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Original Article

Influence of COVID-19 lockdowns on NO_2 levels in Urmia city: a comparative analysis between 2018 and 2020

Saeed Hosseinpoor [1], Leila Ebrahimi Gangchin [1], Zahra Mirzazadeh [1], Aven Nuraldin Chaman [1], Amir Mohammadi [2,1]*

[1] *Student Research Committee, Urmia University of Medical Sciences, Urmia, Iran*

[2] *Social Determinants of Health Research Center, Clinical Research Institute, Urmia University of Medical Sciences, Urmia, Iran*

***Corresponding author:** Amir Mohammadi, **Address**: Social Determinants of Health Research Center, Clinical Research Institute, Urmia University of Medical Sciences, Urmia, Iran, **Email**: mohammadi_a@umsu.ac.ir, **Tel**: +98 (44) 3245 2907

Abstract

***Background & Aims*:** The COVID-19 pandemic and associated lockdowns imposed unprecedented changes in urban environments, impacting air quality worldwide. This study investigates the influence of COVID-19 lockdowns on nitrogen dioxide (NO_2) levels in Urmia City, Iran, between 2018 and 2020. NO_2, a key air pollutant emitted from various sources including motor vehicles and heating systems, poses significant health risks. Through comparative analysis, this study examines NO_2 concentrations during pre-pandemic and pandemic periods, aiming to understand the environmental consequences of lockdown measures.

***Materials & Methods*:** Data collected from the Environmental Protection Agency of West Azerbaijan Province and analyzed using rigorous quality assurance measures reveal intriguing trends in NO_2 levels across different seasons.

***Results*:** Despite expectations of reduced emissions during lockdowns, findings suggest complex dynamics influencing air pollution levels, with notable increases observed during certain periods of stringent restrictions. Further research is recommended to explore discrepancies in air quality trends and develop sustainable environmental management strategies for future challenges.

***Conclusion*:** This study contributes valuable insights into the environmental impacts of COVID-19 lockdowns, emphasizing the need for proactive measures to safeguard public health and the environment. However, another source of NO_2 emissions needed to be controlled.

***Keywords*:** COVID-19 lockdowns, Nitrogen dioxide (NO_2), Urban environment, Urmia City

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Introduction

The increase in population, industrial advancement, and rising use of motor vehicles worldwide, particularly in major cities of developing nations, has turned air pollution into a significant environmental concern (1). Nitrogen dioxide (NO_2) serves as an important air pollution marker, primarily emitted from heating systems, motor vehicles, and other sources (2).

Exposure to NO_2 concentrations, both short-term and long-term, can lead to conditions such as high blood pressure, diabetes, lung damage, cardiovascular and respiratory diseases, as well as respiratory-related deaths (3-5). Previous studies have found a meaningful connection between NO_2 levels and fatalities from respiratory-cardiac diseases among air pollutants (6-8). In late December 2019, the outbreak of an unknown disease named COVID-19 occurred in Wuhan, Hubei Province, China (9). This led to countries implementing quarantine measures, resulting in the global shutdown of industrial activities. Among various sectors, the transportation industry suffered the most due to these restrictions (10). Bao et al. (2020) conducted research to evaluate the impact of the COVID-19 pandemic on NO_2 pollution using TROPOMI and OMI observations. Satellite-based observations showed a significant decrease in NO_2 levels in China, South Korea, Western Europe, and the United States from January to April 2020 due to public health measures targeting COVID-19 (11).

Pacheco et al. (2020) investigated the impact of post-COVID-19 quarantine on NO_2 levels in Ecuador, discovering a 13% reduction in NO_2 concentration (12). Zhang et al. (2021) explored the correlation between air pollution and the COVID-19 epidemic during China's quarantine period, observing a notable decrease in air pollutant levels except for ozone (O_3) due to COVID-19 prevention measures (13). Adams (2020) examined air pollution in Ontario, Canada, amid the COVID-19 emergency, revealing declines in NO_2 concentration, which may have led to lower ozone levels without significant alterations in fine particulate matter concentrations compared to historical data (14). Shami et al. (2020) analyzed changes in air pollutant levels during the COVID-19 outbreak in Iran using Sentinel-5 satellite data, indicating a reduction in NO_2 concentrations associated with transportation and human activities (15). Boromandi et al. observed decreases in SO_2 and NO_2 levels and an increase in Aerosol Optical Depth (AOD) in various parts of Iran following the COVID-19 outbreak, suggesting beneficial impacts of quarantine on air quality due to reduced industrial activities, flight cancellations, and decreased vehicular traffic (16).

Due to Urmia city's ranking as the second-largest urban center with heavy traffic in northwestern Iran, along with intermittent air quality issues during colder periods, this research investigated how COVID-19 pandemic-related lockdowns and holidays affected NO_2 pollutant levels in Urmia city's atmosphere. The study aimed to compare NO_2 concentrations between the years 2018 and 2020, examining both pre-pandemic and current conditions during the COVID-19 pandemic and subsequent lockdowns. This focus underscores the novelty and significance of understanding the environmental impacts of pandemic-related changes, including lockdown measures, on air quality in urban areas like Urmia.

Materials & Methods

Study Area Characteristics:

The study area encompasses Urmia, which serves as the administrative center of West Azerbaijan Province, covering an extensive area of approximately 5,895 km^2 and situated at an elevation of approximately 1,312 meters above sea level. Positioned along the shores of Lake Urmia, the region extends for about 70 km in length and 30 km in width. Geographically, it is located between 45°4' to 46°13' east longitude and 37°32' to 36°32' north latitude (17, 18).

Urmia experiences a moderate climate, with an average temperature of around 8.9 ˚C, reaching a maximum of about 34 ˚C in August and dropping to a minimum in December. The annual average maximum temperature is approximately 18.4 °C, while the minimum is 7 °C. The region receives an average annual rainfall of about 370 mm, and relative humidity can vary, occasionally reaching up to 50% (19).

As one of Iran's significant urban centers, Urmia had a population of 1,040,565 according to the 2016 census. The area faces various challenges due to its unique geographical features, including its proximity to Iraq, which contributes to dust problems, as well as factors like urbanization, the appearance of salt flats, increased salinity in water bodies, and the drying of Lake Urmia. These factors have led to disruptions in the local ecosystem and issues related to air pollution. The study area is shown in Figure1. In this figure, Urmia city is depicted along with the main streets and the position of the Shaharchi River.

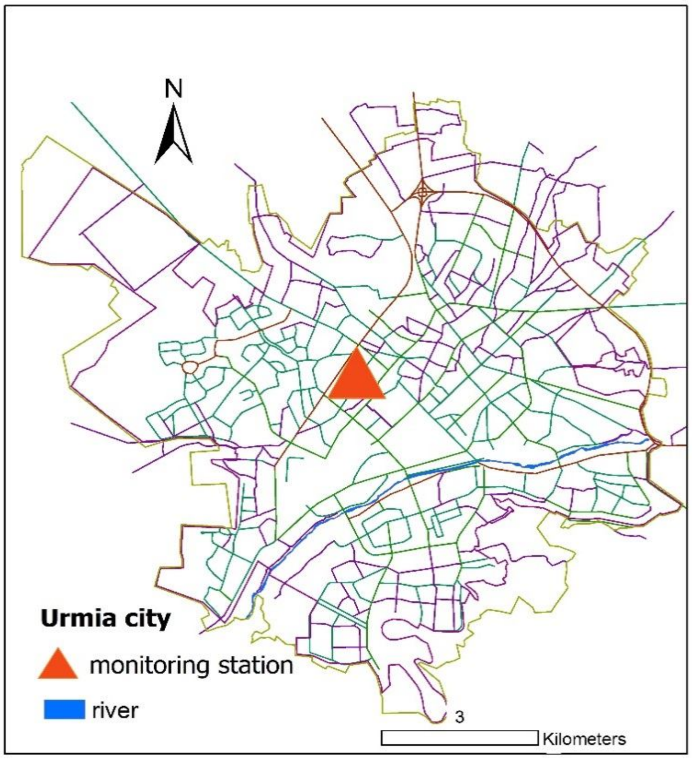

Fig. 1. Map of study area with main street distribution

Data Collection:

This study is an ecological descriptive investigation comprising two phases. Initially, NO_2 data for the years between 2018 and 2020, representing pre-COVID-19 and COVID-19 periods respectively, were obtained from the Environmental Protection Agency of West Azerbaijan Province in Excel format. The dataset covered 365 days of the year, collected hourly and then averaged daily using a moving average method. Subsequently, data analysis was conducted to assess the impact of days characterized by traffic restrictions and the closures of offices and schools on air pollution levels and NO_2 concentrations. The positioning of the online air monitoring device is depicted in Figure 1, utilizing an Ecotec™ Enviro SA™ analyzer.

Quality Assurance and Quality Control (QA/QC):

The quality assurance and quality control (QA/QC) measures employed in this study encompass various steps to ensure the accuracy and reliability of the collected data. These procedures include verifying the source and consistency of NO_2 data obtained from the Environmental Protection Agency of West Azerbaijan Province, as well as conducting accuracy assessments and validation checks against known standards. Additionally, data cleaning techniques are utilized to remove outliers or erroneous data points, while instrument calibration of the Ecotec™ Enviro SA™ analyzer ensures precise measurement of NO_2 concentrations. Cross-referencing with meteorological data aids in identifying correlations and anomalies, and thorough documentation of the methodology ensures transparency and reproducibility of results. Finally, subjecting the study to peer review by experts in the field validates the rigor and reliability of the research process and findings, thereby ensuring the integrity of the study's conclusions.

Results

The chart depicted as Figure 2 illustrates the average monthly values for the spring season. Analysis reveals that the average spring monthly values in 2020 surpass those of 2018 across all months. Notably, the disparity is most pronounced in May compared to March and April, with NO_2 concentrations increasing by 7.6% in March, 3.7% in April, and 20.8% in May. Figure 3 illustrates the average monthly NO_2 concentrations during the summer season. Based on the analysis, it was found that in June of 2020, there was a 3.8% increase in NO_2 levels compared to 2018. However, a decreasing trend was observed in the July and August months. In July of 2020, there was a notable decrease of 42.3%, and in August, a decrease of 23% in NO_2 concentration was recorded. Thus, according to the data, the most significant reduction occurred in July of 2020. Figure 4 illustrates the average monthly NO_2 concentration during the autumn season. Based on the analysis conducted during this season, there has been a rise in NO_2 levels in the months of September and November in the year 2020 compared to 2018. Specifically, in September 2020, NO_2 concentration increased by 42.8%, while in November 2020, it surged by 107.6%. Conversely, in October 2020, there was a decrease of 16.6% in NO_2 concentration. Figure 5 represents the average monthly NO_2 concentration during winter. As per the observations and analyses, there is a consistent decrease in NO_2 levels throughout all winter months in the year 2020-2021. The most notable reduction is seen in February with a decline of 6.6%, and in January of 2021, there is a decrease of 14.2%. Figure 6 depicts the pattern of NO_2 concentration variations pre- and post-COVID-19 outbreak. NO_2 levels were elevated during the peak lockdown and quarantine periods compared to 2018. The cause could be related to traffic, residential heating, and power plant operations. However, they decreased during the summer and winter after the restrictions were eased. This reduction in NO_2 levels could be attributed to increased public transportation usage and decreased traffic during that period.

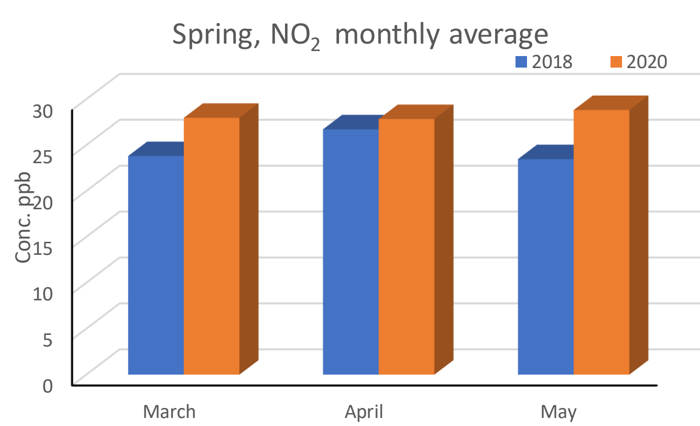

Fig. 2. The NO_2 value in spring

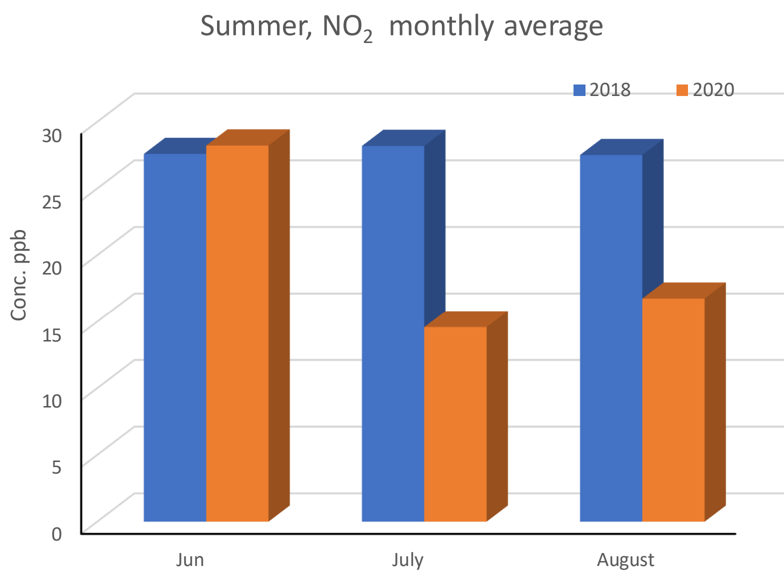

Fig. 3. The NO_2 value in summer

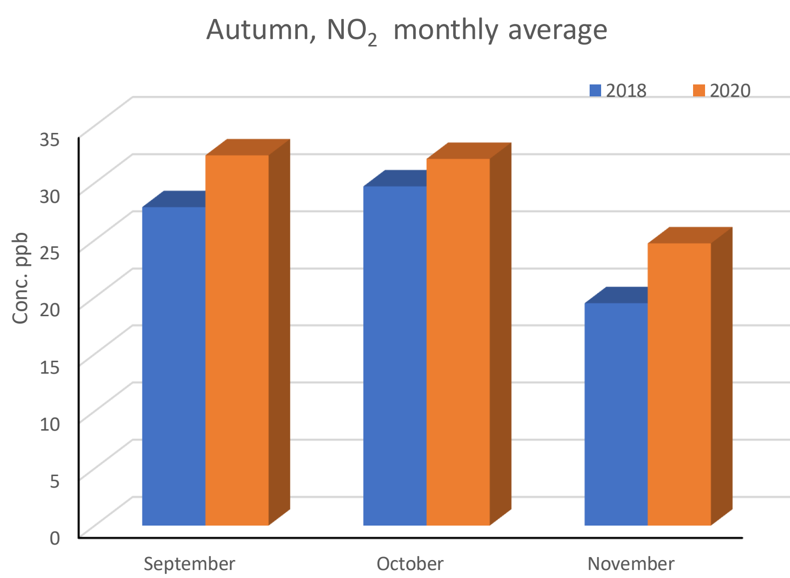

Fig. 4. The NO_2 value in autumn

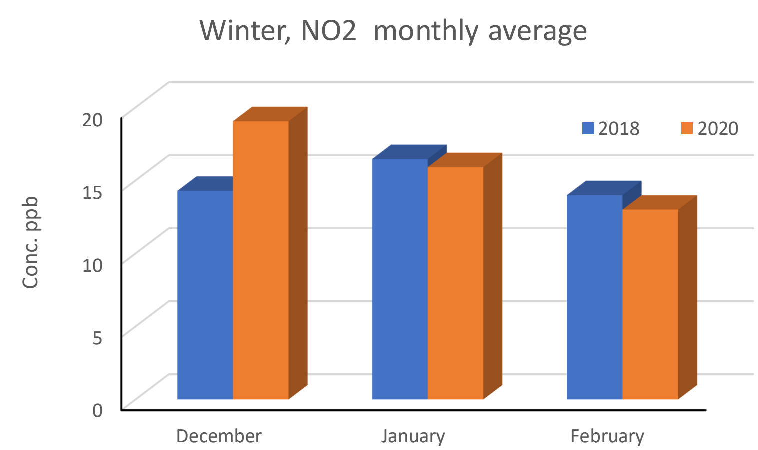

Fig. 5. The NO_2 value in winter

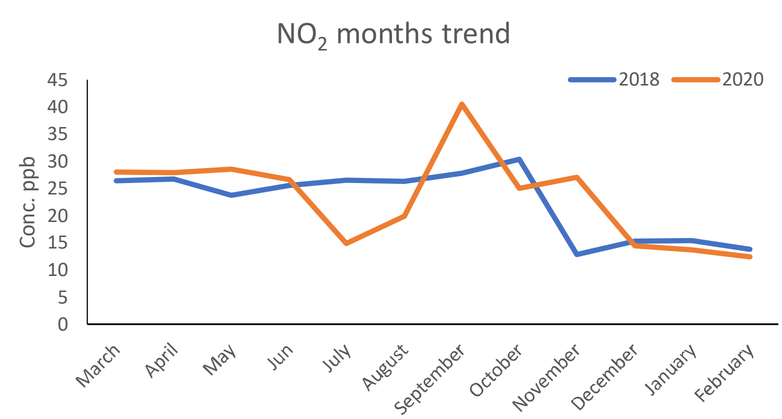

Fig. 6. Monthly trend of NO_2

Discussion

During spring and autumn 2020, Urmia implemented extensive restrictions that caused a rise in NO_2 levels in the city's air. These restrictions led to quieter surroundings as people stayed home under quarantine, resulting in a higher use of natural gas for heating. Moreover, there was a noticeable shift towards using personal vehicles for transportation. However, these results contradict other studies since the general public faced restrictions due to the COVID-19 outbreak, which typically leads to reduced emissions. Nevertheless, according to this study's findings, these restrictions contributed to the increase in NO_2 levels, although this conclusion isn't supported by other research. The Sentinel-5P satellite image from Iraq indicates that in and around Basra and Baghdad, during approximately 2020, there was a recorded upsurge in NO_2 levels by up to 40%. This escalation is linked to reported constraints and obligatory shutdowns during that period (20).

The study on atmospheric NO_2 levels across 27 European Union member countries from 2019 to 2021 due to the COVID-19 pandemic revealed that the pandemic-induced social and economic disruptions led to reduced social activities, mobility, and industrial activities, resulting in decreased traffic and reduced emissions from vehicles and industrial sources. Analyzing regions and urban-rural areas showed that urban areas with high population density experienced the most significant reductions in NO_2 levels in 2020 compared to 2019. However, this trend reversed in 2021 in some countries with higher per capita gross domestic product. Determining the impact of intervention policies on pollution levels highlighted varied effects across Europe, with minimal impact observed in Eastern European regions, while relaxation of restrictions in 2021 led to a renewed deterioration in air quality in many areas. The study also discussed the role of the geographical environment in pollutant dispersion, emphasizing the influence of both socio-economic factors and natural geography, along with weather conditions, on air pollution levels (21, 22).

A study in Tehran, the capital city of Iran, showed that levels of pollutants, particularly NO_2, decreased by 1 to 33 percent during the COVID-19 restrictions in 2020 and 2021. However, on some days of the year, they exceeded the guidelines set by the World Health Organization. Conversely, a prominent study in Urmia city indicated that although NO_2 levels increased during the COVID-19 period, according to Table 1, they remained within the permissible range set by the Environmental Protection Agency on all days (16). Another study showed that NO_2 levels in Tehran, Mashhad, Isfahan, and Tabriz decreased by 5 percent in 2020 compared to 2019. However, in 2021, the second year of the COVID-19 pandemic, there was a 5 percent increase relative to 2019. The increase was attributed to heightened traffic and relaxation of restrictions and limitations (15).

Table 1. Statistical descriptive of NO_2 levels in the study area (µg/m^3)

NO_2	The year 2018	The year 2020
Mean	22.53	23.36
Standard deviation	7.93	8.09
Max	76.06	47
Min	9.78	11.32
Iran EPA guideline	Maximum hourly	200
	Annually	100

Suggestions:

- Evaluate the effectiveness of lockdown measures and pandemic-related restrictions on NO_2 levels in urban areas like Urmia, considering the unique environmental challenges and geographical characteristics of the region.
- Conduct further research to explore the discrepancies observed between studies regarding the impact of COVID-19 restrictions on NO_2 concentrations, particularly in regions with heavy traffic and industrial activities.
- Investigate the role of seasonal variations and meteorological factors in influencing NO_2 levels, aiming to develop a comprehensive understanding of air pollution dynamics in different climatic conditions.
- Implement comprehensive air quality monitoring programs in cities like Tehran, Mashhad, Isfahan,

and Tabriz to continuously assess pollutant levels and ensure compliance with international health standards, particularly during periods of heightened traffic and industrial activity.

Collaborate with international organizations and research institutions to share data and insights on air quality trends, facilitating a global understanding of the environmental impacts of the COVID-19 pandemic and related containment measures.

Conclusion

The comparative analysis of NO_2 levels in Urmia City from 2018 to 2020 during the COVID-19 lockdowns provides valuable insights into the environmental impacts of pandemic-related restrictions. The study revealed significant fluctuations in NO_2 concentrations across different seasons, with notable increases observed during spring and autumn 2020, coinciding with stringent lockdown measures. Despite expectations of reduced emissions due to quarantine measures, the findings indicate a contrary trend, suggesting a complex interplay of factors influencing air pollution levels during pandemic-induced restrictions. The discrepancies observed between this study and previous research underscore the need for further investigation into the specific drivers of air pollution in urban areas like Urmia. Additionally, the study emphasizes the importance of comprehensive air quality monitoring and effective policy interventions to mitigate the adverse effects of air pollution on public health, particularly in densely populated regions with high traffic volume. Further research focusing on the long-term implications of COVID-19 lockdowns on air quality and exploring strategies for sustainable environmental management in urban areas is warranted to address emerging challenges and ensure the well-being of communities in the face of future pandemics or environmental crises.

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Authors' Contributions

Leila Ebrahimi Gangchin: Conceptualization, Data curation, Writing. Zahra Mirzazadeh: Methodology, Writing. Aven Nuraldin Chaman: Conceptualization, Writing. Saeed Hosseinpoor: editing. Amir Mohammadi: Conceptualization, Methodology, Supervision, Funding acquisition, Writing.

Data Availability

Data will be made available on request.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to affect the work reported in this paper.

Ethical Statement

Research Ethics Committee of Urmia University of Medical Sciences has approved all stages of this study (IR.UMSU.REC.1402.245).

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