Preliminary Assessment of Air During COVID-19 Lockdown: An Unintended Benefit to Environment

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ARTICLE INFO
Received: 14 May 2020
Received in revised: 12 Jul 2020
Accepted: 22 Jul 2020
Published online: 11 Aug 2020
DOI: 10.32526/ennrj.18.4.2020.35

Keywords:
Air SDGs/ Coronavirus and air pollution/ COVID-19 and SDGs/ Lahore air quality index

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ABSTRACT
The death rate of people is increasing globally during the current outbreak of coronavirus. To combat with COVID-19 havoc, the world has adopted lockdown policies, including Pakistan. Ironically, the invisible virus is suffocating humans at a fast rate but on the other side, there is a visible monster in the world gobbling up human health, i.e., air pollution. Therefore, the main rationale of the present research is to visualize the air quality during the ‘Lockdown’ period in Lahore, Pakistan by mapping via online tools and techniques using a geospatial system. According to the present findings, the concentrations of air pollutants, such as particulate matters (PM10 and PM2.5), nitrogen oxides as NO and NO2, and sulphur dioxide, are below the maximum permissible levels of the Punjab Environmental Quality standards (PEQs), although ozone exceeds its PEQs. So in light of the results, once this COVID-19 crisis is over, the government should speed up measures to lessen air pollution to achieve targets of sustainable development goals (SDGs). Moreover, the present results of air assessment during COVID-19 would serve as a useful reminder for the government of Punjab to cut down air emission levels after the pandemic.

1. INTRODUCTION
In Pakistan, the first coronavirus case was reported in Lahore on 26th February, 2020 (Badshah et al., 2020) and cases spurted rapidly all over Pakistan within a short span of time (Saqlain et al., 2020). All provinces of Pakistan were affected by COVID-19 (Ahmad et al., 2020) and amongst them Sindh was the most vulnerable province reported with the largest number of coronavirus cases initially (Waris et al., 2020). In the meantime, the wide spread of deadly disease suspended all the religious, academic, social, and administrative activities at international levels (Chauhan and Singh, 2020).

During COVID-19 pandemic, the world faced its highest mortality rate, but on the other side, it proved to be a significant factor in the reduction of air emissions by altering anthropogenic activities. It is the one and only virus that demonstrated a new era to get rid of all the preceding impossible environmental problems in a possible way. As per early published statistics, Pakistan’s neighboring country China reported the highest death rate (Saqlain et al., 2020). Meanwhile, a significant reduction in nitrogen dioxide was also reported during COVID-19 in China (Wang et al., 2020). Similarly, a decline in air pollution was also reported in Italy, which is one of the countries in the world most affected by COVID-19 (Gatto et al., 2020).

Hence, air pollution is one of the serious threats (Gupta et al., 2013) to life diversity and is reported as a factor for the high fatality due to COVID-19 in Italy (Ogen, 2020). Its destructive nature has detrimental effects on humans, animals (Camargo and Alonso, 2006) and plants (Najjar, 2011). Ecologically, it damages the quality of water and soil (Mellouki et al., 2016). Further, its toxicology is one of the causes of
acid rain and temperature inversion (Singh and Agrawal, 2007). Likewise, the escalating global concern is one of the largest environmental problems in Pakistan (Ali and Athar, 2008; Colbeck et al., 2011). In 2018, Pakistan ranked 169 out of 180 countries in the Environmental Performance Index (EPI) (Pakistan Today, 2020), even though its environmental sector is highly prioritized to achieve SDGs (Elder and Olsen, 2019).

Given above the planetary scenario of air pollution, the highest concentration of atmospheric pollutants (Mansha et al., 2012) were reported at an alarming level in Lahore (Colbeck et al., 2019), namely particulate matter PM$_{2.5}$ (Rasheed et al., 2015) and PM$_{10}$ (Stone et al., 2010). As a result, the consequences of air pollution have led to poor health issues (Ashraf et al., 2019) in the city. Despite the fact that environmental legislations, rules and regulations have been formulated in Punjab, Pakistan to control the air pollution, the environmental development is at a noticeably poor level under EPI.

So with respect to the COVID-19 lockdown plan to overcome the pandemic in the city, the contingency plan altered the existing air quality of Lahore. Considering the above scenario, the aim of the present study is to provide a bird’s eye view of air quality during COVID-19 lockdown. So, the objectives of the present study are three fold: (1) to map the air pollution level in Lahore during lockdown of COVID-19; (2) to review the air pollution level in 2019 and compare its concentration with the lockdown period of 2020; (3) to evaluate the key air pollutant concentrations in the lockdown period. Thus, findings of the present study provide updated information of air quality during the COVID-19 lockdown. Further, this information can be used to prepare alternative strategies to mitigate the air pollutants to improve the environment of urban areas.

2. METHODOLOGY
2.1 Site description
Lahore, a well-known historical and cultural city of gardens (Ghaffar, 2015; Pervaiz et al., 2019), was chosen to carry out the present study. Lahore is located in the north-east of Punjab. Neighboring country, India lies on the east of Lahore (Lodhi et al., 2009; Akhtar et al., 2015) and linked with the Indian state of Punjab (Tariq and Ali, 2016). District Sheikhupura is located on the North West of the city, Kasur on the south and River Ravi flows in the north (Riaz, 2010). Geo-spatially, the city is situated between 31°15ʹ-31°45ʹ North, 74°01ʹ74°39ʹ East (Colbeck et al., 2011) and consists of 1,172 km$^2$ land surface area (Figure 1).

Figure 1. Map of the study area
2.2 Demography

Lahore (Nawaz et al., 2015) is among the mega cities of the world and the second largest metropolis of the country. The population of the city has grown very rapidly during the past decades (Jan and Iqbal, 2008; Aziz et al., 2015) and having 11 million dwellers (Ali et al., 2020) in 2017 (Pakistan Bureau of Statistics, 2017).

2.3 Climate

Lahore has a semi-arid climate (Batool and Ch, 2009; Ali et al., 2020) where extreme and intense weather conditions are observed during different seasons. Lahore experiences summer (April to June with the average temperature above 40°C (Rana and Bhatti, 2018). Whereas, monsoon season (July to September) is associated with heavy rainfalls. December to February is the months of winter with dense fog when temperature falls at low level i.e., 0°C (Alam et al., 2013). Moreover, metrological variables (Kinney, 2008) vary seasonally such as precipitation, temperature, humidity, wind velocity and speed (Sadiq and Qureshi, 2010) which determine the quality of air (Table 1).

Table 1. Metrology of study area in March 2019 and March 2020

| March     | Wind speed (knot) | Wind speed (knot) | Rain (mm)  | Min. Temp. (°C) | Max. Temp. (°C) | Humidity (%)  |
|-----------|-------------------|-------------------|------------|-----------------|-----------------|---------------|
|           | 300 UTC           | 1,200 UTC         | 2019       | 2020            | 2019            | 2020          | 2019          | 2020          |
| 20        | 11                | 7                 | 3          | 0               | 0               | 14            | 15            | 29            | 29            | 74            | 78            | 47            | 41            | 47            | 41            |
| 21        | 3                 | 11                | 8          | 4               | TR              | TR            | 14           | 16            | 26            | 29            | 74            | 76            | 39            | 54            | 39            | 54            |
| 22        | 5                 | 0                 | 9          | 3               | 0               | 0             | 14           | 14            | 27            | 26            | 71            | 75            | 29            | 42            | 29            | 42            |
| 23        | 7                 | 0                 | 14         | 0               | 0               | 16            | 15            | 28            | 29            | 55            | 63            | 35            | 35            | 35            | 35            |
| 24        | 4                 | 0                 | 7          | 4               | TR              | TR            | 14           | 18            | 25            | 31            | 70            | 61            | 59            | 61            | 59            | 61            |
| 25        | 5                 | 4                 | 6          | 3               | 0               | 4             | 14           | 14            | 26            | 22            | 84            | 77            | 38            | 51            | 38            | 51            |
| 26        | 5                 | 6                 | 13         | 4               | 0               | 13            | 13           | 29            | 26            | 68            | 51            | 27            | 27            | 27            | 27            |
| 27        | 0                 | 5                 | 4          | 12              | 0               | 6.4           | 15           | 16            | 29            | 28            | 80            | 95            | 33            | 85            | 33            | 85            |
| 28        | 0                 | 6                 | 5          | 5               | 0               | 14            | 17           | 14            | 31            | 20            | 65            | 89            | 32            | 57            | 32            | 57            |
| 29        | 3                 | 4                 | 4          | 3               | 0               | 0             | 18           | 14            | 32            | 26            | 82            | 81            | 41            | 38            | 41            | 38            |
| 30        | 6                 | 5                 | 12         | 9               | 0               | 0             | 19           | 15            | 33            | 29            | 82            | 60            | 40            | 37            | 40            | 37            |
| 31        | 0                 | 8                 | 10         | 3               | 0               | 0             | 17           | 17            | 32            | 27            | 68            | 63            | 31            | 86            | 31            | 86            |

Max. 11 11 14 12 - 14 19 18 33 31 79 50 59 86
Min. 0 0 4 0 - 0 13 13 25 20 55 51 27 25
Avg. 4.1 4.1 8.3 4.4 - 2.4 15 15 29 27 73 72 38 52

*TR=0.01 mm

2.4 Environmental overview

Environmentally, the city of gardens ‘Lahore’ has been converted into the city of concrete in the past three decades. Urban sprawl (Liaqat et al., 2017; Sabir and Anjum, 2017), economic development (Pervaiz et al., 2019), industrial expansion (Raja et al., 2010; Rehman et al., 2019) vehicular emissions (Ilyas, 2007; Shirwani et al., 2019; Ali et al., 2020) and biomass burnings (Sidra et al., 2015; Abas et al., 2019) are the variety of sources deteriorating the natural environment (Pervaiz et al., 2019) of the city. On the top, semi-arid climate of the city strongly supports to accumulate the air pollutants in the atmosphere (Shahid et al., 2013). Thus, the city is vulnerable by having air borne diseases (Aziz and Bajwa, 2007; Raja et al., 2010) caused by the combination of multiple pollutants. Besides, the pernicious air pollution has been also reported to elevate the death rate during the outbreak of COVID-19 (Wang et al., 2020). On the basis of above discussion, Table 2 lists the air pollutants defined in PEQs, their prescribed limit and the impacts on the environment of Lahore.

2.5 Data

The present study relied on the data derived from the official website of Environment Protection Department (EPD), Punjab to examine and compare the pollutant concentrations of the study site in March 2019 and during the COVID-19 lockdown (Figure 2 and Figure 3), (EPD, 2020a). Further, the Punjab Environmental Quality Standards (PEQs) for air
(Table 2) were also obtained from the official source of EPD, Punjab (EPD, 2020b).

In addition, considering that meteorological elements are closely associated with air pollution (Yen et al., 2013) the city level data of weather consisting of wind speed (300 and 1,200 Knot), rain (millimeter per hour), temperature (degree Celsius), and humidity (300 UTC and 1,200 UTC) (Bao and Zhang, 2020) was obtained from Pakistan Meteorological Department for the analysis (Table 1).

Table 2. Air pollutants source, environmental effects and PEQs

| Sr. No. | Pollutant Source | Environmental effect | PEQs |
|---------|------------------|----------------------|------|
| 1       | Particulate (PM10) | Diesel-powered vehicles; Factories; Power plants; Industries; Incinerators; Construction activities; Windblown dust. (Mabahwi et al., 2014). | Major source of haze; Damages buildings and other materials. | 150 µg/m³ |
| 2       | Particulate (PM2.5) | Transportation; Combustion of fossil fuels; Biomass and waste burnings; Construction sites. (Malashock et al., 2018). | Same effects as PM10. (Zha et al., 2013). | 35 µg/m³ |
| 3       | Nitrogen oxides as (NO) | Motor vehicles; Emissions from the industrial and domestic fossil fuels; (Cheng et al., 2012). | Acid rain; Smog; Damages buildings; Destroys vegetation growth. (Najjar, 2011). | 40 µg/m³ |
| 4       | Nitrogen oxides as (NO2) | Fuel combustion (gasoline, coal or oil); Automobile emissions. (Barone-Adesi et al., 2015) | Acid rain; Smog; Deleterious to the cell membrane of plants; Deplete soil fertility. (Chen et al., 2007). | 80 µg/m³ |
| 5       | Sulphur dioxide (SO2) | Mining and quarrying; Manufacturing of chemicals; Petroleum refineries; Metal industries; Power generation; Transportation; Community services; Industries;Brick kilns; Combustion of coal and oil. (Haider et al., 2017) | Haze; Formation of acid rain; Damages vegetation growth; Deteriorates surface water and soil by increasing acidification; Corrodes buildings and monuments. | 120 µg/m³ |
| 6       | Ozone (O3) | Secondary pollutant formed by chemical reaction of VOCs and NOx in the presence of sunlight. (Guo et al., 2019). | Smog; Damages rubber, fabric and other materials; Reduces plants growth and yield (Munzi et al., 2017). | 130 µg/m³ |

2.6 Air quality index (AQI)

AQI (Tiwari and Ali, 1987) is based on the concentration values using six key pollutants including Nitrogen Oxides as NO2 and NO, O3, PM2.5, PM10 and SO2 (Table 2) and calculated according to the following Equation:

\[
\text{AQI} = \frac{\text{NO}_2 + \text{NO} + \text{O}_3 + \text{PM}_{2.5} + \text{PM}_{10} + \text{SO}_2}{6}
\]

2.7 Data analysis

In order to determine the results, the geospatial technique (Javid et al., 2020) is adopted to analyze and compare the AQI (Chattopadhyay et al., 2010) using six key criteria pollutants. Moreover, the metrological factors were also evaluated by using the minimum, maximum and average criteria.

3. RESULTS AND DISCUSSION

3.1 Air quality index and metrology of Lahore in March 2019 and March 2020

In order to achieve objectives of the study, the AQI was encompassed and classified on six criteria pollutants to analyze the air pollution level during COVID-19 lockdown and compared with the period of March, 2019. Table 2 describes the PEQs level and the Figures 2 and 3 summarizes the results and supports the similar findings which were observed in India (Gautam, 2020). According to Table 2 and Figure 3, the concentration levels of air pollutants in the study area
were below the maximum permissible levels of PEQs in March, 2020, except the northwestern part of Lahore. Moreover, the overall air quality of other towns has also improved significantly during lockdown like other neighboring countries of Pakistan such as India (Mitra et al., 2020) and China (Xu et al., 2020).

![Image](https://example.com/image1)

**Figure 2.** Air quality index level of Lahore in March 2019 and March 2020

![Image](https://example.com/image2)

**Figure 3.** Air quality index of Lahore in March 2019 and March 2020

(The studies conducted by Kambalagere (2020), Ramasamy (2020), Isaifan (2020), Zambrano-Monserrate et al. (2020) supported the above results globally during COVID-19.)

On the other hand, rain showers reduced the concentration of air pollutants during the lockdown. So, the recorded 22°C average temperature (Bao and Zhang, 2020) and the average rainfall (2.4 mm) had a strong influence on the state of air in March 2020 (Table 1).

Furthermore, analyzing the results (Figure 3), it is recorded that the air quality index has dropped from
188 to 92 in Iqbal Town (IT), 198 to 118 in Gulberg Town (GT), 186 to 103 in Shalamar Town (ST), 193 to 114 in Ravi Town (RT), 201 to 124 in Data Gunj Baksh Town (GBT), 200 to 105 in Samanabad Town (SBT), 181 to 84 in Nishtar Town (NT), 157 to 63 in Aziz Bhatti Town (ABT) and 194 to 62 in Wagha Town (WT) and 178.25 to 93.50 in Cantonment (Cantt) area. In contrast, the ground based measurements of air pollutants exhibited on the south-eastern and north-western side of Lahore experienced the highest concentrations of air pollution and did not meet PEQs in March 2019. Extraordinarily high concentrations of air pollution in these parts of Lahore are mainly due to the industrial estates, small and medium industrial units, vehicular fumes and burning trash.

3.2 NO$_2$ assessment in March 2019 and March 2020

Based upon the results of NO$_2$ level in March 2019 and 2020 (Figure 4) it was reflected that the highest trends of air pollutant in terms of NO$_2$ were found in Ravi Town (RT), Shalamar Town (ST), Data Gunj Baksh Town (DGBT) and Samanabad Town (SBT). This is attributed to the industrial and population density in all towns that have increased the levels of toxic air pollution. On the other side, during lockdown a huge demand of home delivery has suddenly increased for groceries, food, household and medical items which accelerates the NO$_2$ values. Furthermore, in crowded areas stay-at-home policy was not followed strictly. So, the high concentration of NO$_2$ can be attributed due to the non-seriousness of the people towards social distancing which is also reported in the study of Dantas et al. (2020). Similarly, another reason is the operational movement of heavy duty vehicles (HDV) used to transport food in the market during lockdown. Additionally, the combustion of fuels in industries may also have increased the trend of NO$_2$ as the towns of Lahore have big industrial network and diesel based vehicles are common in the city. Apart from that, the nitrogen in the air compresses at high temperature and reacts with oxygen in the combustion chambers of gasoline and diesel driven vehicles and emits NOx. That is why no significant drop in NO$_2$ emissions has been recorded and supports the similar results of a previous study (Goyal et al., 2006). Moreover, the previous study of Jafary and Faridi (2006) has also reported the highest concentration of NO$_2$ in one of the crowded towns of Lahore i.e., Samanabad. Moreover, the similar result of the present study is also reported during the lockdown period in the capital city of Iran (Bauwens et al., 2020). Additionally, considering the results of other towns the NO$_2$ values has declined during lockdown and presents the improvement in air quality. Therefore, in support of this result, several studies have been reported globally (Aloi et al., 2020; Bao and Zhang, 2020; Bashir et al., 2020; Kerimray et al., 2020; Kaplan and Avdan, 2020; İban, 2020).

Figure 4. NO$_2$ level of Lahore in March 2019 and March 2020
3.3 NO assessment in March 2019 and March 2020

According to Figure 5, the air quality index classes have shown reduction in the NO level during March 2020 when the lockdown came into effect. Based on the results of Figure 5, the urban air quality of Lahore has exhibited good air quality index level in Nishtar Town (NT), Iqbal Town (IT), Samanabad Town (SBT). While in Wagha Town (WT), air quality index was recorded as moderate under and displayed similar trends as in 2019. Moreover, Gulberg Town (GT) showed an unhealthy air quality index which is one of the largest hubs of industrial estates of Lahore and located in the north-western part of the city. Further, the highest values of air quality index (hazardous) have been recorded in the Ravi and Data Gunj Buksh Towns. Basically, the hazardous level of air quality index is associated with the burning of substandard fuel commercially. In addition, the Lahore’s air pollutants are the compound results of industrial and vehicular emissions with the inclusion of metrological elements (Table 2). So, the concentration level of NO is relatively unhealthy for sensitive group in 2019 and supports the similar findings of earlier study (Gorai et al., 2015). However, the overall results indicate that air quality index has improved in few towns of Lahore due to the closure of anthropogenic activities.

Figure 5. NO level of Lahore in March 2019 and March 2020

3.4 O₃ assessment in March 2019 and March 2020

Figure 6 exhibits the mean concentration level of O₃ in Lahore in March 2019 and the lockdown period of March 2020. In comparison with the results of 2019, the overall situation in terms of O₃ in 2020 was recorded at unhealthy to hazardous levels. Basically, a rise in O₃ usually occurs when the NO level decreases (Quan et al., 2014). In the present case of COVID-19 lockdown, the O₃ mean concentration level rose compared to 2019, which supports the findings of the study conducted by Dantas et al. (2020). Thus, in the current lockdown, the highest concentration of O₃ (unhealthy) was recorded in Iqbal Town (IT) and Shalamar Town (ST). Moreover, the hazardous level of ozone has been recorded in Gulberg Town (GT), Samanabad Town (SBT) and Data Gunj Buksh Town (DBT). Thus analyzing Figure 5, the lower NO concentration helped to increase the concentration of O₃ and supported the results of the study conducted in Italy during lockdown (Collivignarelli et al., 2020).
3.5 PM$_{2.5}$ assessment in March 2019 and March 2020

According to Figure 7, PM$_{2.5}$ mean concentration level has dropped from unhealthy to moderate level during lockdown as compared to the last year data. Further, it is evident from results that eight out of nine towns have a moderate range of PM$_{2.5}$. This is because the main social and economic restrictions were enforced during the lockdown period. Similarly, not only the noticeable fall of PM$_{2.5}$ concentration was witnessed in Lahore, but also recorded in the several cities of India during the precautionary measures of COVID-19 (Sharma et al., 2020). Further, the results of Figure 7 also state that PM$_{2.5}$ concentration is inconsistent all over the Lahore in 2019 due to the operational sources of air pollutants such as commercial, industrial and transportation. On the other side, metrological variables of 2019 were also the leading cause to elevate the concentration of air pollution which is documented in the study of EEA (2020). Hence, the significant reduction in PM$_{2.5}$ encourages and motivates us to mitigate unnecessary social activities to avoid the havoc of air pollution and get a chance to breathe in the clean air.

3.6 PM$_{10}$ assessment in March 2019 and March 2020

PM$_{10}$ is well documented for the disastrous health effects on urban dwellers. In addition, with the combination of coronavirus, the pollutant became adverse for human life in metropolitan cities. Similarly, Lahore is the leading city of Pakistan which experiences the worst air pollution level and also choked in pandemic. But the adopted control measures of COVID-19 have improved the air quality of Lahore within a short period. Conversely from PM$_{2.5}$, notable reduction was recorded in PM$_{10}$ during lockdown period (Figure 8). Moreover, the similar results of PM$_{10}$ reduction are also reported in the current study conducted in Delhi, India during lockdown (Mahato et al., 2020). Nevertheless, the basic reasons behind the moderate tendency of PM$_{10}$ levels are the closure of construction sites, economic and social activities during the pandemic. Closing these dominant sources of air pollutants in towns such as Lahore improved the AQI, i.e., good to moderate. In addition, another study of Otmani et al. (2020) also reported the similar results in the wake of lockdown. Overall, after comparison with 2019, it is exhibited that the moderate level of PM$_{10}$ is measured throughout the study period which is also attributed with the metrological conditions. Thus, the minimal level of PM$_{10}$ is clear evidence that Lahore can achieve its emissions reduction targets by adopting concrete measures to avoid air borne diseases.
3.7 $SO_2$ assessment in March 2019 and March 2020

$SO_2$ is one of the leading pollutants that are infamous for smog and their presence in the air is highly poisonous for the respiratory system of humans. Notably, since 2016 Lahore is experiencing its worst episode of smog during October to February.

During February, when the city was facing the havoc of smog, the fatal pandemic broke out. In this regard, the adopted contingency measures to overcome pandemic has altered the concentration level of air pollutants and resulted in a significant reduction of $SO_2$ range in Lahore. Thus, according to the present
findings (Figure 9), the concentration level of SO$_2$ is recorded under the maximum prescribed limit of PEQs. This may be attributed to major SO$_2$ emitting industries being non-functional during the pandemic lockdown. Besides, the metrological aspect in terms of scattered rains has also improved the quality of air in a short span of time (Table 1). So, the overall air quality index in all towns of Lahore is remarkably visible under the category of ‘Good’. Further, comparing results with 2019, the SO$_2$ levels were also under the permissible level of Punjab’s ambient air quality standards and categorized in good to moderate in all towns. But in 2020, the AQI range of SO$_2$ is improved and associated with the suspension of industrial activities (Otmani et al., 2020) and attributed with the frequent rainfall which cleaned the air during coronavirus lockdown (Kapil, 2020).

**Figure 9.** SO$_2$ level in March 2019 and 2020

### 4. CONCLUSION

The findings of the present study infer that quarantine and metrological factors strongly influence the air quality. Thus, the cohesive situation of the pandemic lockdown combining with the weather influence has benefitted the air by lowering the magnitude of NO, PM$_{10}$, PM$_{2.5}$ and SO$_2$ in the study area. Although the diffusion of air pollutants is diminishing for a short span of time due to control measures of COVID-19, this practice cannot be carried out on a long term basis when the pandemic will be over. Therefore, the regulatory authorities should take necessary measures to reconsider the existing mechanism and redevelop strategies to combat deteriorated air. Moreover for the time being, the air quality can be maintained using the same steps which are initiated during lockdown such as to promote remote working, expand online dealings, and discourage unnecessary travelling. Moreover, the new technologies should be introduced in the industrial sector like zig zag technology in the brick kiln industry to overcome the air pollution level.

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