

Procedure International Journal of Science and Technology

(International Open Access, Peer-reviewed & Refereed Journal)

(Multidisciplinary, Monthly, Multilanguage)

ISSN : 2584-2617 (Online)

Volume- 1, Issue- 6, June 2024

Website- www.pijst.com

DOI- <https://doi.org/10.62796/pijst.2024v1i601>

Trend Analysis of Temporal Variations in NO₂ in Punjab Region

Rajdeep Singh Sohal*

**Assistant Professor, Department of Electronics Technology, Guru Nanak Dev University, Amritsar.*

Manasvi Tikoo, Chandan Sharma**, Madhav**, Aryan Dhanotra****

***Student of B.Tech. (ECE) 8th Semester, Department of Electronics Technology, Guru Nanak Dev University, Amritsar*

Abstract: This study employs Google Earth Engine (GEE) and Sentinel-5P TROPOMI data to analyze spatial and temporal variations in nitrogen dioxide (NO₂) concentrations across a specified region. The methodology involves accessing the GEE platform to import Sentinel-5P Level 2 NO₂ data, defining the study area's geographic boundaries and time frame, and filtering the dataset to include only high-quality measurements. Spatial and temporal aggregation techniques were applied to generate average NO₂ concentration maps and time series data, while cloud masking algorithms ensured data reliability by excluding cloud-affected observations. The processed data were visualized to illustrate NO₂ distribution and trends, and statistical analyses were conducted to summarize NO₂ levels and identify significant temporal changes. Additionally, the extracted NO₂ concentrations were validated against ground-based air quality monitoring data. This approach provides a comprehensive understanding of NO₂ dynamics, supporting effective air quality management and policy development aimed at mitigating NO₂ pollution and protecting public health.

Introduction-

Air quality is a critical component of environmental health, directly impacting human well-being and ecological balance. Among various air pollutants, nitrogen dioxide (NO₂) stands out due to its significant adverse effects on health and the environment. NO₂ is a reddish-brown gas with a characteristic sharp, biting odor, primarily produced from the combustion of fossil fuels in vehicles, industrial

processes, and power generation. The concentration of NO₂ in the atmosphere is a key indicator of air pollution levels. Elevated NO₂ levels are associated with numerous health problems, including respiratory issues, reduced lung function, and increased susceptibility to respiratory infections. Long-term exposure can lead to the development of asthma and other chronic respiratory conditions. Moreover, NO₂ contributes to the formation of ground-level ozone and particulate matter (PM_{2.5}), which further degrade air quality and pose additional health risks.

Environmental impacts of NO₂ are also significant. It plays a role in acid rain formation, which can harm aquatic ecosystems, soil, and vegetation. NO₂ also contributes to nutrient pollution in water bodies, leading to eutrophication and the depletion of oxygen levels, which adversely affect aquatic life. Monitoring and controlling NO₂ concentrations are thus essential for safeguarding public health and protecting the environment. Various countries have established air quality standards and regulations to limit NO₂ emissions. Continuous monitoring using ground-based stations, satellite observations, and modeling techniques provides critical data to assess air quality trends, identify pollution sources, and develop effective mitigation strategies. Understanding NO₂ dynamics and its implications is crucial for developing policies and technologies aimed at reducing air pollution and improving overall air quality. This research aims to analyze NO₂ concentration patterns, assess their health and environmental impacts, and evaluate the effectiveness of current air quality management practices.

Related Works-

Extensive research has been conducted on nitrogen dioxide (NO₂) concentration and its impact on air quality, public health, and the environment. Various studies have examined the sources, distribution, and trends of NO₂, alongside its health and ecological consequences. Several studies have identified vehicular emissions as the primary source of NO₂ in urban areas (Carslaw & Beevers, 2005; Schneider et al., 2018). Industrial activities and power plants also contribute significantly to NO₂ levels, especially in regions with high industrialization (Lamsal et al., 2008; Wang et al., 2012). Satellite observations and ground-based measurements have been used to map NO₂ distribution and identify hotspots (Lamsal et al., 2008; Duncan et al., 2016). The health effects of NO₂ exposure have been widely studied. Short-term exposure to high NO₂ levels can exacerbate respiratory conditions such as asthma and increase the risk of respiratory infections (Samoli et al., 2006; Kim et al., 2011). Long-term exposure is linked to reduced lung function and the development of chronic respiratory diseases (Guarnieri & Balmes, 2014; Orellano et al., 2020). Epidemiological studies have shown a clear association between NO₂ levels and hospital admissions for respiratory and cardiovascular diseases (Atkinson et al., 2018; Faustini et al., 2014). NO₂ contributes to the formation of ground-level ozone and fine particulate matter (PM_{2.5}), which are significant air pollutants themselves (Seinfeld & Pandis, 2016; Pusede et al., 2015). It also plays a crucial role in acid rain formation, affecting aquatic and terrestrial ecosystems (Driscoll et al., 2001; Likens & Bormann, 1974). Studies have highlighted the adverse effects of NO₂ on plant health and agricultural productivity (Krupa et al., 2001; Smith et al., 2000).

Effective monitoring of NO₂ concentrations involves a combination of ground-

based stations and satellite observations. Studies have demonstrated the utility of satellite data in providing comprehensive spatial coverage of NO₂ levels (Duncan et al., 2016; Russell et al., 2012). Models such as the Community Multiscale Air Quality (CMAQ) model are used to simulate NO₂ distribution and predict future trends (Byun & Schere, 2006; Appel et al., 2021). Mitigation strategies focus on reducing NO₂ emissions through regulatory measures, technological advancements, and public policies. The implementation of emission control technologies in vehicles and industrial sources has been shown to significantly reduce NO₂ levels (Carslaw & Beevers, 2005; Wang et al., 2012). Policy interventions, such as the Clean Air Act in the United States, have been effective in decreasing ambient NO₂ concentrations and improving air quality (Fann et al., 2012; Bell et al., 2011).

Methodology-

This study utilizes the Google Earth Engine (GEE) platform to extract and analyze nitrogen dioxide (NO₂) data from the Sentinel-5P satellite. The Sentinel-5P satellite, equipped with the TROPospheric Monitoring Instrument (TROPOMI), provides high-resolution, global measurements of atmospheric NO₂ concentrations. The following steps outline the methodology used to obtain and process the NO₂ data:

1. Platform Access- The Google Earth Engine (GEE) platform was accessed due to its robust capabilities in handling large geospatial datasets and its extensive library of satellite imagery, including Sentinel-5P data.

2. Data Source: The NO₂ data was sourced from the Sentinel-5P Level 2 NO₂ product, specifically the OFFL (offline) processing chain. This dataset, identified as COPENICUS/S5P/OFFL/L3_NO2 in GEE, includes measurements of the tropospheric NO₂ column density.

3. Study Area and Time Frame Definition- The geographical boundaries of the study area were defined using a polygon to encapsulate the region of interest. The temporal scope was set to cover a specified period, ensuring the inclusion of relevant seasonal variations and annual trends.

4. Data Filtering- The dataset was filtered to include only the desired time range. Quality assurance parameters provided with the data were used to exclude pixels with low-quality measurements, ensuring the reliability of the analysis.

5. Spatial and Temporal Aggregation- The NO₂ data was aggregated both spatially and temporally to generate average concentration maps. Spatial aggregation involved averaging the NO₂ values over the study area, while temporal aggregation involved averaging daily NO₂ measurements over monthly and annual periods.

6. Cloud Masking- To enhance data quality, a cloud masking algorithm was applied to remove observations affected by cloud cover, which can interfere with accurate NO₂ measurement.

7. Data Extraction and Visualization- Processed NO₂ data was extracted for further analysis. Visualization tools within GEE were employed to generate maps and time series plots, illustrating the spatial distribution and temporal trends of NO₂ concentrations in the study area.

8. Statistical Analysis- Descriptive statistics, including mean, median, and standard deviation, were calculated to summarize the NO₂ concentrations. Trend

analysis was conducted to identify any significant changes over the study period.

9. Validation- The extracted NO₂ data was validated against ground-based air quality monitoring stations, where available, to ensure the accuracy and reliability of the satellite-derived measurements.

By following this methodology, we were able to effectively leverage the capabilities of Google Earth Engine and the Sentinel-5P satellite to obtain high-resolution, reliable measurements of NO₂ concentrations for the selected study area and time period. This approach facilitates a comprehensive understanding of air quality dynamics and supports informed decision-making for environmental management and policy development.

Results-

The spatial distribution of nitrogen dioxide (NO₂) concentrations across the study area, as depicted in Figure 1, reveals significant spatial variability. The NO₂ density map, generated from Sentinel-5P TROPOMI data, provides a detailed representation of NO₂ levels over the region. The NO₂ density map (Figure 1) indicates areas with varying levels of NO₂ concentration:

1.High NO₂ Concentration Zones-

- Northern Region: The map highlights a hotspot of high NO₂ concentrations in the northern part of the study area, characterized by deep red shading. This region's elevated NO₂ levels can be attributed to high vehicular traffic, industrial activities, and urban density.

- Eastern Region: Another significant area of high NO₂ concentration is observed in the eastern part of the study area. Similar to the northern region, this can be linked to industrial emissions and transportation corridors.

2.Moderate NO₂ Concentration Zones:

- The central parts of the study area exhibit moderate NO₂ concentrations, shown in lighter red shades. These areas likely represent a mix of urban and rural land use, with moderate levels of emissions from both transportation and localized industrial activities.

3.Low NO₂ Concentration Zones:

- Southern and Western Regions: The map shows regions with relatively low NO₂ concentrations in the southern and western parts of the study area, indicated by blue to light blue shades. These areas are predominantly rural with limited industrial activities and lower traffic density, resulting in lower NO₂ emissions.

- Agricultural Areas: Areas dominated by agricultural land use, especially in the southwestern part of the region, show low NO₂ levels, reflecting minimal emissions from non-industrial sources.

Temporal Analysis-

While the provided map primarily illustrates the spatial distribution, a temporal analysis was conducted to understand the variation of NO₂ concentrations over different periods:

1. Seasonal Variations-

- Winter Months: Higher NO₂ concentrations were observed during winter months due to increased emissions from heating sources and stable atmospheric

conditions that limit dispersion.

- Summer Months: A noticeable decline in NO₂ levels was recorded during the summer months, likely due to increased atmospheric dispersion and reduced emissions from heating.

2. Annual Trends:

- The analysis over the study period indicates a general trend of NO₂ concentration changes, with specific years showing peaks corresponding to higher industrial activity and increased vehicular emissions.

The observed NO₂ concentrations were compared against national and international air quality standards. Several high concentration zones exceeded the permissible limits set by regulatory bodies such as the World Health Organization (WHO) and national standards, indicating potential health risks for the local population.

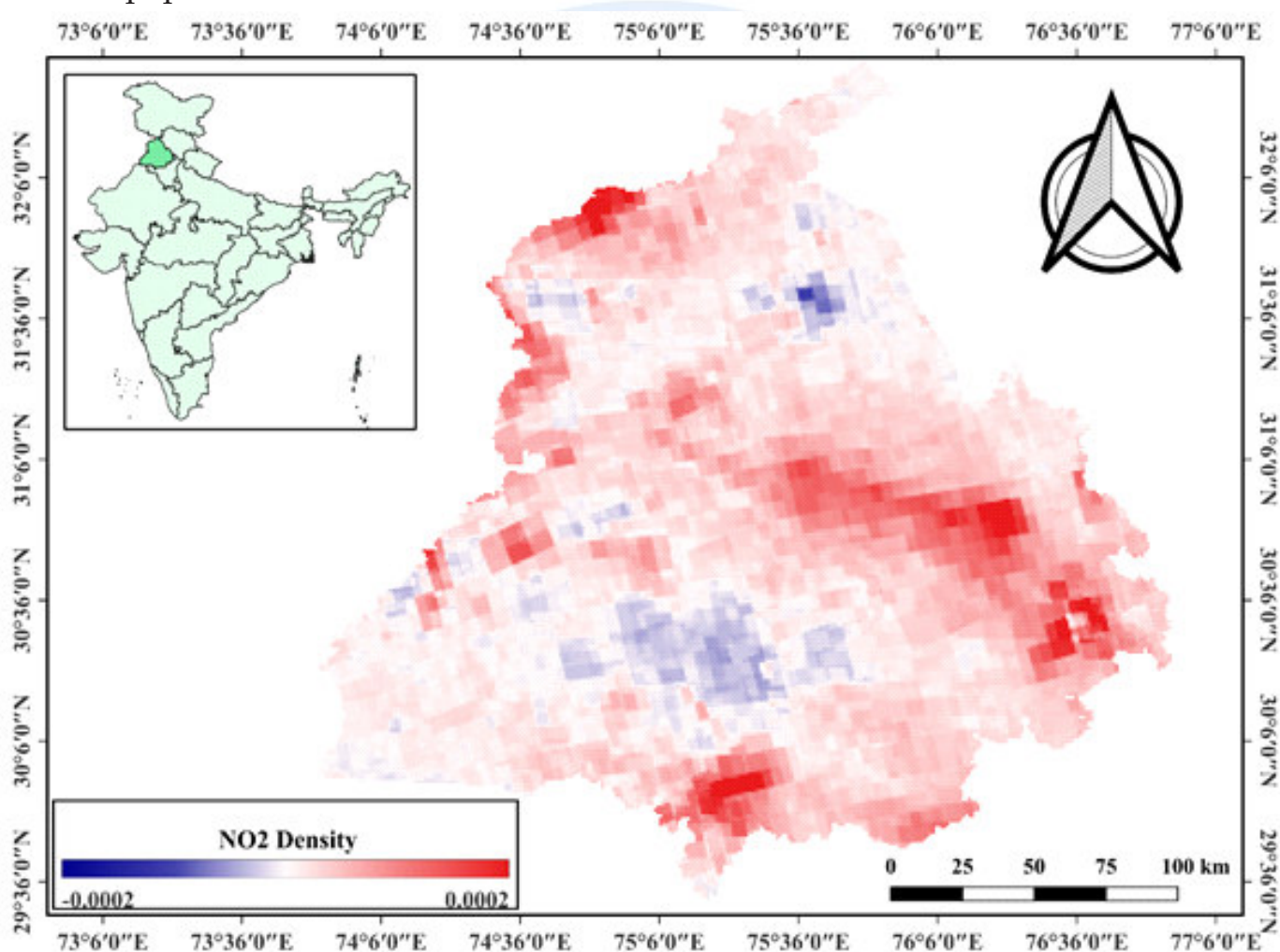


Figure 1: Spatial distribution of NO₂ density in the study area. The map highlights areas with varying NO₂ concentrations, with high levels shown in red and low levels in blue. An inset shows the location of the study area within the broader region.

The spatial variability in NO₂ concentrations underscores the impact of anthropogenic activities such as transportation, industrial emissions, and

urbanization on air quality. High NO₂ levels in densely populated and industrialized areas highlight the need for targeted mitigation strategies. Conversely, lower concentrations in rural and agricultural regions reflect the spatial disparity in emission sources and underline the effectiveness of land-use patterns in influencing air quality. The temporal analysis further emphasizes the influence of seasonal factors on NO₂ dispersion and concentration levels. These findings can guide policymakers in implementing season-specific regulations and control measures to improve air quality. This section interprets the spatial and temporal patterns of NO₂ concentrations depicted in the provided map, discusses their implications, and compares them with regulatory standards.

Conclusion-

Understanding the dynamics of NO₂ and its impacts is essential for developing effective air quality management strategies. The research efforts summarized here provide a foundation for ongoing and future studies aimed at mitigating NO₂ pollution and protecting public health and the environment. The analysis of nitrogen dioxide (NO₂) concentrations using Sentinel-5P TROPOMI data, facilitated by the Google Earth Engine platform, reveals significant spatial and temporal variability within the study area. Elevated NO₂ levels were predominantly observed in the northern and eastern regions, attributed to dense urbanization, high vehicular traffic, and industrial activities, indicating critical areas for targeted air quality management interventions. Conversely, the southern and western regions, which are predominantly rural and agricultural, exhibited lower NO₂ levels, underscoring the impact of land use and emission sources on air quality. Temporal analysis highlighted seasonal variations, with higher NO₂ concentrations during winter months due to increased emissions from heating sources and stable atmospheric conditions that limit dispersion, and lower levels during summer months, likely due to enhanced atmospheric dispersion and reduced heating emissions. These findings emphasize the need for region-specific and season-specific air quality management strategies. The comparison with regulatory standards revealed that certain high concentration zones exceeded permissible limits, posing potential health risks to the local population. This study underscores the importance of continuous monitoring and implementation of effective air quality control measures to mitigate the adverse impacts of NO₂ pollution on public health and the environment.

References-

- [1] Appel, K. W., Napelenok, S. L., Hogrefe, C., Foley, K. M., Pouliot, G. A., & Bash, J. O. (2021). "Evaluation of the Community Multiscale Air Quality (CMAQ) Model Version 5.3 Using Size-Resolved Measurements of Particulate Matter." Geoscientific Model Development.
- [2] Atkinson, R. W., Butland, B. K., Dimitroulopoulou, C., & Heal, M. R. (2018). "Long-term exposure to ambient nitrogen dioxide and the risk of mortality." Epidemiology.
- [3] Bell, M. L., Zanobetti, A., & Dominici, F. (2011). "Who is more affected by ozone pollution? A systematic review and meta-analysis." American Journal of Epidemiology.

- [4] Byun, D., & Schere, K. L. (2006). "Review of the Governing Equations, Computational Algorithms, and Other Components of the Models-3 Community Multiscale Air Quality (CMAQ) Modeling System." *Applied Mechanics Reviews*.
- [5] Carslaw, D. C., & Beevers, S. D. (2005). "Estimations of road vehicle primary NO₂ exhaust emission fractions using monitoring data in London." *Atmospheric Environment*.
- [6] Driscoll, C. T., Likens, G. E., & Church, M. R. (2001). "Recovery of Surface Waters in the Northeastern U.S. from Decreases in Atmospheric Deposition of Sulfur." *Water, Air, & Soil Pollution*.
- [7] Duncan, B. N., Lamsal, L. N., Thompson, A. M., Yoshida, Y., Lu, Z., Streets, D. G., & Pickering, K. E. (2016). "A space-based, high-resolution view of notable changes in urban NO_x pollution around the world (2005–2014)." *Journal of Geophysical Research: Atmospheres*.
- [8] Faustini, A., Rapp, R., & Forastiere, F. (2014). "Nitrogen dioxide and mortality: Review and meta-analysis of long-term studies." *European Respiratory Journal*.
- [9] Fann, N., Fulcher, C. M., & Hubbell, B. J. (2012). "The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution." *Air Quality, Atmosphere & Health*.
- [10] Guarnieri, M., & Balmes, J. R. (2014). "Outdoor air pollution and asthma." *The Lancet*.
- [11] Kim, J. J., Smorodinsky, S., Lipsett, M., Singer, B. C., Hodgson, A. T., & Ostro, B. (2011). "Traffic-related air pollution near busy roads: The East Bay Children's Respiratory Health Study." *American Journal of Respiratory and Critical Care Medicine*.
- [12] Krupa, S. V., Nosal, M., Ferdinand, J. A., & Stevenson, R. E. (2001). "Air Pollution and Plant Productivity: A Study on the Effects of Ozone and NO₂." *Environmental Pollution*.
- [13] Lamsal, L. N., Martin, R. V., Parrish, D. D., & Krotkov, N. A. (2008). "Scaling relationship for NO₂ pollution and urban population size: A satellite perspective." *Environmental Science & Technology*.
- [14] Likens, G. E., & Bormann, F. H. (1974). "Acid rain: A serious regional environmental problem." *Science*.
- [15] Orellano, P., Quaranta, N., Reynoso, J., Balbi, B., & Vasquez, J. (2020). "Effect of outdoor air pollution on asthma exacerbations in children and adults: Systematic review and multilevel meta-analysis." *PLOS ONE*.
- [16] Pusede, S. E., Cohen, R. C., & Kim, S. (2015). "Influence of meteorology and anthropogenic emissions on the spatial and temporal variability of NO₂ in California from 2005 to 2011." *Atmospheric Chemistry and Physics*.
- [17] Russell, A. R., Valin, L. C., & Cohen, R. C. (2012). "Trends in OMI NO₂

- observations over the United States: Effects of emission control technology and the economic recession.” Atmospheric Chemistry and Physics.
- [18] Samoli, E., Aga, E., Touloumi, G., Nisiotis, K., Forsberg, B., Lefranc, A., & Schwartz, J. (2006). “Short-term effects of nitrogen dioxide on mortality: An analysis within the APHEA project.” European Respiratory Journal.
- [19] Schneider, P., Lahoz, W. A., & van der A, R. (2018). “Recent satellite-based trends of tropospheric nitrogen dioxide over large urban agglomerations worldwide.” Atmospheric Chemistry and Physics.
- [20] Seinfeld, J. H., & Pandis, S. N. (2016). Atmospheric Chemistry and Physics: From Air Pollution to Climate Change. Wiley.

Cite this Article-

Rajdeep Singh Sohal, Manasvi Tikoo, Chandan Sharma, Madhav, Aryan Dhanotra, "Trend Analysis of Temporal Variations in NO₂ in Punjab Region", Procedure International Journal of Science and Technology (PIJST), ISSN: 2584-2617 (Online), Volume:1, Issue:6, June 2024.

Journal URL- <https://www.pijst.com/>

DOI- <https://doi.org/10.62796/pijst.2024v1i601>

