



Proceeding Paper

Analysis of NO₂ Pollution over Bangladesh between the Two COVID-19 Caused Lockdowns 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 saw a drastic drop in air pollution. In Bangladesh, there were two nationwide lockdowns. The first lockdown was imposed on 26 March-30 May in 2020 and the second lockdown was imposed on 3 April until the study period of 31 May in 2021. This study aimed to analyze the NO_2 pollution over Bangladesh during the two periods of lockdown. Tropospheric NO₂ column spatial configuration was measured over Bangladesh using Sentinel-5P data. A map of the monthly average concentration of tropospheric NO2 in 2020 and 2021 over Bangladesh was produced using the HARP toolkit and Python. Then, the map was compared with same period Sentinel-5P product's map for the same period in 2019. It was found that during the first lockdown in Bangladesh between 26 March and 30 May 2020, NO₂ concentration drastically decreased in April but increased in May. However, during the second lockdown from 3 April to 31 May in 2021, the NO₂ concentration was found to be much higher. Most of the pollution occurred in the Dhaka district. During the second lockdown, the restrictions were much lighter than those during the first one, which impacted the NO₂ concentration. This kind of study can be essential for the authorities 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; NO₂



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1. Introduction

The COVID-19 pandemic has caused significant changes in society, the economy, and the lifestyles of people worldwide. To contain the spread of the SARS-2 virus, countries all around the world have been imposing different types of measures such as wearing masks, maintaining physical distancing, and vaccines. Initially, lockdowns were the most used strategy for most of the countries around the world to stop the transmission of the COVID-19 virus. The temporary or total closure of international borders, educational institutions, and non-essential businesses and restrictions on citizen mobility, have been some of the measures taken during lockdowns [1]. These lockdowns have led to some positive impacts on the environment, especially in improving air quality. A number of studies have proved that lockdowns have temporarily improved the air quality around the globe [1–4]. Several papers have also suggested a significant reduction of air pollution in Bangladesh [5,6]. Most of these papers investigated multiple air pollutants (CO₂, O₃, NO₂, SO_2 , $PM_{2.5}$, PM_{10} , etc.). Nitrogen dioxides (NO₂) are one of the important air constituents. The main sources of NO₂ gases are industry, 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 the oxidation process. NO₂ is a great indicator of human-made

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combustion activities and is a 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 result from exposure to NO_2 [8]. Moreover, it can lead to environmental deterioration by producing acid rain [9].

The objective of this study was to collect and analyze the air quality data of Bangladesh during the lockdown periods (March to May) in 2019, 2020, and 2021. The analysis of 2019 was 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 Asia 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 km² [10]. Geographically, Bangladesh, a low-lying riverine country, is most vulnerable to climate change [6]. Bangladesh was the most polluted country in 2019 according to the world air quality report by IQAir [10]. There is a lack of air pollution source inventory in Bangladesh [11]. The industrial sector of Bangladesh has been experiencing some expansion, and vehicular and industrial emissions are considered the main sources of air pollution in Bangladesh [12].

2.2. Data

The Sentinel-5 Precursor is an earth orbiting single satellite system dedicated to providing 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 the upcoming Sentinel-5 [14]. Sentinel-5P consists of the TROPOspheric Monitoring Instrument (TROPOMI) [9]. TROPOMI is a passive-sensing hyperspectral imager that allows acquisitions of 8-band imagery covering the domain of UV, visible to near-infrared, and shortwave infrared [9,14]. TROPOMI has a spatial resolution of $7 \times 3.5 \text{ km}^2$, which is higher than that of all of its predecessors. The high spatial resolution of Sentinel-5P provides new potential for monitoring air pollution sources [9].

The data used for the study were downloaded from NASA's Earthdata website [4]. The data were downloaded using the subset data option available on the website. Data were downloaded only for the extent of Bangladesh. The data came in netCDF format, which stores multidimensional scientific information, including dimensions, variables/parameters, attributes, and coordinates [9]. A total of 276 offline L2 NO₂ products were used for the study. A total of 93, 90, and 93 products were used, respectively, for 2019, 2020, and 2021, covering 26–31 March and the 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 in "Monitoring Pollution with Sentinel-5p", a case study in Italy during 2019–2020 [15], using the Python language with the HARP atmospheric toolbox provided by ESA. The NO_2 Level 2 product had been converted to Level 3 using the HARP tool in Python. The Sentinel-5P NO_2 Level 2 product was resampled to the spatial resolution of 0.01×0.01 degrees covering the extent of Bangladesh between 20 and 27 degrees of latitude. The data were filtered to a tropospheric NO_2 column density value quality over 75. This process was done to avoid errors due to cloud cover. During the conversion of the Level 2 product, tropospheric NO_2 column density was derived from the main product, and the unit was converted to Pmolec/cm² from the default unit of mol/m^2 . Then, 6-day mosaics of average tropospheric NO_2 column density were produced for the month of March for each year. Monthly mosaics of average tropospheric NO_2 column density were produced in April and May for each year. The tropospheric NO_2 column density data for the time series analysis of specific cities (Dhaka and Chattogram, Bangladesh) were

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extracted from the Level 3 product using the Python programming language. The data were then plotted in a graph using WPS Office.

3. Results and Discussion

3.1. NO₂ Concentration Distribution over Bangladesh

This study focused on the NO_2 pollution over Bangladesh during the two lockdown periods in 2020 and 2021. It was found that the most NO_2 pollution occurs in Dhaka and its surrounding districts, such as Narayanganj and Gazipur. 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 an industrial zone. The comparative analysis of maps produced from the monthly average mosaic of the Sentinel-5P product for tropospheric NO_2 vertical column density showed various trends in each month of the lockdown. In March 2020, when the first lockdown was announced by the government of Bangladesh, the density of NO_2 declined sharply in other cities of Bangladesh compared to the pollution of the same period in 2019. However, in 2021, there was 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 that of the same period in 2019. Figure 1 shows the distribution of NO_2 over the country between 26–31 March of each of the three studied years.

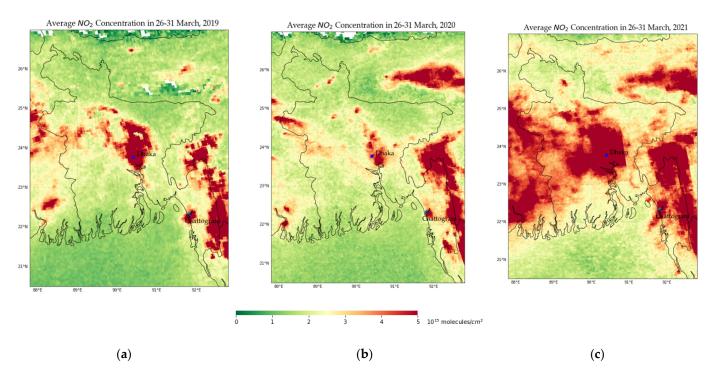


Figure 1. Average NO₂ pollution over Bangladesh in March (a) 2019, (b) 2020, and (c) 2021. March 2021 was more polluted than the same time period in 2019 and 2020 throughout Bangladesh.

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

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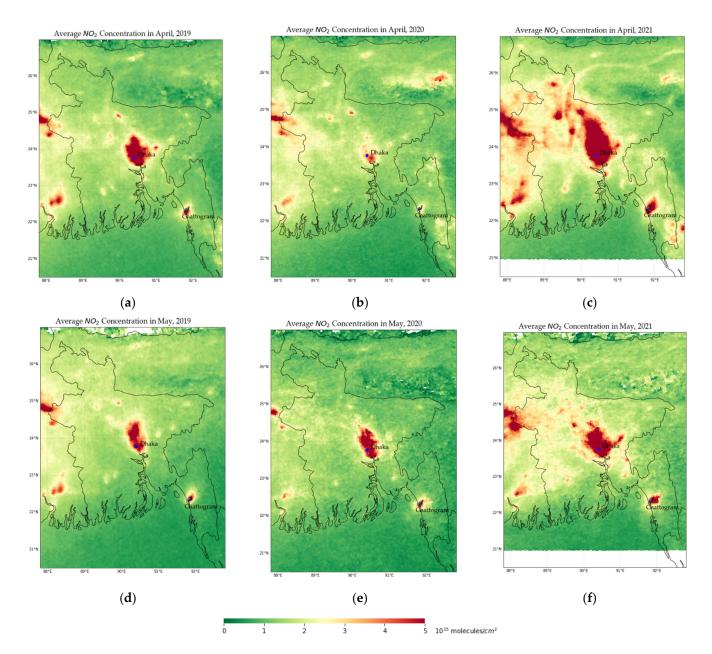


Figure 2. Average NO₂ pollution over Bangladesh in April (a) 2019, (b) 2020, and (c) 2021 and May (d) 2019, (e) 2020, and (f) 2021. Bangladesh saw a drastic drop of NO₂ pollution all over the country. Pollution decreased in April and May 2020 but increased in 2021.

In May 2020, the strictness of lockdown was compromised by the government. Transports such as private cars and buses began to return to the road and industries started their working process slowly. This was reflected in the NO_2 concentration across the country. The concentration of NO_2 increased compared to that in April 2020 but it was still less polluted compared to the same period of NO_2 pollution in 2019. In 2021, the lockdown was compromised and public transports started taking half of its capacity. This was reflected in the NO_2 pollution throughout the county.

3.2. NO₂ Concentration over Selected Cities: Dhaka and Chattogram

Dhaka and Chattogram districts were found to be hotspots of NO_2 pollution in Bangladesh as can be seen from Figures 2–4. We had analyzed the concentration of NO_2 in these two specific cities to understand the difference and impact of lockdown in detail. The time series of weekly average tropospheric NO_2 vertical column number density de-

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rived from the Sentinel-5P product shows that Dhaka city underwent a significant drop of NO₂ concentration from 26 March to 5 May 2020 compared to 2019. After 5 May, the concentration increased in the next week and it continued to increase until the end of the study period. In contrast, the concentration of NO₂ was higher than that in 2019 and 2020 from 26 March until 26 May. After 26 May, there was a drop of NO₂ concentration until the study period. Figure 3 shows the time series of NO₂ pollution over the Dhaka district.

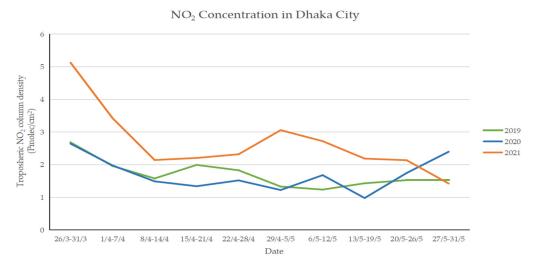


Figure 3. NO₂ Concentration in Dhaka city during the study period on weekly average.

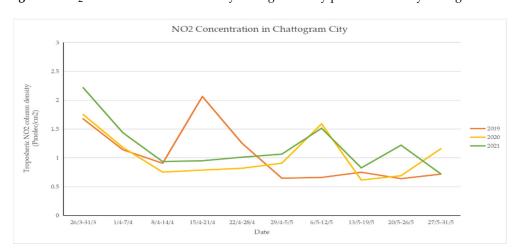


Figure 4. NO₂ concentration in Chattogram city during the study period on weekly average.

Chattogram district showed a different trend compared to Dhaka district. The concentration of NO_2 was observed to decline in 2020 compared to 2019 until the sixth week of the study period, which was 29 April–5 May. After that period, the concentration fluctuated compared with 2019.

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

4. Conclusions

This study was carried out to examine the variations in NO_2 concentrations during the lockdowns 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. However,

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when the lockdown was loosened by the government and people started their daily lives as 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 in NO₂ pollution. However, during the second lockdown in 2021, the lockdown was only partially implemented and thus did not impact much on the NO₂ pollution.

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

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