International Journal of Applied and Scientific Research (IJASR)
Vol. 3, No. 11, 2025: 1073-1082

How Clean is the Air We Breathe? A Study of Hazardous No_2 Gas at Jumbo Supermarket in Manado

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ARTICLE INFO

Keywords: Nitrogen Dioxide (NO_2), Ambient Air Quality, Jumbo Swalayan, Environmental Health, Shopping Center

Received : 5 September
Revised : 23 October
Accepted: 23 November

ABSTRACT

Ambient air quality is a crucial environmental health determinant, particularly in densely populated areas like shopping centers. Nitrogen Dioxide (NO_2), a primary pollutant from vehicle emissions, poses significant risks to respiratory and cardiovascular health. Traders who are active in these locations long-term represent a vulnerable group. Data on NO_2 concentrations in the Jumbo Swalayan area of Manado remains limited, while morbidity data for Acute Respiratory Infections (ARI) in this region is notably high. This study aimed to measure the ambient NO_2 concentrations in the Jumbo Swalayan area of Manado City. This observational study with a cross-sectional design was conducted from May to July 2025. Ambient air samples were collected using a purposive sampling method at three points representing areas with the highest intensity of merchant and vehicle activity. Sampling was performed at three time intervals (morning, noon, afternoon) using a Low Volume Air Sampler (LVAS). The samples were analyzed in a laboratory according to the Indonesian National Standard (SNI) 7117.3:2016 using the spectrophotometric method. Data were analyzed using univariate descriptive statistics and compared against the national ambient air quality standard (Government Regulation No. 22 of 2021). The measurement results showed that NO_2 concentrations varied between 25 $\mu g/m^3$ and 102 $\mu g/m^3$. The highest concentration was found during noon at the point with the highest traffic intensity (102 $\mu g/m^3$). Overall, all measured values remained below the national ambient air quality standard of 200 $\mu g/m^3$. The concentration pattern showed an increase during noon and was associated with higher air temperatures and lower wind speeds. The ambient air quality in the Jumbo Swalayan area of Manado City, based on the NO_2 parameter, still complies with the national quality standard. However, significant temporal and spatial variations, with concentrations nearing half the standard limit at certain points, indicate a potential risk of chronic exposure for traders. Traffic management and periodic monitoring at identified hotspots are recommended as preventive measures

DOI: https://doi.org/10.59890/ijasr.v3i11.138
ISSN-E: 3025-7670
https://journal.multitechpublisher.com/index.php/ijasr/

INTRODUCTION

Environmental health is one of the important determinants in efforts to improve the public's health status. One of the main aspects of environmental health is air quality, which directly affects human health, particularly in areas with dense activity such as shopping centers. Air pollution, defined as the presence of physical, biological, or chemical substances in the atmosphere in harmful amounts, largely comes from motor vehicle emissions. This poses a real threat in urban areas with high traffic density and limited ventilation (Sumampouw & Nelwan, 2024; Siburian, 2020). One of the critical primary air pollutants is Nitrogen Dioxide (NO_2), a reactive gas formed from the combustion of fossil fuels and contributing to the greenhouse effect (World Health Organization [WHO], 2021; Sumampouw, 2020).

Exposure to NO_2 causes serious health impacts, ranging from respiratory tract disorders, increased risk of respiratory infections, bronchitis, and asthma (Brunekreef & Holgate, 2002), to an increased risk of death due to cardiopulmonary diseases in long-term exposure (Hoek et al., 2013). Populations working in polluted environments, such as traders, are more vulnerable due to chronic exposure.

LITERATURE RIVIEW

The Jumbo Swalayan area in Manado City is one of the busiest shopping centers in North Sulawesi, located on a busy traffic route, making it highly susceptible to air pollutant accumulation. Several previous studies in Manado have indicated issues related to NO_2. Research in the basement parking area of Jumbo Swalayan itself showed NO_2 levels ranging from 21.10-134.04 $\mu g/Nm^3$ (Farikah et al., 2018). More concerning, research in the Manado Shopping Center area, which has similar characteristics, found that although NO_2 concentrations (130.69-205.10 $\mu g/Nm^3$) are still below the Threshold Value (NAB), they have already posed health risks both in real-time and over a lifetime to street vendors (Wenas et al., 2020). This finding confirms that regulatory limits do not always align with the absence of health risks. Support from local epidemiological data reinforces the urgency of this issue. Acute Respiratory Infections (ARI) consistently remain the most common diseases in Manado City. Data from Wenang Health Center, which covers the Jumbo Supermarket area, recorded 2,781 ARI cases in 2024. Initial interviews at the research site also revealed that several vendors who have been selling for 10-20 years experienced respiratory problems such as ARI and asthma. This indicates a potential link between long-term exposure to air pollution and the burden Morbidity in the community. Although there is data from the basement parking area (Farikah et al., 2018), ambient air quality monitoring throughout the entire Jumbo Swalayan area, which includes areas with the highest vendor activity and traffic, is still limited. Comprehensive monitoring is highly necessary to depict the actual exposure profile faced by vendors and visitors. Therefore, this study aims to measure ambient air quality based on NO_2 parameters in the Jumbo Swalayan area of Manado City. The results of this study are expected to serve as essential baseline data for planning environmental health interventions and protection for at-risk populations in the area..

METHODOLOGY

Types and Research Design

This study is an observational study with a descriptive approach. The design used is cross-sectional, where the measurement of nitrogen dioxide (NO_2) levels is conducted at a specific point in time (May-July 2025) to describe the ambient air quality conditions at the research location. Time and Place of Research The study was conducted from May to July 2025 in the Jumbo Swalayan area, Manado City, located on Jalan Suprapto, Pinaesaan Sub-district, Wenang District, Manado City, North Sulawesi. Research Subjects The subjects of this study are the ambient air in the Jumbo Swalayan area, Manado City. Ambient air samples were taken at three sampling points. The technique used was purposive sampling based on certain criteria. The criteria for selecting sampling points are:

1. Locations with the highest human activity (vendors and visitors).
2. Locations with the highest motor vehicle traffic intensity.

Locations representing the main area, parking area, and disposal area. Air sampling was carried out at 3 (three) predetermined points. At each point, samples were taken at three different time intervals in one day, namely:

1. Morning: 08:30 - 09:30 WITA
2. Afternoon: 11:15 - 12:15 WITA
3. Evening: 15:30 - 16:30 WITA

Measurements were repeated on different days during the study period to ensure data representativeness. Research Variables and Operational Definitions The variable in this study is the concentration of nitrogen dioxide (NO_2) in ambient air. NO_2 concentration is defined as the mass concentration of NO_2 measured in the ambient air at human breathing height (approximately 1.5 - 2 meters above ground level), expressed in micrograms per cubic meter ($\mu g/m^3$) or parts per billion (ppb). Tools and Materials:

1. Equipment: Calibrated Low Volume Air Sampler (LVAS) equipped with an impinger containing an absorbing solution.
2. Chemicals: Sodium Arsenite ($NaAsO_2$) absorbing solution or according to standard methods (for example, referring to the EPA Method or SNI 7117.3:2016).
3. Laboratory Analysis: NO_2 concentration analysis is carried out using the Visible Spectrophotometry method at a wavelength of 540 nm, based on the Griess-Saltzman reaction, producing a colored compound whose intensity is proportional to the NO_2 concentration.

Sample Collection and Measurement Procedure

1. Preparation: The impinger is filled with a specific absorbing solution according to standard operating procedures.
2. Sample Collection: The LVAS is installed at predetermined sampling points with an inlet height of 1.5–2 meters. Air samples are drawn at a certain flow rate (e.g., 1 L/min) for 60 minutes at each time interval.

3. Storage and Transportation: After sample collection, the impinger is tightly closed, labeled, and stored in a cool box to be taken to the laboratory for analysis within a maximum of 24 hours.

Laboratory Analysis: Samples were analyzed in the laboratory using spectrophotometry methods to determine NO_2 concentration. Data Collection and Analysis The data collected were primary data in the form of NO_2 concentration measurement results from the laboratory. 1. Data Analysis: Data analysis was conducted univariately. NO_2 concentration data from all locations and measurement times were summarized and presented in the form of frequency distribution tables, as well as descriptive statistical measures such as mean, standard deviation, minimum, and maximum values. 2. Comparison with Quality Standards: The average NO_2 concentration measurements were then compared with the national ambient air quality standards listed in the Government Regulation of the Republic of Indonesia No. 22 of 2021 regarding Environmental Protection and Management. Ethical Research Aspects This study did not involve human subjects directly. The research ethics aspect focused more on safety procedures and occupational health and safety (OHS) during sample collection, as well as the management of chemical waste from laboratory analysis according to applicable procedures to prevent environmental pollution.

RESULT

This section describes the concentration of NO2 in a descriptive manner, as shown in Table 1.

Table 1. Results of NO2 Air Concentration Measurements and Meteorological Parameters

Sampling Point	**Measurement Time**	**Air Temperature (°C)**	**Humidity (%)**	**Wind Speed (m/s)**	**NO_2 (μg/m³)**
Point 1 N: 1°29′51.9″ E: 124°54′50.8″	Morning (09:00-10:00)	33,3	47,5	0,2	**25**
	Day (11:05-12:05)	37,1	46,5	0,3	**67**
	Evening (15:30-16:30)	33,1	58,1	0,3	**69**
Titik 2 N: 1°29′51.7″ E: 124°50′28.1″	Morning (08.15-09.15)	33,8	49,5	0,5	**39**
	Day (11.45-12.45)	33,8	49,5	0,5	**39**
	Evening (15:05-16:05)	32,8	58,0	0,3	**36**
Titik 3 N: 1°29′53.3″ E: 124°50′25.4″	Morning (08.40-09.40)	33,1	56,6	0,3	**40**
	Day (11.30-12.30)	38,2	46,8	0,5	**102**
	Evening (15:00-16:00)	32,8	60,5	0,4	**48**

Overview of NO_2 Concentration

Overall, NO_2 concentrations at the three sampling points showed significant variations, both between points and over measurement times. Measured NO_2 concentrations ranged from 25-102 μg/m³. The lowest concentration was 25 μg/m³, measured at Point 1 in the morning. The highest concentration was 102 μg/m³, measured at Point 3 at noon. According to Indonesian Government Regulation No. 22 of 2021, the ambient air quality standard for the NO_2 parameter with a 1-hour measurement time is 200 μg/m³. Therefore, all NO_2 measurement results in this study are still below the national standard. However, values approaching half of the standard (such as 102 μg/m³) indicate a level of pollution that should be monitored.

Analysis Based on Measurement Time

NO_2 concentration patterns tend to follow human and vehicle activity patterns, which is taken into consideration in purposive sampling techniques.

a. Morning (08:15 - 10:00 WITA): NO_2 concentration is relatively lower (25 - 40 μg/m³). This is suspected to be related to activities that have not yet reached their peak. The air temperature, which is not too high yet, also affects the rate of photochemical reactions.
b. Midday (11:05 - 12:45 WITA): NO_2 concentration shows a significant increase at all points, even reaching its peak at Point 3 (102 μg/m³). This time corresponds to the peak of trade activities and vehicle traffic, which are sources of NO_2 emissions. The higher air temperature during midday (recorded at 37.1°C at Point 1 and 38.2°C at Point 3) can accelerate the formation of secondary pollutants.
c. Afternoon (15:00 - 16:30 WITA): NO_2 concentrations show a variable pattern. At Point 1, the afternoon concentration is actually higher than during the day (69 μg/m³), which may be related to heavy vehicle traffic during rush hour or afternoon visitor activity. In contrast, at Points 2 and 3, the afternoon concentration is lower compared to daytime. 3. Analysis Based on Sampling Points Comparison among sampling points provides an overview of the spatial distribution of NO_2 pollution.
    - Point 1: Shows a consistent increase in concentration from morning to afternoon (25 → 67 → 69 μg/m³). This indicates that this location is continuously exposed to emission sources, consistent with the criteria of the "busiest location."
    - Point 2: Shows stable and relatively low concentrations at all measurement times (around 36-39 μg/m³). The same meteorological parameters between morning and daytime (temperature 33.8°C, humidity 49.5%) need to be re-verified, but these conditions and Higher wind speeds (0.5 m/s) are suspected to play a role in better pollutant dispersion.
    - Point 3: Shows very sharp fluctuations, with the highest concentration of the entire study (102 μg/m³) occurring during the daytime. This reinforces the suspicion that Point 3 (representing an area with the

highest traffic intensity) is a hotspot for NO_2 pollution in the area. This spike is very likely caused by the peak motor vehicle density at that time.

Relationship with Meteorological Parameters

Meteorological parameters measured also affect the observed NO_2 concentration.

a. Air Temperature: The highest temperature (38.2°C at Point 3 in the afternoon) coincided with the highest NO_2 concentration. High temperatures can increase evaporative emissions from vehicles and accelerate the reactions that form pollutants in the atmosphere.
b. Humidity: No consistent relationship pattern was observed between humidity and NO_2 concentration.
c. Wind Speed: At Point 2, a relatively higher wind speed (0.5 m/s) is suspected to contribute to lower and more stable NO_2 concentrations, as the wind helps disperse and dilute pollutants. Conversely, low wind speeds (0.2-0.3 m/s) at Point 1 in the morning and afternoon may hinder dispersion, causing NO_2 concentrations to tend to accumulate.

DISCUSSION

The results of this study reveal the dynamics of nitrogen dioxide (NO_2) concentrations in the Jumbo Supermarket area of Manado City, providing an overview of ambient air quality and its implications for health and the environment. The finding that all NO_2 measurements (25–102 µg/m³) are still below the national ambient air quality standard (200 µg/m³) (Indonesian Government Regulation No. 22 of 2021) is consistent with previous studies in similar locations. For example, a study in the basement parking area of Jumbo Supermarket Manado also reported NO_2 levels (21.10–134.04 µg/Nm³) that did not exceed the standard (Farikah et al., 2018). Similarly, a study on the Puuruy-Morosi road found that NO_2 levels in the morning, afternoon, and evening (70.30–106.20 µg/m³) were still within safe limits (Asrudin, 2023). The consistency of these findings indicates that although exposed to human and vehicle activities, NO_2 pollution levels in urban commercial areas like Manado can still be managed.

However, the fact that NO_2 concentrations are still below the quality standards does not automatically eliminate the risk. The observed temporal pattern, where NO_2 concentrations increase significantly during the daytime and peak at Point 3 (102 µg/m³), confirms Muhammad's (2018) findings that human and vehicle activities are the main sources of emissions. This pattern is logical considering that daytime is the peak period for trade activities and traffic. The fluctuations in concentration between sampling points, with Point 3 as the hotspot, reinforce the principle in environmental health that pollutant distribution is uneven and highly dependent on local characteristics (Pinontoan et al., 2020; Sumampouw & Nelwan, 2024). Point 3, suspected to be the area with the highest traffic intensity, becomes the epicenter of NO_2 emissions from motor vehicle combustion processes.

This variation in concentration cannot be separated from the role of meteorological parameters. The study results showed that the highest NO_2 concentration (102 µg/m³ at Point 3) occurred simultaneously with the highest air temperature (38.2°C). This supports Muhammad's (2018) findings, which reported a strong correlation between temperature and NO_2 concentration. High temperatures can increase the rate of photochemical reactions in the atmosphere and evaporative emissions from vehicles. Conversely, higher wind speeds (0.5 m/s) at Point 2 are suspected to contribute to lower and more stable NO_2 concentrations through dispersion and pollutant dilution mechanisms, a phenomenon also explained in the context of air pollutant dynamics (Sumampouw, 2020).

Although the concentration is below the threshold, exposure to NO_2 at measurable levels, especially those approaching 100 $\mu g/m^3$, has the potential to cause health effects, particularly for populations exposed over the long term, such as vendors. Research in the Manado Shopping Center area provides concerning evidence, where 56% of vendors have a lifetime NO_2 Risk Quotient (RQ) exceeding 1, indicating they are at risk of experiencing chronic health effects (Wenas et al., 2020). These findings are relevant to the context of research at Jumbo Swalayan, given the similar characteristics of the location and at-risk population.

The health impacts of NO_2 exposure are multi-faceted. As an irritant gas, NO_2 can cause acute respiratory disorders such as coughing and shortness of breath, as well as decreased lung function, as found among vendors in gas station environments (in Putri, 2018). The mechanism of damage involves airway inflammation, ciliary damage, and reduced local immune function such as alveolar macrophage phagocytosis (Wardhana, 2008). Furthermore, long-term exposure is associated with an increased risk of chronic diseases such as asthma, bronchitis, and even cardiovascular disorders through mechanisms of oxidative stress and systemic inflammation (Syaiful & Sembiring, 2024). Therefore, even though ambient concentrations are still considered safe, the accumulation of daily and annual exposure for vendors remains a serious threat that requires attention.

From a broader environmental perspective, NO_2 emissions not only affect direct health. NO_2 gas is a precursor to the formation of acid rain and fine particles (PM2.5), and it is also a greenhouse gas that contributes to global warming and climate change (Sumampouw, 2020). Therefore, controlling NO_2 emissions from urban commercial areas is not only a local public health issue but also part of a global responsibility in climate change mitigation..

CONCLUSION AND RECCOMENDATION

The conclusions of this study are:

1. The ambient air quality in the Jumbo Swalayan area of Manado City based on NO_2 parameters during May-July 2025 still meets the quality standards of Government Regulation No. 22 of 2021.
2. There are significant temporal and spatial variations. NO_2 concentrations tend to increase during the daytime and reach levels of concern at Point 3, which is associated with the area of highest traffic intensity.
3. Meteorological parameters, particularly air temperature and wind speed, show a correlation with the accumulation and dispersion levels of NO_2 concentrations.

Therefore, it is recommended to implement traffic management, especially during peak hours (midday and afternoon), conduct regular and real-time air quality monitoring in densely commercial areas, and further research is suggested to include additional variables such as the number of vehicles (traffic counting) and to identify stationary emission sources (generators, and others). Inferential statistical analysis (such as correlation tests and ANOVA) can also be applied to examine significant relationships between these variables.

REFERENCES

Asrudin, N., Assiddieq, M. and Rosdiana, R., 2023. Analisis Nitrogen Dioksida (NO2) terhadap Penurunan Kualitas Udara Ambien: Studi Kasus: Desa Puuruy, Kecamatan Morosi, Kabupaten Konawe, Provinsi Sulawesi Tenggara. Jurnal TELUK: Teknik Lingkungan UM Kendari, 3(1), pp.022-026.

Brunekreef, B. and Holgate, S.T., 2002. Air pollution and health. The lancet, 360(9341), pp.1233-1242.

Farikah, T., Maddusa, S. S., & Sumampouw, O. J. (2018). Analisis Kadar Nitrogen Dioksida (NO2) di Area Parkir Basement Jumbo Swalayan Kota Manado Tahun 2018. KESMAS: Jurnal Kesehatan Masyarakat Universitas Sam Ratulangi, *7*(5).

Hoek, G., Krishnan, R.M., Beelen, R., Peters, A., Ostro, B., Brunekreef, B. and Kaufman, J.D., 2013. Long-term air pollution exposure and cardio-respiratory mortality: a review. Environmental health, 12(1), p.43.

Muhammad, F. (2018). *Distribusi Spasial-Temporal Konsentrasi Nitrogen Dioksida (NO2) di Beberapa Kawasan Permukiman Kota Padang* [Tesis tidak dipublikasikan]. Universitas Andalas.

Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021 tentang Penyelenggaraan

Peraturan Pemerintah RI Nomor 41 Tahun 1999 Tentang "Pengendalian Pencemaran Udara"

Pinontoan, O. R., Sumampouw, O. J., & Nelwan, J. E. (2020). Epidemiologi kesehatan lingkungan. Deepublish.

Pinontoan, O. R., Sumampouw, O. J., & Nelwan, J. E. (2020). Epidemiologi kesehatan lingkungan. Deepublish.

Prabowo, K., & Musim, B. (2018). Bahan Ajar Kesehatan Lingkungan; Penyehatan Udara (Cetakan Pertama ed.).Pusat Pendidikan SDM Kesehatan Kemenkes RI.

Purnomo, H. (2013). Antropometri dan Aplikasinya. Graha Ilmu. Yogyakarta

Putri, R. (2018). Hubungan paparan nitrogen dioksida (NO2) dengan penurunan fungsi paru pada pedagang di SPBU. Jurnal Kesehatan Masyarakat Nasional, *12*(1), 1-10.

Qamarya, N., Rahim, I. & Madjid, A. J. J. I. M. D. K. 2022. Pengaruh Risiko Paparan Asap Kendaraan Terhadap Kualitas Kesehatan Pada Polantas Polres Kota Parepare. 5, 468-474. Rahman, A. 2005. Prinsip-Prinsip Dasar,

Qolifah, L. N., Wahyuningsih, N. E., & Darundiati, Y. H. (2023). Karakteristik Risiko Kesehatan Non Karsinogenik Akibat Paparan Gas SO2 dan NO2 pada Pemulung di TPA Jatibarang Kota Semarang. Jurnal Kesehatan Lingkungan Indonesia, 23(1), 50-58.

Radjiman, E. A. (2024). Analisis Risiko Kesehatan Lingkungan Akibat Pajanan Sulfur Dioksida (SO2) Dan Nitrogen Dioksida (NO2) Di Kawasan Industri PT. Semen Tonasa= Analysis of Environmental Health Risk Due To Exposure To Sulfur Dioxide (SO2) And Nitrogen Dioxide (NO2) In The Industrial Area Of PT. Tonasa Cement (Doctoral dissertation, Universitas Hasanuddin).

Rahmatika, N. I. (2017). analisis risiko paparan nitrogen dioksida dari polutan ambien terhadap kesehatan masyarakat di kabupaten Magelang tahun 2015 (Bachelor's thesis, UIN Syarif Hidayatullah Jakarta: Fakultas Kedokteran dan Ilmu Kesehatan, 2017).

Resti Putri (2018). Analisis Risiko Kesehatan Lingkungan Akibat Paparan Gas Nitrogen Dioksida (No2) Terhadap Operator Stasiun Pengisian Bahan Bakar Umum (Spbu) Di Spbu 13.251. 501 Pitameh, Padang (Doctoral Dissertation, Universitas Andalas).

Saidal Siburian, M.M. and Mar, M., 2020. Pencemaran Udara dan Emisi Gas Rumah Kaca. Kreasi Cendekia Pustaka.

Serlina, Y., 2020. Pengaruh Faktor Meteorologi Terhadap Konsentrasi NO2 di Udara Ambien (Studi Kasus Bundaran Hotel Indonesia DKI Jakarta). Jurnal Serambi Engineering, 5(3).

Shafarina, M. I., Rachmaniyah, R., & Sari, E. (2023). Analisis Risiko Pajanan Gas Nitrogen Dioksida pada Petugas Parkir di Pasar Kapasan Surabaya. Jurnal Keselamatan Kesehatan Kerja dan Lingkungan, 4(2), 91-102.

Siburian, R. (2020). Dampak polusi udara terhadap kesehatan pernapasan. Penerbit Buku Medika.

Stieb, D., Berjawi, R., Emode, M., Zheng, C., Salama, D., Hocking, R., Lyrette, N., Matz, C., Lavigne, É., & Shin, H. (2021). Systematic review and meta-analysis of cohort studies of long term outdoor nitrogen dioxide exposure and mortality. PLoS ONE, 16. https://doi.org/10.1371/journal.pone.0246451

Sumampouw, O. J. (2020). Perubahan Iklim dan kesehatan masyarakat. Deepublish.

Sumampouw, O. J., & Nelwan, J. E. (2024). Dasar Kesehatan Lingkungan Konsep Dasar Dan Pencemaran Lingkungan. Deepublish.

Suwari., Kotta, H., & Bhuja, P. (2020). Environmental Health Risk Assessment Of Nitrogen Dioxide Exposure To Ambient Air Pollution In Kupang City. International Journal of Research -GRANTHAALAYAH. https://doi.org/10.29121/granthaalayah.v8.i6.2020.519

Syaiful, M., & Sembiring, C. D. A. (2024). Dampak pajanan nitrogen dioksida (NO2) jangka panjang terhadap risiko penyakit kardiovaskular: Sebuah tinjauan sistematis. Jurnal Kardiologi Indonesia, *45*(1), 23-34.

United States Environmental Protection Agency (US EPA). (2022). Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A).

Wardhana, A. W. (2008). Dampak pencemaran lingkungan. Penerbit Andi.

Wenas, R. A., Pinontoan, O. R., & Sumampouw, O. J. (2020). Analisis Risiko Kesehatan Lingkungan Pajanan Sulfur Dioksida (SO2) dan Nitrogen Dioksida (NO2) di Sekitar Kawasan Shopping Center Manado tahun 2020. Indonesian Journal of Public Health and Community Medicine, *1*(2), 053-058. https://doi.org/10.35801/ijphcm.1.2.2020.29431

World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization.

Xue, T., Tong, M., Wang, M., Yang, X., Wang, Y., Lin, H., Liu, H., Li, J., Huang, C., Meng, X., Zheng, Y., Tong, D., Gong, J., Zhang, S., & Zhu, T. (2023). Health Impacts of Long-Term NO2 Exposure and Inequalities among the Chinese Population from 2013 to 2020. Environmental science & technology. https://doi.org/10.1021/acs.est.2c08022

Yorifuji, T., & Kashima, S. (2020). Long-term exposure to nitrogen dioxide and natural-cause and cause-specific mortality in Japan. The Science of the total environment, 741, 140465. https://doi.org/10.1016/j.scitotenv.2020.140465

Young, B., Ingwersen, W.W., Bergmann, M., Hernandez-Betancur, J.D., Ghosh, T., Bell, E. and Cashman, S., 2022. A system for standardizing and combining us environmental protection agency emissions and waste inventory data. Applied Sciences, 12(7), p.3447