

Spatial variation of tropospheric NO₂ concentration during first wave CoVID-19 induced lockdown estimated from Sentinel-5 Precursor

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Abstract

CoVID-19 pandemic has forced many countries to shut down their industries as most of these countries observed complete state-wide lockdown during the first wave of this contagious virus. Factories and vehicles on the road are a major source of nitrogen dioxide (NO₂), which is also one of the major air pollutants. The emission of NO₂ is considered as a good indicator of prevalent global economic activities as its predominant corollary affairs typically involve industrial operations and these emissions are evidently visible from space. Sentinel-5 Precursor (launched in July 2018), equipped with spectrometer Tropomi (Tropospheric Monitoring Instrument), is a low-earth-orbit atmosphere mission satellite dedicated towards monitoring air pollution sensing remotely. This study is focused primarily on, estimation and variation of NO₂ emission over different parts of the world, before and during the first wave of CoVID-19 epidemic (07 weeks duration). It is found that in most of the countries during the lockdown period (7 weeks), air quality was cleaner by about 40 to 50 % over the last year, mainly due to the shutdown of industry and traffic activities. The technology is quite promising and provides a tool to access if a country or place followed complete lockdown.

Keywords: Nitrogen Dioxide; CoVID-19 Pandemic; Sentinel-5 Precursor

Introduction

The rapid increase of population in the world has led to an anthropogenic impact on the natural environment of the Earth. Urbanization can be seen to have increased in the world, rapidly [1]. During the last few decades, industrialization, energy consumption, transportation, motorization, economic-growth, and power plants, etc. of the countries have proliferated with time and turn out to be the main cause of air pollution [2]. Growth in population has an adverse effect on the concentration of NO₂ in the atmosphere [2]. Particulate matter (PM) (e.g., soot, dust, smokes, fumes, mists, etc.), NO₂, sulfur dioxide (SO₂), ozone (O₃), carbon dioxide (CO₂) and carbon monoxide (CO) are major pollutants of the air and has an acute harmful effect on the health of human beings [3-15]. One of the major sources of NO₂, contributing to the air, is the combustion of fossil fuels such as coal, oil, and gases due to vehicles, power stations, and heating. In any case, the role of extraterrestrial impact on the vacillation of these gases cannot be excluded [16]. In urban areas, automobile emissions contribute approximately 80% of the NO₂. Burning of petrol, metal-refining, coal-fired power sta-

tions based electricity generation, food processing units and other manufacturing industries are other sources of NO₂ contributing to the air (Kaplan et al., 2019). Above mentioned sources also contribute SO₂ to the air [9, 10, 17].

The CoVID-19 pandemic situation has caused lockdown in almost all the major countries of the world with the traffic and industrial activities suspended. Such a scenario creates an excellent opportunity for researchers to relatively access dynamic parameters; particularly the ones which are anthropogenic in nature. Several studies regarding relative variation of air quality before and during the lockdown has been carried with an emphasis on decrease in contaminant levels, such as the extent of the reduction of major pollutants, like carbon monoxide (CO), nitrogen dioxide (NO₂) and sulfur dioxide (SO₂) in India and China during January to April, 2020, variation of fine particulate matter (PM_{2.5}) and nitrogen dioxide (NO₂) in the continental United States, impacts on the air quality of São Paulo state, Brazil during lockdown, affect of CoVID-19 lockdown on NO₂, O₃, PM_{2.5} and PM₁₀ concentrations in Bagh-

dad, Iraq, etc [18-21]. The present study is a contribution towards this body of literature with the results derived employing efficient and robust techniques.

The Copernicus Program which comes within the ambit of the European Space Agency operates a certain number of Earth perception satellites dedicated to measuring both the physical and Earth science parameters [22]. Recently launched Sentinel-5 Precursor (Sentinel-5 P) satellite by the European Space Agency (October 2017), installed with Tropospheric Monitoring Instrument (TROPOMI), which senses in the shortwave infrared (SWIR), the near-infrared (NIR), the visible (VIS) and the ultraviolet (UV) spectral bands, is a low-earth-circle atmosphere crucial to observing air quality and air contamination [22-25]. It completes near-global coverage in one day and has a high spatial-resolution of approximately $7 \times 3.5 \text{ km}^2$.

Sentinel, assembles various satellites which makes it one of the most important Earth observation programs. Key atmospheric constituents, such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), methane (CH_4), formaldehyde (HCHO), aerosols and clouds are sensed by selected wavelengths range for TROPOMI installed on the Sentinel-5 P [22, 23]. Copernicus Open Access Data Hub facilitates the freely download-

able near-real-time, offline and reprocessed data of the Sentinel-5 P. This study attempts to establish the effect of lockdown on the relative composition of NO_2 in the troposphere towards inferring significant improvement in air quality compared to last year using the Sentinel-5P data.

Data and Methods

The NO_2 data of the Sentinel-5 P, which was launched on 13 October 2017, were brought in to the public domain on 10 July 2018. A comparative study between the worldwide NO_2 emission in the present phase of 2020 and the same of 2019 was made using the Google Earth Engine tools. The correlation between the present pandemic and better air quality can be easily concluded from this study. It can be observed from the recently released satellite images by the European Space Agency that there has been a considerable decrease in the emission of NO_2 during this global crisis, which has led to a reduction in NO_2 spots in the atmosphere. From the study, it can be inferred that this decreased emission in specific regions is directly related to the decrease in human activities such as the use of motor vehicles, running of power plants and other industrial endeavors related to fossil fuel usage and economic activity, in those particular regions [17, 27, 28, 29]. AMFv6 package has been used to derive Tropospheric NO_2 , VCDs of POMIC-NO-TROPOMI (Figure 1) [30].

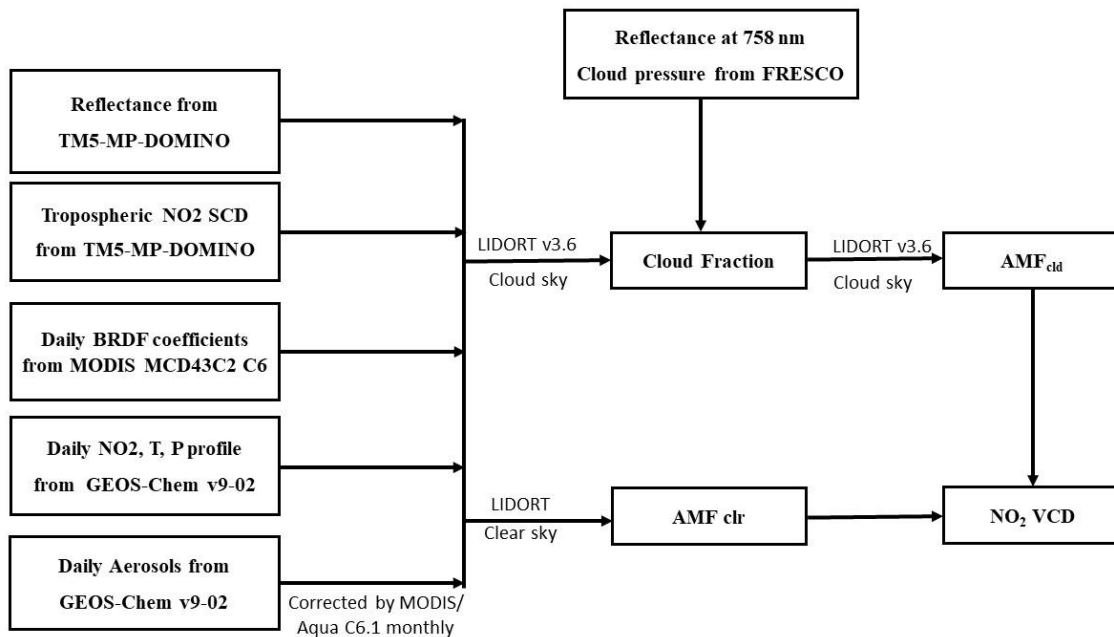


Figure 1: Flowchart of the POMINO-TROPOMI algorithm (after Liu, et al., 2020).

Result and Discussion

COVID 19 Impact on worldwide NO_2 Emission

In order to curb the transmission rate of the deadly virus and to flatten the curve of the spread of COVID-19 most countries have imposed restrictions such as shutting down offices, factories, schools, etc. and canceling all public events so as to avoid the possibility of any mass gathering which was bound to fan the spread even more.

Many countries have requested their citizens to stay at home and to implement self-imposed travel restrictions, moving out of their houses only in case of emergencies or to facilitate absolute needs. As an obvious result of such lockdowns, there has been a considerable reduction in the road and air traffic which has further led to a reduction in emission of poisonous gases in the atmosphere due to a reduction in the consumption of fossil fuel and anthropogenic activities. Thus, in the light of this deadly epidemic it can be said

that although there have been colossal and long-lasting social and economic impacts, the positive impact on the environment-howsoever temporary in nature-cannot be ignored.

Readings from the Sentinel-5 P from the Satellite imagery released by the European Space Agency clearly show that over the past 7 weeks, the levels of nitrogen dioxide (NO_2) over cities and industrial clusters in the USA, Europe, and Asia were remarkably re-

duced, as evident from a comparison with last year. This decrease shall have several health benefits as NO_2 released from automobiles, factories, etc. are a major cause of exacerbation respiratory illnesses such as asthma, bronchitis, and pneumonia and have decreased several thousand deaths related to respiratory diseases caused by the air pollution [31-37]. Global tropospheric NO_2 emission has been shown in Figures. 2 and 3 for the same period of the year 2019 and 2020, respectively.

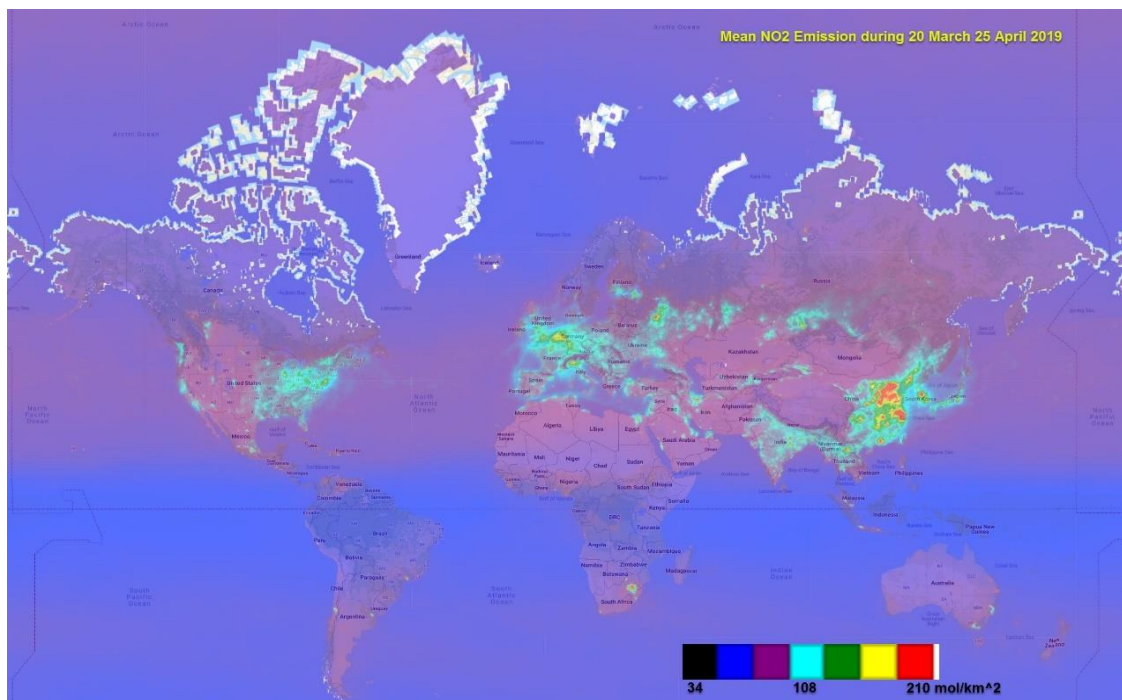


Figure 2: NO_2 Emission over the world during 2019 (20 March to 25 April)

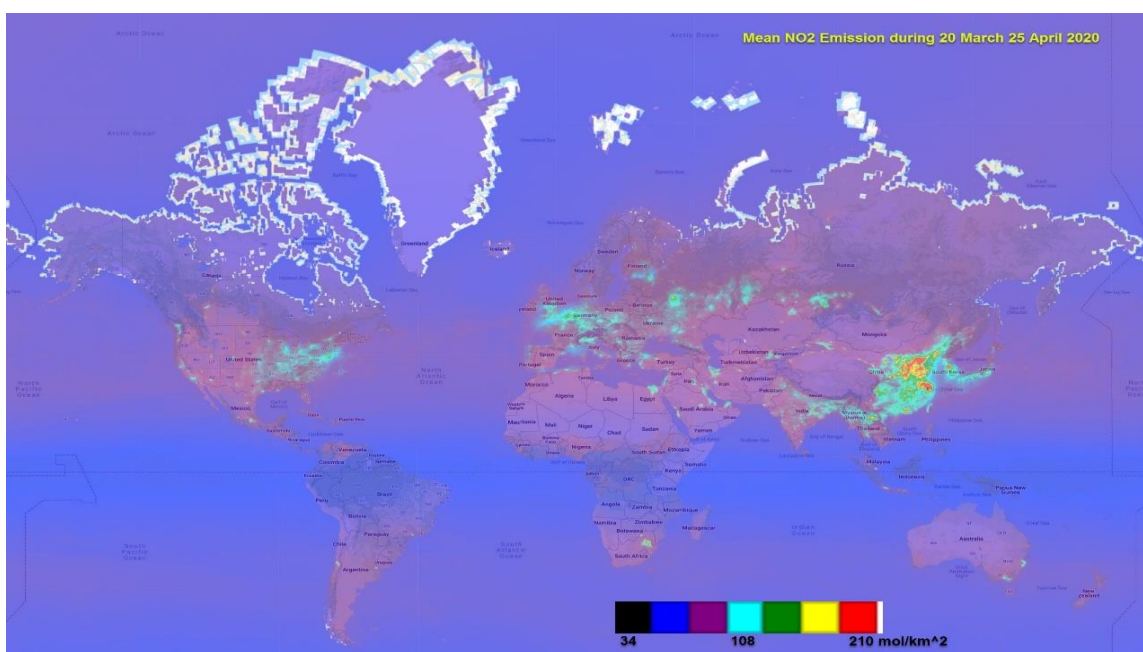


Figure 3: NO_2 Emission over the world during 2020 (20 March to 25 April)

Impact on the United States of America

It is observed that NO_2 concentration has decreased by 50% in most parts of the North East, Southeast, and Midwest of the United States (US) during the studied time period (Figure. 4). From Figure. 4 it can be inferred that suspension of industry and activities during

these seven weeks lead to reduction in consumption of fossil fuel and as a result it has improved the air quality of the US. Figure. 5 shows daily average NO_2 emission of 2019 and 2020 for the North East, South East and Midwest regions of the US for the studied 7 weeks duration and confirms improvement in air quality.

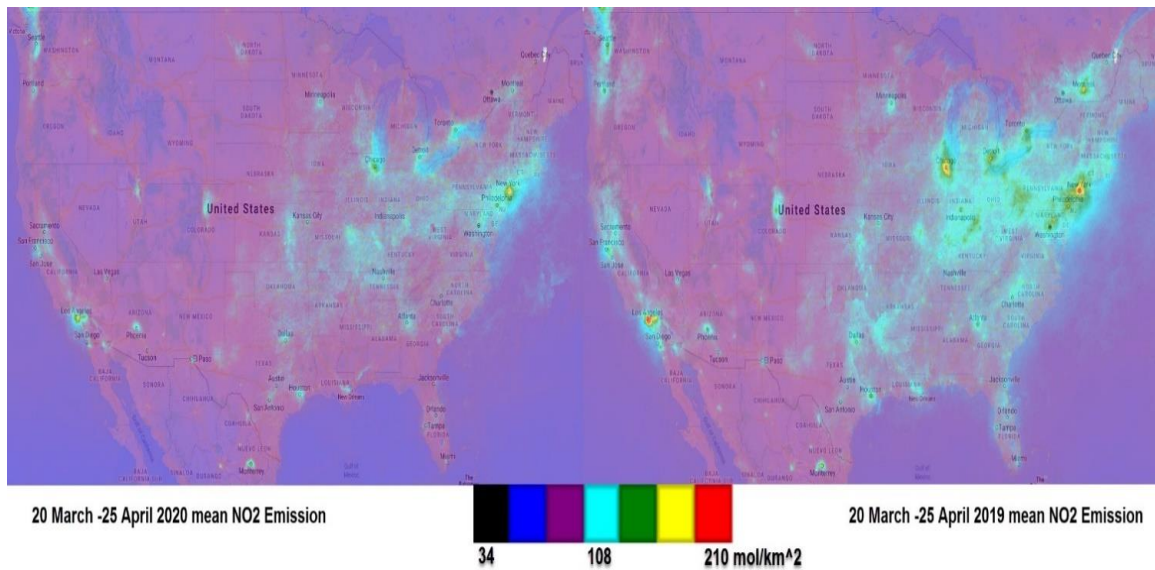


Figure 4: NO_2 Emission over the US during 2020 and 2019 (20 March to 25 April)

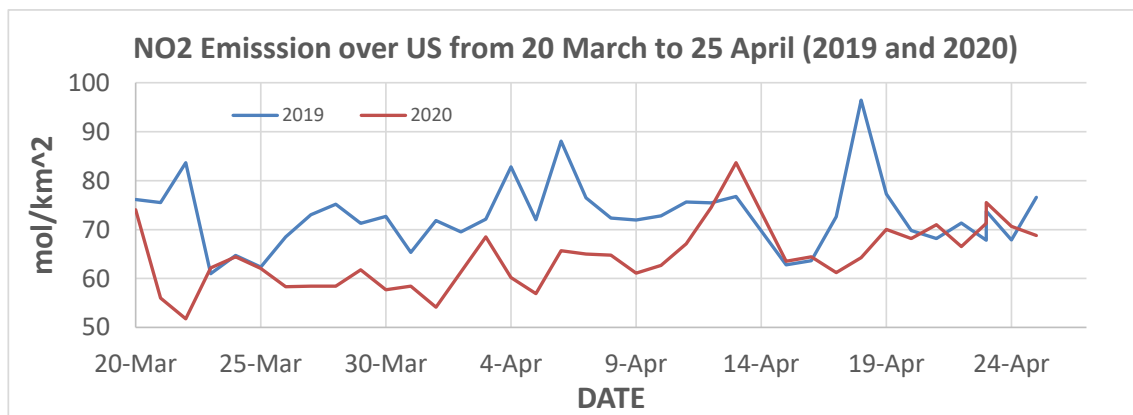


Figure 5: NO_2 Emission time series over the US during 2019 & 2020 (20 March to 25 April)

Impact on European Countries

With the rapid escalation of CoVID-19 in Lombardy, Italy, the country which was the first in Europe to become a hotspot of the disease and declared complete lockdown on March 9, 2020, which was followed by Spain on March 14, issuing general confinement and further toughening the measures on 28 March; France declared complete lockdown on March 17 and Germany, rather, opted for strict social distancing measures since March 22, while the UK announced a complete lockdown on March 23 ("Coronavirus: What are the lockdown measures across Europe?" DW; 14.04.2020; and "When did the UK lockdown start and how long will it last? - Heart"; 28.05.2020). Comparing the mean NO_2 emissions for the identical months and dates for the year 2019 and 2020 (Figures. 6 & 7) a unique observation is observed in the world context that the patches of highest concentration, of about 200 mol/km^2 fell sharply less than 150 . In most of the other countries, although

shades of concentrations lightened the kernel spots remained consistent. Declination of European nitrogen oxide emissions is unambiguously portrayed. Highest emission, during the lockdown, is spotted in Antwerp, Belgium followed by southwestern Cologne and Dortmund city of Germany and westerly neighboring Brussel, Netherland. These cities in the cluster, along with London, Paris, and Milan appear to emit the highest emission also during the year 2019. However, London, Paris, and Milan registered a very steep decline of NO_2 emission in 2020. The prominent decline is also observed in Barcelona and Madrid of Spain. The precipitous decline could be attributed to the fact that a significant portion of the NO_2 emission of most of these high yielding cities derives from traffic [38-41]. It is estimated that more than 11,000 deaths have been avoided in Europe due to coal and oil consumption plummet during COVID-19 lockdown [35, 41].

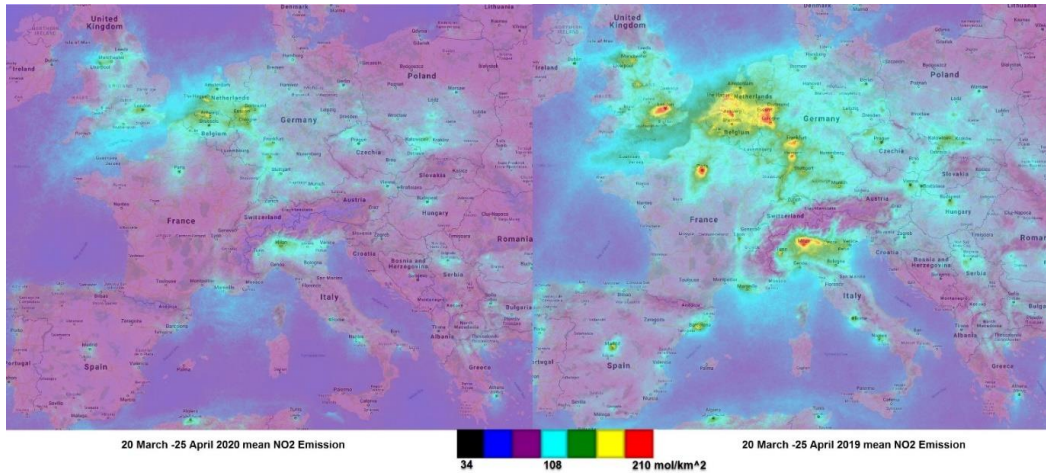


Figure 6: NO₂ Emission over the European countries during 2020 and 2019 (20 March to 25 April)

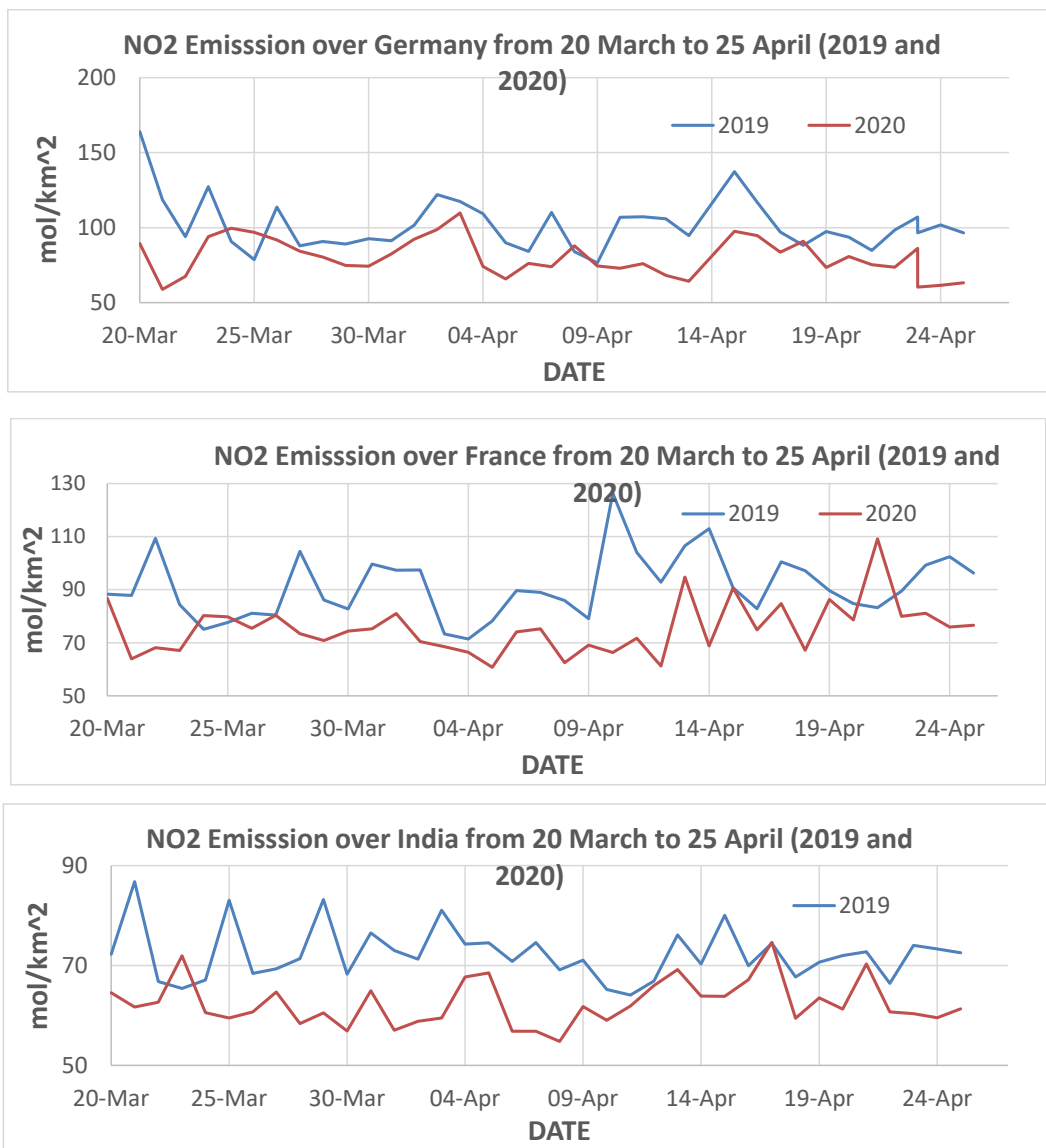


Figure 7: NO₂ Emission time series over the Germany, France & Italy during 2019 & 2020 (20 March to 25 April)

Impact on India

In India, it's evident from both the figures (Figures. 8 & 9) that a significant and essential drop in NO₂ emission is observed all over the country with the atypical exception in few northeastern states, where the subtle increase in the emission concentration is detected (Figures 8 & 9). The highest concentrations, during the lockdown period, are conspicuous to the coal excavated central-eastern sectors, while the industrial belt of Gujrat-Maharashtra appears to indicate reduced NO₂ emission by more than 70%. Similar depletion is also observed in the central and southern states where the

blistering NO₂ concentration zones from 2019 appears mildewed or even nullified. The area in and around Delhi, considered as one of the worst air quality index cities by the World Meteorological Organization, has seen a significant drop in NO₂ release. As such, all the hotspots of nitrogen oxides clearly show dramatic declination [42, 43]. The uninhabited or sparsely populated northern regions, quintessentially, show no difference. The temporal shutdown of industries and less traffic explains the considerable decrease, while for the coal-bearing zones, emission may be expected even without anthropogenic interventions. (Reference can be added)

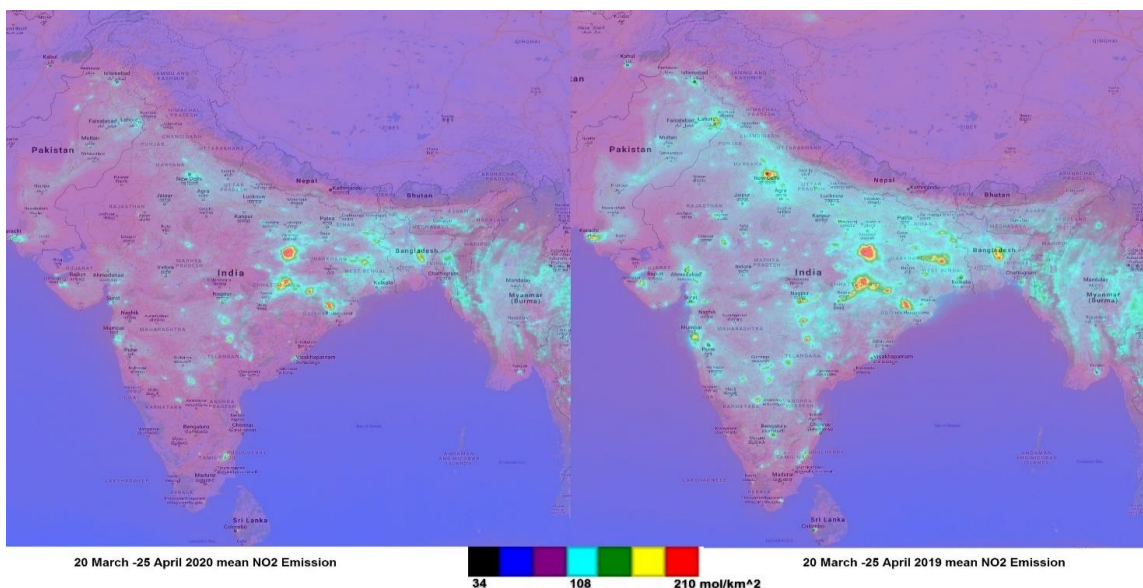


Figure 8: NO₂ Emission over India during 2020 and 2019(20 March to 25 April)

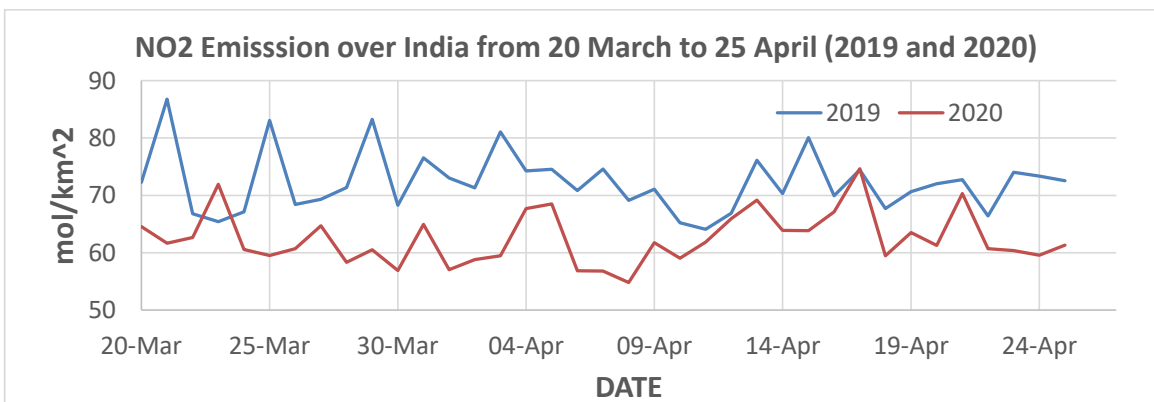


Figure 9: NO₂ Emission time series over India during 2019 &2020 (20 March to 25 April)

Impact on China

The most subtle change in NO₂ concentration, across the globe, is observed in China(Figure. 10). While NO₂ emanation drastically declined in most of the industrial and populated cities across the globe, Beijing and its adjacent northern cluster of cities recorded the highest emanation in the world at a time when, almost, the whole world was under a lockdown or restricted public activity. Here, the efficacy of time series evaluation (Figure.11) plays a key role in distinguishing and elucidating the fall in emission. No perceptible variation in NO₂ emission could be traced from the un-

inhabited terrains. In a nutshell, the NO₂ emanating sources were actively functioning in China as usual years, as evidenced by the high emissions stemming from industrially captivated Beijing and its neighbored regions, with the remarkable exception of the Hubei province. With this premise, it may be inferred that China, well-nigh, operated its traffic and effluent emanating industries conventionally, diametric to global scenario. Incidentally, the prime reason for the eccentric pattern in global NO₂ emission stems from China [44, 45].

Further, the Hubei province is studied with supplementary inclusion of November and December 2019 and January to April 2020.

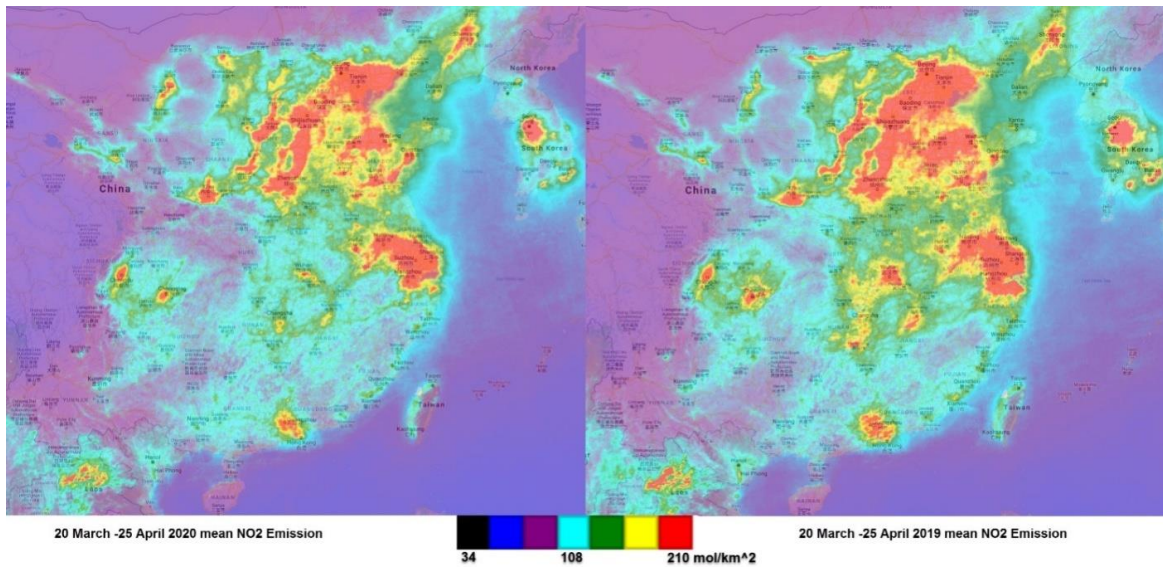


Figure 10: NO₂ Emission over China during 2020 and 2019 (20 March to 25 April)

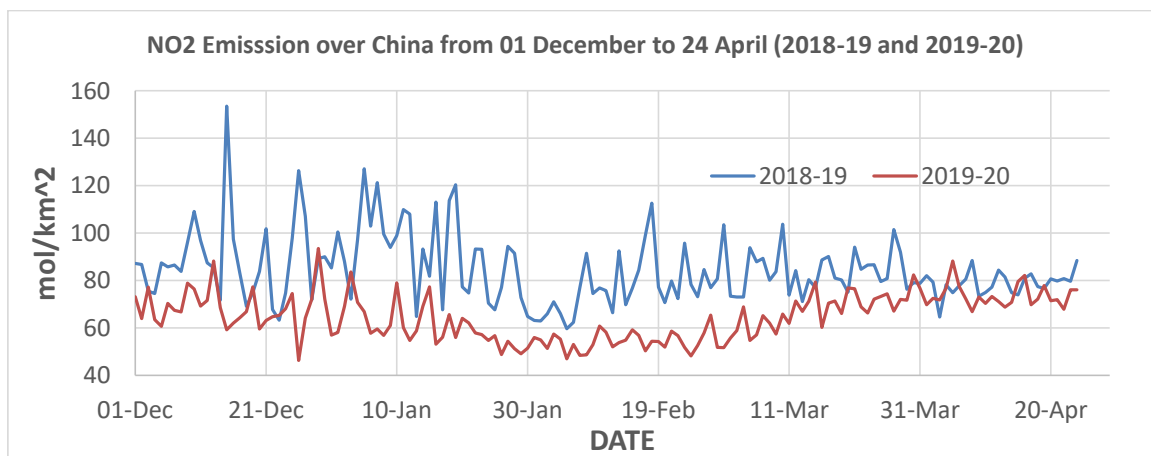


Figure 11: NO₂ Emission time series over China during 2018-19 & 2019-20 (1 December to 25 April)

Impact on Wuhan (China)

Even as the declining trend in NO₂ emission is observed in China, the Hubei Province with Wuhan as its capital city, where the CoVID-19 case reportedly emerged for the first time, however, recorded a sharp fall. Such contrasting variation within similar geographical expanses prompted a localized study of mean NO₂ emission in Hubei province [46]. It is evident from the map that in January 2020 lowest ever emission is detected which sluggishly increased over the two months. Now, it is imperative to note that public traffic was suspended within Wuhan city on 23 January, showing stark inconsistency with the NO₂ emission findings

as shown in the map (Figure 12) and time-series variation (Figure 13) [46].

Ideally, the declining volume of NO₂ for a week could never average out the higher emission of the remaining three weeks to produce the lowest ever emission volume for the entire month of January 2020. However, the emissions were typically high during November and December 2019. The discordant correlation suggests that restriction in public traffic was imposed well before the last week of January, as known widely across the globe [47].

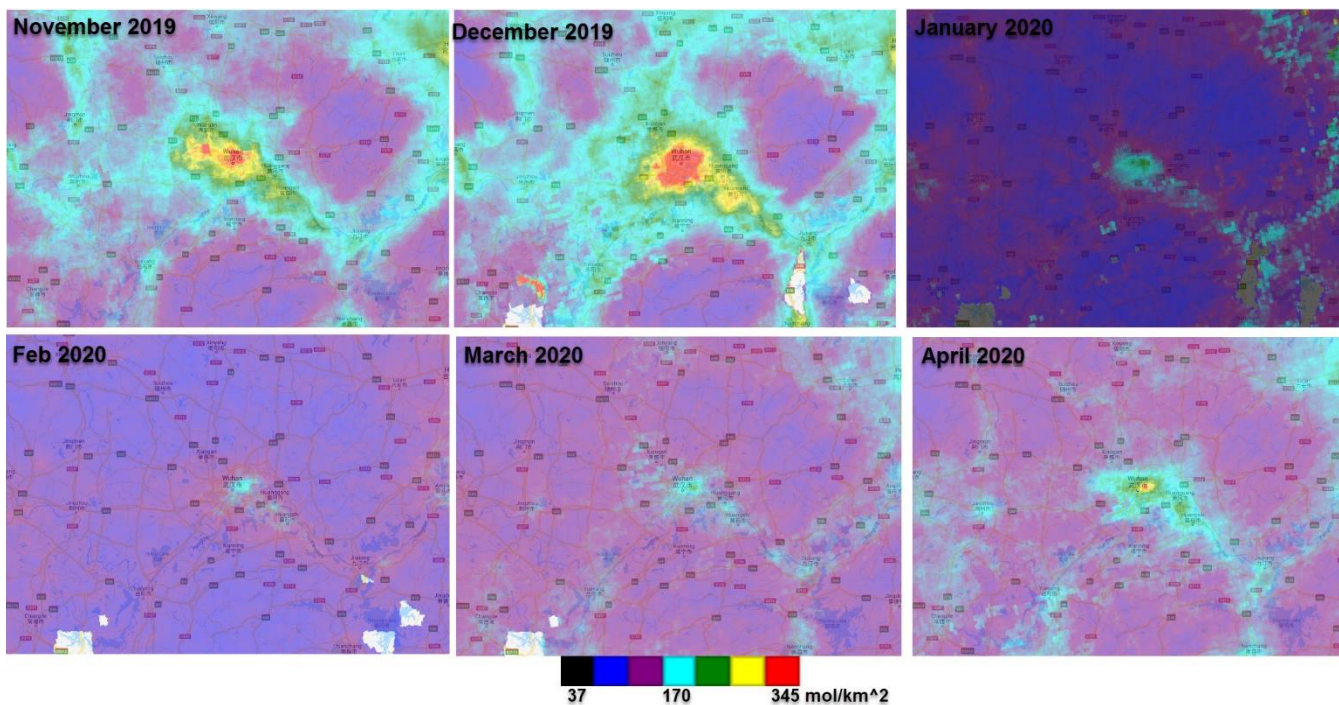


Figure 12: NO₂ Emission over Wuhan city from 2019 to 2020 (November to April)

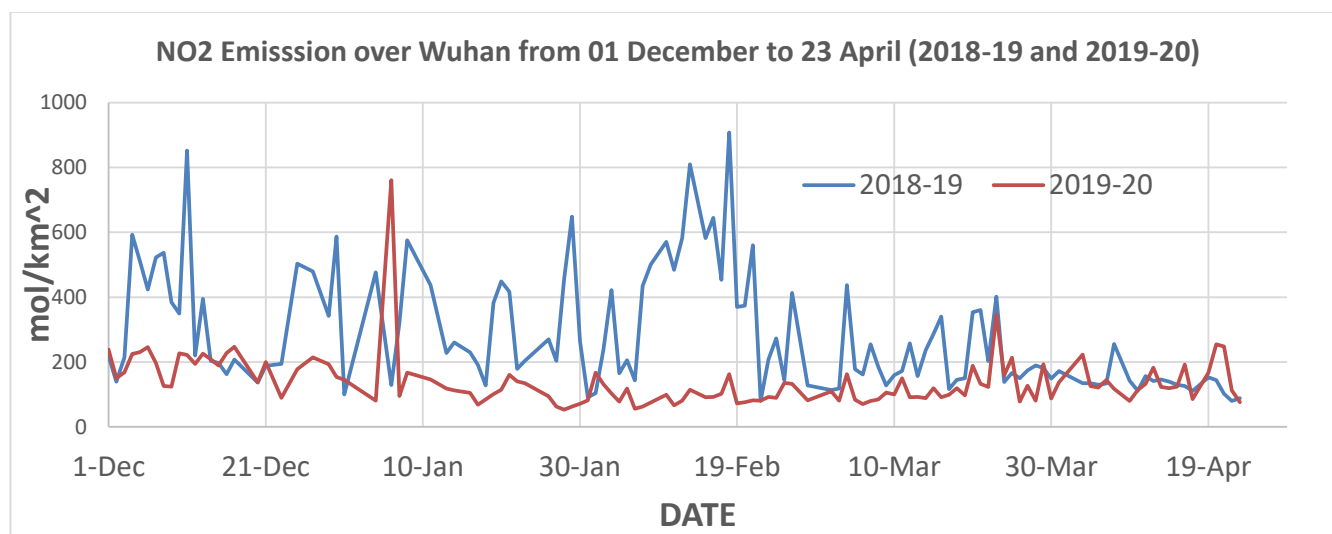


Figure 13: NO₂ Emission time series over Wuhan during 2018-19 & 2019-20 (1 December to 25 April)

Conclusion

The pandemic brought about by the novel Corona Virus-2019, known for causing one of the most contagious diseases in the recent past, has paralyzed several aspects of day-to-day life. Most importantly, from a broader perspective, it has inflicted deceleration in global economic growth. While the pandemic meted out multifaceted abominable repercussions, it ironically engaged mankind to contemplate on the environmental exploitation due to industrialization with vivid and life-size examples and recognize climate change. This paper scientifically documents one such example in the form of depletion in NO₂ emission in some of the ma-

yor developed and developing countries of the world due to lockdown or restricted public activity. In presenting the moderate to the steep decline in NO₂ concentrations in major cities, the results also portray a grim picture of how most of the public activities are still dependent on processes which yield environmentally hazardous effluents even after widespread awareness on promoting a switch over to the 'clean and green' technologies.

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(To be written after the review and before the final publication)

Declarations

(A) The Data Availability Statement (DAS)

Data was downloaded from the sites mentioned in the text and processed. There is no data uploaded to the journal.

Declaration of interest

This is to declare by all the authors that no financial and personal relationships directly or indirectly with other people or organizations have been taken and there is no conflict of interest directly or indirectly with other people or organizations.

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