Trends of CO and NO\textsubscript{2} Pollutants in Iran during COVID-19 Pandemic Using Timeseries Sentinel-5 Images in Google Earth Engine

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Abstract: The first case of COVID-19 in Iran was reported on 19 February 2020, 1 month before the Nowruz holidays coincided with the global pandemic, leading to quarantine and lockdown. Many studies have shown that environmental pollutants were drastically reduced with the spread of this disease and the decline in industrial activities. Among these pollutants, nitrogen dioxide (NO\textsubscript{2}) and carbon monoxide (CO) are widely caused by anthropogenic and industrial activities. In this study, the changes in these pollutants in Iran and its four metropolises (i.e., Tehran, Mashhad, Isfahan, and Tabriz) in three periods from 11 March to 8 April 2019, 2020, and 2021 were investigated. To this end, timeseries of the Sentinel-5P TROPOMI and \textit{in situ} data within the Google Earth Engine (GEE) cloud-based platform were employed. It was observed that the results of the NO\textsubscript{2} derived from Sentinel-5P were in agreement with the \textit{in situ} data acquired from ground-based stations (average correlation coefficient = 0.7). Moreover, the results showed that the concentration of NO\textsubscript{2} and CO pollutants in 2020 (the first year of the COVID-19 pandemic) was 5% lower than in 2019, indicating the observance of quarantine rules, as well as people’s initial fear of the coronavirus. Contrarily, these pollutants in 2021 (the second year of the COVID-19 pandemic) were higher than those in 2020 by 5%, which could have been due to high vehicle traffic and a lack of serious policy- and law-making by the government to ban urban and interurban traffic. These findings are essential criteria that might be used to guide future manufacturing logistics, traffic planning and management, and environmental sustainability policies and plans. Furthermore, using the COVID-19 scenario and free satellite-derived data, it is now possible to investigate how harmful gas emissions influence air quality. These findings may also be helpful in making future strategic decisions on how to cope with the virus spread and lessen its negative social and economic consequences.

Keywords: Sentinel-5P; TROPOMI; air pollution; Google Earth Engine; COVID-19; Iran

1. Introduction

The COVID-19 pandemic has changed human activities on Earth, including social distancing, telecommuting, online shopping, and closure of public places, such as markets,
The direct association of COVID-19 with several factors, such as air pollution, the body immune system, and environmental impacts, is an example of current knowledge from the study of COVID-19 [3].

The first cases of coronavirus infection in Iran were reported on 19 February 2020 [4]. Outbreaks emerged in Asia, Europe, and other countries, and, by the end of March 2020, COVID-19 turned into a global pandemic [5]. As quarantine and lockdown started in many countries, a substantial decline in air pollution was reported due to the closure of factories and businesses, halting of industrial sectors, and reduction in transportation and traffic. These factors consequently resulted in a considerable drop in oil and fuel usage [2,5]. Studies conducted on COVID-19 [2,5–8] showed that exposure to air pollution could cause severe cardiovascular and respiratory problems. Therefore, there could be a potential relationship between air quality and COVID-19 [9–12].

A lockdown was imposed in Iran from 21 March 2020 to 21 April 2020 [13]. During this period, the country witnessed a massive decline in transportation, industrial, and business activities. Traffic was reduced by 73%, which resulted in a 50% reduction in gas consumption in Tehran, the capital city of Iran [14].

Extensive studies have been conducted worldwide to analyze the impact of coronavirus spread on air pollution. For example, the effects of pollutant change due to the decline in anthropogenic activities as a result of COVID-19 have been investigated in the US [2,15,16], England [12,17], Italy [18,19], Spain [20–23], India [24–27], South Korea [28], China [9,10,29,30], the Netherlands [31], Canada [32], France [33], Brazil [34,35], Asia [36,37], Europe [38,39], and worldwide [1,5,40–43]. Some of these studies are detailed in Table 1.

In addition to these studies, as mentioned above, some others focused on modeling the relationship between air pollution and COVID-19-related deaths using advanced machine learning methods. For example, artificial neural networks (ANNs) were used to model the relationship between air pollution and COVID-19 mortality for three French cities [33]. In [44], two different approaches (i.e., timeseries and ML methods) were employed for modeling the relationship among pollution (PM$_{2.5}$, NO$_2$, CO$_2$), economic growth, and COVID-19 deaths in India. In a comprehensive study [45], a GIS-based spatial approach was developed to model county-level variations of COVID-19 incidence across the continental United States. Furthermore, Marinello et al. [46] conducted a comprehensive review of the recent scientific literature to determine the effect of lockdown on human activities and air quality.

Some studies have also assessed the impact of the COVID-19 pandemic on air pollution in Iran. For example, Kaviani Rad et al. [14] studied air pollutants in the first and second waves of the disease in Tehran over 40 days from 1 March to 9 April 2020. Their results showed that the amounts of carbon monoxide (CO), nitrogen dioxide (NO$_2$), PM$_{10}$, and PM$_{2.5}$ pollutants decreased, while SO$_2$ and O$_3$ pollutants increased from 1 March to 9 April 2020, compared to the same period in 2019 [14]. In [13], a variety of environmental pollutants such as O$_3$, NO$_2$, SO$_2$, CO, PM$_{10}$, and PM$_{2.5}$ were monitored using data derived from 12 ground stations from 21 March to 21 April in 2019 and 2020. The results showed that, except for O$_3$ and PM$_{2.5}$, the average concentrations of pollutants were decreased. The concentrations of these pollutants were also measured using 21 monitoring stations in three time periods (23 February 2020 to 15 March 2020, 18 March 18 2020 to 3 April 2020, and 5 April 2020, to 17 April 2020) for Tehran during the pandemic [47]. This study showed a significant reduction in CO and NO$_2$ among pollutants in the lockdown period due to lower traffic. Moreover, the main pollutants, including PM$_{2.5}$, PM$_{10}$, NO$_2$, SO$_2$, O$_3$, and CO, were inspected from 1 January to 30 July 2016 to 2020 to demonstrate the relationship lockdown and trend of pollutants in a part of Tehran [48]. The results showed that the concentration of all pollutants, especially O$_3$, increased after the lockdown period, with the removal of traffic control plans as the leading cause.
Table 1. The details of some studies on the impact of COVID-19 lockdowns on reducing air pollution.

| Source | Study Area | Period | Atmospheric Gases Studied | Data | Variations in Concentrations |
|--------|------------|--------|---------------------------|------|------------------------------|
| [2]    | US         | 2017–2020 | NO₂, PM₂.₅             | Air quality station | A 25.5% reduction with an absolute decrease of 4.8 ppb PM₂.₅. |
| [16]   | US         | 2019–2020 | NO₂                   | Sentinel-5 (TROPOMI) | The concentration of NO₂ reduced by 20–40% in California during the COVID-19 lockdown. |
| [12]   | England    | 2018–2019 | PM₂.₅, NO₂, NO, and O₃ | Air quality station | An increase of 1 m² in the long-term average of PM₂.₅ was associated with a 12% increase in COVID-19 cases. |
| [18]   | Italy      | 2010–2020 | NO₂, O₂, PM₁₀/PM₂.₅   | Air quality station | Long-term air-quality data correlate with COVID-19 in the Italian provinces. |
| [22]   | Spain      | 2019–2020 | NO₂, PM₁₀             | Sentinel-5 (TROPOMI) | After the lockdown, the PM₁₀ was reduced by 86.89%, 70%, 86.8%, and 87.8%, respectively, in Valencia, Madrid, Barcelona, Sevilla, and Bilbao. The same tendency was shown for NO₂. |
| [24]   | India      | 2020     | NO₂                   | Sentinel-5 (TROPOMI) | The NO₂ value decreased by 40–50% in Mumbai and Delhi compared to the previous year. |
| [28]   | Korea      | 2020     | NO₂, CO, PM₁₀/PM₂.₅   | Air quality station | In March 2020, the mean levels of PM₂.₅, PM₁₀, NO₂, and CO were decreased by 16.98 µg/m³, 21.61 µg/m³, 4.16 ppb, and 0.09 ppm compared to the same period of the previous year. |
| [9]    | China      | 2020     | NO₂, SO₂, CO, O₃, PM₂.₅/PM₁₀ | Online platform and meteorological data | After lockdown, the PM₂.₅, PM₁₀, NO₂, and O₃ increased by 10 µg/m³. |
| [30]   | China      | 2017–2020 | NO₂, SO₂, CO, O₃, PM₂.₅/PM₁₀, AOD | Sentinel-5 (TROPOMI), MODIS | After the Spring Festival, the NO₂ and SO₂ concentrations decreased, and then began to increase after a few days, except in 2020 when they remained low. CO, PM₂.₅, and PM₁₀ concentrations also decreased during the Spring Festival, but not as much as SO₂ concentrations. |
| [32]   | Canada     | 2015–2020 | NO₂, O₃, PM₂.₅         | Air quality station | There is some evidence that ozone concentrations are decreasing. The concentrations of nitrogen dioxide and nitrogen oxides appear to be declining. |
| [34]   | Brazil     | 2019–2020 | NO₂, PM₂.₅/PM₁₀       | Sentinel-5 (TROPOMI) | The PM₂.₅, PM₁₀, and NO₂ levels were reduced by 45%, 46%, and 58%, respectively, compared to the control period in 2019. |

Although these studies thoroughly investigated the relationship between air pollutants and COVID-19 in Iran, they mainly focused on the capital of Iran (i.e., Tehran) and used only ground station data, which are not available in most cities of Iran. Moreover, ground station measurements are sparsely distributed in Iran and are sometimes unable to record data, resulting in potential difficulty in spatiotemporal analysis [49]. To address these...
issues, some studies have been conducted to investigate the effects of COVID-19 spread on air pollution using Sentinel-5P Tropospheric Monitoring Instrument (TROPOMI) data. The accuracy of the results obtained from the TROPOMI sensor has been confirmed in several recent studies. For example, in a study in Helsinki, Finland [50], a correlation coefficient of 0.68 was obtained between the results of satellite-based TROPOMI NO2 and ground observations. Correlation coefficients of 0.44 and 0.75 for Frankfurt and Barcelona were also obtained in another research [51]. This indicates that this sensor has a high potential for accurately estimating air pollutants, especially large-scale NO2 concentrations. Several studies have also used the Sentinel 5P data to clarify the relationship between air pollutants and COVID-19 lockdown. For instance, the relationship between COVID-19 lockdown and air pollutants was analyzed in Tehran through processing multitemporal Sentinel-5P data within the Google Earth Engine (GEE) [52]. In a subsequent study [49], the accuracy of the predictive models was improved for analyzing the COVID-19 effects on the air pollutants in Iran using timeseries analysis of remote sensing (RS) data (e.g., Terra Moderate Resolution Imaging Spectroradiometer (MODIS), Sentinel-5 Precursor (Sentinel-5P), Global Precipitation Measurement (GPM), Soil Moisture Active Passive (SMAP), National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR), and Global Land Data Assimilation System (GLDAS)).

Although such studies generated valuable information for public health decision-makers and showed the importance of the RS data in monitoring air pollutants in Iran, their exact lockdown period was not studied. Therefore, in this study, we aimed to explore in detail the effect of the temporal and spatial distributions of CO and NO2 pollutants produced by vehicles and urban traffic using Sentinel-5P data. The analyses were conducted in Iran (in the four cities of Tehran, Tabriz, Isfahan, and Mashhad) in three years of 2019 (1 year before the outbreak), 2020 (start of the outbreak), and 2021 (1 year after the outbreak).

2. Materials and Methods

2.1. Study Area

The study area (see Figure 1) was Iran (within 25°3′ to 39°47′ latitude and 44°5′ to 63°18′ longitude), the second most populated country in the Middle East area, with a population of more than 83 million. Among its cities, Tehran, Mashhad, Isfahan, and Tabriz are the highest populated cities with 9, 3, 2, and 1.5 million people, respectively. A detailed investigation of the effect of the COVID-19 pandemic on the concentration of pollutants was mainly conducted over these metropolises.

2.2. Datasets

In this study, the open-access Sentinel-5P satellite data were used to monitor Iran’s air pollutants during the COVID-19 pandemic. The European Space Agency (ESA) launched the Sentinel-5P satellite on 13 October 2017, following its program for daily environment monitoring and analyzing air pollutants throughout the planet. One of the missions of Sentinel-5P is monitoring atmospheric gases, such as NO2, CO, sulfur dioxide (SO2), ozone (O3), formaldehyde (CH2O), methane (CH4), and aerosol using the TROPOMI sensor [53]. NO2 is emitted into the atmosphere as a result of anthropogenic activities (e.g., combustion of fossil fuels and biomass burning) and natural processes (e.g., microbiological processes in soil, firing, and lightning) [7,38]. CO is also a result of the incomplete combustion of carbon-containing fuels, such as oil and natural gas. Both pollutants negatively affect human health and the environment in general, which is why these pollutants were selected for this study.

The NO2 and CO products derived from Sentinel-5P data collected between 11 March and 8 April in 2019, 2020, and 2020 were used in this study (Table 2). This selected period starts a few days before the Iranian new year holidays (Nowruz) and ends several days after Nowruz, during which people do their new year’s shopping, travel, and get together.
Figure 1. The study area and the selected cities (Tehran, Mashhad, Isfahan, and Tabriz) for assessing the effects of COVID-19 spread on air pollution.

Table 2. The detail of the Sentinel-5P TROPOMI products used in this study.

| TROPOMI Products                                      | Processing Levels | Unit  | Pixel Size | Source                                      |
|-------------------------------------------------------|-------------------|-------|------------|---------------------------------------------|
| nitrogendioxide_tropospheric_column_count             | Level 2           | mol   | 0.01 arc degrees | Sentinel-5 variables                        |
| carbonmonoside_total_column_count                     | Level 2           | mol   | 0.01 arc degrees | https://developers.google.com/earth-engine/datasets/tags/tropomi (accessed on 10 January 2022) |

In addition, the data from 19 ground-based stations in Tehran were used to compare the NO$_2$ results obtained from the Sentinel-5 satellite.

Changes in the number of cases and deaths due to COVID-19 for March/April 2020 and March/April 2021 were studied using data provided by the Ministry of Health of Iran for the whole country.

2.3. Data Processing Methodology

As mentioned before, the NO$_2$ and CO distribution patterns were investigated using Sentinel-5P TROPOMI products in the period as previously defined. Overall, the processing and analyses were conducted in Google Earth Engine (GEE) through the method illustrated in Figure 2. The GEE was launched by Google in 2010 for cataloging and processing a wide variety of Earth observation data in a cost- and time-efficient manner [54–57]. This platform is precious when the objective is to process big open-access Earth observation data over a large area and within a long time [58,59].

According to Figure 2, the Sentinel-5P data were first converted from level 2 to level 3 through the harpconvert tool by bin_spatial operation [54]. Then, after applying the spatial and temporal filters, NO$_2$ and CO products from the study area were generated. It is worth noting that the products were filtered to remove pixels with values less than 75% and 50% quality assurance (QA) for NO$_2$ and CO, respectively [60].

After processing the data, two types of outputs, including maps and statistical reports of the pollutants, were produced. In situ data obtained from the ground-based air pollution stations were used to verify the produced results.
3. Results and Discussion

In this section, the results of the experiments are presented in two subsections. First, the concentrations of NO$_2$ and CO during the COVID-19 pandemic were examined to investigate the impact of quarantine and traffic ban. In the second subsection, the values obtained in Tehran were compared with the corresponding values in 19 ground-based air monitoring stations to validate the remote sensing results.

3.1. Spatiotemporal Distribution of the NO$_2$ and CO

The results of the spatiotemporal distribution of NO$_2$ and CO in Iran and, more specifically, over Tehran, Tabriz, Isfahan, and Mashhad, are demonstrated in Figures 3–6.

According to Figures 3 and 4, the NO$_2$ concentration in 2021 (the second year of the COVID-19 pandemic) was similar to that in 2019 (before the start of the pandemic) on some days (e.g., 23–30 March). Its values were even higher in 2021 than in 2019 on several days (e.g., 4–8 April). This might be due to the fact that the necessary and practical measures of reducing traffic and shutting down businesses during the pandemic in 2021 were not effectively implemented. On the other hand, the NO$_2$ concentration throughout Iran during the March/April period in 2020 decreased by an average of 5% compared to 2019 and 2021. This result can be mainly due to the strict regulations and actions adopted by the government to reduce traffic between 20 to 31 March 2020 (coinciding with the Nowruz holidays) and the closure of many industrial and business sectors, as well as the high panic of people in the initial encounter with the coronavirus (see Figure 4).

The concentration of this pollutant in the four cities in these three periods was not the same. For example, the trend of NO$_2$ concentration in Tehran during the Nowruz holidays in 2019, 2020, and 2021 did not considerably change. However, after the Nowruz holidays (4–10 April), NO$_2$ concentration was significantly increased compared to the same period in 2019 and 2020 (See Figure 4). This can be due to the acceleration of businesses and the influx of many employees from other cities to Tehran. On the other hand, the trend of
NO2 concentration in the other three cities was different from Tehran. For instance, the average NO2 concentrations in Tabriz, Isfahan, and Mashhad in 2020 were decreased by 19%, 13%, and 17%, respectively, compared to those in 2019. However, the concentration of this pollutant was increased in 2021 in all three cities. This might have mainly been due to the increased gathering and parties in Nowruz, as well as the increase in travel to these cities during the 2021 Nowruz holidays. Moreover, the role of wrong policymaking of the government in the implementation of the inter-provincial traffic ban during Nowruz 2021 should not be ignored.

Figure 3. The comparative representations of the 30 day (11 March–8 April) average value of NO2 over the entire country of Iran and its four districts (Tehran, Tabriz, Isfahan, and Mashhad) in (a) 2019, (b) 2020, and (c) 2021.

According to Figures 5 and 6, the concentrations of CO in 2019, 2020, and 2021 in Iran’s northern and southern parts were greater than in other regions. The results showed that the average concentration of this pollutant in the country in each of these 3 years was approximately 0.029 mol/m². A nationwide analysis of the CO timeseries data showed that the level of this pollutant was significantly increased from 23 March to 5 April 2021 compared to the same period in 2019 and 2020, ranging between 0.03 to 0.035 mol/m² (See Figure 6). These results corresponded well with those of NO2 and indicated the high
volume of vehicles and the traffic ban violation during the COVID-19 pandemic in the 2021 Nowruz holidays.

Figure 4. The trend of NO$_2$ over (a) Iran, (b) Tehran, (c) Tabriz, (d) Isfahan, and (e) Mashhad for the 30 day period (11 March–8 April).

On a local scale, the concentration of the CO pollutant in the period of 2021 in the three cities of Tabriz, Isfahan, and Mashhad significantly increased compared to 2020 and 2019. This might be because these cities welcome many tourists every year during the Nowruz holidays due to their rich historical and leisure attractions. During Nowruz 2021, many people from Tehran and other cities traveled to these three cities because of the lack of a specific law on traffic ban, paving the way for the widespread outbreak of COVID-19 and the beginning of its fourth peak in Iran (See Figure 6). In Isfahan, the average CO concentration from 10 March to 10 April 2021 increased by approximately 7% compared to the same period in 2019 and 2020. Although the average concentration of CO in Tehran in 2021 increased by 8% compared to 2020, this amount did not significantly change compared to the same period in 2019. In general, the concentration of this pollutant in all four cities in 2020 significantly decreased compared to that in 2021 and 2019, confirming the observance of the traffic ban and quarantine during Nowruz 2020 by people. Furthermore, it showed
that the government improved the implementation of sound policies (telecommuting, prohibiting traffic, and locking down the parks, public, and leisure places).

Figure 5. The comparative representations of the 30 day average CO over Iran (left column) and its four districts (Tehran, Tabriz, Isfahan, and Mashhad) (right column) during the period 11 March to 8 April in (a) 2019, (b) 2020, and (c) 2021.

To be more specific, the difference in the daily NO$_2$ amount during March/April 2020 from the same period in 2019 in Iran and its four major cities is shown in the first row of Figure 7. If the daily NO$_2$ value during March/April 2020 is higher than the same period in 2019, the chart of that day is positive, whereas, if it is lower, the chart of that day is negative. The difference between the daily NO$_2$ for the whole country of Iran during the mentioned period in 2020 and 2019 shows that the chart was negative on 23 days and positive on 6 days. In other words, the amount of NO$_2$ in 2020 was less than in 2019 on 23 days, indicating a decrease in air pollution in the first year of the coronavirus pandemic in Iran. The four major cities also experienced more negative days than positive days, indicating a decrease in pollution levels in 2020 compared to the same period in 2019.

In addition, the study of the difference between the daily NO$_2$ amount during March/April 2021 from the same period in 2020 in the middle row of Figure 7 shows that, unlike the first-row diagrams, the number of positive days was greater than the number of negative days. In other words, the daily NO$_2$ concentration during March/April 2021
was higher than the same period in 2020. Thus, for the whole country of Iran, 20 positive days and eight negative days were recorded. More positive days were recorded for large cities in Iran than negative days. Thus, the daily NO\(_2\) content for most days studied during March/April 2021 was higher than the same period in 2020.

![Graph](image)

**Figure 6.** The trend of CO over (a) Iran, (b) Tehran, (c) Tabriz, (d) Isfahan, and (e) Mashhad for the 30 day period (11 March–8 April).

The difference between the daily NO\(_2\) levels during March/April 2021 from the same period in 2019 is shown in the last row of Figure 7. The number of positive days in the third-row diagrams shows that, in the second year of the coronavirus pandemic in Iran, on some days, the amount of NO\(_2\) per day was even higher than in 2019 when there was no pandemic. In other words, in 2021, air pollution increased, and no restrictions or quarantines were observed.

The difference in the daily amount of CO during March/April 2020 from the same period in 2019 in Iran and its four major cities is shown in the first row of Figure 8 with the same logic in Figure 7. The difference between the daily amount of CO for the whole country of Iran during 2020 and 2019 shows that the chart was negative on 10 days and
positive on 18 days. Specifically, the amount of CO in 2020 was higher than in 2019 on 18 days, indicating an increase in the amount of CO in the first year of the coronavirus pandemic in Iran. The four big cities also had almost the same number of negative days as the number of positive days, indicating an increase in CO in 2020 compared to the same period in 2019. In contrast to NO\textsubscript{2}, CO in 2020 did not decrease compared to the same period in 2019 in Iran.

**Figure 7.** The difference charts of the daily NO\textsubscript{2} amount during March/April 2020–2019 (**first row**), 2021–2020 (**middle row**), and **last row** (2021–2019).

**Figure 8.** The difference charts of the daily CO amount during March/April 2020–2019 (**first row**), 2021–2020 (**middle row**), and **last row** (2021–2019).
In addition, the study of the difference in the daily amount of CO during March/April 2021 from the same period in 2020, in the second row of Figure 8, shows that the number of positive days was greater than the number of negative days. Strictly speaking, the daily amount of CO during March/April 2021 was higher than the same period in 2020. Thus, for the whole country of Iran, 22 positive days and seven negative days were recorded. More positive days were recorded for large cities in Iran than negative days. Thus, the daily CO for most days of March/April 2021 was higher than the same period in 2020, indicating that air pollution was higher.

The difference in daily CO amount during March/April 2021 from the same period in 2019 is shown in the third row of Figure 8. The number of positive days in the third-row diagrams shows that, in the second year of the coronavirus in Iran, daily CO was even higher than in 2019 when there was no COVID-19 pandemic. In other words, in 2021, air pollution increased, and no restrictions or quarantines were put into effect.

3.2. Sentinel-5P NO\textsubscript{2} vs. Ground-Based Measurements

The reported CO data from the selected ground stations had many gaps and, therefore, only the \textit{in situ} measurements of NO\textsubscript{2} were used in this study. In this regard, due to the high importance of Tehran as the capital of Iran and the existence of a large number of ground stations with appropriate distribution, the stations of this city were used as a basis for verification. For this purpose, NO\textsubscript{2} concentration from 19 ground stations in Tehran between 11 March and 8 April in 2019, 2020, and 2021 was acquired. Then, the correlation between these \textit{in situ} data and those obtained from the TROPOMI sensor was investigated, and the results are demonstrated in Figure 9. As shown in Figure 9, the lowest and highest correlation coefficients were 0.36 and 0.86, obtained at the S5 and S17 stations in 2019 and 2021, respectively. Moreover, the average correlation coefficients in most stations in Tehran were higher than 0.6, indicating the high potential of the TROPOMI sensor for NO\textsubscript{2} estimation.

![Figure 9. The location of the NO\textsubscript{2} ground stations in Tehran and the correlation coefficients obtained by comparing their \textit{in situ} measurements with those of the Sentinel-5P.](image-url)
4. Conclusions

In this study, the effect of quarantine and traffic reduction on CO and NO$_2$ pollutant concentration during the COVID-19 pandemic in Iran was investigated. To this end, timeseries data of Sentinel-5P/TROPOMI were analyzed in GEE. The results showed that the TROPOMI sensor with consistent data had acceptable accuracy in estimating NO$_2$ pollutants for Iran. Analysis of the Sentinel-5P NO$_2$ and CO data during the Nowruz holidays in 2019, 2020, and 2021 showed that these pollutants in 2021 were 5% higher than in 2020. This could be due to high vehicle traffic and the government’s failure to consider serious policies and laws to ban urban and interurban traffic.

On the contrary, the NO$_2$ and CO pollutant concentrations during Nowruz 2020 were 5% lower than those of 2019. The reduction in the amount of these pollutants in 2020 compared to 2019 indicated the observance of quarantine rules, as well as people’s initial fear of getting infected with the disease. Furthermore, the timeseries analysis of NO$_2$ and CO pollutants during Nowruz 2020 and 2021 showed an increase in air pollutants, indicating higher urban and interurban traffic. Therefore, 2021 witnessed an increase in NO$_2$ and CO pollutants compared to the same period in the last 2 years.

Sentinel-5P data enabled the present study with in-depth analysis and more accurate results of air pollution during the COVID-19 pandemic in Iran. On the other hand, with the help of Sentinel-5 sensor data, air pollution changes in areas that do not have ground stations can be studied well and on a daily basis. It is also possible to study the relationship between changes in air pollution and the cases and mortality of coronavirus due to the impact of air pollution on public health and the direct impact of air pollution on respiratory diseases. Additionally, traffic and transportation can be better controlled by assessing air pollution and identifying busy places. In other words, this study shows that air pollution in urban areas can be reduced if appropriate policies are implemented to control traffic due to transportation and vehicle traffic, such as the quarantine period during the COVID-19 pandemic.

These findings are crucial criteria that might be utilized to drive future policies and strategies in factory logistics, traffic planning and management, and environmental sustainability. Furthermore, the COVID-19 scenario, together with free satellite-derived data, makes it feasible to examine how polluting emissions affect air quality. These results also can be helpful to adopt future strategic decisions to deal with the spread of the virus and mitigate its adverse welfare and economic effects.

This study was conducted only with Sentinel-5P products, but other factors (e.g., winds and rainfall) could have resulted in different air pollution levels for the 3 years. Therefore, the results of this study will be further improved regarding wind and rainfall data in addition to satellite data. The integration of ground station data with satellite data can be adopted to obtain more reasonable results for spatiotemporal air quality monitoring.

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