Sentinel 5P Observations of NO_2 Variability During COVID-19 Lockdown in Mega-cities of Pakistan

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Abstract

Lockdown in Pakistan due to global pandemic disease COVID-19 have reduced air pollution in mega-cities (Lahore, Karachi, Islamabad and Peshawar) during March, April and May, 2020. A prominent decrease in Nitrogen dioxide (NO_2) concentrations was observed over mega-cities during the period March-May of 2020 in comparison with the same months of the previous year 2019. Satellite observations from Sentinel-5P over these cities indicate that the NO_2 dramatically reduced in March 2020 as compared to the same month of previous year, with a maximum decrease of ~16% in Lahore. In April 2020, a remarkable decline in NO_2 concentrations was observed over Lahore from 102×10-6 mol/m2 to 87×10-6 mol/m2, Karachi from 101×10-6 mol/m2 to 91×10-6 mol/m2, Peshawar from 76×10-6 mol/m2 to 75×10-6 mol/m2 and Islamabad from 93×10-6 mol/m2 to 82×10-6 mol/m2 as compared to the previous months of 2020 caused by diminished transport, industrial and economical activities during the lockdown. Satellite observations over mega-cities also showed that Aerosol Optical Depth (AOD) dramatically reduced in 2020 during the lockdown as compared with corresponding months of 2019, with a maximum decrease of ~52% in Lahore. Ground-based monitoring networks show a marked decrease in Particulate matter ($PM_{2.5}$) concentration of ~40.4% in Lahore, ~48.6% in Karachi, ~22.5% in Islamabad and ~37.1% in Peshawar due to mandatory restrictions during lockdown as compared with pre-lockdown.

I. Introduction

- *Air pollution levels in most of the cities of Pakistan exceeds the air quality standards which engaged the attention of research community towards Pakistan .*
- *Air pollution, specifically, in overwhelmed urban hubs eradicate essence of life and contributes to environmental and climate system destruction.*
- *Rapid urbanization, environmental issues and industrialization are few major factors responsible for air pollution in Pakistan (Tariq and Ali, 2015)*
- *High concentration of air pollutants can cause severe health issues (Ogen et al., 2020).*
- *Recent studies have found relationship of air pollutants with acute respiratory diseases and asthma (Mehmood et al., 2021; Qayyum et al., 2021)*
- *COVID-19 is a spreadable disease and an ongoing global event which was initially discovered in Wuhan province of China in December 2019.*
- *In-situ ground-based monitoring networks can accurately measure the air pollutants but with restricted spatial coverage, which limits our understanding of air pollution variations in response to COVID-19 lockdown period at the national level. To address this problem, satellite-based observations along with in-situ data can be used to detect the variations of air pollutants during the COVID-19 lockdown period at local, regional and national scale .*

II. Instrumentation

TROPOMI

- *Sentinel-5P Tropospheric Monitoring Instrument (TROPOMI) was launched on 13 October 2017 in the near polar sun- synchronous orbit at an altitude of 817 km with an overpass time of 13:30 LT.*
- *The spatial resolution of TROPOMI is 3.5 km × 7 km with swath width of ~2600 km.*
- *The Sentinel-5P TROPOMI provides daily global coverage of Nitrogen dioxide (NO_2), Ozone (O_3), Carbon monoxide (CO), Sulphur dioxide (SO_2), Methane (CH_4), Formaldehyde (CH_2O) and aerosols.*
- *TROPOMI is spaceborne, nadir-viewing instrument and consists of UV, VIS, NIR and SWIR bands.*
- *In the present study, we have used the Sentinel-5P TROPOMI OFFLINE L2 products of NO_2 over Pakistan during the period March to May of 2019 and 2020.*

MODIS

- *Moderate Resolution Imaging Spectroradiometer (MODIS) is an instrument aboard the Aqua and Terra polar orbiting satellites.*
- *MODIS has 36 wavelength channels ranging from 0.41 to 14 μm at moderate spatial resolutions of 250m, 500m and 1km.*
- *MODIS has temporal resolution of 1 to 2 days with swath width of 2330 km.*
- *MODIS aboard the Terra and Aqua satellites provides spectral aerosol measurements globally.*
- *In the present study, we have used the Aqua-MODIS AOD over Pakistan during the period March to May of 2019 and 2020.*

Ground based Measurements

- *Daily $PM_{2.5}$ data of mega-cities (Lahore, Karachi, Peshawar and Islamabad) was obtained from US consulates in Pakistan during the months of March, April and May of 2020.*

III. Methodology

- *Assessment of air quality over Pakistan during the ongoing COVID-19 span was studied by analyzing NO_2 concentration and aerosol loading during the pre-lockdown, during lockdown period and previous year.*
- *Monthly mean spatial distribution maps of NO_2 and AOD over Pakistan are made using Sentinel-5P and Aqua-MODIS observations.*
- *The datasets of NO_2 over Pakistan were downloaded from Google Earth engine and AOD from GIOVANNI.*
- *The relative percentage change of NO_2, AOD and $PM_{2.5}$ over megacities (Lahore, Karachi, Islamabad and Peshawar) is calculated using the formula mentioned below:*

$$\% \text{ relative change} = (\text{Final value} - \text{Initial value}) / \text{Initial value} * 100$$

IV. Results

Variations in NO_2 over Pakistan

- *Fig 1 displays the monthly tropospheric NO_2 concentrations over Pakistan acquired from Sentinel 5P.*
- *Spatial and temporal variations of NO_2 over Pakistan shows decreasing trend during the lockdown period as compared with previous months.*
- *Generally, the major sources of NO_2 emissions over mega-cities are soil emissions, crop residue burning, exhaust from vehicles, industrialization, agricultural activities, biomass burning and consumption of fossil fuels.*
- *A decline in NO_2 concentration was observed over Pakistan from March to May of 2020 as compared with previous year.*
- *In April 2020, the satellite observations of NO_2 concentration showed decline of ~31% in Lahore, ~17.2% in Karachi, ~7.4% in Peshawar and ~27% in Islamabad as compared to the same period of 2019.*
- *The concentrations of NO_2 in April 2020 was dropped from 102×10-6 mol/m2 to 87×10-6 mol/m2 in Lahore, 101×10-6 mol/m2 to 91×10-6 mol/m2 in Karachi, 76×10-6 mol/m2 to 75×10-6 mol/m2 in Peshawar and 93×10-6 mol/m2 to 82×10-6 mol/m2 in Islamabad as compared to the previous month of the same year.*

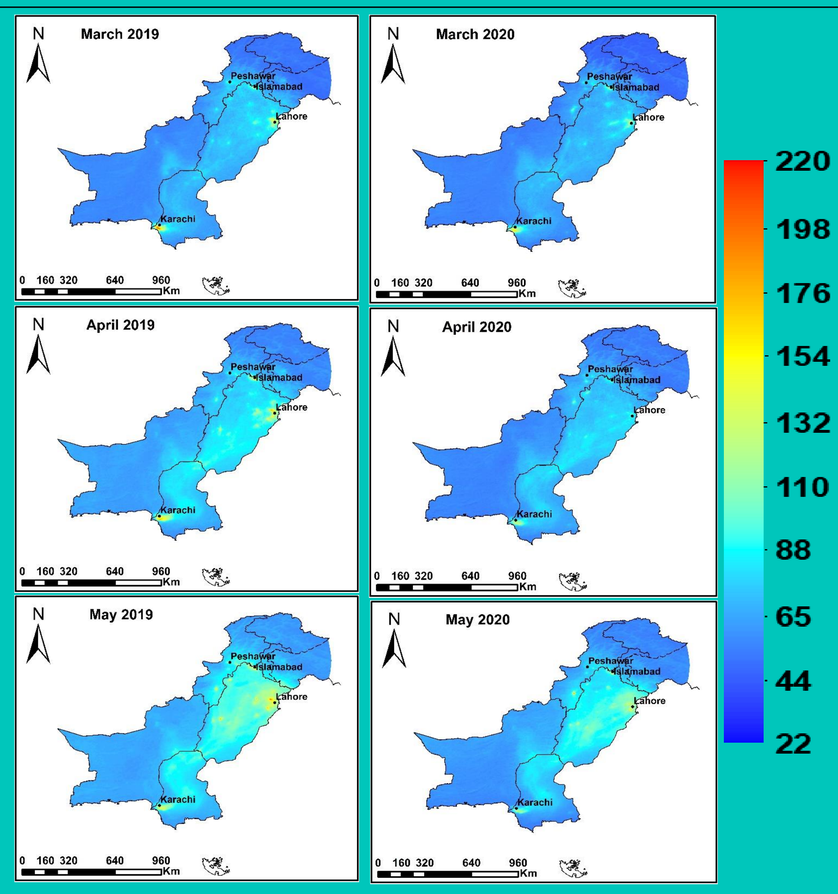

Fig 1. *Spatial and temporal variations of tropospheric NO_2 column values (×10^{-6} mol/m^2) over Pakistan.*

Variations in AOD over Pakistan

- *The spatial and temporal variations of AOD from March to May of 2019 and 2020 over Pakistan are shown in Fig 2.*
- *A significant decrease in AOD levels were observed over Karachi from 0.3 to 0.23 and Islamabad from 0.27 to 0.2 while increase in AOD values are seen over Peshawar from 0.2 to 0.3 and Lahore from 0.39 to 0.43, respectively in March 2020 as compared to the same month of the previous year 2019.*
- *In April 2020, a drastic decline in AOD levels were observed over Lahore from 0.43 to 0.24, Peshawar from 0.3 to 0.2 and Karachi from 0.23 to 0.21 as compared with previous month of 2020 due to diminished transport and industrial activities.*
- *Fig 3 shows that all the megacities of Pakistan showed a prominent decrease in AOD concentrations during the lockdown, however, relatively larger reduction was observed in Lahore, Karachi and Peshawar.*
- *In April 2020, AOD values dropped by ~52% (Lahore), ~47.5% (Karachi) and ~33.3% (Islamabad) as compared with same month of the previous year.*
- *The AOD increased significantly in May 2020 over Pakistan as compared to previous months of 2020 due to reopening of construction industries, businesses and transportation in the country.*

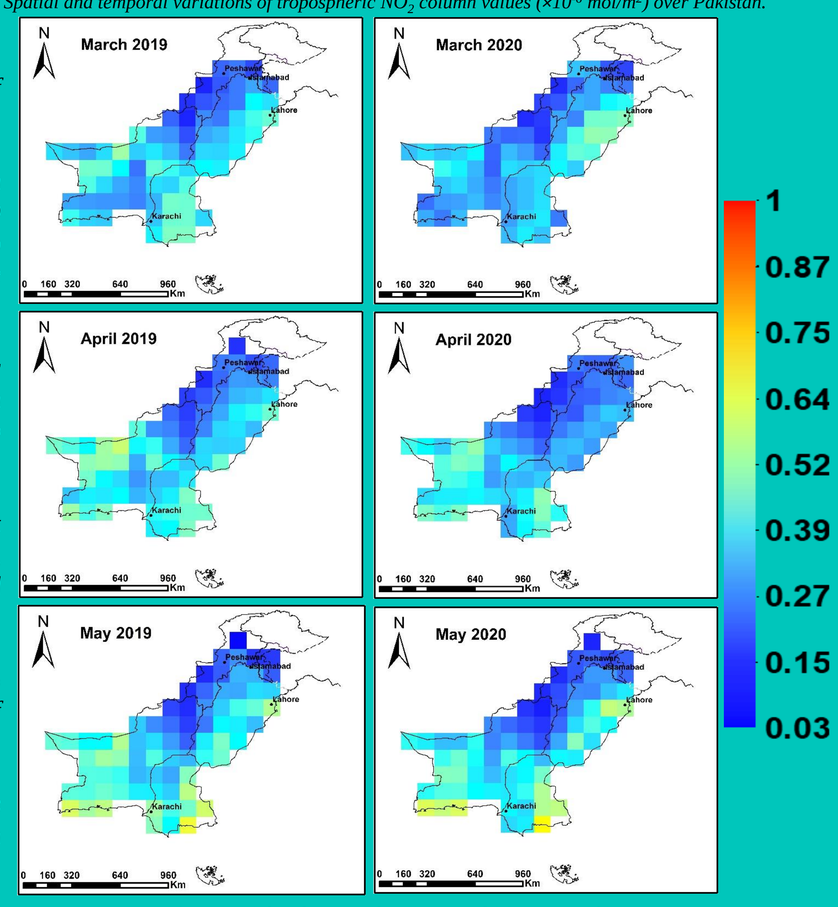

Fig 2. *Spatial and temporal variations of AOD over Pakistan.*

Variations in $PM_{2.5}$ over megacities

- *Table 1 presents the average $PM_{2.5}$ concentration (μg/m3) over mega-cities during the pre-lockdown and lockdown period along with difference and relative percentage change.*
- *Vehicular emissions, sea salts, dust and smoke are major sources of $PM_{2.5}$.*
- *A strict lockdown was imposed in these cities due to increase in number of COVID-19 patients.*

Table 1. Average PM2.5 concentration (μg/m3) over mega-cities during pre-lockdown and lockdown period..

Cities	Pre-lockdown	During lockdown	Difference	Relative % change
Lahore	81.16	48.34	-32.82	- 40.4
Karachi	49.29	25.32	-23.97	- 48.6
Islamabad	35	27.14	-7.86	- 22.5
Peshawar	57.54	36.22	-21.32	- 37.1

- *The concentrations of $PM_{2.5}$ showed decreasing trend from 81.16 to 48.34 μg/m3, 49.29 to 25.32 μg/m3, 35 to 27.14 μg/m3 and 57.54 to 36.22 μg/m3 over Lahore, Karachi, Islamabad and Peshawar, respectively.*
- *The highest % relative change of -48.6 is observed over Karachi due to diminished transportation, economic and industrial activities during the lockdown period.*

V. Conclusion

The study examines the spatio-temporal variations of NO_2, AOD and $PM_{2.5}$ over Pakistan during the lockdown period as compared with same period of previous year. In Pakistan, due to COVID-19, a countrywide lockdown was implemented from 20th March to 9th May causing poor economic and transport activities. The tropospheric NO2 monthly average maps retrieved from Sentinel 5P showed almost similar results to AOD measurements during the period of March, April and May of 2020. The tropospheric NO_2 concentrations decreased significantly in April 2020, with maximum reduction of ~31% in Lahore as compared to April 2019. A remarkable decrease in MODIS-AOD was observed in Karachi, Lahore, Islamabad and Peshawar during the COVID-19 lockdown. The surface monitoring network data of $PM_{2.5}$ displayed a maximum decline of air pollution in mega-cities during lockdown as compared to the pre-lockdown time period.

VI. References

- Mehmood, U., Azhar, A., Qayyum, F., Nawaz, H., Tariq, S., Haq, Z. ul, 2021. Air pollution and hospitalization in megacities: empirical evidence from Pakistan. Environ. Sci. Pollut. Res. https://doi.org/10.1007/s11356-021-14158-0
- Spatio–temporal distribution of absorbing aerosols over Pakistan retrieved from OMI onboard Aura satellite. Atmos. Pollut. Res. 6, 254–266. https://doi.org/10.5094/APR.2015.030
- Qayyum F, Mehmood U, Tariq S, et al (2021) Particulate matter (PM2.5) and diseases: an autoregressive distributed lag (ARDL) technique. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-021-151786
- Ogen, Y., 2020. Science of the Total Environment Assessing nitrogen dioxide (NO 2) levels as a contributing factor to coronavirus (COVID-19) fatality. Sci. Total Environ. 726, 138605. https://doi.org/10.1016/j.scitotenv.2020.138605