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ORIGINAL RESEARCH PAPER

The impact of coronavirus induced general holiday on air quality in urban area

A.A. Nayeem*, A.K. Majumder, W.S. Carter

Department of Environmental Science, Stamford University Bangladesh, Dhaka-1209, Bangladesh

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ABSTRACT

BACKGROUND AND OBJECTIVES: The Bangladesh government declared a general holiday beginning on March 26, 2020 aimed to combat coronavirus (COVID-19) pandemic. The aim of this study was to assess the impacts of the general holiday on air quality in Dhaka city area of Bangladesh.

METHODS: Hourly $PM_{2.5}$ (aerodynamic diameter ≤2.5 µm) data was collected from publicly available World's Air Pollution: Real-time Air Quality Index Project from March 1 to May 16 for the five years 2016 to 2020. Tukey Multiple Comparison test was conducted to address the observable level of air quality changes between the years. Additionally, Moderate Resolution Imaging Spectroradiometer using the Aerosol Optical Depth with 550_{nm} wavelength was analyzed during the same time period.

FINDINGS: This Study found that, between April 7 and May 16, the mean daily reading of $PM_{2.5}$ was less in 2020 when compared to previous years. The mean hourly reported $PM_{2.5}$ during working hours of 6AM and 8 PM for 2020 was statistically lower (at α= 0.01 level) than all other years 2019, 2018, 2017 and 2016. The mean hourly reported $PM_{2.5}$ for 2019 was statistically higher (at α = 0.01 level) than all other years 2020, 2018, 2017, and 2016. The Bus Rapid Transit and Mass Rapid Transit Construction in 2019 contributed between 24.2% and 38.6% of the $PM_{2.5}$ dust during this period. The elimination of diesel bus traffic during working hours in 2020 reduced the dust levels between 15.9% and 36.3% compared to the previous four years. A declining trend of AOD550 values was observed from April 7 to May 16, 2020 compared to previous four years (2016-2019).

CONCLUSION: During the general holiday period in Dhaka, the daily and working hour $PM_{2.5}$ as well as daily Aerosol Optical Depth were reduced compared to previous four years (2016-2019). Government action is recommended to reduce dust created during major construction projects. It is recommended the government authorize the replacement of buses with less polluting vehicles.

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*Corresponding Author:
Email: *nayeem@stamforduniversity.edu.bd*
Phone: +8801815622852
Fax: +880-2-9143531

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INTRODUCTION

A previously unknown coronavirus disease (COVID-19) was first introduced in Wuhan City, China in December 2019 and was capable of infecting the human's body (Cui *et al.,* 2019; Lu *et al.,* 2020). World Health Organization (WHO) declared the COVID-19 outbreak a public health emergency of international concern on 30 January 2020 (WHO, 2020). Around the world the COVID-19 pandemic has brought devastating consequences (Wang *et al.,* 2020). Due to the COVID-19 outbreak the global economy could suffer from \$5.8 to \$8.8 trillion loss, equivalent to 6.4% to 9.7% of global gross domestic product (GDP) (ADB, 2020). In addition, more than 25 million people could be unemployed by the end of 2020 depending on how quickly the economy recovers in the second half of the year (ILO, 2020). The first three confirmed cases of COVID-19 in Bangladesh were identified on March 8, 2020 by the country's epidemiology institute, Institute of Epidemiology Disease Control and Research (IEDCR). According to IEDCR report, the case number remained low until the end of March but subsequently the number of infections in the country has grown significantly. As of June 4, 2020, there have been a total of 57,563 confirmed cases in Bangladesh, with 12,161 recoveries and 781 deaths (IEDCR, 2020). To avoid the COVID-19 spread, the government of Bangladesh closed all education institutions since March 17, 2020. On March 26, 2020 the government declared a nationwide general holiday to combat COVID-19 outbreak. During this holiday all non-essential businesses were shuttered. This included the brick kilns, cement factories, garment factories, other small factories and office buildings. As a result the amount of emissions in the air from factories and businesses was reduced. Most construction was halted including the large Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT) projects. Buses were not allowed to operate during this holiday period (Razib *et al.,* 2020). Only private automobiles, Compressed Natural Gas (CNG) vehicles, and rickshaws were permitted during daytime hours. Trucks delivering essential goods were not allowed to travel in the city during working hours, 6AM to 8 PM. Despite the severe negative impacts of COVID-19 on human health and economy, it has had positive results in air pollution reduction due to limited social and economic activities (Dutheil *et al.,* 2020). Dhaka was ranked the world's second most polluted city after Delhi in 2019 for $PM_{2.5}$ exposure (IQAir, 2019). In the city of Dhaka there appear to be many sources contributing to the airborne fine particular matter (referred to as $PM_{2.5}$ since the particles measured are less than 2.5 microns in diameter). Previous studies have identified brick kilns located near Dhaka, particularly to the north and west of the city, as significant contributors (Nayeem *et al.,* 2019; Rana *et al.,* 2016). Uncontrolled open burning of trash occurs in many areas of the city. Vehicle exhaust has been identified as a significant source, particularly from diesel operated buses and heavy trucks (Rana *et al.,* 2020). Heavy trucks have been restricted from traveling in downtown Dhaka during daylight hours (6 AM until 8 PM) (Begum *et al.,* 2011). During these working hours, buses facilitate the commuting of workers to workplaces and students to school. More recently, additional dust has been created with the construction of the new mass transportation systems Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT) (Hossain *et al.,* 2019). Overriding these sources resulting from human activities is the variation in weather conditions (Kayes *et al.,* 2019). While storm fronts may temporarily clear the air and bring in fresh non-polluted conditions, a stationary front or lack of wind for any length of time increases pollution resulting in higher measured levels of $PM_{2.5}$ and other air contaminants (Rana *et al.,* 2016; Begum *et al.,* 2011). These weather conditions may lead to reported levels of $PM_{2.5}$ of very high variability (Majumder *et al.,* 2020). Air Quality Index (AQI) standards have been established by United States Environmental Protection Agency (USEPA) to describe how polluted the air currently is or it is forecast to become (USEPA, 2012). The internationally accepted AQI standards are presented in Table 1. Due to lockdown to combat the coronavirus outbreak with vehicles off the road and industries shut, the presence of major air pollutants have reduced significantly in several countries and territories (Singh and Chakraborty, 2020; Shrestha *et al.,* 2020; Nadzir *et al.,* 2020). Recent satellite based scientific studies conducted in a number of countries and cities (Nakada and Urban, 2020; Tobías *et al.,* 2020; He *et al.,* 2020**)** show air pollution reduction rate during this pandemic period. Approximately 20-30% reduction of particulate matter ($PM_{2.5}$) in China in February 2020 was reported when compared to

Table 1. Internationally Accepted Air Quality Index (AQI) Standard for $PM_{2.5}$

$PM_{2.5}$ µg/m^3 (24hour)	Air Quality Index (AQI) Values	Levels of Health Concern	Colors
0.0-12.5	0 to 50	Good	Green
12.1-35.4	51 to 100	Moderate	Yellow
35.5-55.4	101 to 150	Unhealthy for Sensitive Groups	Orange
55.5-150.4	151 to 200	Unhealthy	Red
150.5-250.4	201 to 300	Very Unhealthy	Purple
250.5-500+	301 to 500	Hazardous	Maroon

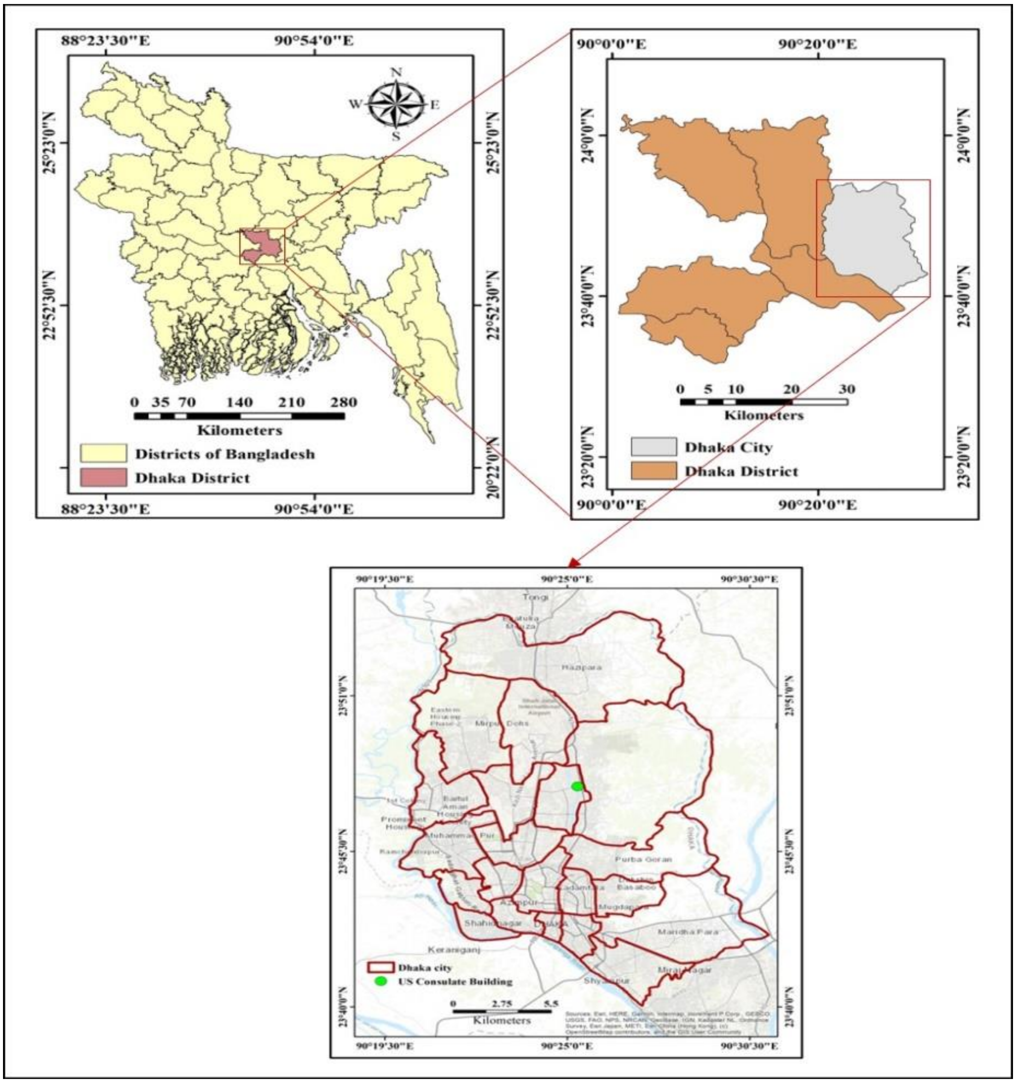

Fig. 1: Geographic Location of the Study Area Showing Dhaka City in Bangladesh

monthly averages of February 2017, 2018 and 2019 (Zambrano-Monserrate *et al.,* 2020) In India, there is a reported 43% and 31% reduction of $PM_{2.5}$ and PM_{10} respectively, during the lockdown compared to the same time period of the past four years (Sharma *et al.,* 2020). In Chittagong city, Bangladesh $PM_{2.5}$ is reduced almost 40% during the COVID-19 shutdown compare to previous 8 years (Masum and Pal, 2020).

This paper analyzes the variations of ground based $PM_{2.5}$ and satellite derived Aerosol Optical Depth (AOD) in Greater Dhaka Region, Bangladesh during the five years (2016–2020) at the same time span of March 1 to May 16. Comparison of data in the five years helps in understanding the potential Impact of the General Holiday declared by the government during this COVID-19 outbreak. Policymakers may get recommendations from this study to combat future air pollution in Bangladesh.

MATERIALS AND METHODS

$PM_{2.5}$ Data Collection and Analysis

Hourly $PM_{2.5}$ with real-time Air Quality Index (AQI) data were retrieved from publicly available air quality data provided by the World's Air Pollution: Real-time Air Quality Index Project. In Bangladesh the ground based monitoring station is located at the United States (US) Embassy in Dhaka, on a building located at 23°47`4.93``N, 90° 25`19.09``E approximately 10 m above ground level to minimize highly concentrated local sources of PM from mechanically generated dust, and immediate local traffic and construction (Fig. 1). This monitoring site is close to the heavily trafficked Bir Uttam Rafiqul Islam Avenue and Madani Avenue. To investigate the effect of COVID-19 pandemic, data from March 1 to May 16 for the last five years (2016-2020) was analyzed. While data from a single monitoring station cannot be applied to an entire city, however, this analysis provides some indication of the relative impact on $PM_{2.5}$ resulting from the general holiday shutdown. SPSSv20 and Microsoft Excelv10 were used for data processing, analysis and to prepare necessary tables and graphs. Using Tukey Multiple Comparison, testing was conducted to address the level of changes between the years.

Moderate Resolution Imaging Spectroradiometer (MODIS) Product

The daily AOD study data was obtained from MODIS instrumentation on board the Terra and Aqua satellites. Level 3 data was downloaded from National Aeronautics and Space Administration (NASA) GIOVANNI website. MODIS Level 3 data are quality checked and globally gridded over 1° × 1° grid resolution (Levy *et al.,* 2019). Deep Blue (DB) algorithm at 550_{nm} wavelength over the box shape corresponding to region: 90.33E, 23.67N, 90.53E, 23.9N was used in this study (Hsu *et al.,* 2012). These coordinates encompass the Dhaka mega city area. AOD data were collected from March 1 to May 16 in 2016-2020 respectively. The AOD data have discontinuities in some of the days. Daily mean AOD values were used in this study to identify the influence of COVID-19 pandemic on atmospheric aerosols over Dhaka city.

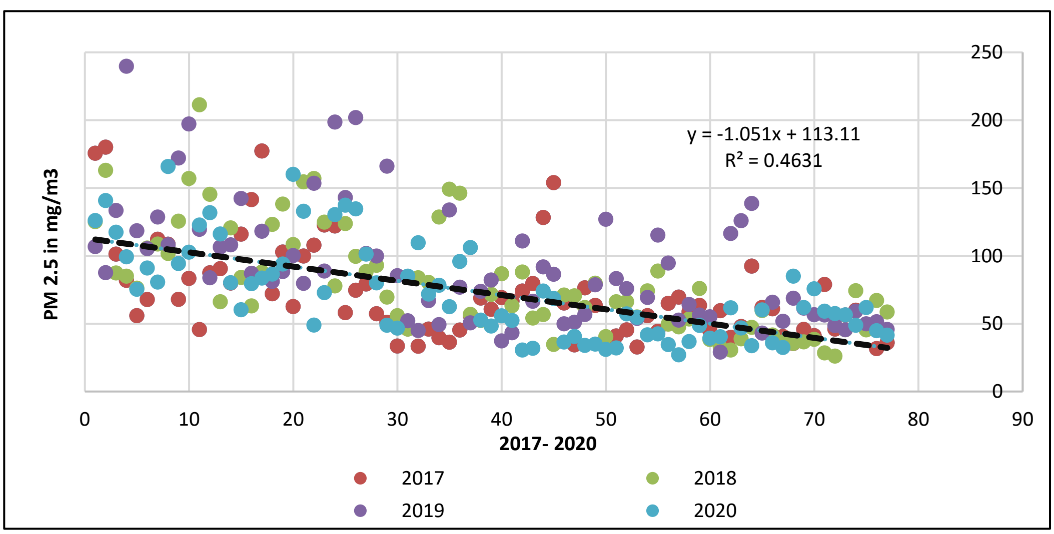

Fig. 2: Scattered Plot of Daily mean $PM_{2.5}$ (μg/m³) in Dhaka during 2017-2020 (March 1 to May 16)

RESULT AND DISCUSSION

Variation of $PM_{2.5}$

The $PM_{2.5}$ daily average data collected from March 1 to May 16 for the years 2016 to 2020 was plotted and analyzed using a linear regression (Fig. 2). From the plot it is evident that the daily average values vary from 26 µg/m^3 to 236 µg/m^3 an almost 10 fold range. Inspection of the hourly values showed an even wider range from 5 µg/m^3 to 500 µg/m^3. This data reflects a considerable variation from day to day. The plot shows higher values before the 30th day (April 1). After April 1 most brick kilns cease operation each year. Besides, it is also shows that the 2020 air pollution ($PM_{2.5}$) is lower than the previous three years.

The mean daily values for the time periods of March 1 to May 16 (77 days) and April 7 to May 16 (40 days) are shown in Table 2. This table shows that the average $PM_{2.5}$ for the 77 day period of each year exceeded the 55.4 µg/m^3 set for the maximum level described as "Unhealthy for Sensitive Groups". Only in 2017 and 2019 were the mean values higher during the 40 day period after most brick kilns were shut down. In 2020 during the shutdown and business restriction due to the coronavirus (April 7 and after) was the average $PM_{2.5}$ in the mid-range of "Unhealthy for Sensitive Groups" category. The daily $PM_{2.5}$ was 31.7 % less during COVID-19 outbreak in Dhaka when compared to 2019 period. It was 36.3% less if compared with working hour concentration (6 AM-8 PM). The concentration was also less in 2020 when compared with 2016, 2017 and 2018.

Table 3 shows the hourly US Air Quality Index (AQI) for the days from April 7 through May 16 (40 days) for the years 2016-2020. In 2017, 2018, 2019 and 2020 data points were missing for 5, 95, 68 and 5 respectively out of possible 960 data points. This investigation found a few "Good Air Quality" hours only in 2018 and 2020. The number of "Moderate Air Quality" hour was higher in 2020 for the 40 day April 7 to May 16 period when compared to previous years at the same time, and there were fewer days of "Unhealthy for Sensitive Groups", "Unhealthy", and "Very Unhealthy" as defined in the AQI Categories than the previous four years. There were 4 "Hazardous" air quality hours reported in 2017 and 11 in 2019; there were no "Hazardous" air quality

Table 2: Daily mean of $PM_{2.5}$ (µg/m^3) with relative changes (%) during 2016-2020 in Dhaka mega city

Year	Daily Mean of $PM_{2.5}$					Relative Changes (%)			
	2016	2017	2018	2019	2020	A	B	C	D
March 1- May 16 (77 days) (24 hours)	75.4	57.2	64.3	76.6	57.8	-23.3	+1.0	-10.1	-24.5
April 7- May 16 (40 days) (24 hours)	52.4	59.4	54.6	69.7	47.6	-9.2	-19.9	-12.8	-31.7
April 7- May 16 during 6AM -8 PM (15hours)	53.3	57.0	50.9	70.3	44.8	-15.9	-21.4	-12.0	-36.3

Note: A= 2020 vs 2016; B = 2020 vs 2017; C= 2020 vs 2018; D=2020 vs 2019

Table 3: Number of Hour of US AQI Category in Dhaka from April 7 to May 16 (2016-2020)

AQI Category	2016	2017	2018	2019	2020
Good (0-50)	-	-	9	-	5
Moderate (51-100)	129	170	234	114	357
Unhealthy for Sensitive Groups (101-150)	284	411	308	403	291
Unhealthy (151-200)	546	352	313	331	301
Very Unhealthy (201-300)	1	22	10	44	6
Hazardous (301+)	-	4	-	11	-
Total Hour	960	955	865	892	955

Table 4. Daily Average Statistical Comparison of $PM_{2.5}$ during April 7- May 16

Year	2019	2018	2017
2020	Lower at α = 0.05	Not Significantly Different	Lower at α =0.10
2019		Higher at the α = 0.05	Higher at the α =0.20
2018	Lower at α =0.05		Not Significantly different
2017	Lower at α = 0.20	Not Significantly different	

hours reported in 2016, 2018 and 2020.

To test whether the 2020 data from the time of the General Holiday (April 7 until May 16) was significantly lower, a Tukey Multiple Comparison test with equal sample size of the daily $PM_{2.5}$ data was conducted. Initially the daily average values were compared and analyzed (Table 4). The 2020 daily average was significantly lower than the 2019 daily average at the 0.05 confidence level but was only significantly lower than the 2017 daily average at the 0.10 confidence level. The 2020 daily average was not significantly lower than the 2018 daily average. The 2019 daily average was higher than the 2018 daily average at the 0.05 confidence level and higher than the 2017 daily average at the 0.20 confidence level. The mean daily data showed trends but less than convincing statistical differences.

Further examination evaluated the reported hourly data for working hours from 6AM to 8 PM (15 hours) for the 40 days from April 7 through May 16 for the years 2016, 2017, 2018, 2019, and 2020 using the Tukey Multiple Comparison test. It should be noted that in 2018 data points were missing for 68 out of a possible 600 data points. In 2019 data points were missing for 31 out of 600 possible data points. It appears there were some equipment problems during these years. To allow for calculations, the average of the remaining data for each of those years was added to the respective data sets so that each of the five years had 600 data points. The results of these calculations provided more convincing results as reflected in Table 5. The hourly reported $PM_{2.5}$ for 2020 was statistically lower (at α = 0.01 confidence level) than all other years 2019, 2018, 2017, 2016. The hourly reported $PM_{2.5}$ for 2019 was statistically higher (at α = 0.01 level) than all other years 2020, 2018, 2017, and 2016. The 2018 hourly reported $PM_{2.5}$ was statistically lower than the 2017 hourly data (at α = 0.01 level) but not the 2016 hourly data. There was no statistical difference between the hourly reported data for 2017 and 2016.

Fig. 2 shows that there is a great deal of scatter in the daily $PM_{2.5}$ data reported from the AQI station at the US Embassy in Dhaka. What is not obvious is the relative importance of various cofactors that contribute to the $PM_{2.5}$. Weather conditions contribute to the day to day (and even hour to hour) scatter of the data. This study investigated the effect of human activities that contribute to the $PM_{2.5}$ levels. The inspection of all data collected each year from March 1 to May 16 (77 days) showed that the highest daily reading reported in each year was 180 µg/m^3 in 2017; 211 µg/m^3 in 2018; 240 µg/m^3 in 2019;, and 166 µg/m^3 in 2020. These highest levels occurred in all years during March when several factors simultaneously contribute to the $PM_{2.5}$ air pollution. These include emission from brick kilns, combustion products from unauthorized open burning, dust generated from construction, emission from diesel trucks (that operate in central Dhaka at night only), diesel emission from buses, and emission from autos and CNG vehicles. Clearly all of these daily maximum values exceed the "Very Unhealthy" level of 150 µg/m^3 for 24 hours and represent a significant risk to people living and working in Dhaka. In an attempt to determine the impact of each of these emission sources this study stratified the data to eliminate factors as contributing sources. In the 40 day time period between April 7 and May 16 the highest daily reading was 90.5 µg/m^3 in 2016; 153.9 µg/m^3 in 2017; 88.7 µg/m^3 in 2018; 138.5 µg/m^3 in 2019; and 84.9 µg/m^3 in 2020. This period is after most brick kilns have shut down for the season. Only in 2017 was there a daily value that exceeded the 150.5 µg/m^3, "Very Unhealthy" AQI standard. In 2016, 2018, 2019, 2020 the highest daily value reached the "Unhealthy" range (55.4-150.4 µg/m^3). As shown in Table 2 the mean values were lower after most brick kilns were shut down for the season for 2018, 2019, and 2020. In 2017 the mean daily value was

Table 5. Statistical Comparison between Working Hourly $PM_{2.5}$ Data (6AM-8PM) during April 7 - May 16

Year	2019	2018	2017	2016
2020	Lower at α=0.01	Lower at α =0.01	Lower at α=0.01	Lower at α= 0.01
2019		Higher at α=0.01	Higher at α=0.01	Higher at α=0.01
2018	Lower at α =0.01		Lower at α=0.01	No Statistical Difference
2017	Lower at α =0.01	Higher at α=0.01		No Statistical Difference
2016	Lower at α =0.01	No Statistical Difference	No Statistical Difference	

Table 6. AOD_{550} Values (Both Aqua and Terra Satellite) during Study Period in Dhaka

Platform	Date	Daily Mean AOD_{550}					Relative Changes (%)			
		2016	2017	2018	2019	2020	A	B	C	D
Terra	March 1- May 16 (77 days)	0.94	0.87	0.90	0.91	0.66	-29.8	-24.1	-26.7	-27.8
	April 7- May 16 (40 days)	0.89	0.82	0.87	0.90	0.46	-48.3	-43.9	-47.1	-48.9
Aqua	March 1- May 16 (77 days)	0.75	0.77	0.76	0.80	0.64	-14.7	-16.9	-15.8	-20.0
	April 7- May 16 (40 days)	0.68	0.69	0.71	0.75	0.53	-22.0	-23.2	-25.4	-29.3
Terra+	March 1- May 16 (77 days)	0.86	0.82	0.84	0.87	0.59	-31.8	-28.5	-30.4	-32.6
Aqua	April 7- May 16 (40 days)	0.77	0.76	0.78	0.82	0.54	-29.7	-28.5	-30.3	-33.5

Note: A= 2020 vs 2016; B=2020 vs 2017; C= 2020 vs 2018; D= 2020 vs 2019

somewhat higher during this same period. This study evaluated for all five years (2016-2020) the mean hourly average during working hours of 6 AM to 8 PM, employing the Tukey Multiple Comparison test. The 2019 $PM_{2.5}$ values are significantly higher than 2020, 2018, 2017 and 2016 at α= 0.01 level. When reviewing this data it was brought to the researcher's attention that there was extensive construction involving the BRT and MRT projects during the time measurement period. Thus the data shows construction added a significant amount to the $PM_{2.5}$ levels. The ratio of the mean for 2019 to 2018 is 1.38; for 2019 to 2017 is 1.23; and 2019 to 2016 is 1.32. Since during the previous three years buses were running on the streets, trucks were restricted from the inner city, and the brick kilns were not operating, this would indicate that the construction was contributing between 23% and 38% of the $PM_{2.5}$ dust during the day in 2019. To determine if the reduction in truck and bus traffic significantly impacted the $PM_{2.5}$ levels, this study evaluated the mean hourly levels during working hours of 6AM to 8 PM. During these hours heavy diesel trucks are restricted from traveling in the Dhaka city and diesel buses were not allowed to operate in 2020. The above statistical analysis demonstrates that these vehicles contribute significantly to the $PM_{2.5}$. For the 40 days from April 7 to May 16 the 2020 $PM_{2.5}$ average decreased to 44.8 µg/m^3 and is statistically lower at α= 0.01 level than the other years. Since construction was not operating and diesel traffic was restricted in 2020, the ratio of the 2020 mean value of 44.8 µg/m^3 to the mean value 2019 of .64 reflects the reduction in $PM_{2.5}$ due to both of these factors, a 36% reduction in $PM_{2.5}$. The mean ratio for the working hours measured in 2020 to 2018 is .88; 2020 to 2017 is .79; and 2020 to 2016 is .84. Based on this information the elimination of diesel buses would reduce the $PM_{2.5}$ between 12% and 21%.

Aerosol Optical Depth (AOD)

The aerosol optical depth used in this study, the AOD at 550_{nm} (AOD_{550}), from 2016 to 2020 (March 1 to 16 May) at Dhaka region, Bangladesh is presented in Table 6. There was discontinuity of satellite derived daily AOD values, therefore, both Aqua and Terra satellites data of MODIS instrument are represented here. From the Terra satellite data, the peak AOD_{550} was .94 in 2016 while the lowest peak value was .66 in 2020. From the Aqua satellite the peak value was .80 in 2019 and lowest peak value .64 in 2020. During the COVID-19 general holiday in 2020, the AOD_{550} value reported from the Terra satellite was .46 and .53 reported from the Aqua satellite. During April 7- May 16, the 2020 values are 48.9 and 29.3% of the 2019 values; 47.1 and 25.4% of the 2018 values; 43.9 and 23.2% of the 2017 values; and 48.3 and 22% of the 2016 values were less for both terra and aqua satellites respectively. The AOD_{550} ratio of aerosol reported from the Terra satellite is higher than the Aqua satellite data. The mean AOD_{550} for both Aqua+Terra was .54 during the 40 day April 7 to May 16 time period in 2020 denotes the aerosol concentration reduction of 33.5%, 30.3%, 28.5%, 30.4% and 29.7% in Dhaka mega city compared to previous four years respectively. This is in agreement with a media report that on March 25, 2020, the AOD_{550} value was 0.3 over north India and fell to 0.2 around April 1 and 0.1 on April 5 (Kapil, 2020). The observed reduction in the Dhaka region might be attributed to anthropogenic activities, though meteorological factors may have contributed. During the COVID-19 general holiday, different emission sectors such as most industries, businesses, residential and commercial construction activities were closed. Additionally, traffic was largely reduced and people were restrained to their homes attributing to a dramatic decline of the aerosol values in the atmosphere.

CONCLUSION

A dramatic reduction was observed in the MODIS AOD_{550} data during the general holiday period established by the government during this time. AOD_{550} concentration reduced between 28.5% and 33.5% (Terra+Aqua) from the previous four years (2016-2019) from April 7 to May 16 in Dhaka mega city. During the working hours of 6AM to 8 PM over this same time period in 2020 the $PM_{2.5}$ average decreased to 44.8 μg/m^3. This is statistically lower at $\alpha = 0.01$ confidence level than for 2016, 2017, 2018, and 2019. The ratio of the 2020 mean value of 44.8 μg/m^3 to the mean value of 2019 is 63.7% reflecting the reduction in $PM_{2.5}$ due to restricted construction and diesel travel. Based on the $PM_{2.5}$ hourly data collected from the AQI monitoring station located at the US Embassy it can be concluded that both constructions associated with the BRT and MRT as well as diesel emissions from buses contribute significantly to the air pollution in portions of Dhaka city. Construction from the BRT and MRT may contribute as much as 35% of the $PM_{2.5}$ airborne dust. Diesel buses may contribute as much as 21% of the $PM_{2.5}$ airborne dust. As a result of this study an investigation into construction dust control measure should be initiated by the government. The use of frequent watering with water trucks near major roadways would reduce airborne dust. Dust curtains placed near each of major project would lessen airborne dust. The government could require all buses be converted to a cleaner operating fuel system, such as CNG or electric operation and retire the old diesel buses. This would greatly improve air quality particularly between 6 AM and 8 PM when people are most often on the streets and roads of Dhaka city.

AUTHOR CONTRIBUTIONS

A.A. Nayeem has performed the paper conceptualization, methodology, investigation and writing the draft. A. K. Majumder has done the methodology, writing, editing and visualization. W.S. Carter helped in the formal analysis, revised the draft manuscript and overall supervision.

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CONFLICTS OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

ABBREVIATIONS

α	Level of significance
%	Percentage
$	Dollar
μg/m3	Microgram per cubic meter
AOD	Aerosol Optical Depth
ADB	Asian Development Bank
AQI	Air Quality Index
BRT	Bus Rapid Transit
CNG	Compressed Natural Gas
DB	Deep Blue
GDP	Gross Domestic Product
IEDCR	Institute of Epidemiology Disease Control and Research
ILO	International Labour Organization
MODIS	Moderate Resolution Imaging Spectroradiometer
MRT	Mass Rapid Transit
NASA	National Aeronautics and Space Administration
nm	Nanometer
$PM_{2.5}$	aerodynamic diameter of particles ≤2.5 μm

USEPA	United States Environmental Protection Agencies
WHO	World Health Organization

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