**Ambidextrous: Journal of Innovation, Efficiency and Technology in Organization**
https://journal.takaza.id/index.php/ambidextrous
Vol. 4, No. 04, 2026, pp. 288-291
E-ISSN: 3031-7002
E-mail:ambidex@takaza.id



# Analysis of Nitrogen Oxide (NOx) and Sulfur Oxide (SOx) Concentration Trends in Ambient Air in Malang City: Secondary Data Approach (2019–2023)

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**Article History:**
Received : 04-11-2026
Revised : 12-11-2026
Accepted : 19-11-2026

**Keywords:** ***Air Quality, NOx, SOx, Air Pollution, Malang City, Secondary Data***

***Abstract:****Malang City is an educational and tourism hub experiencing a significant increase in motor vehicle volume, which potentially degrades ambient air quality. This study aims to analyze the trend of Nitrogen Oxide (NOx) and Sulfur Oxide (SOx) pollutant concentrations in Malang City over a five-year period (2019–2023). This study uses a descriptive quantitative method using secondary data from the ambient air quality monitoring reports of the Environmental Agency (DLH). Data analysis was conducted by comparing annual average values against the National Ambient Air Quality Standards based on Government Regulation No. 22 of 2021. The analysis results show that NOx concentrations fluctuated with a significant decrease in 2020 due to COVID-19 mobility restrictions, but increased again in 2022-2023 along with the recovery of urban activities. On the other hand, SOx concentrations tend to be stable and well below the quality standard threshold, considering the lack of heavy industrial activity in Malang City. In conclusion, air pollution in Malang City is dominated by mobile sources (transportation) which contribute to NOx emissions, while SOx parameters are still in a very safe category. Stricter traffic management policies are needed to control the upward trend of NOx emissions in the future.*

**How to Cite:** Muhammad Aqil Sammakh, Dewangga Abi Saputra, Muhammad Pandu Islam Jundullah, AM Fatri Ramadhan, Mochamad Hanif Dwi Wicaksono (2026). *Analysis of Nitrogen Oxide (NOx) and Sulfur Oxide (SOx) Concentration Trends in Ambient Air in Malang City: Secondary Data Approach (2019–2023*). *4l*(04). Pp.288-291. https://doi.org/10.61536/ambidextrous.v4i04.1004

https://doi.org/10.61536/ambidextrous.v4i04.1004

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## Introduction

Air quality is one of the key indicators of environmental health and urban sustainability. Population growth, rapid urbanization, and the increasing number of motorized vehicles contribute significantly to the degradation of ambient air quality in urban areas. Malang City, one of the major cities in East Java, is recognized as an educational center and a popular tourism destination. These characteristics generate considerable population mobility, particularly from students, tourists, and local residents, with private motorized vehicles remaining one of the primary modes of transportation. The

high intensity of transportation activities can increase traffic density and vehicle exhaust emissions, potentially contributing to declining ambient air quality at various strategic locations throughout the city (Huda et al., 2020). Therefore, monitoring air pollutant concentrations is essential to evaluate the environmental consequences of urban mobility and support sustainable urban development.

Among the major air pollutants in urban environments, Nitrogen Oxides (NOx) and Sulfur Oxides (SOx) are important parameters because of their potential impacts on human health and environmental quality. NOx emissions, particularly nitrogen dioxide (NO2), are primarily generated through high-temperature combustion processes in motor vehicle engines and other fuel combustion activities. Consequently, increasing traffic density and vehicle mobility may contribute to higher NOx concentrations in ambient air. Meanwhile, SOx emissions, particularly sulfur dioxide (SO2), originate from the combustion of sulfur-containing fossil fuels, including industrial activities, power generation, and certain transportation sources. The concentration of these pollutants is therefore influenced by differences in fuel characteristics, combustion activities, and local emission sources (Wardhana, 2018; Mulyana, 2021). Prolonged exposure to NO2 and SO2 may cause respiratory problems and eye irritation, while these pollutants can also contribute to atmospheric reactions associated with acid rain and environmental degradation (Pratiwi & Setiani, 2019). These characteristics make NOx and SOx important indicators for assessing urban air pollution patterns.

Previous studies have provided an initial understanding of the relationship between urban activities and air pollution. Huda et al. (2020) examined the impact of traffic density on ambient air quality in urban areas, highlighting the relevance of transportation activities in evaluating air pollution. Similarly, Susanto (2019) investigated the fluctuation of NOx pollutants using secondary data in Surabaya and demonstrated the importance of examining changes in pollutant concentrations in relation to urban transportation activities. Other studies have discussed the environmental characteristics and health risks associated with NOx and SOx exposure (Wardhana, 2018; Pratiwi & Setiani, 2019). However, the existing discussion has not sufficiently addressed the simultaneous temporal patterns of NOx and SOx concentrations in Malang City over an extended observation period. In particular, a descriptive comparison of both pollutants across pre-pandemic, pandemic, and post-pandemic conditions remains important because changes in mobility restrictions and the recovery of educational, tourism, and economic activities may influence urban emission patterns differently. Furthermore, examining both pollutants simultaneously allows for a broader understanding of urban air pollution, considering that NOx is strongly associated with transportation and combustion activities, whereas SOx may originate from several sources, including industrial processes, fuel combustion, and transportation.

The COVID-19 pandemic provides an important context for evaluating these temporal changes because restrictions on public mobility during 2020 and the gradual recovery of economic and social activities in subsequent years may have influenced the intensity of emission-generating activities. Nevertheless, the extent to which these changes are reflected in the annual concentrations of NOx and SOx in Malang City requires further descriptive examination. This study therefore aims to analyze the trends and fluctuations in ambient NOx and SOx concentrations in Malang City during the 2019–2023 period using secondary data obtained from the Malang City Environmental Agency (DLH). By comparing annual pollutant concentrations with the national ambient air quality standards stipulated in Government Regulation of the Republic of Indonesia Number 22 of 2021, this study provides a descriptive assessment of changes in urban air pollution levels before, during, and after the COVID-19 pandemic. The findings are expected to contribute empirical information for local environmental monitoring and support the formulation of more appropriate environmental management and urban transportation policies, particularly in controlling emissions from mobile and other combustion-related sources.

## Research Methods

This study used a descriptive quantitative research design with a retrospective observational approach. This design was chosen to examine the overview, trends, and patterns of changes in air pollutant concentrations over time.

## Data source

This study utilizes entirely secondary data. Data were obtained from the Regional Environmental Status Report (SLHD) and the Air Pollution Standard Index (ISPU) summary officially


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published by the Malang City Environmental Agency (DLH) and the Malang City Central Statistics Agency (BPS). The data spanned the last five years, from 2019 to 2023.

**Data Analysis Techniques**

Annual average concentration data of NOx (usually measured as NO2) and SO2 (a representation of SOx) were obtained, compiled, and processed using statistical software (Microsoft Excel/SPSS). The data were analyzed quantitatively and presented in tables and trend graphs (time series).

Furthermore, pollutant concentration data was evaluated and compared with the national ambient quality standards referring to Appendix VII of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management, where the quality standards for NO2 are 200 µg/Nm³ (1 hour) or 65 µg/Nm³ (1 year average), and SO2 is 150 µg/Nm³ (1 hour) or 50 µg/Nm³ (1 year average).

**Results and Discussion**

**Fluctuation Characteristics of NOx (Nitrogen Oxide) Parameters**

Based on secondary data processing, the concentration of NOx gas in the ambient air of Malang City during the 2019–2023 period showed fluctuations that were greatly influenced by the level of activity and mobility of vehicles on the highway.

***Table 1. Average Annual Ambient Air Concentration in Malang City (2019–2023)***

| Year | NO2 concentration (µg/Nm³) | SO2 concentration (µg/Nm³) | External Mobility Information |
|---|---|---|---|
| 2019 | 28.40 | 12.10 | Normal (Pre-Pandemic) |
| 2020 | 18.25 | 11.80 | Strict Restrictions (PSBB/COVID-19) |
| 2021 | 22.10 | 11.95 | Gradual Recovery (PPKM) |
| 2022 | 31.50 | 12.30 | Normalization of Urban Activities |
| 2023 | 35.80 | 12.60 | Full Activity & Vehicle Upgrades |

From the secondary data, it can be seen that the highest NO2 concentration occurred in 2023. In 2020, there was a drastic decrease in NOx concentration. This anomaly aligns with the conditions of the COVID-19 pandemic, where the government implemented Large-Scale Social Restrictions (PSBB), resulting in the temporary closure of most universities and the tourism sector in Malang City. The decrease in vehicle volume directly reduced NOx emissions significantly. Entering 2022 and 2023, the return of students from outside the region and the reopening of the tourism sector caused the NOx trend to climb again beyond pre-pandemic levels (2019). Although the trend is increasing, this value is still below the annual average Quality Standard according to Government Regulation No. 22 of 2021 (namely 65 µg/Nm³).

**Fluctuation Characteristics of SOx (Sulfur Oxide) Parameters**

In contrast to NOx, which is highly reactive to changes in traffic volume, the SO2 parameter trend shows a pattern that tends to be stagnant and very flat.

The low fluctuations and minimal SO2 levels in Malang City are due to the city's characteristics as a trade, service, and education area, rather than a heavy industrial area (manufacturing, smelting plants, or coal-fired power plants). Sources of SOx pollution generally rely heavily on industrial activities that use coal or high-sulfur fuel oil (Mulyana, 2021). The sulfur content in motor vehicle fuels


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in Indonesia has now been gradually reduced through the Euro-4 standard, so the contribution of motor vehicles to total SOx in Malang City is very minimal. The highest SO2 concentrations are also still well below the annual hazard threshold (50 µg/Nm³).

**Policy Implications**

These quantitative data prove that the main challenge to air quality in Malang City is not industrial waste pollutants (SOx), but rather mobile source pollutants (NOx). If the growth rate of motorized vehicles (especially two-wheeled vehicles and private cars powered by conventional gasoline/diesel) is allowed to continue without adequate traffic engineering, NOx concentrations in Malang City are projected to reach the quality standard threshold (65 µg/Nm³) within the next 5-7 years. Therefore, strengthening mass transportation (such as revitalizing city transportation), expanding green lanes, and regular exhaust emission testing are crucial mitigation measures.

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**Conclusion**

Research based on secondary data on ambient air quality in Malang City for the 2019-2023 period shows a contrasting pattern between NOx and SOx pollution levels. NOx concentrations fluctuate dynamically in line with vehicle traffic intensity, with the lowest point occurring during the 2020 pandemic and the highest point in 2023. Meanwhile, SOx concentrations are very stable and low due to the absence of heavy industrial activity. Overall, NOx and SOx pollution levels in Malang City still meet the National Ambient Air Quality Standards based on Government Regulation No. 22 of 2021, but the increasing trend in NOx requires more sustainable urban transportation management policy interventions.

**Acknowledgment**

The author would like to thank the Malang City Environmental Service for the availability of secondary data used in this study.

**Abbreviations**

- **NOx:**Nitrogen Oxide
- **SOx:**Sulfur Oxide
- **DLH:**Environmental Service

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