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Analysis of NO_2 Pollution over Bangladesh between the Two COVID-19 Caused Lockdown in 2020 and 2021 Using Sentinel 5P Products †

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Abstract: Due to the COVID-19 pandemic, all countries around the world have imposed nationwide lockdowns to control the spreading of the virus. During the lockdown period, many countries had seen a drastic drop in air pollution. In Bangladesh, two nationwide lockdowns were imposed on 26 March–30 May in 2020 and on 3 April to now in 2021. This study was aimed to analyze the NO_2 pollution over Bangladesh during the two periods of lockdown. Tropospheric NO_2 column spatial configuration was measured over Bangladesh using Sentinel 5P data. Map of monthly average concentration of Tropospheric NO_2 of 2020 and 2021 over Bangladesh had been produced using HARP toolkit and python. Then the map was compared with the same period Sentinel 5P products map of 2019. It had been found that during the first lockdown in Bangladesh between 26 March–30 May 2020, a drastic decrease of NO_2 concentration had been observed in April month but increased in May. But during the second lockdown from 3 April in 2021, the NO_2 concentration was found much higher in concentration. Most of the pollution occurred in the Dhaka district. During the second lockdown, the restriction was much easier than the first one that impacted the NO_2 concentration. This kind of study can be the essence for the authority to look closely at air quality and use sentinel data to improve air quality monitoring in the future.

Keywords: Sentinel 5P; air quality; COVID-19 lockdown; NO_2

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1. Introduction

The COVID-19 pandemic has caused significant changes in the society, the economy and lifestyle of the people worldwide. To contain the spread of SARS-2 virus, the countries all around the world are trying to impose different types of measures such as wearing masks, maintaining physical distancing, vaccines etc. Initially, lockdowns were the most used strategy for most of the countries around the world to stop transmission of the COVID-19 virus. Temporary or total closure of international borders, educational institutions, and non-essential businesses, and restriction on citizen mobility etc. are some of the measures of lockdowns [1]. These lockdowns have led to some positive impacts on environment, especially improving its air quality. A number of studies has proved that lockdowns have temporarily improved the air quality of the globe [1–4]. Several papers are also suggested the significant reduction of air pollution in Bangladesh [5,6]. Most of those papers investigated multiple air pollutants (CO_2, O_3, NO_2, SO_2, $PM_{2.5}$, PM_{10} etc.). Nitrogen dioxides (NO_2) is one of the important air constituents. The main sources of NO_2 gases industries, power plants, residential heating, and vehicle exhausts in the form of Nitric Oxide (NO) [7]. This reddish brown gas is produced from NO conversion through oxidation process. NO_2 is a great indicator of human-made combustion activities and precursor of Ozone (O_3) and aerosols. Respiratory diseases and asthma can

be caused by NO_2. About 4 million cases of pediatric asthma annually are resulted from the exposure of NO_2 [8]. It can lead to environmental deterioration by producing acid rain [9].

The objective of this study is to collect, analyze the air quality data of Bangladesh during the lockdown period (March to May) from 2019, 2020 and 2021. The analysis of 2019 will be the baseline to compare the trends of NO_2 found during the lockdown periods in 2020 and 2021.

2. Methods and Materials

2.1. Study Area

Our study was focused on Bangladesh. Bangladesh is located in South Asian at 20°34′ and 26°38′ N and 88°01′ and 92°42′ E [6]. Bangladesh is a densely populated country with a density of 1265 people per km^2 [10]. Geographically Bangladesh, a low-lying riverine country, is mostly vulnerable to climate change [6]. Bangladesh was the most polluted country in 2019 according to world air quality report by IQAir [10]. There are lack of air pollution source inventory in Bangladesh [11]. The industrial sector of Bangladesh has been experiencing some expansion. Mostly vehicular and industrial emissions are considered the main sources of air pollution in Bangladesh [12].

2.2. Data

Sentinel 5 precursor is an earth orbiting single satellite system dedicated to provide information and services on air quality, climate and the ozone layer [13]. The satellite mission was launched to continue the data between previous missions such as SCIAMACHY, GOME-2, OMI and upcoming Sentinel 5 [14]. Sentinel 5P consist of instrument TROPOspheric Monitoring Instrument (TROPOMI) [9]. TROPOMI is a passive-sensing hyperspectral imager which allows acquisitions of 8-band imagery covering domain of UV, visible to Near-infrared and Shortwave infrared [9,14]. TROPOMI has spatial resolution of 7×3.5 km^2 that is higher than all of its predecessors. High spatial resolution of Sentinel 5P provides a new potential for monitoring air pollution sources [9].

The data used for the study had been downloaded from NASA's Earthdata website [4]. The data were downloaded using the subset data option available in the website. Data were download only for the extent of Bangladesh. The data came in netCDF format which stored multidimensional scientific information, including dimensions, variables/parameters, attributes, and coordinates [9]. A total number of 276 offline L2 NO_2 products were used for the study. Total of 93, 90 and 93 products used respectively for 2019, 2020 and 2021 covering 26–31 March and full month of April and May for each year.

2.3. Methodology

The analysis was carried out following the methodology presented in the RUS Copernicus training on MONITORING POLLUTION WITH SENTINEL-5p Case Study: Italy 2019–2020 [15] using Python languages with HARP atmospheric toolbox provided by ESA. The NO_2 Level 2 product had been converted to Level 3 using the HARP tool in python. Sentinel 5P NO_2 Level 2 product was resampled to spatial resolution of 0.01 × 0.01 degree covering the extent of Bangladesh between 20 and 27 degree latitude. The data were filtered to tropospheric NO_2 column density value quality over 75. This process was done to avoid the errors due to cloud cover. During the conversion of Level 2 product, tropospheric NO_2 column density was derived from the main product and the unit was converted to Pmolec/cm^2 from the default unit of mol/m^2. Then 6-days mosaics of average tropospheric NO_2 column density were produced of March month for each year. Monthly mosaics of average tropospheric NO_2 column density were produced of April and May for each year. The tropospheric NO_2 column density data for time series analysis of specific cities (Dhaka and Chattogram) were extracted from the Level 3 product

using python programming language. The data were then plotted in graph using WPS Office.

3. Results and Discussion

3.1. NO_2 Concentration Distribution over Bangladesh

The study had been focused on the NO_2 pollution over Bangladesh during the two lockdown periods in 2020 and 2021. It had been found that the most NO_2 pollution occurs in Dhaka and its surrounding districts such as Narayanganj, Gazipur etc. Most of the industries are situated in these districts which could be the reason for the pollution. Additionally, Chattogram district also faced NO_2 pollution because of having industrial zone. Comparative analysis of maps produced from monthly average mosaic of Sentinel 5P product for Tropospheric NO_2 vertical column density showed various trends in each month of the lockdown. In the March 2020, when the first lockdown was announced by Bangladesh government, the density of NO_2 declined sharply in other cities of Bangladesh compare to the pollution of same period in 2019. But in 2021, there were no lockdown in March, so it was expected and found that the concentration of NO_2 was high all over the country. The concentration of NO_2 was much higher than same period of 2019. Figure 1 shows the distribution of NO_2 over the country between 26–31 March of each three years.

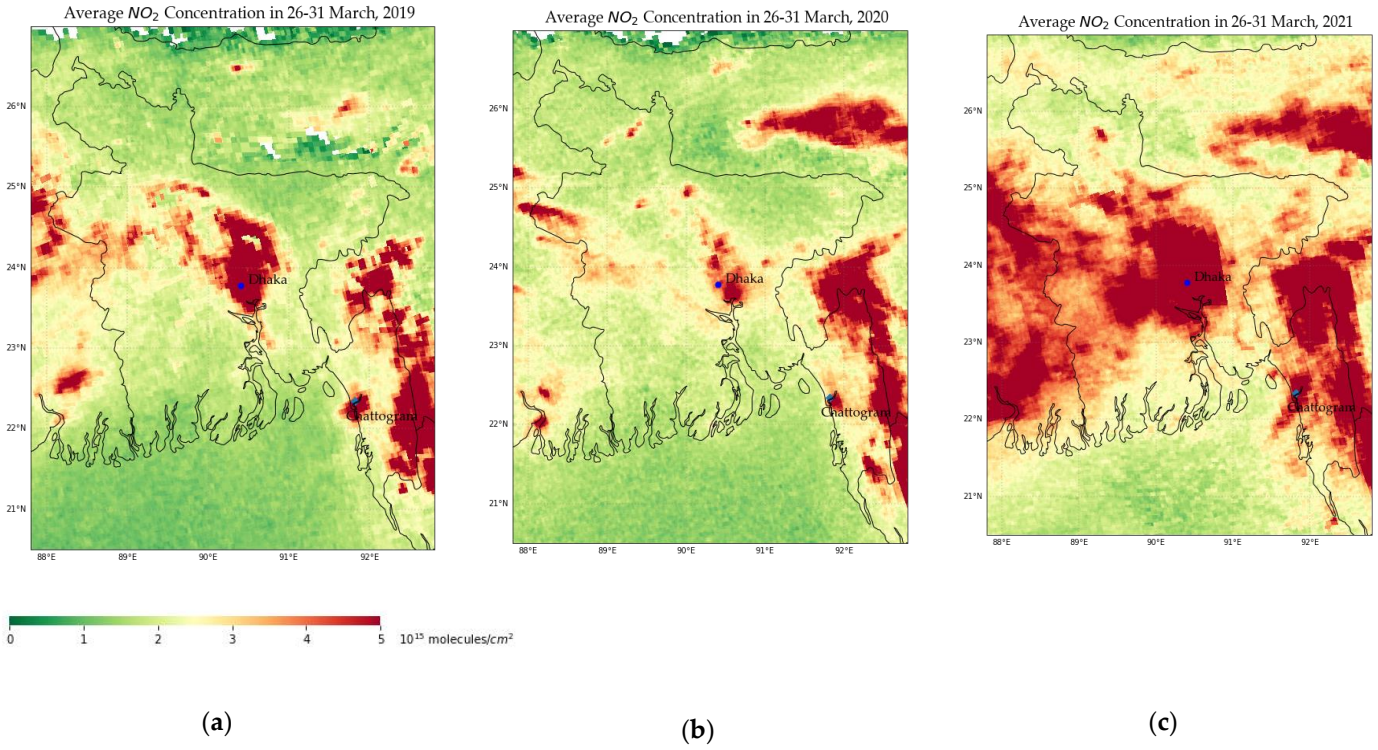

Figure 1. Average NO_2 Pollution over Bangladesh in the March of (**a**) 2019 (**b**) 2020 (**c**) 2021.

In April 2020 government strengthened the strictness of the lockdown and we can observe that there are a significant drop of NO_2 concentration in 2020. Compare to the concentration of 2019, the concentration of NO_2 dropped drastically all over the country including Dhaka and Chattogram city. In 2021, lockdown was declared on 1st April but the lockdown not implemented strictly. That resulted in no such difference of NO_2 pollution in the major cities like Dhaka, Chattogram, Rajshahi etc. Rather the concentration of NO_2 was higher compare to April 2019. Figure 2 shows the comparative cartography of NO_2 concentration over the Bangladesh.

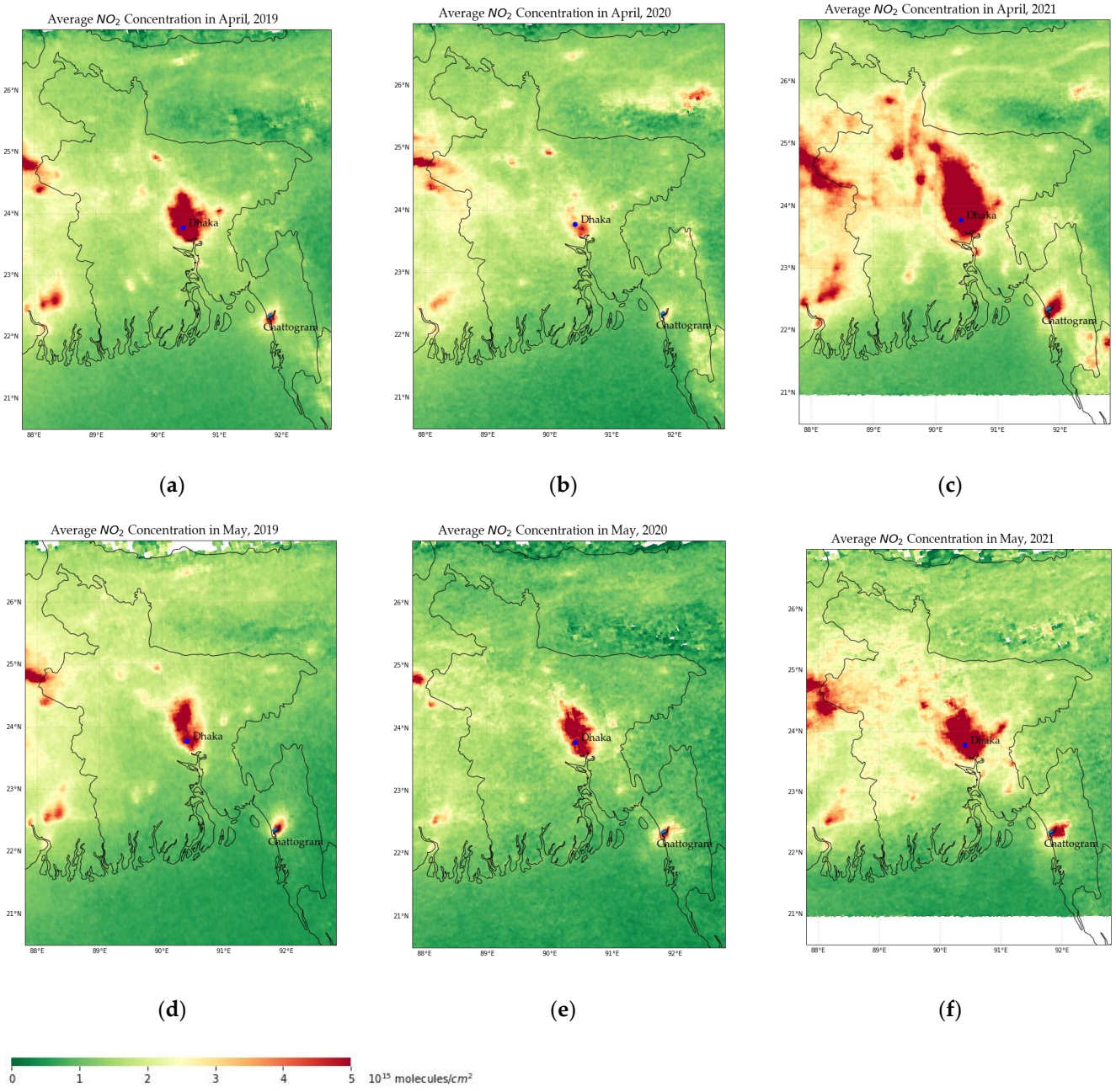

Figure 2. Average NO_2 Pollution over Bangladesh in the April of (**a**) 2019 (**b**) 2020 (**c**) 2021 and May of (**d**) 2019 (**e**) 2020 (**f**) 2021.

During May 2020, the strictness of lockdown was compromised by government. Transports such as private cars, buses etc. began to drive in the road and industries had started their working process slowly. That reflected in the NO_2 concentration over the country. The concentration of NO_2 had been increased compare to April 2020 but it was still less polluted compare to the same period NO_2 pollution in 2019. In 2021, the lockdown was compromised and public transports started with taking half of its capacity. It reflects the NO_2 pollution throughout the county.

3.2. NO_2 Concentration over Selected Cities: Dhaka and Chattogram

A Dhaka and Chattogram districts are found the hotspot of NO_2 pollution in Bangladesh as we can see from Figures 2–4. We had analyzed the concentration NO_2 in this two specific city to understand the difference and impact of lockdown in details. Time

series of weekly average tropospheric NO_2 vertical column number density derived from Sentinel 5P product shows that Dhaka city had undergone some significant drop of NO_2 concentration from 26 March to 5 May 2020 compare to 2019. After 5 May, the concentration increased in the next week and it continued to increase till the end of the study period. In contrast, the concentration of NO_2 was higher than the 2019 and 2020 from the 26 March till 26 May. After 26 May, there are a drop of NO_2 concentration until the study period. Figure 3 shows the time series of NO_2 pollution over Dhaka district.

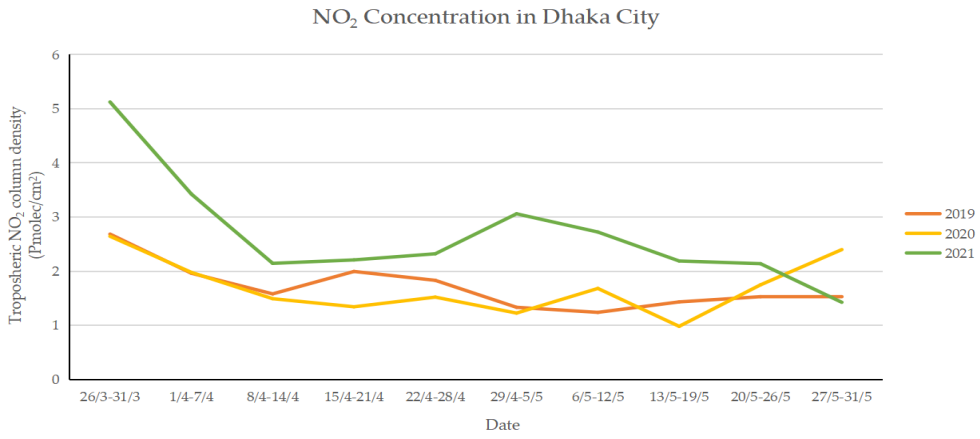

Figure 3. NO_2 Concentration in Dhaka city during the study period on weekly average.

Chattogram district showed different trend compare to Dhaka district. The concentration of NO_2 observed declining in 2020 compare to 2019 till 6th week of the study period which is 29 April–5 May. After that period, there had been up and down of concentration comparing with 2019.

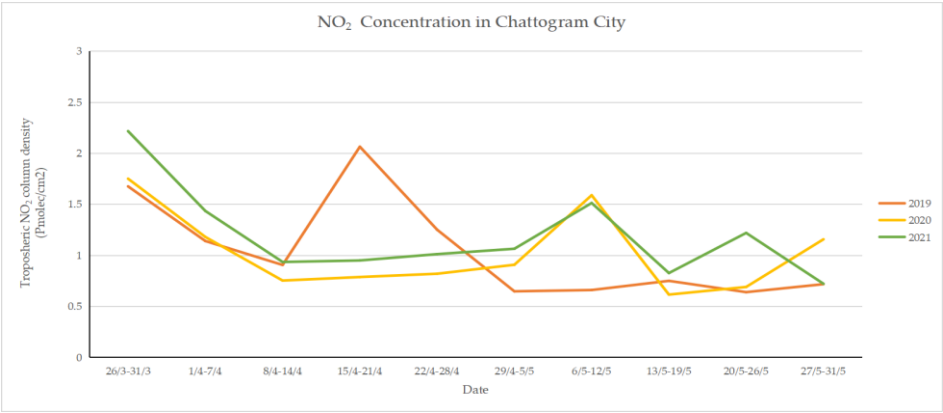

Figure 4. NO_2 Concentration in Chattogram city during the study period on weekly average.

In 2021, the concentration was very high from both 2019 and 2020 throughout the study period. There were not very decline observed of NO_2 concentration in 2021, compare to 2019 and 2020 in Chattogram. Figure 4 shows the time series of weekly average NO_2 concentration in Chattogram city.

4. Conclusions

The study was carried out to examine the variations in NO_2 concentrations during the lockdown in the years 2020 and 2021. At the time of the strict lockdown in April 2020, there was a significant variation in the concentration of NO_2 compared with 2019. NO_2 levels had dropped dramatically across the country, including in Dhaka and Chattogram. But when the lockdown was loosened by the government and people started their daily

lives like before, the concentration of NO_2 again became higher than in the lockdown period.

Overall, it has been found that the strict lockdown imposed in 2020 showed a decrease of NO_2 pollution. But during the second lockdown in 2021, the lockdown was partially implement and that did not impacted much on the NO_2 pollution.

Continuous data collection is quite difficult for developing countries like Bangladesh as it requires lot of efforts and costs. Sentinel 5P mission provides a continuous and various types of data that can be useful for monitoring air quality and air pollution in Bangladesh. In future, Sentinel 5P and remote sensing analysis can be implement effectively to monitor and control the air pollution in Bangladesh.

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