

Using Artificial Intelligence Techniques during the COVID-19 Pandemic to Monitor Nitrogen Dioxide (NO₂) Gas in Kirkuk Governorate

Yousif Nazzal Hosee

Department of Environment, College of Engineering, Tikrit University, Iraq

Nada Waleed Hammuod

Tikrit Education Department, Salah al-Din Education Directorate, Ministry of Education, Iraq

Ali Issam Mamdooh, Umer Jameel Ibrahim

Department of Biology, College of Science, Tikrit University, Iraq

Abstract: Artificial intelligence (AI) has become a valuable tool in the field of air pollution monitoring. By leveraging AI technologies, researchers and authorities can collect and analyze large amounts of data to gain insights into air quality, predict pollutant levels, and assess environmental and health risks. Analysis of data from NASA's Sentinel-P5 satellite revealed a significant decrease in nitrogen dioxide levels in Kirkuk Governorate during the COVID-19 pandemic. The study examined climate conditions and the spread of nitrogen dioxide in the governorate throughout 2020, and divided the analysis into different stages. The first phase included the months from January to February, which is a curfew-free period. The second phase, which extended from March to June, represented the period in which the full and partial curfew was in effect. The third phase, which began in July, included lifting the comprehensive curfew in the governorate. Maps of the spatial distribution of nitrogen dioxide clearly show a significant reduction in the dispersion of nitrogen gas in the air. This decrease can be attributed to the measures implemented by Iraq and Kirkuk Governorate to combat the spread of the Coronavirus. These measures, including closures and travel restrictions after the World Health Organization declared the Corona virus a global pandemic, led to a decrease in nitrogen dioxide emissions due to the decrease in energy demand resulting from citizens remaining in their homes and limited movement between governorates.

Key points: Artificial Intelligence Techniques, COVID-19, Monitor Nitrogen Dioxide.

Introduction

Artificial intelligence techniques are widely used in monitoring air pollution. The use of artificial intelligence can analyze data on atmospheric pollutant concentrations and predict future changes in air quality. This data is collected from air quality monitoring stations, satellites, mobile devices and other sources. This data is analyzed using artificial intelligence to identify models, trends, and forecast air pollution (En Xin Neo *et al.*, 2023).

Nitrogen dioxide, a major and widespread air pollutant, is actively monitored by artificial intelligence, especially through the Sentinel-P5 satellite system. Inhalation of nitrogen dioxide can cause poisoning. Although traffic emissions are the main source of NO_x, power plants and some industrial activities also contribute to its presence, although to a lesser extent. Emissions from industrial sites and power plants often exceed those recorded at monitoring stations, aggravating the

spread of pollutants into the atmosphere. Urban residents face a higher risk of exposure to nitrogen oxide gases. Given this scenario, traffic emissions emerge as the main source of NO_2 . The use of artificial intelligence technologies to monitor air pollution improves the ability to predict pollutant concentrations, understand their impact on public health and the environment, and make informed decisions. These technologies play a crucial role in facilitating better decision-making and formulating strategies to mitigate and control air pollution effectively.

The Problem of study: Kirkuk Governorate suffers from a rise in nitrogen dioxide in the air due to human activity, especially when gasoline is burned in vehicles, cars, and power-generating devices in electric power generation stations. The presence of nitrogen dioxide in the atmospheric air leads to many diseases of the respiratory system and cardiovascular diseases, and since the new coronavirus infects the respiratory system, which allows it to be assumed that there is a link between air pollution and the death rate from the emerging coronavirus.

Study hypothesis: The measures implemented by Iraq as a whole, specifically Kirkuk Governorate, to limit the spread of the Corona virus, had a noticeable impact on energy demand. This is mainly due to the majority of citizens' compliance with the stay-at-home directives and restrictions on movement between governorates resulting from the governorate's lockdown. These measures were adopted in all Iraqi governorates after the World Health Organization declared the Corona virus a global pandemic. As a result, there has been a decrease in energy consumption rates, especially in the transportation sector. However, the lack of data on nitrogen emissions during this period made it difficult to determine the precise effects of declining emission levels.

The importance of studying:

1. Monitoring air pollution with nitrogen dioxide gas and knowing its spatial distribution in Kirkuk Governorate.
2. Knowing the relationship between COVID-19 and nitrogen dioxide.

Location of the study Area: Kirkuk Governorate is located in the northern part of Iraq, within the semi-mountainous region between longitudes ($18^\circ 43' - 47^\circ 44'$) east, and latitudes ($50^\circ 34' - 53^\circ 35'$) north. It is bordered to the north and northwest by Erbil Governorate, to the west by Mosul Governorate, and from the eastern side is bordered by both Sulaymaniyah and Salah al-Din Governorates, and the southern and southwestern sides are bordered by the Salah al-Din Governorate. Figure (1):

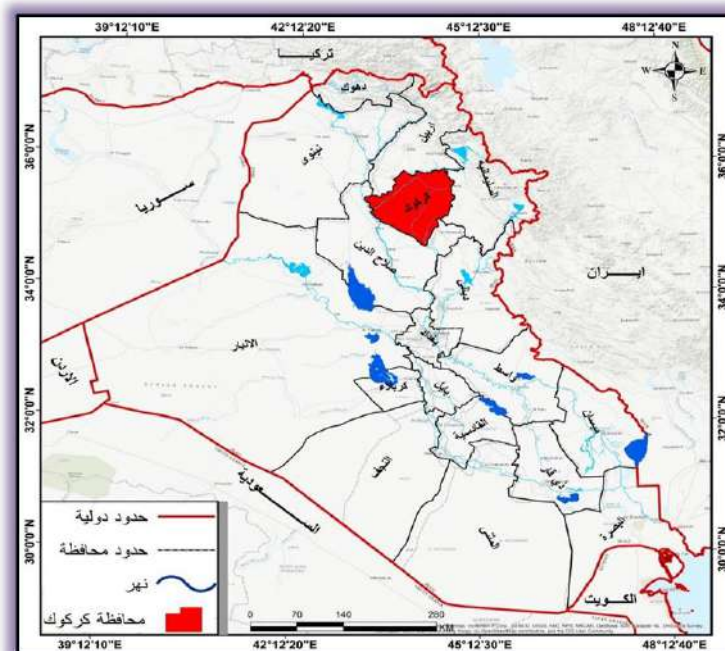


Figure (1) Location of the study area

Materials and methods of work:

1- Tropomi sensor: The Sentinel-p5 satellite uses artificial intelligence techniques. The satellite carries the Tropomi as a spectrograph in the ultraviolet, visible, near, and short infrared. The device maps several gases that affect air quality, our health, and our climate, Artificial intelligence is used to analyze the data collected by the device to determine concentrations of air pollutants and monitor air quality. This information can be used to make better decisions concerning monitoring and improving air quality and developing strategies to deal with air pollution.

The satellite operates in a sun-synchronous orbit and maps many air pollutants around the world. Following its launch in 2017 and subsequent calibration periods, Sentinel-5P reached routine operations in early 2019. ESA (European Space Agency) has since made available the final set of Level 2 atmospheric gas data products providing coverage daily from around the planet. Earth at a resolution of 7 x 7 km, Figure 2 and Table 1.

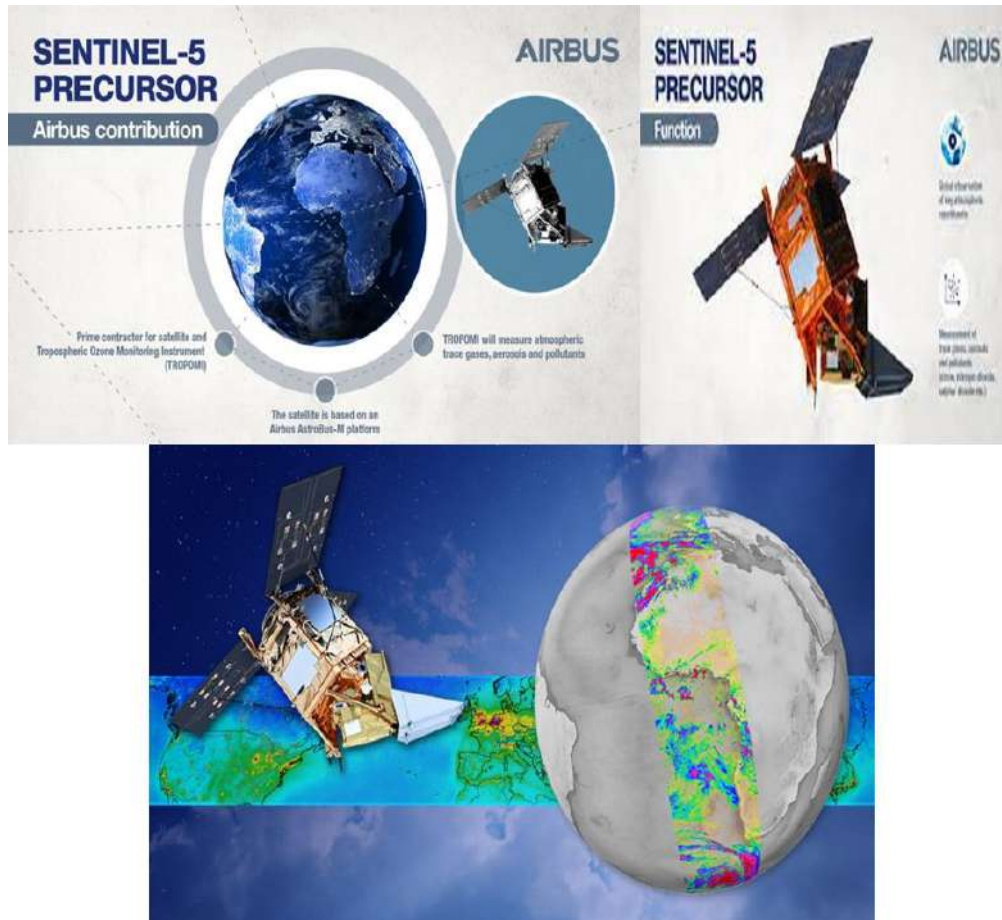


Figure (2): Tropomi sensor in 5 Sentinel-P.

Table (1): Tropome dataset specifications.

Temporal coverage	Since 01-07-2021. From May 1, 2018 to November 14, 2021 (see the “How to access this data” section below). Reprocessed dataset (RPRO): 04-30-2018 to 07-25-2022
Spatial coverage	~ 2600 km of strip. Complete daily surface coverage of radiation and reflectance measurements for latitudes >7° and <-7°, and >95% coverage for latitudes in the range [-7°, 7°].
Spatial resolution	3.5 x 7.0 km (along the runway), at the start of the mission 3.5 x 5.5 km (per x per track), as of August 6, 2019
Processor Version	02.xx.xx, with x=any number between 0 and 9

2- Nitrogen dioxide: Nitrogen, a prevalent environmental pollutant, is a major contributor to global warming. Nitrogen dioxide (NO₂) and nitrogen oxide (NO) are usually grouped as nitrogen oxides

(NO_x = NO + NO₂), minor gases in the atmosphere. These compounds are introduced into the atmosphere through various human activities, particularly the burning of fossil fuels, the burning of biomass and natural processes such as microbiological activities in the soil, forest fires and lightning. During daylight hours, under the influence of sunlight, a photochemical process involving ozone (O₃) facilitates the conversion of nitrogen oxide into nitrogen oxide (NO₂) and vice versa in a matter of minutes. As a result, NO₂ is a strong indicator of NO levels. Nitrogen dioxide concentrations in both the troposphere and stratosphere are monitored worldwide using a variety of instruments, including ground-based instruments, in situ techniques (such as those from balloons or airplanes), and satellite systems.

3- The dangers of nitrogen oxide gas: Nitrogen oxide gas of all kinds is considered poisonous and harmful. This gas can lead to eye and respiratory irritation, while long-term exposure to it leads to cardiovascular or pulmonary diseases. Urban residents are more at risk from inhaling nitrogen oxide gases. Gases also have a harmful effect on animals, plants and soil. Nitrogen oxide gases are unwanted byproducts in cars combustion engines - especially diesel engines - and are also in the case when burning coal, oil, gas, wood and waste. Air pollution causes more than 400,000 premature deaths annually in the European Union, in addition to those who suffer from respiratory and cardiovascular diseases, which costs the Union's economy more than 20 billion euros every year, according to the Commission ⁽²⁾.

4- Temporal and spatial analysis of nitrogen dioxide concentration in Kirkuk Governorate: When comparing nitrogen dioxide concentrations in Kirkuk Governorate before the Corona pandemic (Covid-19), that is, through the increase of human activities during this period from January to February, with the severe spread of the virus and the decrease in human activities from March to June 2020, the third period is the period of lifting curfew from July to the present time.

➤ **The first period:** This period represents the period of absence of roaming urbanites in the governorate, which extends from January to February, with three monitoring processes per month to determine the spread of nitrogen dioxide in the governorate. It is clear from Figure (3) that the percentage of nitrogen dioxide gas increases in the governorate. The reason for this is the lack of a curfew in the governorate, as all human activities that pollute the air carry out their work in the governorate. In addition to traffic, the governorate faces traffic congestion resulting from the large number of cars, as the largest percentage of nitrogen dioxide emission is concentrated in the northern and southern parts of the governorate, represented in the centers of districts and areas that are witnessing population momentum as well as human activities.

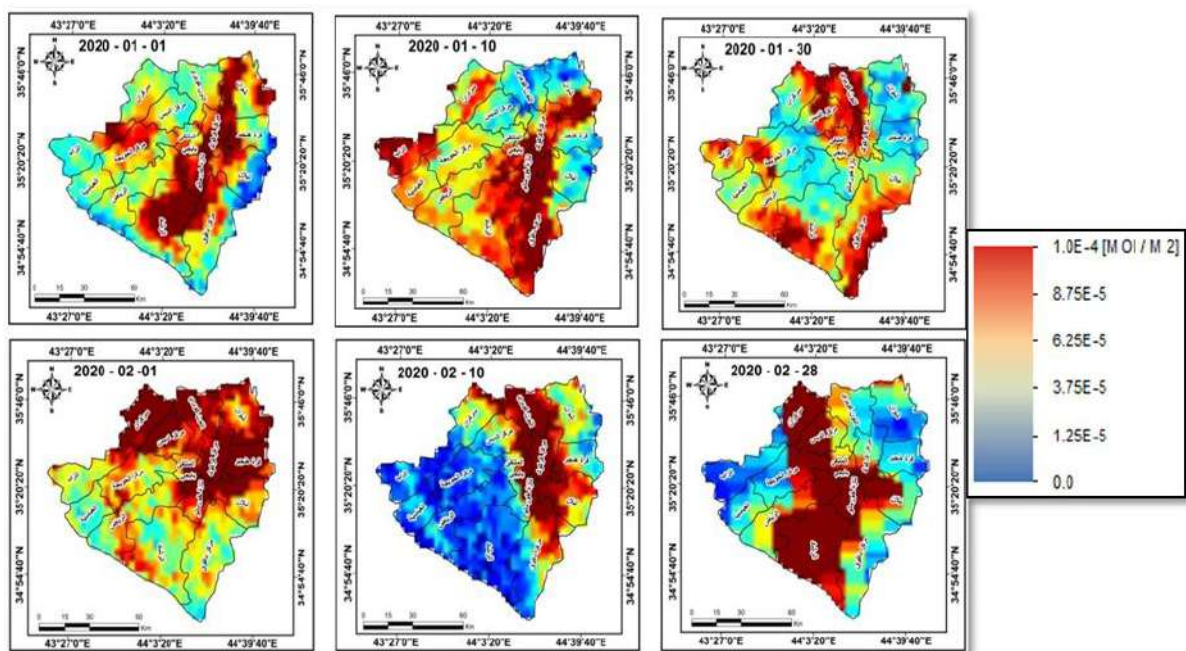


Figure (3) Nitrogen dioxide emission rate before the curfew

- **The second period:** This period is represented by the presence of total and partial curfew in the governorate as a result of the spread of the Covid-19 epidemic. This period extends from May to June of the year 2020, with my first observations at the beginning of the month and the other at the end of the month, to find out whether the gas concentration rate at the beginning of the month is greater than at the end or vice versa? It is clear from Figure (4) that the percentage of nitrogen dioxide in the atmosphere decreased at the beginning of May as a result of total curfew and the cessation of all industries. This percentage increases at the end of the month due to the increased movement into the city at the end of the month. However, in the month of June, it is observed that the percentage of gas in the city's atmosphere increases at the beginning of the month, extending to the last week of the preceding month, and then the percentage decreases at the end of the month as a result of the total curfew of the last week of June and stopped all human activities in the governorate, except for the directorates that related to health and the local police in the governorate.

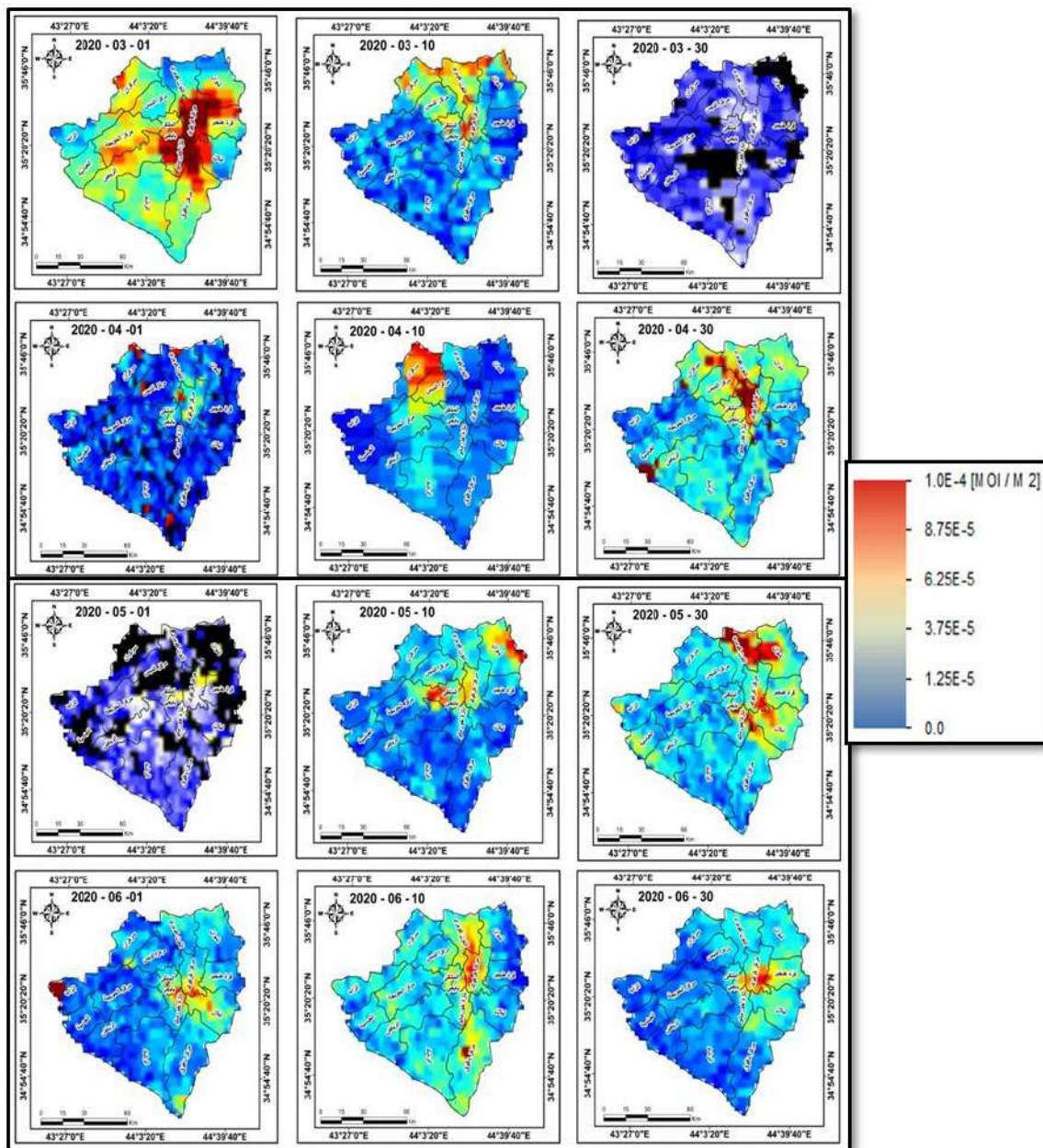


Figure (4) Nitrogen dioxide emission rate during the period of total and partial curfew in Kirkuk Governorate

- **Third period:** This period represents the period after the curfew period that extends from the month of July to the present. The Supreme National Health and Safety Committee for

combating Corona virus in Iraq announced the lifting of the total curfew. As a result of this, life has returned to normal, as airports have been opened and business can be conducted. Daily activity of industries and traffic congestions returned as they were before Corona pandemic, which led to an increase in the emission of nitrogen dioxide into the atmosphere, especially populated areas in cities centers.

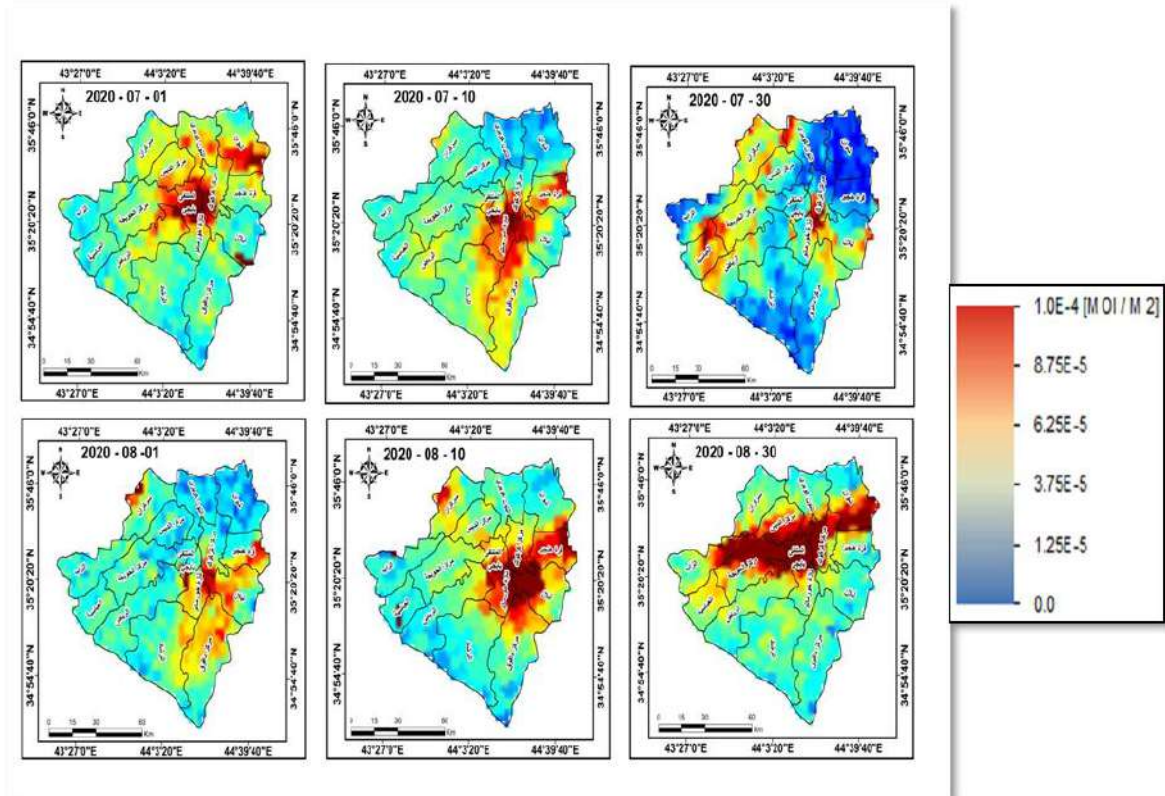


Figure (5) Nitrogen dioxide emission rate after the total and partial Curfew in Kirkuk Governorate

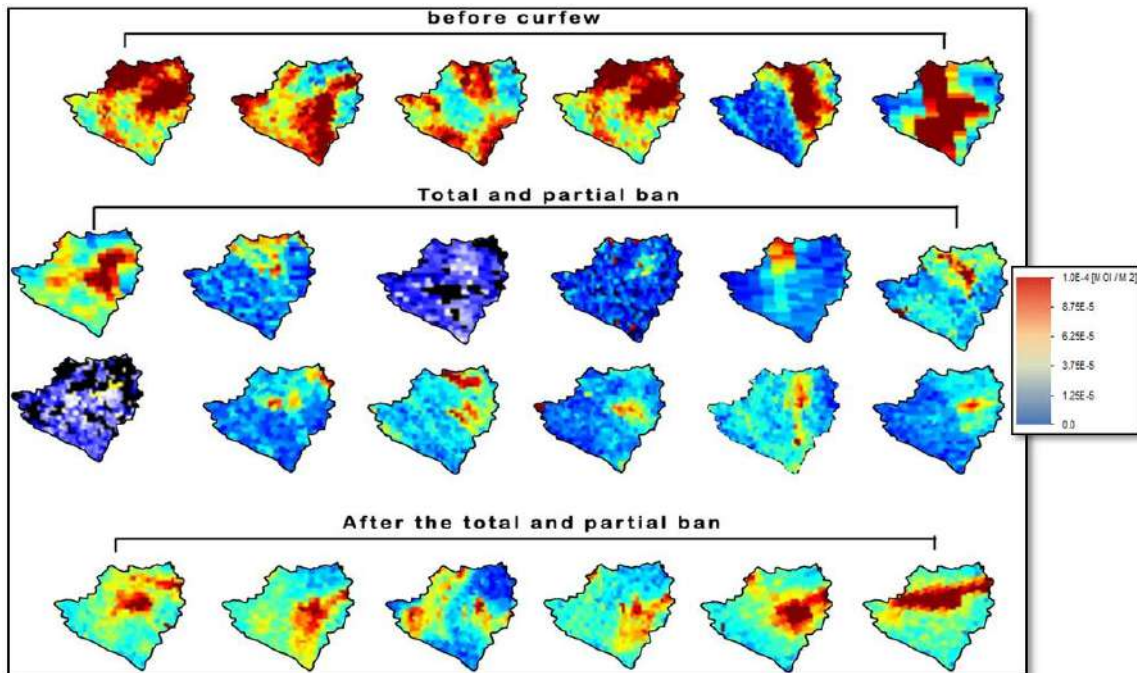


Figure (6) A combined map of nitrogen dioxide concentrations in Kirkuk Governorate for all periods studied.

Figure (6) shows a compiled map of nitrogen dioxide concentrations in Kirkuk Governorate for all periods studied, in order to give a clear picture of the comparison of areas occupied by nitrogen dioxide levels in the study area.

5- Health effects of nitrogen dioxide on human health: Prolonged exposure to nitrogen dioxide can have different effects on the respiratory system, causing bronchitis in healthy people and worsening respiratory symptoms in asthma patients. This pollutant can cause eye irritation and worsen respiratory conditions, which may increase the risk of respiratory infections, especially among asthma patients.

To evaluate the health effects of nitrogen dioxide, researchers used questionnaires and face-to-face interviews to explore its association with asthma. The health effects of indoor air pollutants are important given the significant amount of time people spend indoors, which can exceed 80% for many people. Factors that affect indoor time include geographic location, occupancy, and building type, among others. Better insulation in modern homes can contribute to higher levels of indoor air pollutants, including nitrogen dioxide.

The prevalence of asthma, which ranges between 2 and 20%, lacks a definitive explanation, perhaps arising from factors such as the “hygiene hypothesis” or the influence of Western lifestyles characterized by well-insulated homes and sparsely large families. Studies indicated a statistically significant relationship (odds ratio 2.23, 95% CI 4.72, 1.06) between a diagnosis of asthma and exposure to gas stove emissions.

Gas stoves used for cooking or heating are a major source of exposure to nitrogen dioxide indoors. According to the 2000 Census, more than half of American households relied on gas stoves, resulting in indoor nitrogen dioxide levels at least three times higher than in homes with electric stoves, with higher levels observed in multifamily dwellings. Children with asthma are particularly vulnerable to the harmful effects of exposure to nitrogen dioxide. Research suggests that children who live in homes with gas stoves are more likely to develop respiratory symptoms such as wheezing, coughing, and difficulty breathing. In addition, gas stove use has been linked to decreased lung function in girls with asthma, although this association has not been shown in boys. Adequate ventilation can help relieve respiratory symptoms in children with asthma exposed to gas stove emissions.

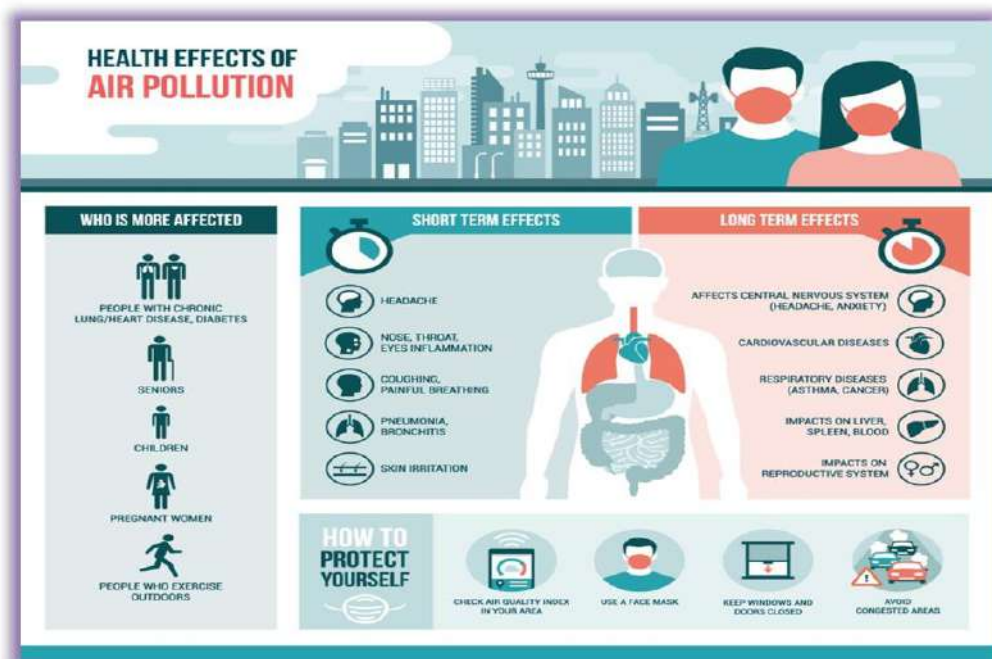


Figure (7) Health effects of air pollution

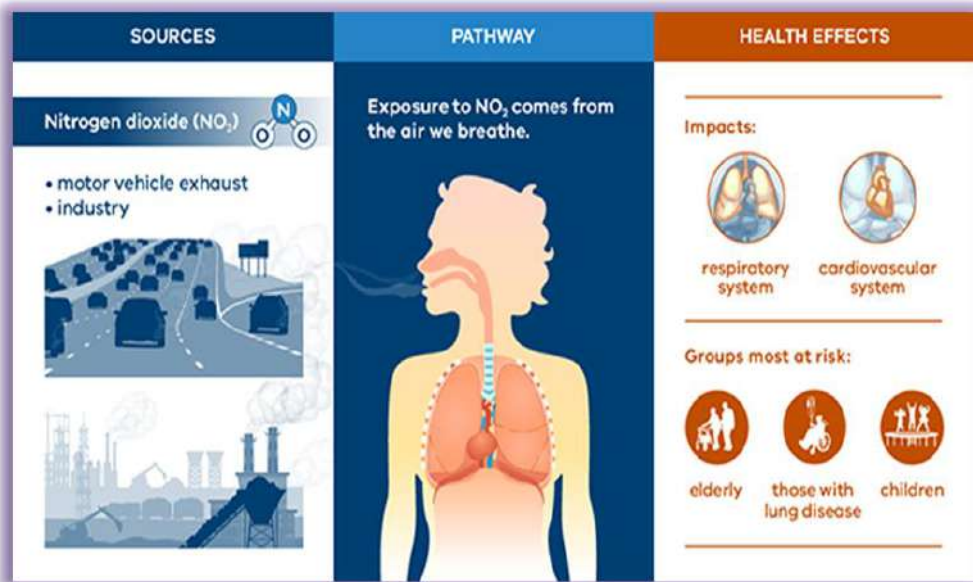


Figure (8): The resulting effects of nitrogen dioxide on humans.

In a study of African American children in Baltimore, researchers investigated the possible relationship between nitrogen dioxide and asthma among children ages 2 to 6 years with a current medical diagnosis of asthma and at least one doctor visit for asthma. It has been observed that families of low socioeconomic status are more likely to use gas stoves in their homes. The study results indicate that elevated indoor nitrogen dioxide levels were associated with more severe respiratory symptoms in the study group, highlighting the potential health risks of children's exposure to nitrogen dioxide.

The research also indicated that the symptoms caused by exposure to nitrogen dioxide are similar to those of COVID-19. The World Health Organization has identified the common symptoms of the Covid-19 epidemic, which are fever, fatigue, dry cough, shortness of breath and respiratory problems. Figure 8 shows the relationship between high levels of nitrogen dioxide in the atmosphere of Kirkuk Governorate and an increase in coronavirus cases during the corresponding periods.

These findings suggest a link between high levels of nitrogen dioxide and a slight increase in COVID-19 infection, suggesting a possible relationship between exposure to nitrogen dioxide and the spread of the COVID-19 virus.

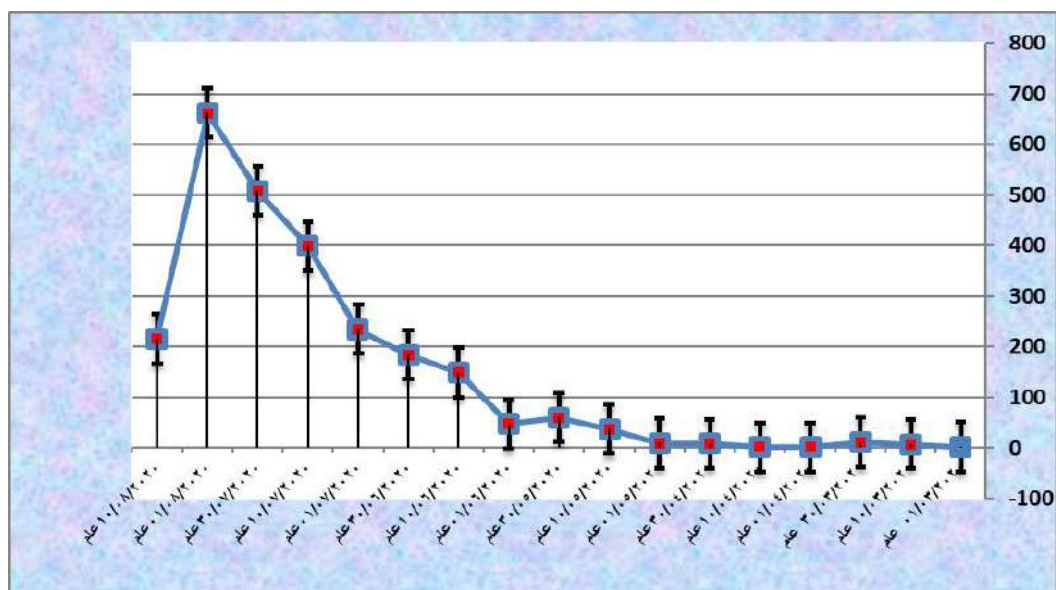


Figure (8) Number of Covid-19 infections in Kirkuk Governorate

From Figure (9), it is clear that all the death cases were concentrated in the months in which the curfew was lifted. This indicates that human activities are a factor causing infection, and as a result of imposing a curfew in the governorate during the second period led to a reduction in the number of infections and deaths in the governorate.

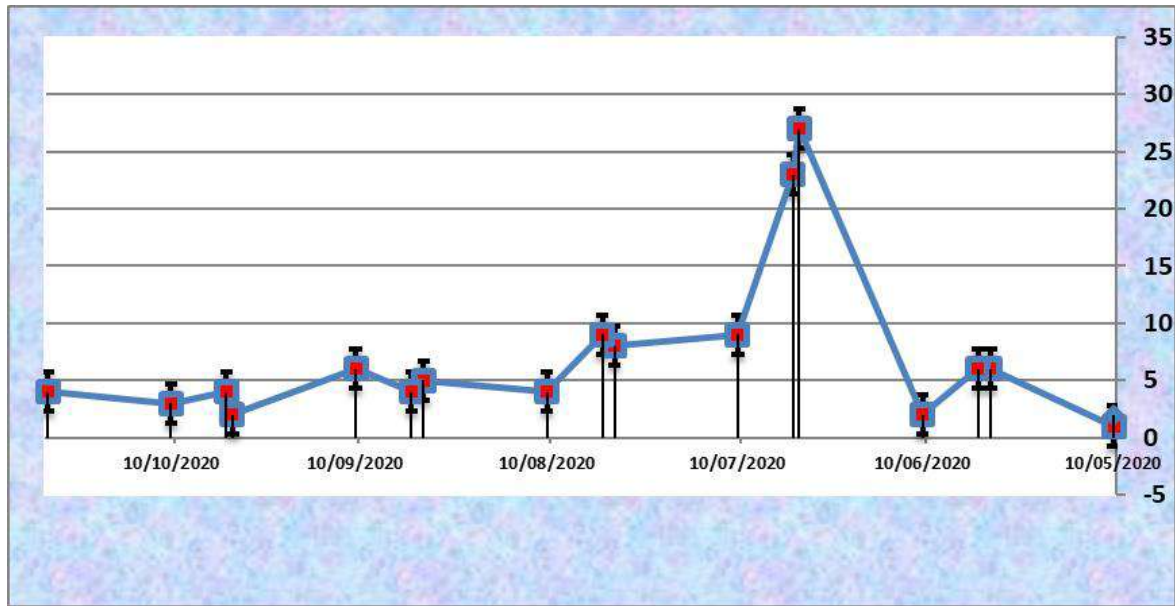


Figure (9) Numbers of the death cases in Kirkuk Governorate

Results and suggestions:

1. The study conducted by the researcher revealed that there is a heavy reliance on traditional fuel sources (gasoline and diesel) as the energy that operates the various types of transportation operating at the governorate level, which leads to high levels of air pollution.
2. It is clear from the study that there is a correlation between the high percentage of nitrogen dioxide in the governorate and the high number of infections with Corona Covid-19 in it, as the number of infections with the epidemic increased during the period in which the curfew was lifted, which increased the area of concentration of nitrogen dioxide gas in the same period. This confirms the relationship between them.
3. One of the negative effects of high levels of nitrogen dioxide is that it attacks the human respiratory system, leading to asphyxia. These symptoms are similar to the symptoms of Covid-19.
4. The importance of taking into consideration activating public transportation and reducing the use of private transportation through a set of decisions that motivate citizens and relevant parties. For example, providing public transportation for state employees or students will enable reducing the percentage of emissions resulting from private transportation.
5. The bad quality of fuel used in Kirkuk Governorate represents one of the most important problems that result pollutants which are dangerous to the health of citizens because the emissions of means that use this fuel are spatially closest to people, and thus they are more likely to be exposed to these toxins.
6. A decline in the level of regulatory, administrative and informational procedures assigned to treat the problem of pollution, which requires intensified efforts and cooperation between various governmental, private and joint bodies and institutions to take into account the conditions associated with protecting the environment and reducing the effects of pollution, by providing material and technical support to establish databases and maps to determine the extent of the spread of pollutants and their concentration according to the city's neighborhoods, and to find appropriate ways to solve the resulting problems.

Conclusion: Data from NASA's Sentinel-P5 satellite revealed a significant decrease in nitrogen dioxide levels in Kirkuk Governorate during the COVID-19 pandemic. This decrease is due to the significant decrease in the spread of nitrogen gases in the air, which was largely affected by the measures implemented by Iraq, especially in Kirkuk Governorate, to limit the spread of the Corona virus. These containment efforts led to a decrease in energy demand as a result of residents' compliance with stay-at-home orders and restrictions on travel between governorates due to regional lockdown measures.

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