



Comparison Of SO_2 And NO_2 Concentrations In Mountainous And Urban Areas In Relation To Respiratory Disorders Among Gas Station Operators

Irma Juliana Mendrofa¹, Sri Malem Indirawati², Taufik Ashar²

¹Master Student, Faculty of Public Health, University of Sumatera Utara, Medan, Sumatera Utara, Indonesia

²Faculty of Public Health, University of Sumatera Utara, Medan, Sumatera Utara, Indonesia

Email : julianairma788@gmail.com

Article details:

Published: January 2025



Abstract

Air Pollution Caused by High Traffic Density and Its Impact on Respiratory Disorders in Gas Station Operators. This study aims to analyze the differences in SO_2 and NO_2 concentrations between mountainous and urban areas and to assess the impact of these pollutant levels on respiratory disorders among gas station operators. This research adopts a quantitative, analytical observational approach using a cross-sectional study design. The study was conducted at gas stations in mountainous and urban

regions, specifically in the sub-districts of Sibolangit and Berastagi for the mountainous area, and in the city of Medan for the urban area. The research period was from October 2023 to June 2024. The study population consisted of all gas station operators in the mountainous and urban areas, totaling 78 operators, with 39 operators from each region. The sample size was 78 operators, selected using a total sampling technique. Data collection involved interviews and observations, along with the measurement of SO_2 and NO_2 concentrations conducted. Data analysis: univariate analysis and bivariate analysis using independent t-tests and simple logistic regression, with a significance level of 95% ($\alpha=0.05$). The results showed significant differences in SO_2 and NO_2 concentrations between mountainous and urban areas ($P\text{-value SO}_2=0.001$; $P\text{-value NO}_2=0.001$). Additionally, SO_2 levels had a significant effect on respiratory complaints among gas station operators ($P\text{-value}=0.004$; $\text{Exp.B}=1.859$). Recommendations include providing masks to gas station operators and enforcing mask usage policies during work hours by PT. Pertamina. Operators are also encouraged to wear masks to minimize inhalation of air pollutants while working.

Keywords: Areas, NO_2 , respiratory disorders, SO_2

To cite this article :

Irma Juliana Mendrofa, Sri Malem Indirawati, T. A. (2025). Comparison Of SO_2 And NO_2 Concentrations In Mountainous And Urban Areas In Relation To Respiratory Disorders Among Gas Station Operators. *International Journal of Health, Education and Social (IJHES)*, 8(1), 96–108.



Introduction

The growth in population is accompanied by an increase in the transportation sector, which continues to rise each year. This trend is evident in the escalating growth rate of motor vehicles, driven by the increasing number of vehicle users (Prasetyo et al., 2020). Motor vehicles emit harmful exhaust gases due to incomplete combustion, leading to air pollution caused by elevated vehicle emissions (Nazila & Sutomo, 2017; Haruna et al., 2019). Motor vehicle activity contributes approximately 85% of air pollution (Alchamdani, 2019).

Globally, air pollution exposure has exceeded maximum permissible levels. According to the World Health Organization (WHO), around 80% of the population is exposed to air pollution, which significantly contributes to increasing mortality rates. World Health Organization (2024), reported that approximately 6.7 million people die annually due to air pollution, with 4.2 million premature deaths recorded globally in 2019. About 89% of these premature deaths occur in low- and middle-income countries, with the highest numbers in Southeast Asia and the Western Pacific regions.

The highest cases are found in Southeast Asia and the Western Pacific, where annual pollution levels exceed the threshold limits. A total of 3.8 million deaths were reported in these regions, including 567,000 deaths caused by respiratory diseases linked to exposure to SO₂ and NO₂. In Indonesia, air pollution-related deaths increased to 61,000 in 2023, up from 50,000 in the previous year (Nurfadillah & Petasule, 2022).

Air pollution is evaluated based on ambient air quality standards as stipulated in the Regulation of the Minister of Environment and Forestry Number 14 of 2020 regarding the Air Pollution Standard Index, the regulation identifies nitrogen dioxide (NO₂) and sulfur dioxide (SO₂) as the most prevalent pollutants contributing to air pollution.

NO₂ is characterized by a sharp odor, reddish-brown color, and yellow appearance at temperatures below 21.2°C. It poses significant health risks, including reduced lung function, shortness of breath, and even fatality (Hidayat et al., 2022). One primary source of NO₂ is gasoline combustion (Jiang et al., 2019). NO₂ has low water solubility but dissolves in alkaline solutions (Sulasmi & Hasanah, 2020). It is known to exacerbate respiratory issues, posing a severe threat to human respiratory health (Shafarina et al., 2023).

SO₂, on the other hand, is a colorless gas with a sharp odor (Sulasmi & Hasanah, 2020). When SO₂ reacts with water vapor, it produces sulfuric acid (H₂SO₄), leading to acid rain. SO₂ exposure negatively affects human health by causing respiratory irritation, reduced lung function, and symptoms such as coughing, shortness of breath, and asthma (Ponga et al., 2018). High doses



of SO₂ exposure can cause eye, nose, throat, and sinus irritation, pulmonary edema, and even death (Angelia et al., 2019).

Climatic factors significantly influence the concentrations of NO₂ and SO₂ in the atmosphere (Wirosodarmo et al., 2020). Changes in climate parameters can substantially impact the dispersion and distribution of air pollutants, both locally and regionally (Kartasapoeltra, 2017). Mountainous areas tend to have higher humidity levels, as ascending air cools and condenses into clouds, potentially increasing rainfall and humidity. In contrast, urban areas often experience higher temperatures, especially during the day. These elevated temperatures reduce atmospheric relative humidity, resulting in drier air conditions (Susilo, 2021).

According to Alchamdani (2019), meteorological factors such as temperature and humidity significantly affect air pollutant concentrations. High temperatures tend to lower air pollutant concentrations, whereas high humidity slows air movement. This occurs due to the presence of water vapor in the atmosphere, which impedes horizontal and vertical airflow, leading to higher pollutant concentrations.

Serlina (2020), found that wind speed and temperature significantly influence NO₂ concentrations. Wind speed plays a crucial role in dispersing pollutants from their sources. Strong winds can create turbulence, mixing pollutants with surrounding air, thereby reducing pollutant concentrations.

The sub-districts of Sibolangit and Berastagi are mountainous regions with elevations ranging from 600 to 1,400 meters above sea level. Temperatures in Berastagi range from 15.6°C to 23°C, with an average humidity level of 89.12%. This topography affects atmospheric circulation and pollutant distribution in Sibolangit and Berastagi. These areas serve as tourism and agricultural hubs, leading to frequent traffic congestion on main roads due to tourist activities and the distribution of agricultural products to urban centers.

Medan, on the other hand, is an urban area with elevations between 25 and 50 meters above sea level. Temperatures range from 24°C to 33°C, with an average humidity of approximately 80%. The flat topography and high population density influence air circulation patterns and pollutant distribution. Medan, as the largest city in North Sumatra, has the highest air pollution levels in the region. It serves as a center for trade, services, and industry, contributing to frequent traffic congestion on main roads, especially on weekends. The high level of urban activity results in an increased demand for motor vehicles, further exacerbating air pollution levels.

PT. Pertamina provides Public Fuel Filling Stations (PFFS) in various areas to efficiently meet the public's demand for fuel. The quality of service and supply in fulfilling the community's fuel needs heavily relies on the vital role of PFFS operators, who serve as the front line in delivering these services. Gas Station Operators are essential workers responsible for ensuring



smooth service operations, yet they face daily exposure to pollutants such as NO₂ and SO₂. Prolonged exposure to high concentrations of these pollutants poses significant health risks to PFFS operators (Takuloe et al., 2023).

Observations at Gas Station locations in Berastagi and Medan revealed that most operators do not use masks while working. This is due to a lack of awareness about the importance of mask use as a preventive measure against air pollution exposure, coupled with the absence of enforcement or sanctions from Gas Station management. To evaluate and quantify the exposure levels of SO₂ and NO₂ among Gas Station Operators, an Environmental Health Risk Analysis (EHRA) approach is necessary.

The health status of Gas Station Operators is increasingly at risk due to the adverse effects of poor air quality. This is primarily caused by vehicle emissions during fuel refilling queues and as vehicles depart after refueling. Additionally, the strategic location of Gas Stations near main roads exacerbates operator exposure to emissions from passing motor vehicles. This study aims to analyze the differences in SO₂ and NO₂ intake and their impact on respiratory disorders among Gas Station Operators in mountainous and urban areas in 2024.

Methods

This quantitative study employed an analytical observational approach with a cross-sectional design. The research was conducted at gas stations in both mountainous and urban areas. Mountainous area Gas Stations included Gas Station 14.203.1161, Gas Station 14.203.174, and Gas Stations 13.221.113 located in Sibolangit and Berastagi subdistricts. Urban area Gas Stations included Gas Station 14.202.1162 in Medan Amplas subdistrict and Gas Station 14.201.138 in Medan Sunggal subdistrict. The study was conducted from October 2023 to June 2024. The study population comprised all gas station operators in the mountainous and urban areas, totaling 78 individuals (39 operators from mountainous areas and 39 from urban areas). The total sampling technique was employed, resulting in 78 respondents, including 39 operators from each area. Ambient air sampling followed the SNI 19-7119-6:2005 standard for determining ambient air quality monitoring locations. Air sampling was conducted using the intermittent sampling technique at two points from the pollutant source, with consistent measurement intervals from 9:00–11:00 AM and 4:00–6:00 PM.

Data collection procedures involved interviews and observations, alongside measurements of SO₂ and NO₂ concentrations performed by laboratory staff from BTKL PP Class I Medan. The questionnaire and observation instruments collected data on respiratory complaints and respondent characteristics, including gender, age, use of personal protective equipment (masks), work duration, and medical history. The measured outcomes included SO₂ and NO₂ concentrations. Data



analysis was performed using SPSS software version 25. Two analytical steps were employed: univariate analysis and bivariate analysis, utilizing independent t-tests and simple logistic regression with a significance level of 95% ($\alpha = 0.05$).

The principal investigator received an ethical clearance certificate from the Health Research Ethics Committee of Universitas Sumatera Utara (No:992/KEPK/USU/2024). Additionally, permissions were obtained from academic administrators and relevant authorities before data collection. Informed consent was acquired from all respondents prior to distributing the questionnaires.

Results

Characteristics of Gas Station Operators in Mountainous and Urban Areas

The characteristics of gas station operators in mountainous and urban areas include age, gender, years of service, use of masks, and history of respiratory diseases. The frequency distribution of gas station operator characteristics in these areas is presented in the table below:

Table 1. Frequency Distribution of Gas Station Operator Characteristics in Mountainous and Urban Areas

Gas Station Operator Characteristics	Areas			
	Mountainous		Urban	
	n	%	n	%
Gender				
Male	23	59.0	23	59.0
Female	16	41.0	16	41.0
Age				
≥ 28 years	19	48.7	13	33.3
< 28 years	20	51.3	26	66.7
Years of Service				
≥ 5 years	15	38.5	15	38.5
< 5 years	24	61.5	24	61.5
History of Respiratory Diseases				
Yes	2	5.1	3	7.7
No	37	94.9	36	92.3
Mask Usage				
Never	17	43.6	10	25.6
Rarely	8	20.5	9	23.1
Occasionally	4	10.3	10	25.6
Often	10	25.6	7	17.9
Always	0	0.0	3	7.7



Based on Table 1, the frequency distribution of Gas Station Operator characteristics in mountainous areas is as follows: Male operators totaled 23 individuals (59%), while female operators accounted for 16 individuals (41%). Operators aged ≥ 28 years constituted 19 individuals (48.7%), whereas those aged < 28 years comprised 20 individuals (51.3%). Operators with ≥ 5 years of service totaled 15 individuals (38.5%), while those with < 5 years of service accounted for 24 individuals (61.5%). Only 2 operators (5.1%) reported a history of respiratory diseases, while 37 operators (94.9%) did not report any respiratory history. A total of 17 operators (43.6%) reported never using masks while working, 8 operators (20.5%) reported rarely using masks, 4 operators (10.3%) used masks occasionally, and 10 operators (25.6%) reported frequent mask usage.

Frequency distribution of Gas Station Operator characteristics in urban areas is as follows: Male operators totaled 23 individuals (59%), while female operators accounted for 16 individuals (41%). Operators aged ≥ 28 years comprised 13 individuals (33.3%), while those aged < 28 years totaled 26 individuals (66.7%). Operators with ≥ 5 years of service totaled 15 individuals (38.5%), while those with < 5 years of service accounted for 24 individuals (61.5%). Only 3 operators (7.7%) reported a history of respiratory diseases, while 36 operators (92.3%) did not report any respiratory history. A total of 10 operators (25.6%) reported never using masks while working, 9 operators (23.1%) reported rarely using masks, 10 operators (25.6%) used masks occasionally, 7 operators (17.9%) reported frequent mask usage, and 3 operators (7.7%) consistently used masks.

SO₂ and NO₂ Concentrations in Mountainous and Urban Areas

The descriptive analysis of SO₂ and NO₂ Concentrations for Gas Station Operators in Mountainous and Urban Areas is summarized as follows:

Table 2. Descriptive Analysis of SO₂ and NO₂ Concentrations for Gas Station Operators in Mountainous and Urban Areas

Parameter	Baku Mutu	Mountainous Areas			Urban Areas	
		Gas Station 1	Gas Station 2	Gas Station 3	Gas Station 1	Gas Station 2
SO ₂ (µg/m ³)	150	81.2	84.8	72.9	94.6	92.9
NO ₂ (µg/m ³)	200	29.3	33.5	38.5	38.3	37.4

Based on the results in Table 2, the descriptive analysis of SO₂ and NO₂ concentrations for Gas Station Operators in Mountainous and Urban Areas is as follows: In the mountainous areas,



the highest SO₂ concentration was recorded at Gas Station 2, measuring 84.8 µg/m³, while the highest NO₂ concentration was observed at Gas Station 3, measuring 38.5 µg/m³. In the urban areas, the highest concentrations of both SO₂ and NO₂ were recorded at Gas Station 1, with values of 94.6 µg/m³ and 38.3 µg/m³, respectively.

Respiratory Complaints Among Gas Station Operators in Mountainous and Urban Areas

Respiratory complaints refer to issues with the respiratory system experienced by Gas Station operators as a result of exposure to SO₂ and NO₂ emitted from vehicle exhaust. The frequency distribution of respiratory complaints among Gas Station operators in mountainous and urban areas is presented in the table below:

Table 3. Frequency Distribution of Respiratory Complaints Among Gas Station Operators in Mountainous and Urban Areas

Respiratory Complaints	Areas			
	Mountainous		Mountainous	
	n	%	n	%
Experienced	25	64,1	30	76,9
Not Experienced	14	35,9	9	23,1

Based on the results in Table 3, the frequency distribution of respiratory complaints among gas station operators in mountainous and urban areas reveals that in mountainous regions, 25 operators (64.1%) reported experiencing respiratory complaints, while 14 operators (35.9%) reported no complaints. In contrast, in urban areas, 30 operators (76.9%) reported experiencing respiratory complaints, whereas 9 operators (23.1%) reported no complaints.

Differences in SO₂ and NO₂ Concentrations Between Mountainous and Urban Areas

The analysis of differences in SO₂ and NO₂ concentrations in mountainous and urban areas highlights the variations in pollutant levels between these regions. The details of the differences are presented as follows:

Table 4. Analysis of Differences in SO₂ and NO₂ Concentrations Between Mountainous and Urban Areas

Areas	Concentrations	n	Mean	SD	Pvalue
Mountainous	SO ₂	39	79,633	5,0480	0,001
Urban		39	93,685	0,8586	
Mountainous	NO ₂	39	33,767	3,8098	0,001
Urban		39	37,815	0,4545	



Based on the results in Table 4, the mean SO₂ concentration in mountainous areas is 79.633 µg/m³ with a standard deviation of 5.0480 µg/m³. Meanwhile, the mean SO₂ concentration in urban areas is 93.685 µg/m³ with a standard deviation of 0.8586 µg/m³. Statistical testing yielded a p-value of 0.001, indicating a significant difference in SO₂ concentrations between gas stations in mountainous and urban areas.

The mean NO₂ concentration in mountainous areas is 33.767 µg/m³ with a standard deviation of 3.8098 µg/m³. Meanwhile, the mean NO₂ concentration in urban areas is 37.850 µg/m³ with a standard deviation of 0.4545 µg/m³. Statistical testing also yielded a p-value of 0.001, indicating a significant difference in NO₂ concentrations between gas stations in mountainous and urban areas.

Effects of SO₂ and NO₂ Concentrations on Respiratory Complaints Among Gas Station Operators in Mountainous and Urban Areas

A bivariate analysis using simple logistic regression was conducted to assess the effects of SO₂ and NO₂ concentrations on respiratory complaints among gas station operators in mountainous and urban areas. The results are presented as follows:

Table 5. Effects of SO₂ and NO₂ Concentrations on Respiratory Complaints Among Gas Station Operators in Mountainous and Urban Areas

	β	Exp B	Confidence Interval (95% CI) for Exp B		Pvalue
			Lower	Upper	
Concentrations SO ₂	-0,338	1,859	1,176	2,306	0,004
Concentrations NO ₂	-0,161	.851	.707	1.025	0,089

Based on the results in Table 5, the effect of SO₂ concentrations on respiratory complaints among gas station operators in mountainous and urban areas showed an Exp(B) value of 1.859. This indicates that SO₂ concentrations are associated with a 1.8 times higher likelihood of respiratory complaints among gas station operators. The statistical test yielded a p-value of 0.004, signifying a significant relationship between SO₂ concentrations and respiratory complaints among gas station operators in these areas.

Regarding the effect of NO₂ concentrations on respiratory complaints among gas station operators in mountainous and urban areas, the Exp(B) value was 0.851. This suggests that NO₂ concentrations are associated with a 0.8 times likelihood of respiratory complaints among gas station operators. However, the statistical test yielded a p-value of 0.089, indicating that there is



no significant relationship between NO₂ concentrations and respiratory complaints among gas station operators in these areas.

Discussion

Respiratory complaints encompass various symptoms that can disrupt the respiratory system, such as shortness of breath, chest pain, coughing, sore throat, and sneezing (Rahman et al., 2021). These complaints can be attributed to multiple factors, including medical conditions, environmental factors, lifestyle choices, and genetic predisposition (Grigorieva & Lukyanets, 2021). Poor environmental quality, often caused by air pollution, results from motor vehicle emissions, industrial activities, and other combustion processes, which lead to the formation of chemical reactions in the atmosphere (Haruna et al., 2019; Gita et al., 2024)

Gas station operators represent a vulnerable group at risk of developing respiratory complaints due to prolonged exposure to motor vehicle exhaust fumes and fuel vapors during their eight-hour work shifts (Takuloe et al., 2023). Vehicle emissions contain hazardous substances, including sulfur dioxide (SO₂) and nitrogen dioxide (NO₂) (Shabrina & Pratama, 2022). The primary sources of SO₂ and NO₂ are motor vehicles, particularly diesel-powered engines (Asri et al., 2022). Gasoline-powered vehicles predominantly emit NO₂, while diesel-powered vehicles produce higher concentrations of SO₂ due to the combustion of diesel fuel (Apriyana et al., 2023).

The findings of this study indicate that SO₂ and NO₂ concentrations at the research locations remain within permissible limits. This is likely because the primary sources of SO₂ and NO₂ pollution at these sites are limited to transportation activities, such as motor vehicles refueling and passing through sampling points.

According to Fitriana & Siwiendrayanti (2019), the absence of high concentrations of SO₂ and NO₂ in areas distant from pollution sources does not imply that these pollutants are absent or minimally generated. Instead, SO₂ and NO₂ may have undergone chemical transformations into other compounds, such as sulfites or sulfates.

The findings of this study indicate significant differences in SO₂ and NO₂ concentrations between mountainous and urban areas, with a p-value of 0.001. Mountainous areas tend to have lower temperatures and higher humidity, which can facilitate the deposition of some pollutants. In contrast, urban areas experience higher temperatures due to the greenhouse effect, exacerbating air pollution levels.

Mountainous regions are characterized by abundant vegetation that serves as a natural absorber of pollutants. Additionally, the topography of mountainous areas often promotes better airflow, enabling pollutants to disperse more effectively. Conversely, urban areas are often densely built with tall buildings that can trap pollutants within the area. Human activities also contribute



to the observed differences in SO₂ and NO₂ concentrations. Urban activities such as transportation, industrial processes, and combustion significantly increase SO₂ and NO₂ concentrations. In contrast, these activities are limited in mountainous regions, resulting in lower pollutant levels.

This study aligns with the findings of Alchamdani (2019), who reported differences in SO₂ and NO₂ concentrations between mountainous and coastal areas, attributed to temperature variations. Elevated air temperatures reduce air density near the Earth's surface compared to higher altitudes, causing upward convection currents that carry pollutants such as SO₂ and NO₂ away from the surface. As a result, SO₂ and NO₂ concentrations tend to be lower near the surface in areas with high temperatures.

The findings of this study indicate that SO₂ concentrations significantly influence respiratory complaints among gas station operators in both mountainous and urban areas. Higher exposure to SO₂ correlates with an increased risk of respiratory complaints. However, NO₂ concentrations were found to have no significant effect on respiratory complaints in these areas.

Even low concentrations of SO₂ exposure can cause respiratory issues in the lungs, especially when exposure is continuous, as experienced by outdoor workers like gas station operators. Additionally, it is essential to consider the potential combined effects of other gases, such as NO₂, when both are present simultaneously. Prolonged exposure to SO₂ and NO₂ can irritate the respiratory tract, potentially leading to a gradual decline in lung function.

These findings are consistent with study of Masito (2018), which reported that exposure to NO₂ and SO₂ affects respiratory complaints. Prolonged and continuous exposure to ambient air pollutants increases the likelihood of respiratory complaints. Although the frequency and duration of complaints were not specifically quantified due to recall challenges, individuals reported symptoms such as coughing, shortness of breath, itchy or dry throats, cough accompanied by breathlessness, and runny noses.

Conclusion and Recommendation

The findings of this study can be concluded as follows: there is a significant difference in the concentrations of SO₂ and NO₂ between the mountainous and urban areas (P-value SO₂ = 0.001 and P-value NO₂ = 0.001), and there is a significant effect of SO₂ concentrations on respiratory complaints among gas station operators in both mountainous and urban areas (P-value = 0.004; Exp.B = 1.859).

Recommendations for PT. Pertamina include providing masks for gas station operators and implementing a policy requiring the use of masks while working. Gas Station Operators are encouraged to wear masks to minimize the inhalation of air pollution during their work. The



Environmental and Forestry Agency is advised to regularly and continuously monitor and control air pollutants. Local governments should focus on reforestation and planting initiatives to counteract air pollution in line with their environmental functions. Furthermore, efforts to reduce the number of motor vehicles, such as implementing progressive taxes and enhancing public transportation use, are recommended.

References

- Alchamdani. (2019). No₂ and so₂ exposure to gas station workers health risk in Kendari City. *Jurnal Kesehatan Lingkungan*, 11(4), 319-330. <https://10.20473/jkl.v11i4.2019.319-330>
- Angelia, G.C., Akili, R.H., & Maddusa, S S. (2019). Analisis kualitas udara ambien karbon monoksida (co) dan nitrogen dioksida (no₂) di beberapa titik kemacetan di Kota Manado. *Jurnal KESMAS*, 8(6), 378-387.
- Apriyana, M., Ergantara, R.I., & Nasoetion, P. (2023). Analisis emisi karbon monoksida akibat kemacetan kendaraan di Kota Bandar Lampung (Studi Kasus: Palang Pintu Perlindungan Kereta Api Jl. Hi. Komarudin). *Jurnal Serambi Engineering*, 8(3), 6573–6581. <https://doi.org/10.32672/jse.v8i3.5512>
- Asri, L.N., Sari, K.E., & Meidiana, C. (2022). Emisi co kendaraan bermotor pada ruas jalan dengan tingkat pelayanan rendah di Kota Malang. *Planning for Urban Region and Environment*, 11(1), 31–38. <https://purejournal.ub.ac.id/index.php/pure/article/view/266>
- Fitriana, D., & Siwiendrayanti, A. (2019). Kualitas udara dan keluhan sesak napas pemulung di Tempat Pembuangan Akhir. *HIGEIA (Journal of Public Health Research and Development)*, 3(3), 357-368. <http://journal.unnes.ac.id/sju/index.php/higeia>
- Gita, A., Kania, N. P., & Zahra, T. A. (2024). Gangguan dan penurunan fungsi paru pada pekerja jalanan. *Jurnal Anestesi: Jurnal Ilmu Kesehatan dan Kedokteran*, 2(3), 118-131. <https://doi.org/10.59680/anestesi.v2i3.1202>
- Grigorieva, E., & Lukyanets, A. (2021). Combined effect of hot weather and outdoor air pollution on respiratory health: Literature review. *Atmosphere*, 12(6), 790. <http://doi.org/10.3390/atmos12060790>
- Haruna, H., Lahming, L., Amir, F., & Asrib, A.R. (2019). Pencemaran udara akibat gas buang kendaraan bermotor dan dampaknya terhadap kesehatan. *UNM Environmental Journals*, 2(2), 57-61. <https://creativecommons.org/licenses/by-nc/4.0/>
- Hidayat, R., Amir, R., & Majid, M. (2022). Polusi udara pada ruang basement parkir a-systematic review. *Journal of Health Educational: J-HESTECH*, 5(2), 135 – 150. <https://doi.org/10.25139/htc.v5i2.4417>



- Jiang, Y., Niu, Y., Xia, Y., Liu, C., Lin, Z., Wang, W., ... & Kan, H. (2019). Effects of personal nitrogen dioxide exposure on airway inflammation and lung function. *Environmental research*, 177, 108620. <https://doi.org/10.1016/j.envres.2019.108620>
- Kartasapoetra, A.G. (2017). *Klimatologi : pengaruh iklim terhadap tanah dan tanaman*. Jakarta : PT. Bumi Aksara.
- Masito, A. (2018). Analisis risiko kualitas udara ambien (NO₂ dan SO₂) dan gangguan pernapasan pada masyarakat di Wilayah Kalianak Surabaya. *Jurnal Kesehatan Lingkungan*, 10(4), 394-401.
- Nazila, Z., & Sutomo, A.H. (2017). Kualitas udara hasil pembakaran avtur dan gangguan fungsi paru pekerja di bandara Supadio Pontianak. *BKM Journal of Community Medicine and Public Health*, 33(6), 277-284.
- Nurfadillah, A.R., & Petasule, S. (2022). Environmental health risk analysis (so₂, no₂, co and tsp) in The Bone Bolango Area Road Segment. *Journal Health & Science: Gorontalo Journal Health and Science Community*, 6(2), 76-89. <http://doi.org/10.35971/gojhes.v5i3.13544>
- Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor 14 Tahun 2020 tentang Indeks Standar Pencemaran Udara (ISPU)
- Ponga, F.C., Akili, R.H., & Sumampouw, O. J. (2018). Gambaran kualitas udara ambien sulfur dioksida di Kecamatan Tuminting Kota Manado Tahun 2018. *Jurnal KESMAS*, 7(4), 1-6.
- Prasetyo, M., Mallongi, A., & Amqan, H. (2020). Analisis risiko pada pedagang pisang epe akibat pajanan gas no₂ di Jalan Penghibur Kota Makassar. *Hasanuddin Journal of Public Health*, 1(1), 71-82.
- Rahman, A.A., Usman, U., & Rusman, A.D.P. (2021). Gambaran Kualitas Udara Ambien Dan Keluhan Gangguan Pernapasan Pada Masyarakat Kota Pare Pare. *Jurnal Ilmiah Manusia Dan Kesehatan*, 4(3), 351-358. <http://jurnal.umpar.ac.id/index.php/makes>
- Sabrina, A. P., & Pratama, R. (2022). Gambaran kualitas udara serta analisis risiko nitrogen dioksida (no₂) dan sulfur dioksida (so₂) di Kabupaten Bekasi. *Journal of Engineering Environtmental Energy and Science*, 1(2), 63–70. <https://doi.org/10.31599/joes.v1i2.1289>
- Serlina, Y. (2020). Pengaruh faktor meteorologi terhadap konsentrasi no₂ di udara ambien (Studi Kasus Bundaran Hotel Indonesia DKI Jakarta). *Jurnal Serambi Engineering*, 5(3), 1228 – 1235. <https://doi.org/10.32672/jse.v5i3.2146>
- 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. <http://jk3l.fkm.unand.ac.id/index.php/jk3l/index>
- Sulasmi, & Hasanah, U. (2020). Analisi kadar co₂ dan no di Basement Trans Studio Makassar. *Sulolipu: Media Komunikasi Sivitas Akademika dan Masyarakat*, 20(2), 295-302. <https://doi.org/10.32382/sulolipu.v2i20.1726>



Susilo, B. (2021). *Mengenal iklim dan cuaca di Indonesia*. Yogyakarta: DIVA Press.

Takuloe, S.R.R., Jusuf, H., Nakoe, M.R., & Arsyad, N. (2023). Risiko paparan sulfur dioksida (so₂) pada petugas stasiun pengisian bahan bakar umum (spbu). *Jambura Journal of Epidemiology*, 2(2), 50-58. <http://ejurnal.ung.ac.id/index.php/jje>

Wirosoedarmo, R., Suharto, B., & Proborini, D.E. (2020). Analisis pengaruh jumlah kendaraan bermotor dan kecepatan angin terhadap karbon monoksida di terminal arjosari. *Jurnal Sumberdaya Alam dan Lingkungan*, 7(2), 57-64. <https://dx.doi.org/10.21776/ub.jsal.2020.007.02.2>

World Health Organization (WHO). (2024). *Ambient (Outdoor) Air Pollution*. Dikases dari [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)



International Journal of Health, Education and Social (IJHES)