noida, Greater Noida, Kanpur, Lucknow, Meerut, Agra, and Muzaffarnagar in Uttar Pradesh, Bhiwani in Rajasthan, Faridabad, Jind, Hisar, Fatehabad, Bandhwaari, Gurugram, Yamuna Nagar, Rohtak and Dharuhera in Haryana, and Muzaffarpur in Bihar [1]. Most of the cities listed in the mentioned section are industrial areas. All the cities are fast growing with respect to population, technological application and economical aspects in comparison to other cities which are not listed. New Delhi is the most polluted capital in the World. Ghaziabad is considered the second most polluted city in the world after Xinjiang in China.

As the activities, discoveries, and uses of energy have manifested in the form of urbanization, green revolution, industrialization, communication, transport, and the comfortable mode of living, the generation of a variety of waste products particularly air pollutants takes place [2]. Along with these, desertification of soil also leads to air pollution due to increased amount of dust in air [3–5]. Air pollution is more complex than most other environmental challenges. Any slight change in the meteorological and topographical condition affects the dispersion and transport of pollutants, which can result in ambient concentrations that may harm people, structures, and the environment. The World Health
Organization (WHO) estimates that a third of all premature deaths in the western Asia–Pacific region are due to air pollution. While globally every year, 7 million people die [6] because of exposure to a high level of air pollutants while many more suffer from breathing ailments, heart disease, lung infections, and even cancer. These problems become severe in all metro cities of the world. In the last decade, the air quality of most metro cities in the world is the poorest [7].

The cities are the hotspots of air pollution due to the high population density which results in more transportation activities. Lack of proper maintenance of vehicles is also a major cause of air pollution which results in worsened air quality. The effect of the pollutant on human health depends on various factors such as the group of individuals involved, organ considered, type and concentration of pollutants, and time of exposure. Vehicular exhaust proves to be one of the significant sources of air pollution in urban areas [8, 9]. Many studies have shown that motor vehicle air pollution-induced cardiovascular and respiratory diseases [10].

In 2020, during the COVID-19 pandemic, the situation has gone disastrous due to the exponential spreading of the corona virus at the global level. To reduce the spreading of this infectious disease, WHO has recommended the lockdown at the global level [11]. This results to the shutdown of human activities throughout the world. Similarly, the Indian government also follow the WHO guidelines and on 23rd March 2020, lockdown starts in all the states of India but the complete lockdown was imposed on 25th March 2020. It has been noticed that during the lockdown, anthropogenic activities such as traveling, and industries were properly stopped which results in improving the air quality [12, 13]. However, after the lockdown, the transportation, industries and different other routine activities starts properly resulting in the air quality degradation in all the major cities at the places and especially in metro cities such as Delhi, Mumbai, Kolkata, and Bengaluru and many others [14, 15].

Like other cities in India, Jaipur is also facing the problem of increased urbanization, industrial emission, traffic congestion, and poor road conditions. Bedside these, Jaipur is also a tourist place. All these factors resulted in increased air pollution in the city [16]. Strict control on all the human activities during COVID-19 lockdown resulted in an improvement in the air quality worldwide [16, 17]. Several authors also reported the significant improvement in the air quality of Jaipur city during COVID-19 lockdown period [18]. But soon after the lockdown, the monitoring station installed by the Governments shows an increase in all the criteria pollutants in all the major cities as well as in Jaipur. Therefore, the present study was carried out to evaluate the air quality of Jaipur City after the COVID-19 lockdown using Air Quality Index (AQI). The obtained results provide baseline data that show the rate of increment in air pollutants in Jaipur City.

## 2 Materials and methods

### 2.1 Study area

Jaipur is situated in the eastern part of Rajasthan, surrounded on three sides by the rugged Aravali hills. Jaipur is located at 26°55' N 75°49' E (26.92° N 75.82° E). It is surrounded by Alwar and Sikar in the North; by Sikar, Nagaur, and Ajmer in the West; by Ajmer, Tonk, and Sawai Madhopur in the South, and by Dausa and Bharatpur districts in the East. It has an average elevation of 430 m (1414 ft). Jaipur has a semi-arid climate. The climate of Jaipur is dry and healthy and is subject to the extremeness of cold and heat in various places. The minimum and maximum temperatures recorded in the Jaipur district vary from 5 to 48 °C. Normal annual rainfall is 50 cm. In this study, we selected the three main places namely Badi Chaupar (SS-01), Choti Chaupar (SS-02), and Bhankrota (SS-03) of the Jaipur city. These selected locations are attractive and always busy and crowdy where tourists enjoyed with various activities. The description of all the sampling sites was presented in Table 1 and Fig. 1.

Sampling site 1 (SS-01) is Badi Chaupar which is also known as “Large Square” or “Manak Chowk” is a residential, commercial area as well as tourist place situated near Hawa Mahal. It is a busy and big market of narrow lanes selling textiles, leather products, and jewelry, to handicrafts. Because of the big market hub, transport is also a big issue in this area. It is surrounded by Ramganj Bazaar (East side), Tripolia Bazar (West side), and Johari Bazaar (South side). Sampling site 2 (SS-02) is Choti chaupar which is also known as “Small Square” or “Amber Chowk” a residential

### Table 1 Sampling sites location

| Code  | Location          | Category                  | Co-ordinates             | Description                                                                 |
|-------|-------------------|---------------------------|--------------------------|-----------------------------------------------------------------------------|
| SS-01 | Badi Chaupar      | Residential/commercial    | 26°55′22.90″ N 75°49′36.78″ E | This site is situated near the Hawa Mahal, Jaipur City, Rajasthan           |
| SS-02 | Choti Chaupar     | Residential/commercial    | 26°55′31.62″ N 75°49′09.26″ E | This site is situated near Police Station Kotwali, Jaipur City, Rajasthan   |
| SS-03 | Bhankrota         | Residential/institutional | 26°52′31.60″ N 75°42′41.34″ E | This site is situated on Ajmer-Jaipur Expressway, Jaipur City, Rajasthan    |
and commercial area. It is located at the midpoint of Chandpole and Kishanpole Bazar. Sampling site 3 (SS-03) is Bhankrota which is a residential as well as institutional area. The market area is small as compared to SS-01 and SS-02.

2.2 Ambient air quality sampling methodology

Ambient air quality was monitored monthly at three locations (Badi Chaupar, Choti Chaupar, and Bhankrota) in Jaipur city after the COVID-19 lockdown for a period of five months from October 2020 to February 2021. The air quality monitoring program was initiated in the morning hours between 7.00 am and 11.00 am and was carried out using a Respirable Dust Sampler (RDS) with gaseous sampling attachment in accordance with Central Pollution Control Board (CPCB) conceptual guidelines and common methodology. The RDS (Model No: Envirotech-ETC APM 415 BL) was placed at the respiratory height (1.5 m). Filter papers were folded lengthwise after monitoring, kept in plastic zip bags, and transported to the laboratory immediately after sampling and weighed after oven drying. Particulate matter (PM$_{10}$, PM$_{2.5}$), non-respirable suspended particulate matter (NRSPM), nitrogen oxides (NO$_2$), sulphur oxides (SO$_2$), and carbon monoxide (CO) were the parameters studied during the study period.

2.3 Data processing and analysis

The obtained data were analyzed using the Air quality index (AQI), Pearson correlation matrix (PCM) as well as Principal component analysis (PCA).

2.3.1 Air quality index (AQI)

AQI is a methodology of conversion of complex air quality data into a single digit, to make it understandable and useable by the common people. It is calculated by aggregating the ratio of pollutant concentration in ambient air to the standard limit of pollutants in ambient air. Several researchers calculated the AQI for the different regions [9, 19, 20] to understand the cumulative impact of pollutants. AQI has been calculated for four criteria pollutants PM$_{10}$, PM$_{2.5}$, SO$_2$, NO$_2$, and CO by the following formula.

Air Quality Index (AQI)

\[
\text{AQI} = \frac{1}{4} \times \left( \frac{\text{PM}_{10}}{\text{PM}_{10}(s)} + \frac{\text{PM}_{2.5}}{\text{PM}_{2.5}(s)} + \frac{\text{SO}_2}{\text{SO}_2(s)} + \frac{\text{NO}_2}{\text{NO}_2(s)} + \frac{\text{CO}}{\text{CO}(s)} \right) \times 100
\]

where:
- PM$_{10}$ = Concentration of PM$_{10}$ in ambient air,
- PM$_{10}(s)$ = Standard limit of PM$_{10}$ in ambient air,
- PM$_{2.5}$ = Concentration of PM$_{2.5}$ in ambient air,
- PM$_{2.5}(s)$ = Standard limit of PM$_{2.5}$ in ambient air,
- SO$_2$ = Concentration of SO$_2$ in ambient air, SO$_2(s)$ = Standard limit of SO$_2$ in ambient air,
- NO$_2$ = Concentration of NO$_2$ in ambient air, NO$_2(s)$ = Standard limit of NO$_2$ in ambient air,
- CO = Concentration of CO in ambient air, CO(s) = Standard limit of CO in ambient air.

2.3.2 Pearson correlation matrix (PCM)

The PCM showed the interaction i.e., positive and negative between the selected air quality parameters at selected sampling locations.

2.3.3 Principal component analysis (PCA)

PCA reduced the large dataset into simple dataset; thereby present the available information in summarized form for understanding which parameters are largely affected by
showing the factor loadings. PCA reduced the number of high loading variables on each component which make the interpretation of variables simple. The PCA showed that using two axes namely PCA 1 and PCA 2 along with its eigenvalue and cumulative percentage using the vector length. The eigenvalue higher than 1 is considered. The PCM and PCA were performed using the ORIGIN Pro (Student Version).

### 3 Results

The results of all the parameters studied during the study period were given in Table 2 and Fig. 2. Results of AQI were given in Table 3 and prediction of AQI range was given in table S4.

#### 3.1 Particulate matter

$PM_{10}$ is a complex mixture of organic and inorganic substances. It causes the greatest risk, after reaching the

| Table 2 | Sites wise average physicochemical properties during the study period |
|---------|-----------------------------------------------------|
| Site/parameters | $PM_{10}$ | $PM_{2.5}$ | RSPM | NRSPM | $NO_2$ | $SO_2$ | CO |
| Badi Chaupar | 200.15* | 89.72* | 289.88* | 444.54* | 45.57* | 13.72* | 1.42* |
| | (189.88-209.89)** | (78.97-98.12)** | (271.58-303.01)** | (403.51-496.80)** | (44.25-46.92)** | (12.71-15.70)** | (1.11-1.63)** |
| Choti Chaupar | 206.18* | 72.22* | 278.40* | 463.66* | 49.81* | 15.38* | 1.36* |
| | (156.20-235.4)** | (55.65-80.65)** | (211.85-316.05)** | (432.21-486.54)** | (46.35-54.56)** | (14.11-16.81)** | (1.01-1.53)** |
| Bhankrota | 121.18* | 44.11* | 165.29* | 323.43* | 37.72* | 12.62* | 0.97* |
| | (82.60-157.91)** | (35.13-55.48)** | (117.73-213.39)** | (268.91-359.95)** | (33.42-44.43)** | (12.12-13.13)** | (0.60-1.25)** |
| Minimum | 82.60 | 35.13 | 117.73 | 268.91 | 33.42 | 12.12 | 0.60 |
| Maximum | 235.4 | 98.12 | 316.05 | 496.80 | 54.56 | 16.81 | 1.63 |
| Average | 175.84 | 68.68 | 244.52 | 410.54 | 44.37 | 13.91 | 1.25 |
| SD | 47.43 | 23.01 | 68.85 | 76.05 | 6.14 | 1.39 | 0.24 |

* Average value of particular parameter at that site, ** Range of particular parameter at that site

| Table 3 | Air quality index of each parameters and cumulative AQI of each site |
|---------|-----------------------------------------------------|
| Parameters/site | Standard values | Site-1 | Site-2 | Site-3 |
| $PM_{10}$ | 100 | 200.15 | 206.18 | 121.18 |
| $PM_{2.5}$ | 60 | 89.72 | 72.22 | 44.11 |
| $NO_2$ | 80 | 45.57 | 49.81 | 37.72 |
| $SO_2$ | 80 | 13.72 | 15.38 | 12.62 |
| CO | 4 | 1.42 | 1.36 | 0.97 |
| AQI | | 114.80 | 110.48 | 70.47 |

*OV = Observed Value *Si = Sub index
sensitive portions of the respiratory system which results in health problems and premature mortality [6]. During the study period, PM10 ranged from 82.60 µg/m³ (at site-3 in October) to 235.40 µg/m³ (at site-2 in January) and the average value was found 200.15 µg/m³ ± 8.52, 206.18 µg/m³ ± 30.67, and 121.18 µg/m³ ± 26.95 at site-1, site-2, and site-3 respectively. A more or less similar result was observed by several researchers during their study [21, 22].

PM2.5 concentration is an important index used in air quality evaluation systems. Due to the increasing public awareness, it is of great significance to analyze and forecast PM2.5 concentrations [23]. These particles are of great concern. Due to its small size, PM2.5 enters the respiratory tract and affects the functioning of the lungs. During the study period, PM2.5 ranged from 35.13 µg/m³ (at site-3 in October) to 98.12 µg/m³ (at site-1 in January) and the average value was found 89.72 µg/m³ ± 7.12, 72.22 µg/m³ ± 10.71, and 44.11 µg/m³ ± 7.55 at site-1, site-2, and site-3 respectively. A more or less similar result was observed by Biswas et al. [24].

The term RSPM is given to denote the amounts of fine particles obtained (having diameters < 10 microns). It includes the sum of both PM10 and PM2.5. During the study period, RSPM ranged from 117.73 µg/m³ (at site-3 in October) to 316.05 µg/m³ (at site-2 in January) and the average value was found 289.88 µg/m³ ± 13.79, 278.40 µg/m³ ± 41.17, and 165.29 µg/m³ ± 34.39 at site-1, site-2, and site-3 respectively. The term NRSPM is given to denote the amounts of coarse particles (having diameters > 10 microns) obtained in the cup attached with a cyclone separator. It shows very less impact on the health of humans and other living beings. During the study period, NRSPM ranged from 268.91 µg/m³ (at site-3 in January) to 496.80 µg/m³ (at site-1 in December) and the average value was found 444.54 µg/m³ ± 43.15, 463.66 µg/m³ ± 23.06, and 323.43 µg/m³ ± 37.93 at site-1, site-2, and site-3 respectively. A more or less similar result was observed by Nasir et al. [25].

### 3.2 Gaseous pollutants

Nitrogen oxide (NOX = NO + NO2) is the common name given to all oxides of nitrogen as nitric oxide (NO) and nitrogen dioxide (NO2), produced by both anthropogenic sources, e.g., the combustion of fossil fuels, thermal power plants, and transportation activities, and natural sources, e.g., microbiological processes in soil and lightening [26]. A lot of studies on the emissions of NO2 have been performed and concluded that it significantly affects tropospheric chemical reactions on Earth [27]. NO2 reacts with carbon monoxide to form ozone in the atmosphere. During the study period, NOx ranged from 33.42 µg/m³ (at site-3 in October) to 54.56 µg/m³ (at site-2 in December) and the average value was found 45.57 µg/m³ ± 1.21, 49.81 µg/m³ ± 3.25, and 37.72 µg/m³ ± 4.48 at site-1, site-2, and site-3 respectively. A more or less similar result was observed by Saxena and Shekhawat [28].

The formation of sulphur di oxide (SO2) takes place due to the burning of agriculture residues and nonconventional fuels in industries and vehicles. The SO2 is also responsible for the formation of acid rain [13]. During the study period, SO2 ranged from 12.12 µg/m³ (at site-3 in October) to 16.81 µg/m³ (at site-2 in December) and the average value was found 13.72 µg/m³ ± 1.31, 15.38 µg/m³ ± 0.98, and 12.62 µg/m³ ± 0.42 at site-1, site-2, and site-3 respectively. All the values were found below the NAAQ value which is 80 µg/m³.

Carbon monoxide (CO) gas is the result of an incomplete combustion process either from vehicles or industries. Forest fires are also responsible for this gas. During the study period CO ranged from 0.60 mg/m³ (at site-3 in October) to 1.63 mg/m³ (at site-2 in December) and the average value was found 1.42 mg/m³ ± 0.19, 1.36 mg/m³ ± 0.21, and 0.97 mg/m³ ± 0.26 at site-1, site-2, and site-3 respectively. Results observed during the study confirmed that the industrial combustion process and transport sectors are the two dominant factors in the production of CO as fewer values were observed at a residential site in comparison to the industrial and commercial sites.

### 3.3 Assessment of air quality using AQI

The purpose of AQI is to reflect the real-time changes in the air quality of the concerned area. The parameter, whose Si value was found higher, became the criteria pollutant for that location. More will be the AQI value, more will be the adverse impact on plant and animal health and damage to property. The AQI scale was divided into five categories based on of impact on human health, i.e. 0–25 (clean air); 26–50 (light air pollution); 51–75 (moderate air pollution); 76–100 (heavy air pollution); > 100 (severe air pollution) [29]. The results were presented in Table 3.

AQI was calculated site-wise and parameters wise. When parameters-wise results were compared, the sub-index (Si) of all the concern parameters was found as 1.76, 1.14, 0.55, 0.17, and 0.31 for PM10, PM2.5, NO2, SO2, and CO respectively. The sum of sub-index was found as 3.94. The AQI value of SS-01, SS-02, and SS-03 was calculated as 114.80, 110.48, and 70.47.

### 3.4 Pearson correlation matrix (PCM)

The PCM showed the positive and negative interaction between the selected parameters shown in Fig. 3. PM10 showed the strong positive correlation with PM2.5 (0.89),
NRSPM (0.80), RSPM (0.99) and NO₂ (0.86) while weak positive correlation with SO₂ (0.59). In addition, PM2.5 showed the strong positive correlation with RSPM (0.95) while weak positive correlation with NRSPM (0.73), NO₂ (0.69), CO (0.77) and SO₂ (0.32) respectively. Moreover, Oxides of Nitrogen, Sulphur, and Carbon showed a moderate positive correlation to each other in selected sampling sites.

### 3.5 Principal component analysis (PCA)

PCA is a widely used statistical technique that provides significant data by reducing the large data into simple data. The vector length showed the factor loading parameters shown in Fig. 4 and Table 4. The PC1 axis showed 75.8% of the cumulative variance of the total...
data variability with an eigen-value of 5.305. The PC1 axis showed the factor loading parameters in the order PM\(_{10}\) > RSPM > NO\(_2\) > PM\(_{2.5}\) > NRSPM > CO > SO\(_2\) respectively. In addition, the PC2 axis showed a 13.7% cumulative variance of the total data variability with an eigen-value of 0.962. PC2 axis showed the major factor loading parameters are in the order SO\(_2\) > NRSPM > NO\(_2\) respectively.

### 4 Discussion

The present study was performed at three sites in which two are residential as well as commercial and one is residential as well as institutional. None of them belongs to an industrial site. At SS-01 and SS-02, PM\(_{10}\) and PM\(_{2.5}\) were found above the limit and this may be due to dust arising from the foot of travelers and transport [30] in the area as two sites are marketing hubs of the city as mentioned in the material and method section. Values of PM\(_{10}\) observed during the study period (82–235 µg/m\(^3\)) were found above the NAAQ value which is 100 µg/m\(^3\) at all the sites. Variation in the PM\(_{10}\) values from the NAAQs was observed less at site-3 (Bhanakrota) was observed as less polluted which may be due to the small market area as compared to sites 1 and 2. During the lockdown period, Rajasthan State Pollution Control Board (RSPCB) published the air quality results which showed the improvements in air quality based on PM\(_{10}\) values (53–97 µg/m\(^3\)) but in the present study which was conducted soon after the lockdown period, a great increase was observed in values of PM\(_{10}\). PCA analysis also declared the PM\(_{10}\) as the highest contributed parameter to degrade the air quality of the study area.

Combustion is considered the major cause of PM\(_{2.5}\) [31]. Several authors reported the decline in the values of PM\(_{2.5}\) during the lockdown phase in Jaipur and other parts of India may be due to cease of industrial and transportation activities [9, 32]. RSPCB also confirms the reduction in values of PM\(_{2.5}\) (18–62 µg/m\(^3\)) during the lockdown period [18]. In the present study, a great increase was observed in the values of PM\(_{2.5}\) (35–98 µg/m\(^3\)). The increase in the values of particulate matter after lockdown reached up to the pre lockdown period which reflects the beginning of all the routine activities (transport, industrial operation, and marketing). Based on PCA analysis, PM\(_{2.5}\) marked the fourth-highest air quality degrading parameter. Moreover, values of PM\(_{2.5}\) observed during the study period (35–98 µg/m\(^3\)) were found above the NAAQ value which is 60 µg/m\(^3\) at sites 1 and 2 while at site 3 below the NAAQ value. The duration of the present study was from October to February i.e. winter season. Thus, high values of particulate matter can be attributed due to low dispersion, wind speed, temperature, and reasonably steady atmospheric circumstances [10].

Similar to particulate matter, gaseous pollutant shows a reduction in their concentration during the lockdown period [33]. The transport sector and industrial operations due to the combustion of fossil fuels are considered the major contributor to gaseous pollutants [34]. The major cause of CO and NO\(_2\) in the environment is the combustion of various fuels in the vehicles and industries [35] while the source of SO\(_2\) in the environment is the combustion of coal [36]. Thus, the concentration of NO\(_2\) was found above the concentration of SO\(_2\) as the study area is residential and commercial so the combustion of coal is very less in comparison to other fuels. Although, during the study period, values of NO\(_2\) (33–54 µg/m\(^3\)) were found below the NAAQ value which is 80 µg/m\(^3\) an increase was observed from the NO\(_2\) values (6–31 µg/m\(^3\)) during the lockdown period. A similar pattern was observed in the case of SO\(_2\) values. Values of SO\(_2\) were observed far below the standard NAAQ value during the lockdown and also in the present study (12–16 µg/m\(^3\)). This may be due to advancements in the industrial, processes automobile sector [12] and reasonably steady atmospheric circumstances. Based on PCA analysis, NO\(_2\) and SO\(_2\) marked the third and seventh rank contributor to the air quality degrading in the study area.

Unfinished combustion of fuels, biomass, and hydrocarbons are the main sources of CO. Out of total CO emissions in urban centres, 3/4th is contributed by vehicular activities [37]. In the initial phase of lockdown decrease in CO concentration was observed but soon after slight enhancement was observed might be due to the permission of transport on roads [18]. Values of CO observed during the study period (35–98 µg/m\(^3\)) were found above the NAAQ value which is 4 mg/m\(^3\). Based on PCA analysis, CO marked the 6th rank contributor to the air quality degrading in the study area. Based on the Si value, PM10 is considered a criteria pollutant in Jaipur city among all the studied parameters (highest Si value among all the studied parameters).

The least concerning parameter is considered SO\(_2\) due to the lowest Si value among all the studied parameters. When site-wise results were compared, Badi Chaupar is considered the most polluted site due to the highest AQI value among

#### Table 4 PCA showed the factor loading air quality parameters

| Parameters | Loadings | PC1 | PC2 |
|------------|----------|-----|-----|
| PM\(_{10}\) | 0.424    | −0.048 | |
| PM\(_{2.5}\) | 0.389    | −0.337 | |
| RSPM       | 0.423    | −0.142 | |
| NRSPM      | 0.374    | 0.241 | |
| NO\(_2\)   | 0.391    | 0.186 | |
| SO\(_2\)   | 0.276    | 0.748 | |
| CO         | 0.344    | −0.457 | |
| Eigenvalues | 5.305   | 0.962 | |
| Cumulative percentage | 75.80% | 13.70% |
all the studied sites while Bhankrota is considered the least polluted site. When the results of AQI obtained is compared with that of the standard scale given by Rao and Rao [29], the air quality of both site 1 and 2 (Badi Chaupar and Choti Chaupar) falls in the category of severe air pollution as residential and commercial activity were dominant at these two sites while the air quality of Bhankrota falls in the category of Moderate air pollution. Bhankrota is a residential as well as an institutional site. None of the sites was observed in the category of clean air class which is a matter of concern for Jaipur Municipal Corporation. Values of PM10 and PM2.5 were found above the standard limit at site 1 and site 2 during the whole study period. Values of NO2 and CO were found within the standard limits but if all the activities on the sites will continue as it is as they were running during the study period, values of NO2 and CO will soon cross the standard limits of NAAQS.

The strong positive correlation between PM10 and other studied parameters confirms the release of variable size particulate matter from the transport sector pressurizing the studies focussing on various size particulate matter and their ill effects. Similar observations were also observed for PM2.5. The observations of the present study also confirm that transport is the major cause of air pollution at the studied sites as a strong positive correlation was observed among oxides of nitrogen, sulphur, and particulate matter of various sizes.

Knowledge regarding pollution prevention measures is limited to the scientific community and for effective implementation; knowledge should be disseminated to common people. Based on the literature study of pre, during, and post lockdown related to air pollution, it was observed that lockdown reduces the air pollution to a great extent but after the lockdown, all the parameters reached to pre lockdown values. As the transport sector is the main contributor to air pollutants, therefore the use of electric vehicles and solar vehicles can reduce air pollution. As the study areas are market places, therefore, water sprinkling on the ground can also be an effective measure of air pollution reduction.

5 Conclusion

Due to the COVID-19 pandemic, all activities were stopped in all states of India due to the lockdown. However, when the lockdown was open, the movement of people from one place to another place increased. Jaipur city is one of the known tourist places of India, where peoples come for enjoyment and to visit the historical monuments of Indian Cultures. So, air quality assessment was carried out at selected sites in Jaipur city of Rajasthan state and AQI was also calculated based on data obtained after the COVID-19 lockdown. The air of the selected sites was found heavily polluted due to excess particulate matter although the concentration of gases was found below the limits of NAAQS. The low concentration of gases may be due to the high dispersion of pollutants due to the high temperature in the study area. Among all the selected sites lowest concentration of all the studied parameters was at site 3. Although, site 3 is a residential, as well as institutional area low concentration of the parameters, may be due to higher vehicular activity, low density of trees in the area, and maybe due to construction activities at these sites. Based on AQI, SS-1&2 were found heavily polluted while site 3 was observed moderately polluted. Based on PCA analysis, the highest loading factor was declared to be PM10 and the lowest loading factor was SO2. The study also concludes that by adopting the control measures of particulate matter (such as scrubber in industries, clean fuel in vehicles and water sprinkling on ground), and periodical transport lockdown air pollution can be minimised at the selected sites as well as other air polluted sites.

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Declarations

Competing interests The authors declare no competing interests.

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