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Research Paper

Effects on Air Quality in Dhaka City Due to COVID-19 Pandemic Induced Nationwide Lockdown

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ABSTRACT

This paper deals with air pollution levels in Dhaka from 2019 to 2021, showing different air pollutant levels before and during the lockdown. The government of Bangladesh was compelled to impose a lockdown because of the global COVID-19 epidemic. This lockdown included limiting people's mobility, shutting down businesses and motor vehicles, and closing public spaces, schools, and marketplaces to control the virus. Selected air contaminants' trends have been determined by Mann-Kendall analysis. It was discovered that during the lockdowns triggered by COVID-19 in the city of Dhaka, the levels of the pollutants in the air drastically altered. $PM_{2.5}$, PM_{10}, and NO_2 levels decreased by approximately 40.1 µg/m^3, 125.58 µg/m^3, and 75.98 µg/m^3, respectively. On the contrary, the O_3 level increased by approximately 18.97 µg/m^3 throughout the same period. An inference was made that significant air pollution mitigation is possible through technological intervention, strict regulation, and behavioral changes in people.

Keywords: *Air Pollution, AQI, Dhaka, COVID-19, $PM_{2.5}$*

COVID-19 is a contagious sickness that results from a serious lung problem (SARS-CoV-2) [1–3]. On December 31, 2019, it was initially discovered in the Chinese province of Hubei's town of Wuhan, where it was associated with openings at a nearby fish market. This modern Covid has spread over the globe and is seriously harmful to everyone's well-being. On March 11, 2020, the World Health Organization (WHO) designated an additional Covid contamination a pandemic. Six months after the first verified case in Wuhan, more than 10.6 million individuals contracted COVID-19, and 514,315 people died as a result of the sickness in 215 different nations, provinces, and regions worldwide [4]. The World Health Organization has classified COVID-19 as a worldwide public health hazard due to its extensive dispersion and persistent nature. (WHO). WHO recommendations released on January 27 informed the public of the actions to be taken to

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stop the virus from spreading further. Then on February 29, a month after the fact, the World Health Organization (WHO) gave further rules, including travel limitations and restrictions. The reconsidered rules recommended 14-day self-checking for side effects for those who returned from affected regions [5]. Considering COVID-19's fast spread, most states have organized a complete public lockdown, requiring self-quarantine, restricting individuals' movement to anybody getting back from nations with high disease rates, and requesting social separation [6]. Bangladesh is struggling with a COVID-19 flare-up, with a populace thickness of 1265 individuals for every square kilometer [4] and a populace of 165 million individuals (as of June 2020).

The results of an investigation into three preliminary instances of COVID-19 were released by the Bangladeshi Institute of Epidemiology, Disease Control, and Research (IEDCR) on March 8, 2020. (As per the IEDCR, the year 2020 will be the 10th commemoration; there have been 1,26,606 affirmed cases as of June 26, 2020, with 1621 passing. Just Dhaka, the nation's capital, has 29% of every confirmed case [7]. The Bangladesh government utilized massive general well-being measures, including local area limits, social distance, transportation limitations, self-quarantine, and lockdowns, to keep COVID-19 from spreading [8]. Travel limitations and superfluous development were set up in Dhaka and the affected regions, bringing about a lockdown. The lockdown became real on March 26, 2020, and went on for a couple of days all through the country. Closures and other forms of strict regulation have an impact on society, especially the climate. These limitations on human action brought about less traffic across the city and a massive drop-in everyday activity, all of which added to limiting air contamination [8]. Due to similar shutdown and control tactics used worldwide, air quality has increased in numerous countries and regions [9]. Since air quality is associated with discharges, a total or fractional lockout further develops air quality [10] detailed a massive drop in NO_2 and fossil fuel by-products in China because of the current closure (i.e., 30 and 25 percent, separately found a 55% decrease in NO_2 levels in India during the closure time frame [11]. What's more, explicit air impurities might have a massive connection to COVID-19 diseases, albeit this still needs to be satisfactorily investigated, and there is still uncertainty [12]. Be that as it may, specific investigations [12, 13] have shown a significant connection between COVID-19 disease and air contamination. The brick kiln and several other industries in and around Dhaka have been closed. The impact of the lockdown on portability and modern movement on Dhaka's air quality is not entirely settled. The closure is anticipated to fundamentally affect air quality in the city, improving it considerably. This study expects to perceive what COVID-19-prompted lockdown measures meant for air contamination levels in Dhaka, Bangladesh, by checking NO_2, O_3, $PM_{2.5}$, and PM_{10} focus varieties during the lockdown. The effects of public lockdowns on air quality changes can be observed and analyzed by looking at air contamination information discoveries from similar periods in 2019-2021.

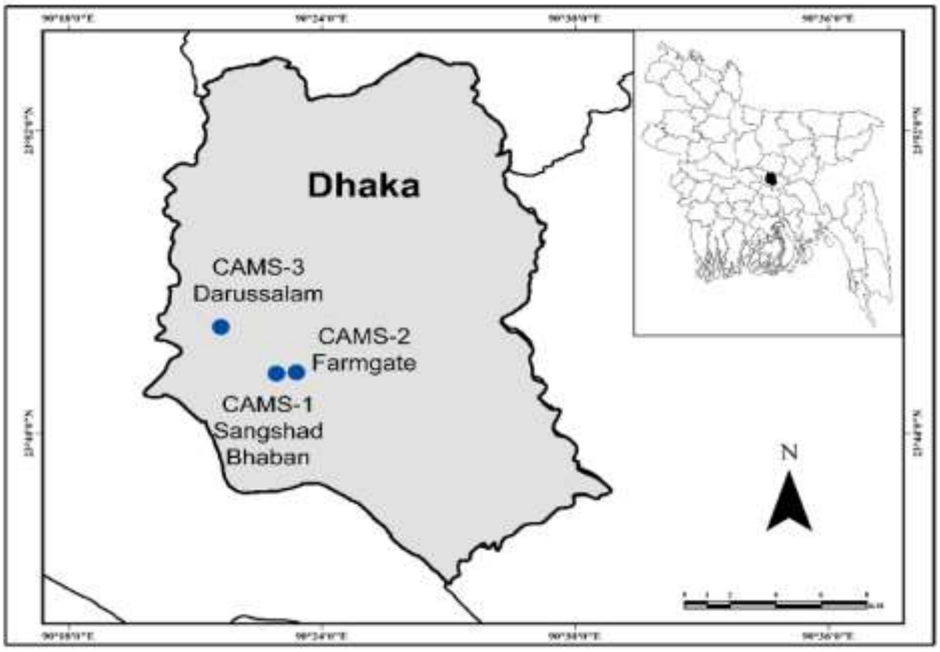
MATERIALS AND METHODOLOGY

Three permanent Continuous Air Monitoring Stations (CAMS) comprise Dhaka's ambient air quality monitoring network. Table 1 gives a quick overview of the monitoring stations and a list of the measured parameters that are recorded at each station.

Description of Monitoring Network Table 1:

ID	Location	Lat/Lon	Monitoring capacity
CAMS-1	Sangshad Bhaban, Sher-e-Bangla Nagar	23.76N 90.39E	PM_{10}, $PM_{2.5}$, CO, SO_2, NO_X, O_3, and HC concentrations with meteorological parameters.
CAMS-2	Farmgate	23.76N 90.39E	PM_{10}, $PM_{2.5}$, CO, SO_2, NO_X, O_3, and HC with meteorological parameters.
CAMS-3	Darus-Salam	23.78N 90.36E	PM_{10}, $PM_{2.5}$, CO, SO_2, NO_X and O_3 with meteorological parameters.

Fig 1 The 3 CAMS Locations



Substances taken into account in this study include ozone (O_3), nitrogen dioxide (NO_2), and particles having a diameter of 10 µg. The Mann-Kendall statistical method is utilized to seek out patterns in the data series of specified parameters. The Mann-Kendall statistical test for the trend is used to ascertain if a set of data values has been trending upward or downward over time and whether the trend in either direction is statistically important.

The Mann–Kendall Test:

Ascending and falling patterns in time series data can be identified with the Mann-Kendall (MK) test, a nonparametric analysis of trends method. Rather than evaluating the data's real values, it investigates the absolute magnitudes of the sample data [14]. Using data representing the monthly average of NO_2, O_3, $PM_{2.5}$, and PM_{10} pollution, the Mann-Kendall and the slope of Sen tests were run. The Mann-Kendall (MK) test was first designed to compare the null hypothesis H_0 of no trend testing, which asserts that the observations xi occur at random in time, with the different hypothesis H_1, which states that a linear pattern is either growing or decreasing. The data values in the sections that follow are contrasted with those determined to be ordered time series. When a data value from a later era is more significant than a data value from an earlier period, the statistic S rises by one. When a subsequent period's data value is lower than the sampled value from the prior period, however, S declines by one. S's final value is the product of every single one of these raises and decrements. [15–18]. The S statistic associated with the Mann-Kendall test is obtained as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=I+1}^{n} sgn(x_j - x_i) \qquad \text{eq. } \mathbf{(1)}$$

Where n stands for the number of data points, x_i, and x_j stand for the data values in time series I and j (j > I, respectively), and Sgn (x_j - x_i) signifies the sign function:

$$sgn(x_j - x_i) = \{+1, \text{ if } x_j - x_i > 0 \;\; 0, \text{ if } x_j - x_i = 0 \quad -1, \text{ if } x_j - x_i < 0 \qquad \text{eq. } \mathbf{(2)}$$

The methods to obtain S's variance are as follows:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \qquad \text{eq. } \mathbf{(3)}$$

W(S) are the standard normal test statistics, where m is the number of connected groups in a data set, t_i is the number of data values in a group, and n is the number of data series:

$$W(S) = \begin{cases} \frac{S-1}{\sqrt{Var(s)}}, if\ S > 0 \;\; 0, if\ S = 0 \;\; \frac{S+1}{\sqrt{Var(s)}}, if\ S < 0 \end{cases} \qquad \text{eq. } \mathbf{(4)}$$

S values that are positive or negative represent rising or declining trends. The significance level in this study is set at a = 0.05.

Sen's Slope or the slope of Sen Estimator:

Sen's slope test is commonly utilized for assessing the strength of the pattern for the set of data N:

$$Qi = \frac{x_j - x_k}{j-k}, for\ i = 1, \ldots, N, \qquad \text{eq. } \mathbf{(5)}$$

N is defined as n (n - 1)/2 when n is the number of periods and 1 is the number of datums. N=n (n - 1)/2, where n represents the total number of observations, is the outcome of several sightings conducted across one or more time periods. A median slope (also known as Sen's slope) is determined after ordering the N values of Qi from lowest to highest:

$$Q_{med} = \begin{cases} Q_{\left[\frac{N+1}{2}\right]}, if\ N\ is\ odd \;\; \frac{\left(\frac{QN}{2} + Q_{\left[\frac{N+2}{2}\right]}\right)}{2}, if\ N\ is\ even \end{cases} \qquad \text{eq. } \mathbf{(6)}$$

The Q_{med} amount, indicating a data pattern, indicates how steep the pattern is. The Q_{med} is determined as follows when the median slope is statistically various from zero:

$$C_\alpha = Z_{1-\alpha/2}\sqrt{Var(s)} \qquad \text{eq. } \mathbf{(7)}$$

Var(S) has been defined in equation (3), and Z_1-a/2 is computed using the traditional standard distribution table. The confidence interval for the study has been set at a = 0.05.
Results and Discussions

Particulate matter ($PM_{2.5}$):

$PM_{2.5}$ describes very small particles, often 2.5 µm or less. A study revealed that the presence of particulate matter was significantly reduced during the COVID'19 lockdown. The report claims that the pre-pandemic $PM_{2.5}$ level was around 76.8 µg/m^3 which is significantly greater than the standard value of 65 µg/ m^3.

Again, from April 4, 2021, to July 14, 2021, the Government imposed a strict/extreme lockdown. During this time, the $PM_{2.5}$ concentration dropped by 28.3 µg/m^3 from the standard value. Thus, these events indicate that during the lockdown, the $PM_{2.5}$ levels during lockdown were much more suitable than usual times. Below, Figure 1 and Figure 2 show the trend of changes in $PM_{2.5}$ value.

Table 2: Summary Stats

Timeline	Variable	Observations	Minimum	Maximum	Mean	Standard deviation
Pre-pandemic	239.71	13	78.44	236.22	155.87	57.48
Strict lockdown	157.30	3	42.72	117.36	86.56	38.98

Table 3: The results of the slope tests conducted by Mann-Kendall and Sen. Before lockdown or Pre-pandemic and Strict lockdown $PM_{2.5}$ data results

	Before lockdown/Two-tailed study (239.71):	Strict lockdown/Two-tailed study (157.30):
Tau of Kendall	0.15	-0.33
S	12.00	-1.00
Var (S)	268.66	3.66
Value of P	0.50	1.00
Alpha	0.05	0.05
The slope of Sen:	3.48	-8.88
Interpreting test results	H0: The series doesn't exhibit any trends.	H0: The series doesn't exhibit any trends.
	Ha: The series exhibits a trend	Ha: The series exhibits a trend

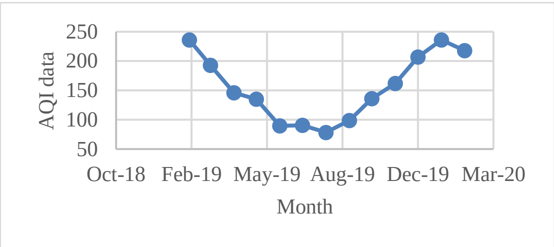


Fig 2: Trend line for $PM_{2.5}$ from January 2019 to June 2019(Pre-lockdown period)

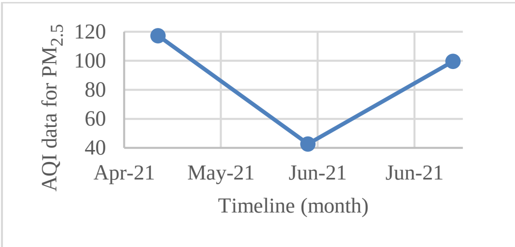


Fig 3: Trend line for PM_{10} from April 2021 to July 2021(Strict lockdown period)

Particulate matter (PM_{10}):

PM_{10} is present in smoke, dust, soot, salts, acids, and metals, and is defined as any particulate matter in the air with a size of 2.5 µm to 10 µm. Particulate matter may also be generated in the atmosphere when gases emitted by vehicles and industries encounter chemical reactions. According to our study, the PM_{10} level before the pandemic (pre-pandemic) was around 167.467 µg/m^3 which is about 17.467 µg/m^3 higher than the standard value of 150 µg/m^3.

Again, during the lockdown period from 4th April 2021 to 14th July 2021, the PM_{10} level was 41.888 µg/m^3 which is 108.112 µg/m^3 lower than the standard value. So, it is evident that the lockdown affected PM_{10} levels in Dhaka City.

Table 4: Summary stats

Timeline	Variable	Observations	Minimum	Maximum	Mean	Standard deviation
Before lockdown	257	5	68.80	239.50	149.56	68.79
Strict lockdown	80.66	3	16.70	52.61	28.96	20.48

Table 5: The results of the slope tests conducted by Mann-Kendall and Sen. Before lockdown or Pre-pandemic and Strict lockdown PM_{10} data results

	Before lockdown/ Two-tailed study (257):	Strict lockdown/ Two-tailed study (80.66):
Tau of Kendall	-1	-0.33
S	-10.00	-1.00
Var(S)	16.66	3.66
Value of P	.027	1.00
Alpha	0.05	0.050
The slope of Sen	-42.92	-0.57
Interpreting test results	H0: The series doesn't exhibit any trends	H0: The series doesn't exhibit any trends
	Ha: The series exhibits a trend	Ha: The series exhibits a trend

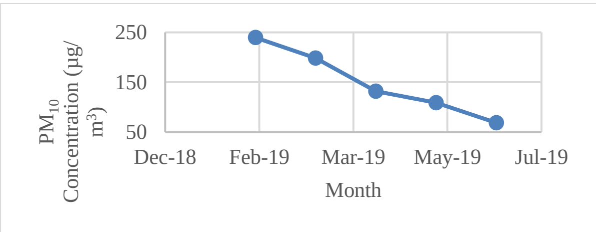


Fig 4: Trend line for PM_{10} from January 2019 to June 2019 (Pre-lockdown period)

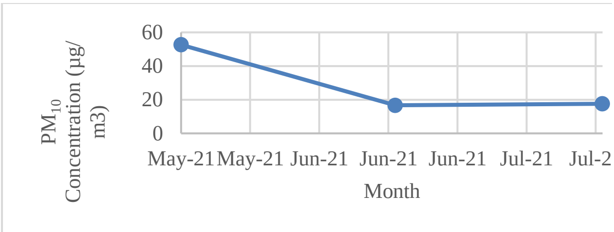


Fig 5: Trend line for PM_{10} from April 2021 to July 2021 (Strict lockdown period)

Nitrogen dioxide (NO_2)

Nitrogen dioxide is the most harmful nitrogen oxide (NO_2). The most prevalent instance of higher molecular weight of nitrogen oxide is NO_2. Such exposures over a brief period of time might cause respiratory disorders, especially asthma, and they may also encourage respiratory symptoms (such as coughing, wheezing, or breathing difficulties) [19]. This study found that the NO_2 level in Dhaka city during the pre-pandemic phase reached 100.413 µg/m^3, which was higher than the normal value of 0.413 µg/ m^3 (100 µg/ m^3).

But because of rising instances of COVID'19, the government of Bangladesh imposed a strict lockdown from April 4, 2021, to July 14, 2021. During this time, the NO_2 concentration dropped by 75.57 µg/m^3 from the standard value; So, so it's apparent that the strict lockdown had a big impact on NO_2 concentration in Dhaka city.

Table 6: Summary stats:

Timeline	Variable	Observations	Minimum	Maximum	Mean	Standard deviation
Before lockdown	186.43	5	29.89	155.47	83.20	54.12
Strict lockdown	32.63	3	15.26	31.67	21.69	8.76

Table 7: The results of the slope tests conducted by Mann-Kendall and Sen. Before lockdown or Pre-pandemic and Strict lockdown NO_2 data results

	Before lockdown/ Two-tailed study (186.433):	Strict lockdown/ Two-tailed study (32.633):
Tau of Kendall	-1	-0.33
S	-10.00	-1.00
Var(S)	16.66	3.66
Value of P	0.027	1.00
alpha	0.05	0.05
The slope of Sen:	-1.06	-0.22
interpreting test results	H0: The series doesn't exhibit any trends	H0: The series doesn't exhibit any trends
	Ha: The series exhibits a trend	Ha: The series exhibits a trend

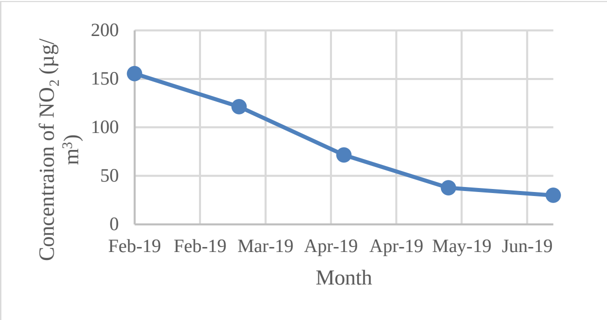


Fig 6: Trend line for NO_2 from January 2019 to June 2019 (Pre-lockdown period)

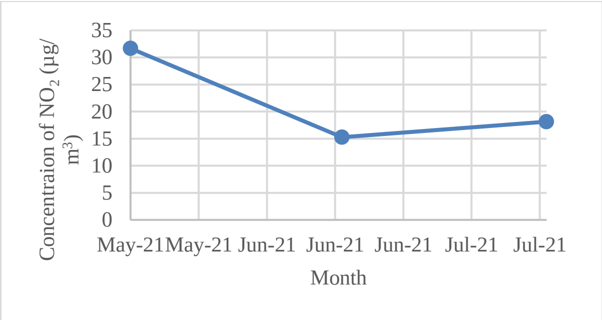


Fig 7: Trend line for NO_2 from April 2021 to July 2021 (Strict lockdown)

Ozone (O_3):

Exposure to ozone raises the risk of acquiring asthma and other difficulties for those engaging in outdoor activities [20]. Ozone affects the Air Quality Index despite not being the top-ranked pollutant on the list. Nitrogen oxides (NOx) and volatile organic molecules both produce and deplete ozone. The O3 level during the pre-pandemic phase, as determined by our research, was 16.410 µg/m^3 which was within the acceptable limit (157 µg/m^3).

But because of an increase in COVID'19 incidents, Bangladesh's government imposed a rigorous lockdown from April 4 to July 14, 2021. Around 35.381 µg/m^{3}oxygen was discovered to be present at this time.

Table 8: Summary stats:

Timeline	**Variable**	**Observations**	**Minimum**	**Maximum**	**Mean**	**Standard deviation**
Before lockdown	10.94	5	10.18	23.52	17.50	5.24
Strict lockdown	34.06	3	28.96	45.63	35.81	8.71

Table 9: The results of the slope tests conducted by Mann-Kendall and Sen. Before lockdown or Pre-pandemic and Strict lockdown NO_2 data results

	Before lockdown / Two-tailed study / Two-tailed test (10.947):	**Strict lockdown/ Two-tailed test (34.067):**
Tau of Kendall	0.60	0.33
S	6.00	1.00
Var(S)	16.66	3.66
Value of P	0.22	1.00
Alpha	0.05	0.05
The slope of Sen:	0.09	0.06
Interpreting test results	H0: The series doesn't exhibit any trends.	H0: The series doesn't exhibit any trends.
	Ha: The series exhibits any trends.	Ha: The series exhibits any trends.

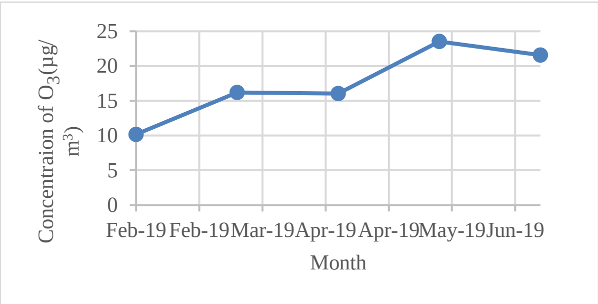


Fig 8: Trend line for O_3 from January 2019 to June 2019 timeline (Pre-pandemic period)

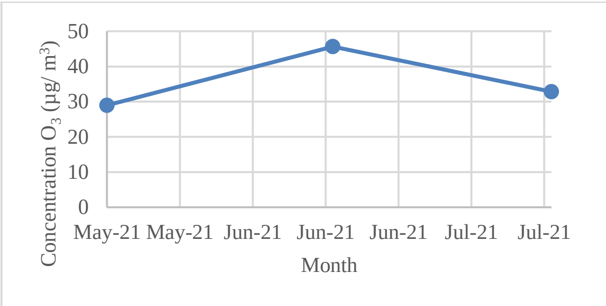


Fig 9: Trend line for O_3 from April 2021 to July 2021 timeline (Strict lockdown period)

CONCLUSION

In this article, the effect of the COVID-19 lockout on the air quality in Dhaka was examined. There was a significant improvement in air quality, although these air quality management techniques are expensive. For excellent air quality, irreversible emission reductions via sustainable process adjustments and long-term goals are essential. However, since the influence of diverse human activities is now being evaluated, measures that may be incorporated into business-as-usual scenarios focus on emission reduction at source, such as dust management, vehicle emissions, industrial operations, and so on, must be found. Lessons learned from the COVID-19 epidemic may be used to focus on source-specific measures that enhance ambient air quality to the greatest extent possible. Furthermore, socio-economic growth and industrialization must be coordinated with a city's carrying capacity.

Some followings are key takeaways from COVID 19 lockdown for air quality management:

1. Technology change: Growth of clean fuel autos, retrofitting older vehicles.
2. Technological progress: an increase in the use of alternative fuel (electric or hydrogen fuel-based vehicles, retrofitting of older vehicles).
3. Strict control, such as traffic management and systems to monitor vehicle emissions.
4. Behavioral change: Minimize workplace mobility and encourage digital innovation.

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Conflict of Interest

The author(s) declared no conflict of interest.

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