

# Effect of COVID-19 pandemic induced lockdown (general holiday) on air quality of Dhaka City

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## Research Article

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# Abstract

A worldwide pandemic of COVID-19 has forced to implement a lockdown during April-May 2020 by restricting people's movement, the shutdown of industries and motor vehicles in Dhaka, Bangladesh, to contain the virus. This type of strict measures returned an outcome of the reduction of urban air pollution around the world. The present study aims to investigate the reduction of the concentration of pollutants in the air of Dhaka City and the reduction of the Air Quality Index (AQI). Necessary time-series data of the concentration of  $PM_{2.5}$ ,  $NO_2$ ,  $SO_2$ , and CO have been collected from the archive of the U.S. Environmental Protection Agency (US EPA) and Sentinel-5P. The time-series data have been analyzed by descriptive statistics, and AQI is calculated following an appropriate formula suggested by US EPA based on the criteria pollutants. The study found that the concentrations of  $PM_{2.5}$ ,  $NO_2$ ,  $SO_2$ , and CO have been reduced by 23, 30, 07, and 07% during April-May 2020, respectively, compared with the preceding year's concentration. Moreover, the AQI has also been reduced by up to 35% than the previous year in April-May 2020. However, the magnitude of pollution reduction in Dhaka is lower than other cities and countries globally, including Delhi, Sao Paulo, Wuhan, Spain, Italy, USA, etc. The main reason includes the poor implementation of lockdown, especially in the first week of April and the second fortnight of May. The findings will be useful for policymakers to find a way to control the pollution sources to enhance Dhaka's air quality.

## Introduction

Nowadays, the ambient air quality of an urban area has become a significant concern for city dwellers worldwide for its significant impact on health, ecology, and climate change (Van Tienhoven and Scholes 2003; WHO 2006; IPCC 2007). From a medical perspective, air pollution is not only responsible for respiratory diseases like bronchitis and asthma but also responsible for cancer and cardiovascular disease (Brook et al. 2004). Several studies found a correlation between inhalable particulate matters and mortality and morbidity (Perez and Reyes 2002; Lin and Lee 2004; Namdeo and Bell 2005). An urban area with high population density and weak organizational capacity for controlling the source of pollution is at high risk of air pollution, including both fine ( $PM_{2.5}$ ) and coarse ( $PM_{10}$ ) particulate matters. In this sense, the megacity Dhaka is one of the hotspots of air pollution for its distinct natures of high population density, unfit vehicle movement that emits fine particles due to the combustion of fossil fuel, weak legislative and organizational capacity, dust, and industrial emission in and around the city. According to an estimation, Dhaka's total population stands more than 15 million, with a density of 33,878 per square kilometer, which is the highest figure in the world (Demographia 2020). Figure 1 shows a map of the study area—Dhaka City.

In recent years, Dhaka has been repeatedly reported as the most polluted city globally in terms of  $PM_{2.5}$  concentration and Air Quality Index (AQI). Most of the time, this city made its place in the top five and or top ten cities with poor air quality. The Department of Environment (DOE) of the Government of Bangladesh reported that the emission from motor vehicles and brick kilns in and around the city are

primary sources of particulate matters in the air of Dhaka City (DOE 2019). An estimation by Begum et al. (2013) using receptor modeling suggests that about 22% and 36% fine particulate matters are originated from the brick kiln and vehicle emission, respectively. Moreover, roadside dirt is a significant source of dust or coarse particulate matter ( $PM_{10}$ ), especially during the dry season from November to February. Furthermore, concurrent construction work of mega project is another source of air pollution inside the city.

However, a global pandemic of COVID-19 – originated from China in December 2019 – forced people to restrict their movement and shut down the operation of industry around the world. The Government of Bangladesh has also declared a general holiday, which is basically a lockdown, in the last week of March 2020 to contain the virus. Suddenly, the movement of motor vehicles has been entirely shut down except for emergency transport like medicine, food, etc. The industries in and around the Dhaka city, including the brick kiln, have also been closed. In these circumstances, a worldwide reduction of pollution has been observed, especially in urban areas. An estimation found that the public mobility is reduced by 90% due to the pandemic that results a reduction of pollution by almost 30% in the epicenters of the disease like Wuhan, Italy, Spain, and the USA (Muhammad et al. 2020). Similar air pollution reduction results have also been found in the neighboring country's capital city, viz. Delhi (e.g., Mahato et al. 2020; Sharma et al. 2020). Moreover, Nakada and Urban (2020) found that the concentration of  $NO$ ,  $NO_2$ ,  $CO$ , and  $O_3$  has significantly been reduced in São Paulo, Brazil, during partial lockdown for COVID-19 pandemic.

The effect of lockdown induced restriction of mobility and industrial operation on the air quality of Dhaka city has not yet been explored. However, it is anticipated that there would be a significant impact of lockdown on air quality that might improve the city air. In these circumstances, this study intends to investigate the reduction of air pollution in Dhaka—one of the world's biggest megacities. To investigate the air quality before and during-lockdown period, the concentration of fine particulate matter ( $PM_{2.5}$ ) and the concentration of various gaseous substances ( $NO_2$ ,  $SO_2$ ,  $CO$ ) have been analyzed. Then, the Air Quality Index has been computed against the concentration of different pollutants, and the difference between the occurrence of various AQI levels before and during-lockdown has been examined. Furthermore, a comparison of the concentration of  $NO_2$ ,  $SO_2$ ,  $CO$  during April in 2019 and 2020 has been assessed from satellite image applying remote sensing technique to show a graphical presentation. In short, the objectives of this study are as follows:

2. To investigate the reduction of the concentration of  $PM_{2.5}$ ,  $NO_2$ ,  $SO_2$ , and  $CO$  in the air of Dhaka City before and during COVID-19 induced lockdown.
3. To examine the changes in the occurrence of different Air Quality Index levels of Dhaka City before and during the lockdown.

## Materials And Methods

### Data Source

This research is based on secondary time-series data of the concentration of PM<sub>2.5</sub> during April-May from 2016 to 2020 and the concentration of NO<sub>2</sub>, SO<sub>2</sub>, CO from 2019 to 2020, and their corresponding AQI values. The time-series data of PM<sub>2.5</sub> were collected from the archive of a real-time air quality monitoring system maintained by the US EPA, which is located in the US Consulate of Dhaka. Although the target year of this study is 2020, the previous four years have also been collected to show the change in the level of pollution. The concentration of PM<sub>2.5</sub> is measured on an hourly basis. Apart from the raw concentration of the pollutant on an hourly basis, US EPA also calculates NowCast data based on the weighted average of most recent 12-hours data to determine AQI. In this study, the NowCast concentration of PM<sub>2.5</sub> has been considered instead of hourly raw concentration. Besides, the time-series data of the concentration of NO<sub>2</sub>, SO<sub>2</sub>, and CO during April-May in 2019 and 2020 have been assessed from the Sentinel-5P satellite applying remote sensing technique.

### Air Quality Index

The Air Quality Index is basically calculated by various government organizations to report how contaminated the current air is or how polluted it will be. The AQI has been calculated from the NowCast concentration of PM<sub>2.5</sub> (from 2016 to 2018) and the concentration of different pollutants, e.g., PM<sub>2.5</sub>, NO<sub>2</sub>, SO<sub>2</sub>, CO (from 2019 to 2020) using the following formula (Eq. 1) (US EPA 2019). This formula returns a number on a scale of 0-500.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_p - BP_{Lo}) + I_{Lo} \quad (1)$$

Here,

$I_p$  = the index for pollutant p

$C_p$  = the truncated concentration of pollutant p

$BP_{Hi}$  = the concentration breakpoint that is greater than or equal to CP

$BP_{Lo}$  = the concentration breakpoint that is less than or equal to CP

$I_{Hi}$  = the AQI value corresponding to BPHi

$I_{Lo}$  = the AQI value corresponding to BPLo

The breakpoints and their corresponding AQI values of PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, and CO can be found in Appendix Table 1. The values of AQI are divided into six classes: (i) Good, (ii) Moderate, (iii) Unhealthy for sensitive groups, (iv) Unhealthy, (v) Very unhealthy, and (vi) Hazardous. Table 1 shows the potential health implications against each of these classes of AQI. In this study, we have calculated AQI based on PM<sub>2.5</sub> from 2016 to 2018 as the time-series data of the concentration data of other criteria pollutants is

not available for this period. However, when the concentration data of other criteria pollutants are available, AQI is normally calculated for each pollutant separately, and the highest value is reported (US EPA 2018). Since the time-series data of NO<sub>2</sub>, SO<sub>2</sub>, and CO is available during April-May from 2019 to 2020, AQI is calculated for all pollutants in this period, and the highest value is considered for analysis.

**Table 1** Classes of AQI values and their health implications (US EPA 2019)

AQI Level	Numeric Value	Meaning
Good	0-50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51-100	Air quality is acceptable; however, for some contaminants, there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for sensitive groups	101-150	Members of vulnerable groups can experience effects on health. The public at large is unlikely to be affected.
Unhealthy	151-200	Everyone can start experiencing health effects; members of sensitive groups may experience more serious effects on health.
Very Unhealthy	201-300	Health warnings of state of emergency. It is more likely that the entire population will get affected.
Hazardous	301-500	Health alert: more severe health effects will affect everyone.

## Assessment of Gaseous Substances

Real-time atmospheric monitoring data of NO<sub>2</sub>, SO<sub>2</sub>, and CO during April-May in 2019 and 2020 have been collected from the Sentinel-5P satellite. The Sentinel-5 Precursor mission instrument collects data that are useful for assessing air quality. The TROPOMI instrument of Sentinel-5P is a multispectral sensor that records reflectance of wavelengths, which are essential for measuring atmospheric concentrations of different gases and cloud characteristics at a spatial resolution of 0.01 arc degrees. In addition to time-series data, the concentration of gaseous substances has been extracted during the last week of April in 2019 and 2020 and presented in a raster format to compare 'before lockdown' and 'during lockdown' scenario.

## Results

### Changes in Concentration of PM<sub>2.5</sub>

The concentration of PM<sub>2.5</sub> for April and May have been analyzed by descriptive statistics technique. Table 2 displays the findings of the statistical analysis of the data in-between 2016 and 2020. The findings show that the mean concentration of PM<sub>2.5</sub> in 2020 has been decreased by about 23% than the mean concentration of 2019. On the other hand, the decreasing rate is almost 11% and 9% compared to

the mean concentration of 2018 and 2017. The maximum concentration of fine particulate matter in 2020 is also decreased by half its concentration in 2019. Around 23% of observations exceeded the standard limit (for Bangladesh,  $65 \mu\text{g}/\text{m}^3$ ) in 2020, whereas it was about 32% in 2019. The value of Standard Deviation also shows that the data series of 2020 is less discrete than the data series of 2019. It implies that the data of 2020 have not varied widely; instead, it shows more closeness and compactness than in 2019. In short, the 2020 Data observed less number of extreme values than previous years during the lockdown period of April-May.

**Table 2** Descriptive statistics of concentration of  $\text{PM}_{2.5}$  during April-May

Criteria	Descriptive statistics of $\text{PM}_{2.5}$ during April-May				
	2020	2019	2018	2017	2016
Mean ( $\mu\text{g}/\text{m}^3$ )	50.0	64.8	55.9	55.2	50.6
Maximum ( $\mu\text{g}/\text{m}^3$ )	220.3	430.6	373.3	267.8	159
Minimum ( $\mu\text{g}/\text{m}^3$ )	5.9	8.3	5.2	11.9	7.7
Mode ( $\mu\text{g}/\text{m}^3$ )	61.3	43.3	42	45.5	47.1
Standard deviation ( $\mu\text{g}/\text{m}^3$ )	29.7	43.9	36.0	29.5	20.3
% Observation exceeded standard limit*	22.6	32.2	27.3	23.7	15.9
% Observation didn't exceed standard limit	77.4	67.8	72.7	76.3	84.1

\*Bangladesh standard:  $65 \mu\text{g}/\text{m}^3$

Another noteworthy finding is that the mean concentrations of 2016 and 2020 are almost the same. Table 2 implies that after 2016, the concentration of fine particulate matter ( $\text{PM}_{2.5}$ ) has increased significantly throughout 2017-2019. In 2019, the air quality of Dhaka had experienced the worst scenario amongst recent history. During the lockdown period of April-May in 2020, the air quality has definitely improved, but it did not cross the concentration of 2016.

### Changes in Gaseous Substances

The criteria pollutants of air include some gaseous substances, such as  $\text{NO}_2$ ,  $\text{SO}_2$ , and CO, which are mainly released from motor vehicles due to fossil fuel combustion. Since the ground-based real-time monitoring system for these gaseous substances are not available, necessary information has been extracted from satellite imageries. Figure 3 shows the time-series plot of the concentration of gaseous substances in April-May 2019 and 2020. The findings from time-series data show that the mean and maximum concentration of  $\text{NO}_2$  in April 2020 reduced by about 30% and 22%, respectively, compared to the mean concentration in April 2019. In the case of CO, the mean and maximum concentration is reduced by about 7% and 5%, respectively, compared with previous years. On the other hand, the mean concentration of  $\text{SO}_2$  has decreased in April-May 2020 by about 7% comparing with the mean concentration in April-May 2019. Figure 4 shows a graphical presentation of the changes in the concentration of  $\text{NO}_2$ ,  $\text{SO}_2$ , and CO over Dhaka during the last week of April in 2019 and 2020.

### Changes in Air Quality Index

The Air Quality Index has been computed against the NowCast concentration of PM<sub>2.5</sub> from 2016 to 2018 using the formula in Equation 1. For the 2019-2020 period, the AQI is calculated for all pollutants separately, and the highest value is considered for analysis. Table 3 shows the percentage of the occurrence of each class of AQI in different years. According to the findings, the percentage of the occurrence of 'Unhealthy' and 'Very Unhealthy' level of AQI has been increased over the years from 2016 to 2019. In contrast, both levels of pollution have been decreased in 2020 by about 21% and 59%, respectively, compared to the pollution level of 2019. Similarly, the percentage of 'Unhealthy for Sensitive Groups' in 2020 has also been decreased by about one-fourth of its occurrence in 2019. On the other hand, the occurrence of 'Good' and 'Moderate' AQI levels have been increased in 2020 by about 9 and 2 times, respectively, than their occurrence in 2019. The AQI of April-May in 2020 did not experience any 'Hazardous' event. In short, the AQI of April-May in 2020 experienced the increasing of 'Good' and 'Moderate' level of AQI and decreasing of 'Unhealthy for Sensitive Groups,' 'Unhealthy,' and 'Very Unhealthy' level that suggests the overall improvement of the air quality of Dhaka during April-May in 2020 comparing to previous years. Table 3 also shows a linear increment in 'Unhealthy' and 'Very Unhealthy' level of AQI over the years from 2016 to 2020. Whereas, the other three levels of AQI, such as 'Good,' 'Moderate,' and 'Unhealthy for Sensitive Group' level followed a zigzag path instead of a linear path throughout their changes from 2016 to 2020.

**Table 3** Percentage of occurrence of each AQI class among the observed data

AQI Level	2020	2019	2018	2017	2016
% of 'Good' AQI	1.23	0.14	2.37	0.14	0.82
% of 'Moderate' AQI	36.71	16.57	26.09	19.74	18.37
% of 'Unhealthy for sensitive group' AQI	28.07	37.39	33.33	42.90	51.16
% of 'Unhealthy' AQI	32.39	41.21	35.85	35.45	29.58
% of 'Very unhealthy' AQI	1.57	3.82	2.07	1.50	0.07
% of 'Hazardous' AQI	0	0.85	0.30	0.27	0

## Discussion

In recent years, Dhaka's air pollution is a major public concern as the AQI of the city has been reported among the world's worst cities for several times. The main source of air pollution in Dhaka includes emission from motor vehicles and industries, construction works, improper transportation of soil and sand through the city, emission from brick kilns around the city, dusty road with dirt, household combustion of fossil fuel, burning of solid waste in open landfill nearer the city, and some trans-boundary pollution (DOE 2014; DOE 2019; Rahman et al. 2020). Table 2 shows that the concentration of PM<sub>2.5</sub> has increased significantly after 2016 in the city. It is because the construction of the first metro rail of the city has begun in mid-2017, which boost the generation of air pollutants in several ways, such as it narrowed down the road that kept vehicles longer time on the road burning more fossil fuel. Moreover, many public vehicles operating inside the city are not fit, and they release finer particles due to poor combustion of diesel and petrol (DOE 2019). Therefore, the combination of unfit vehicles (which portrays the poor

implementation of laws and regulation) and large scale construction works ended up the city on the top of the world's unlivable cities.

In these circumstances, the COVID-19 pandemic brought a halt in all anthropogenic sources of air pollution for two months from April to May 2020. This lockdown resulted in a reduction of pollution; however, the magnitude of this reduction is not as much as anticipated before analyzing the data. However, it has been found in other studies that not only Dhaka but other cities in the world also experienced pollution reduction in this lockdown period due to COVID-19. For instance, an estimation found that the concentration of  $PM_{2.5}$ ,  $NO_2$ , and CO have been reduced by 43, 18, and 10% in Delhi during the lockdown, respectively (Sharma et al. 2020). Another estimation by Mahato et al. (2020) found that the concentration of  $PM_{2.5}$ ,  $NO_2$ , and CO has been reduced by almost 50, 53, and 30%, respectively, in Delhi. Both of Sharma et al. (2020) and Mahato et al. (2020) also reported the reduction of AQI by 30 and 43% on average, respectively. A similar result has been found in another continent also. For example, the concentration of NO,  $NO_2$ , and CO has been reduced by up to 77, 54, and 65%, respectively, in Sao Paulo, Brazil (Nakada and Urban 2020). Furthermore, Muhammad et al. (2020) found that the concentration of  $NO_2$  has decreased by up to 20-30% in China, Spain, France, Italy, and the USA, which are major epicenters of COVID-19. In compare to Delhi and Sao Paulo, Dhaka has also experienced the reduction of  $PM_{2.5}$ ,  $NO_2$ , CO, and AQI but the extent or magnitude of the reduction is less than these two cities (23% for  $PM_{2.5}$ , 30% for  $NO_2$ , 07% for CO, and about 35% for AQI on average). Another significant observation is that Sharma et al. (2020) reported that the change in the concentration of  $SO_2$  is negligible in Delhi. In contrast, Dhaka shows a reduction in the mean concentration of  $SO_2$  by about 07% compared to the concentration of 2019.

It is now evident that the COVID-19 induced lockdown has reduced air pollution around the world, although the extent and magnitude of this pollution reduction are not same in all cities or countries. It is also evident that the magnitude of pollution reduction in Dhaka is lower than in other cities in different countries. Some meteorological factors act like driving force of the accumulation of pollutants. One of them is wind movement that carries out the air pollutants (Dickson 1961; Kim 2011). Rahman et al. (2020) found that around 40% of  $PM_{2.5}$  in Dhaka City during monsoon season are carried in by wind movement from neighboring regions. Another demographic factor is population density (Cole and Neumayer 2004). Since Dhaka is the world's most densely populated city (Demographia 2020), the city dwellers combust a significant amount of fossil fuel (natural gas and charcoal, especially in slum area) that might be a noteworthy source of air pollution. Moreover, despite the shutdown of public transport system during the lockdown, private vehicles were allowed to drive inside the city. Furthermore, the implementation of lockdown became weak as the government declared to open the market and shopping mall in the second fortnight of May 2020. In short, the wind movement, population density (household combustion of fossil fuel), and weak implementation of lockdown might be responsible for less reduction of air pollution in Dhaka.

## Conclusion

This study's main objective was to investigate the reduction in the concentration of various air pollutants during the COVID-19 induced lockdown in Dhaka City. To serve this purpose, the time-series data of PM<sub>2.5</sub> were collected from the US EPA archive during April-May from 2016 to 2020, and the time-series data of NO<sub>2</sub>, SO<sub>2</sub>, CO was collected from Sentinel-5P for the period of April-May 2019 to 2020. Later, AQI was calculated based on PM<sub>2.5</sub> from 2016 to 2018. On the other hand, AQI from 2019 to 2020 was calculated separately based on PM<sub>2.5</sub>, NO<sub>2</sub>, SO<sub>2</sub>, CO, and the highest value is considered for analysis. The study found that all pollutants, including PM<sub>2.5</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and CO, have been decreased during the lockdown period compared to their concentration in the previous year. The highest degree of concentration reduction occurred in NO<sub>2</sub>, followed by PM<sub>2.5</sub>, SO<sub>2</sub>, and CO. The AQI has also been decreased by more than one-third compared to its extent in the previous year. The magnitude of pollution reduction in Dhaka is relatively lower compared to the capital city of the neighboring country, Delhi. It is also lower than other inter-continental cities and countries like Sao Paulo, Wuhan, Spain, Italy, USA, etc. The overall findings suggest that the extent of air pollution has moderately decreased during the lockdown period. This scenario points out the poor implementation of lockdown in Dhaka, Bangladesh. The findings of the study will provide some food of thought to the policymakers that strict measures to control the pollution sources might be useful to improve the city air.

## Declarations

Competing Interests

The authors declare no competing interest

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# Figures

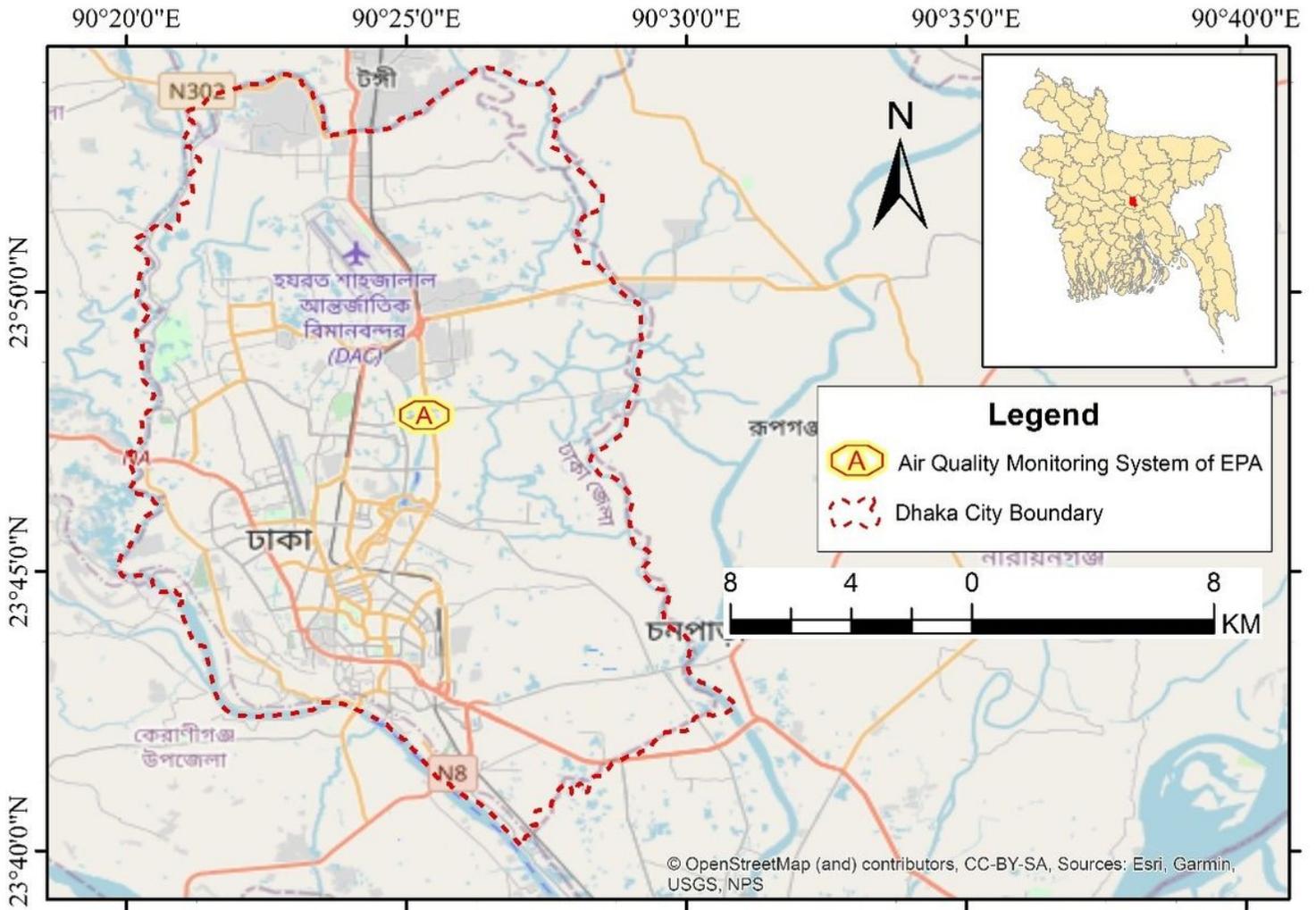
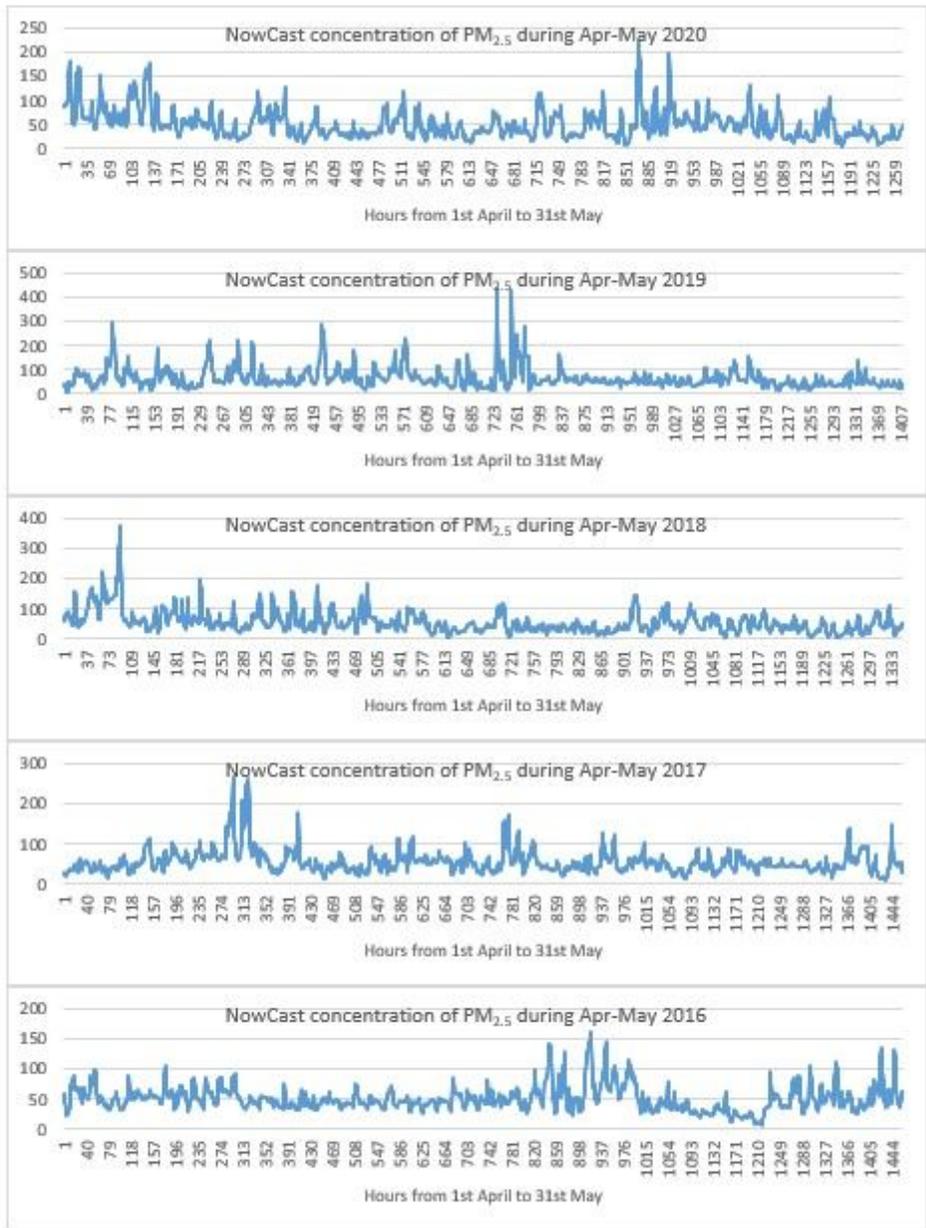


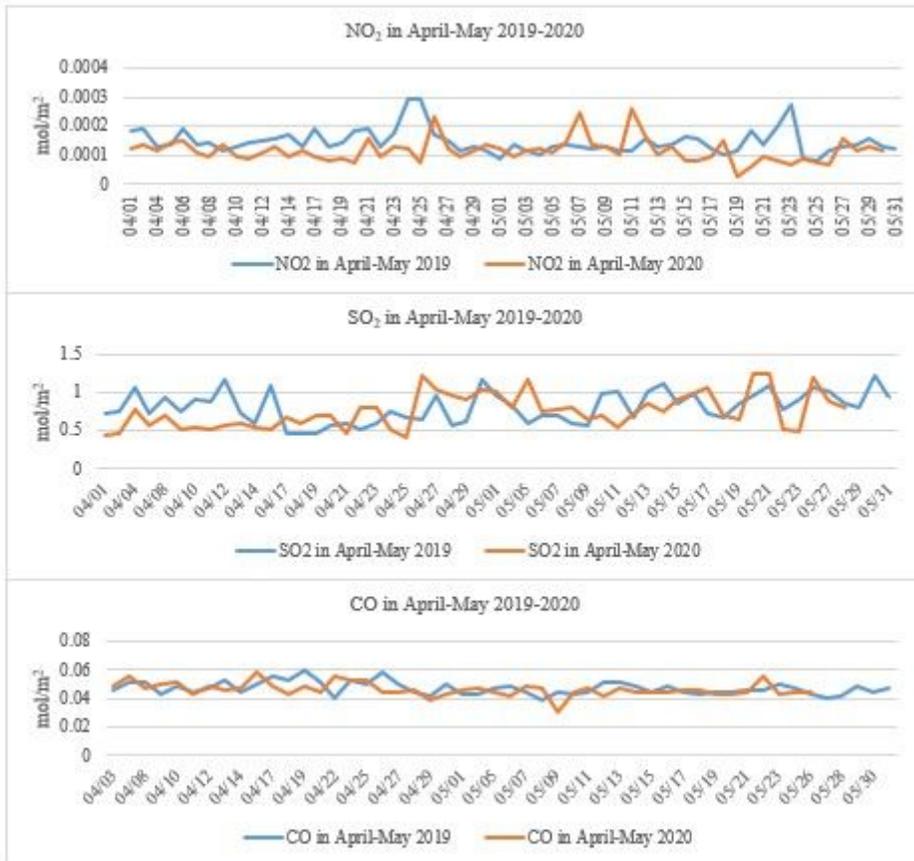
Figure 1

Map of Dhaka City



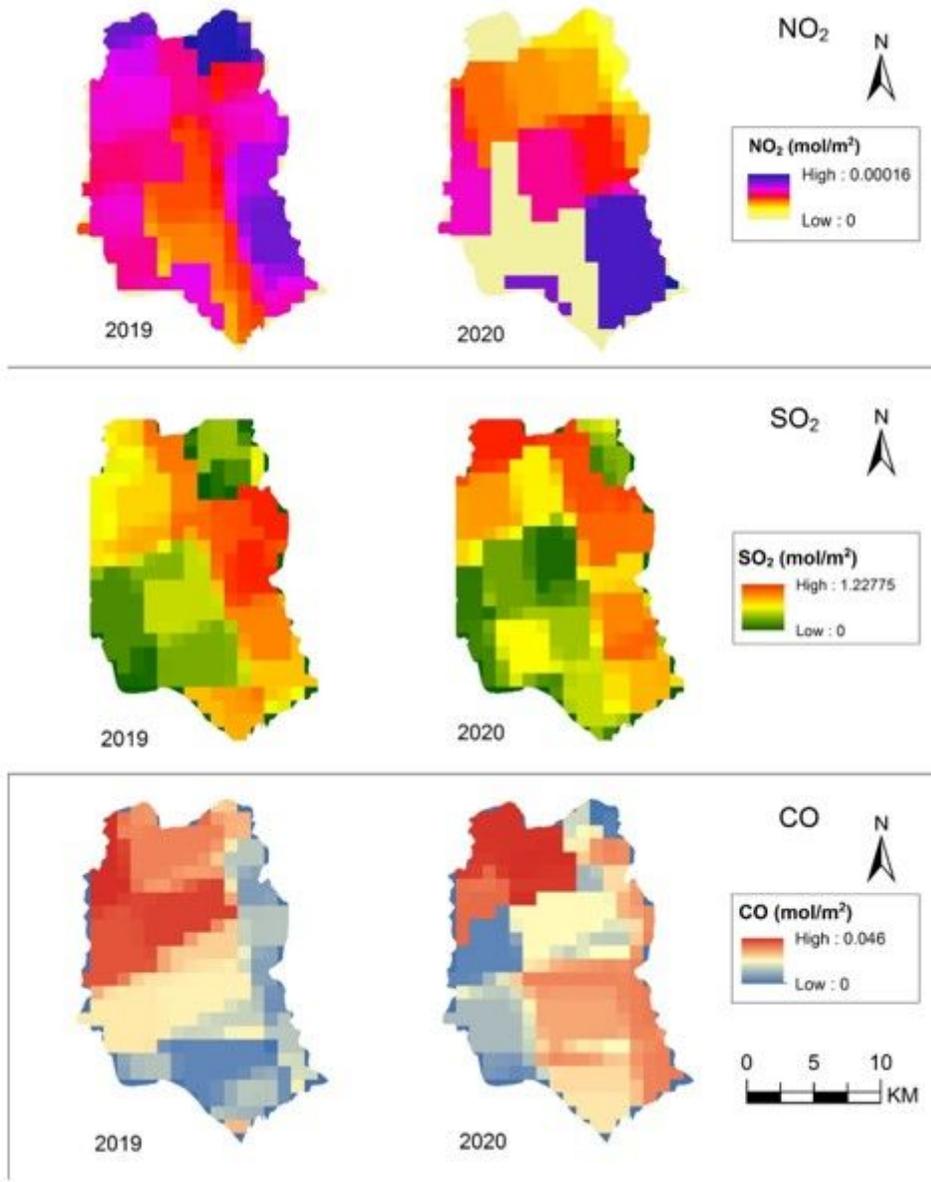
**Figure 2**

Time-series plot of the concentration of PM<sub>2.5</sub> during April-May of 2016-2020



**Figure 3**

Time-series plot of NO<sub>2</sub>, SO<sub>2</sub>, and CO



**Figure 4**

Atmospheric concentration of NO<sub>2</sub>, SO<sub>2</sub>, and CO over Dhaka in April 2019 and 2020

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AppendixTable.png](#)