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IMPACT OF COVID-19 CONFINEMENT ON NO2 EMISSIONS IN MEXICO: TEMPORAL ANALYSIS AND OUTLOOK FOR AIR QUALITY

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ABSTRACT

The decreases and increases in nitrogen dioxide (NO_2) concentrations in Mexico during the periods are mainly due to changes in human activities and not only due to factors such as traffic and weather conditions. The confinement imposed by the pandemic has produced positive effects, such as the reduction of polluting emissions, including nitrogen dioxide (NO_2). The pandemic offered a glimpse into how human activities impact air quality. To investigate the changes in the spatial concentration of NO_2 in Mexico during the COVID-19 confinement and the subsequent period, comparing the months of April 2019 and 2020, as well as April 2023. The Sentinel-5P TROPOMI sensor was used to obtain images of NO_2. They were processed with SNAP software for Geometric Re-projections and ArcGIS 10.2 for change detection. During the confinement in Mexico in April 2020, NO_2 concentrations decreased by 21.45% compared to April 2019. However, in April 2023, concentrations increased by 14.48% compared to 2020. The findings support that the Confinement measures temporarily reduced NO_2 levels in Mexico. Similar patterns were observed globally. However, once normal activities resumed, NO_2 emissions increased. Lockdown restrictions produced a temporary decrease in NO_2 pollution in Mexico, but when the measures were lifted, emissions increased again. More rigorous policies are needed to maintain air quality. Continuous use of Sentinel-5P can help monitor and control air pollution in the country. In addition, the implementation of sustainable practices is suggested to reduce polluting emissions and promote a more resilient and sustainable society.

Key-words: *Air pollution, Nitrogen dioxide (NO_2), COVID-19 pandemic, Sentinel-5P TROPOMI, Climate change*

1. INTRODUCTION

In a future marked by a constantly changing climate, it is expected that natural communities will undergo modifications and many species will become extinct. Ecosystems, which are home to many species globally, have proven to be vulnerable due to factors such as population growth, habitat loss and fragmentation, and climate change, which has caused significant alterations in the state of the planet in recent last 50 years. Additionally, natural hazards, such as wildfires and wind-blown trees during severe storms, also pose a significant risk. All these events, exacerbated by climate change, threaten the integrity of ecosystems, as climate change is expected to increase surface temperatures and alter precipitation patterns (Navas, 2024; Muluneh, 2021).

The loss of biodiversity and the degradation of ecosystem health are closely related to anthropogenic activities that promote the emergence of zoonotic diseases. As wild species move closer to human populations, the risk of outbreaks and transmission of zoonotic diseases increases. Reducing emissions of air pollutants could slow climate change and, in turn, reduce the impact of diseases that can affect human health, as observed during the COVID-19 pandemic (Debone et al., 2020; Lawler et al., 2021).

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The confinements implemented due to the COVID-19 pandemic have shown a notable decrease in atmospheric pollutants. This phenomenon is attributed to the reduction of anthropogenic activities, such as the decrease in transportation, the reduction of industrial activities and the stoppage of construction, which are the main sources of air pollution. Air quality in many urban areas saw considerable improvement during the lockdown period. Likewise, it has been observed that the transmission and mortality rate of COVID-19 decreased in correlation with the reduction in pollution levels in many cities. In addition, research has shown that the decrease in air pollution because of confinement measures has contributed to reducing mortality associated with respiratory diseases (Priya et al., 2023; Saha et al., 2022; Kovacs and Haidu, 2021).

Nitrogen dioxide (NO_2) is an indicator of air quality due to its association with combustion emissions and is classified as one of the six common air pollutants by the World Health Organization (WHO). It is recognized as highly harmful to human health, and can cause respiratory diseases, asthma, cellular inflammation, cardiovascular disorders, high blood pressure and lung cancer. Furthermore, the presence of NO_2 leads to the formation of nitric acid (HNO_3) and acid rain, which is harmful to the environment (Oo et al., 2021; Represa et al., 2021).

The Sentinel-5P TROPOMI sensor has great potential for the estimation of atmospheric pollutants, particularly NO2 concentrations on a broad scale. Several studies have used Sentinel 5P data to investigate the relationship between air pollutants and confinement measures due to COVID-19 (Represa et al., 2021; Debone et al., 2020; Bassani et al., 2021; Kumar et al., 2020; Siddiqui et al., 2022; Naeger and Murphy, 2020; Dutta et al., 2021, Sunarta and Saifulloh, 2022). NASA and ESA have been using this data to track and report the concentration of NO_2 in the atmosphere for air quality monitoring purposes. Recent research based on satellite observations has revealed a marked decrease in NO2 concentrations during the global lockdown period (Shami et al., 2022; Oo et al., 2021; Cárcel-Carrasco et al., 2021; Liu et al., 2021; Priya et al., 2023; Ialongo et al., 2023).

The objective of this study was to investigate the changes in the spatial concentration of NO_2 in Mexico during the COVID-19 confinement, comparing the months of April 2019 and 2020, as well as the post-COVID-19 period in 2023.

2. STUDY AREA

Mexico, a country located in North America, known for its geographical, cultural, and social diversity. With a considerable land area, Mexico is home to a wide range of ecosystems ranging from arid deserts to lush tropical jungles, as well as mountains, plains, and coasts in both the Pacific Ocean and the Gulf of Mexico and the Caribbean Sea.

3. DATA AND METHODS

In Mexico, the confinement due to COVID-19 began on March 16, 2020, and ended on June 1, 2020 (Abarca et al., 2020; Valdez-Santiago et al., 2021). Since June, with the reopening of additional sectors such as mining, construction, automotive and aerospace, it is very likely that economic production has begun to recover (Esquivel, 2020). Therefore, Sentinel-5 Precursor images were used to investigate the changes in the spatial concentration of NO_2 in Mexico during the COVID-19 confinement, comparing the months of April 2019 and 2020, as well as the post-COVID-19 period in 2023.

3.1. Obtaining satellite images

Sentinel-5P TROPOMI is a broom imaging spectrometer that covers wavelength bands between ultraviolet and shortwave infrared. It was launched in October 2017 as part of the Sentinel-5 Precursor satellite mission, carried out by the European Union (EU) and the European Space Agency (ESA). This instrument provides NO_2 measurements with a spatial resolution of 5.5 km × 3.5 km. The width of the scanning swath covers approximately 2600 km in the direction of the satellite track, allowing daily global coverage (Liu et al., 2021). Three satellite images were used to observe NO_2 changes during and post-pandemic (**Table 1**).

Table 1.

Satellite images used.

No.	Satelite	Sensor	Acquisition date	Source
1	Sentinel-5P	TROPOMI	17-04-2019	https://browser.dataspace.copernicus.eu/
2	Sentinel-5P	TROPOMI	30-04-2020	https://browser.dataspace.copernicus.eu/
3	Sentinel-5P	TROPOMI	17-04-2023	https://browser.dataspace.copernicus.eu/

3.2. Software used for data processing

The SNAP software (European Space Agency) was used to make the geometric reprojections of the images, and for the detection of changes, the ArcGIS 10.2 software (ESRI, RedLands, USA) was used to detect changes in the NO_2 level between three different intervals.

4. RESULTS

The NO_2 concentrations were carried out for Mexico on April 17, 2019, where a minimum concentration of 36.56 ppm and a maximum of 283.02 ppm are observed (**Fig. 1**; **Table 2**).

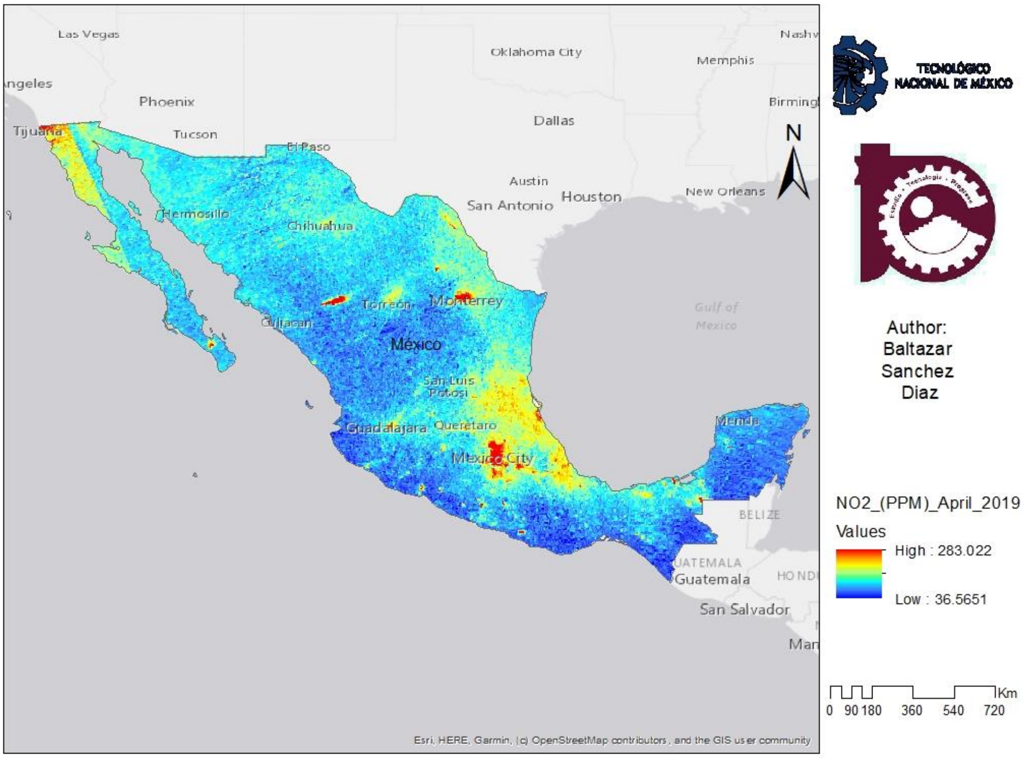

Fig. 1. Map of NO_2 concentrations for Mexico in April 2019.

The NO_2 concentrations were carried out for Mexico on April 30, 2020, where a minimum concentration of 23.87 ppm and a maximum of 222.32 ppm are observed (**Fig. 2**; **Table 3**).

Table 2.
Statistical data of NO2 concentrations in April 2019.

MIN:	36.565093994140625
MAX:	283.0219421386719
RANGE:	246.45684814453125
SUM:	5283191.383289337
MEAN:	66.98097498972231
STD_DEV:	10.810573086224124
SUM_OF_SQUARES:	9218002.184448304

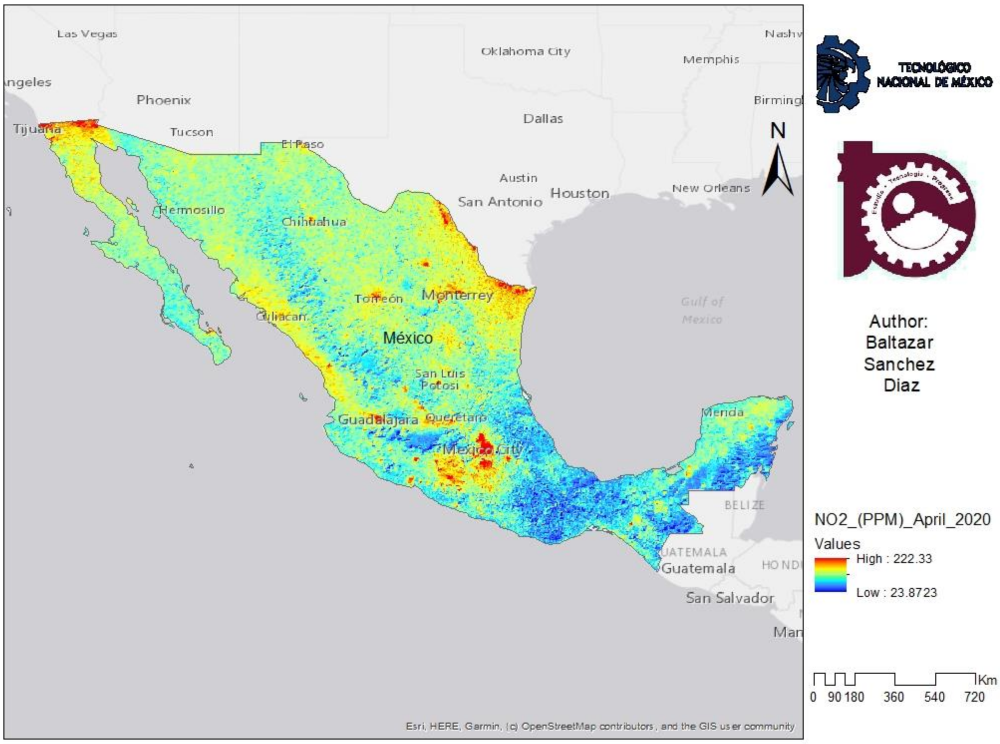

Fig. 2. Map of NO2 concentrations for Mexico in April 2020.

Table 3.
Statistical data of NO2 concentrations in April 2020.

MIN:	23.872339248657227
MAX:	222.3298797607422
RANGE:	198.45754051208496
SUM:	4548913.749929428
MEAN:	60.8249261225805
STD_DEV:	8.659350292238257
SUM_OF_SQUARES:	5607779.410914999

The NO2 concentrations were carried out for Mexico on April 17, 2023, where a minimum concentration of 19.72 ppm and a maximum of 259.95 ppm are observed (**Fig. 3**; **Table 4**).

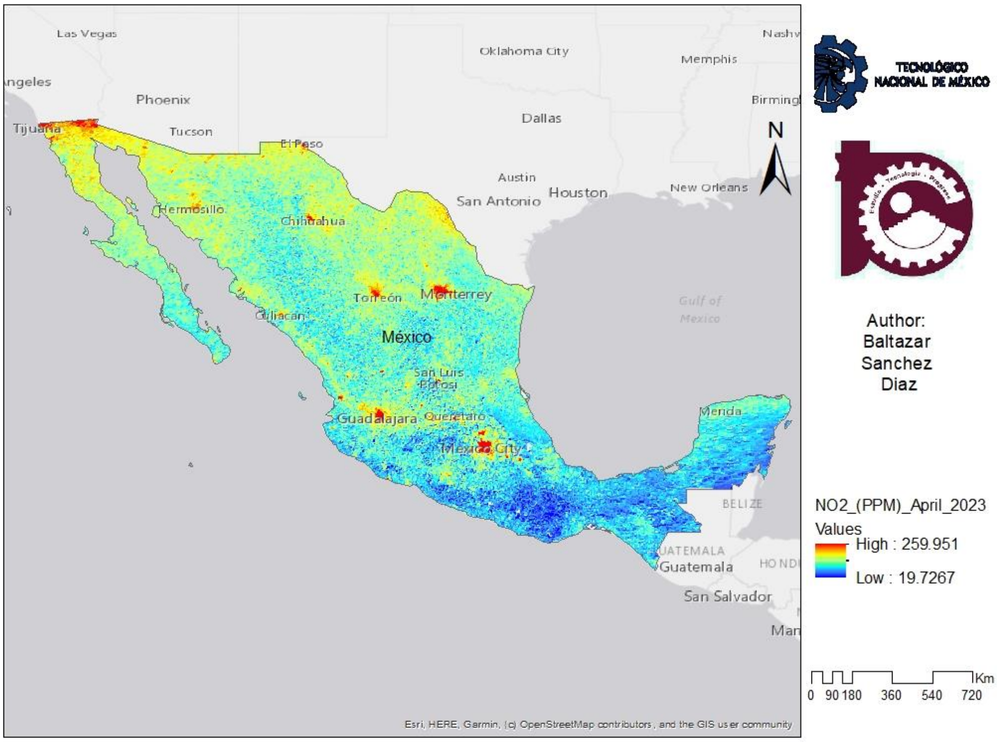

Fig. 3. Map of NO2 concentrations for Mexico in April 2023.

Table 4.
Statistical data of NO2 concentrations in April 2023.

MIN:	19.726686477661133
MAX:	259.950927734375
RANGE:	240.22424125671387
SUM:	4854318.655977249
MEAN:	60.084150113591065

5. DISCUSSION

In Mexico, from April 2019 to April 2020, NO_2 emissions decreased by 21.45%, although from April 2020 to April 2023 emissions increased by 14.48%, which our findings support that these measures temporarily reduced NO_2 levels. Once all sectors resume normally, the amount of NO_2 emissions appears to be picking up.

Similar behaviors were observed worldwide, the decreases during confinement were:

- 39.1 % for Buenos Aires in Argentina (Represa et al., 2021)
- 58 % for Sao Paulo in Brasil (Debone et al., 2020)

- 30% approximately in European countries such as Italy (Bassani et al., 2021), France (Kumar et al., 2020) and Spain (Cárcel-Carrasco et al., 2021)
- Decreases < -50% were mainly recorded in the greater Paris metropolitan area, in Alsace, and other locations of France (Kovacs, 2022)
- 30% in populated cities in China (Liu et al., 2021)
- 42% in India (Liu et al., 2021) but in cities like Delhi by 52.68% (Siddiqui et al., 2022)
- 34.9% on average in in western regions of the United States such as California, 31% in Los Angeles (Naeger and Murphy, 2020) and in southwestern United States (Dutta et al., 2021)
- the average NO_2 concentrations in Tabriz, Isfahan, and Mashhad in 2020 decreased by 19%, 13% and 17%, respectively, compared to those in 2019 (Shami et al., 2022)
- 9.5% throughout Thailand after the curfew was imposed, while in the Bangkok metropolitan area it decreased by 20.1% (Oo et al., 2021)
- in the capital of Ukraine, the monthly average of the tropospheric NO_2 column in April 2022 was almost 60% lower than in 2019 and 2021, and about 40% lower than in 2020 (Ialongo et al., 2023).

6. CONCLUSIONS

The confinement period represented a unique opportunity to examine the environmental environment and analyze the impacts derived from the reduction of various sources of emissions, as well as to evaluate the implementation of more rigorous air quality regulations and regulatory policies. This process demands global collaboration to develop more demanding regulatory standards and climate policies to achieve substantial improvements in air quality.

When the government relaxed confinement measures and the population resumed their daily activities, an increase in NO_2 concentration was observed, exceeding the levels recorded during the strict confinement period. In general, it has been found that the restrictions imposed during 2020 resulted in a decrease in NO_2 pollution. However, continuous data collection represents a considerable challenge for developing countries like Mexico, as it involves high costs and significant efforts. The Sentinel-5P mission provides a variety of continuous data that may be useful for monitoring air quality and pollution in Mexico. In the future, the use of Sentinel-5P and remote sensing analysis could be effectively deployed to monitor and control air pollution in the country.

Permanent or partial adoption of distance work and education, boosting e-commerce and promoting practices that increase energy efficiency and foster a low-carbon economy, along with investments in cleaner transportation alternatives, are suggestions to implement sustainable practices that reduce polluting emissions in urban areas. These measures can facilitate the transition towards urban resilience and sustainability.

The pandemic provided a valuable opportunity to discuss the effects of human activities on air quality and its impact on public health, highlighting the need for a socioeconomic transformation that promotes environmentally friendly transportation policies and a low-carbon economy. This would contribute to the construction of a sustainable and resilient society.

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