



## Analysis of Environmental Health Risks From Exposure to Sulfur Dioxide Among Traders in the Pasar Bersehati Area of Manado City

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### ABSTRACT

Sulfur dioxide (SO<sub>2</sub>) is a pollutant gas that is colorless and has a sharp odor. SO<sub>2</sub> can have a negative impact on human health by causing respiratory tract irritation and decreased lung function. Short-term exposure to SO<sub>2</sub> can be associated with respiratory diseases in children and adults, especially those with asthma and the elderly. Long-term exposure to SO<sub>2</sub> causes an inflammatory response in the lungs that leads to narrowing of the airways and damage to lung tissue known as emphysema. This study aims to analyze the environmental health risks due to exposure to Sulfur Dioxide (SO<sub>2</sub>) on traders in the Bersehati Market area of Manado City, which is an area with heavy trading activities and motorized vehicle traffic. The study was conducted using the Environmental Health Risk Analysis (ARKL) approach with an observational method. Measurements of SO<sub>2</sub> concentrations were carried out at three points (front parking lot, middle parking lot, and back parking lot) at three different times: morning, afternoon, and evening. The method used was Pararosanilin (SNI 19-7119.7-2017) with a spectrophotometer. A total of 10 traders at each point were selected as research subjects. A total of 30 traders were selected as research subjects. Ambient air quality analysis of SO<sub>2</sub> was conducted by a team from the Manado Health Center Laboratory. The results showed that the average SO<sub>2</sub> concentration was around 11.667 µg/m<sup>3</sup> and was still below the quality standard of 150 µg/m<sup>3</sup> (Minister of Health Regulation No. 2 of 2023), so the air quality in the research area was classified as good. The calculation results showed that the highest risk characteristic (RQ) value of the three research points was 0.1397 with an average of 0.06862 (real time) and for the highest lifetime RQ value of 0.1397449 with an average of 0.0047027, indicating that the RQ value of 30 trader respondents at the Bersehati Market in Manado City, namely RQ ≤ 1, indicated that the value was still in the safe category or did not pose a health risk. The conclusion of this study is that the SO<sub>2</sub> concentration in this study was below the quality standard and the RQ value was not risky. Efforts to maintain good air quality and public health at the research location include conducting regular air tests

## **INTRODUCTION**

Air pollution occurs due to the entry or mixing of harmful substances, whether in the form of physical, chemical, or biological elements, into the atmosphere. This can happen naturally or anthropogenically (through human activities). The presence of these substances in certain amounts can have negative impacts on the health of living beings, reduce air quality, cause discomfort, and damage the environment and property (Wihardjo, 2021).

Data from the World Health Organization (WHO) (2018) estimates 4.2 million deaths worldwide due to ambient air pollution, mainly from heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections. According to the Central Statistics Agency (BPS) of North Sulawesi Province, the number of motor vehicles in Manado City in 2023 was recorded at 429,267 units, with vehicle types as follows: passenger cars 78,702 units, buses 699 units, trucks 28,734 units, and motorcycles 321,132 units. Based on data from the Manado City Health Office from December 2024 to early January 2025, Acute Respiratory Infections (ARI) became the leading disease as the most common illness in Manado City, including in Wenang District. The Central Statistics Agency (BPS) of Manado City in 2024 recorded a total of 21,865 ARI cases in Manado. According to data from Wenang Health Center over 5 years (2020-2024), Acute Respiratory Infection (ARI) is the disease with the highest number of patients among the top 10 diseases in outpatient visits at Wenang Health Center, Manado City. Wenang Health Center recorded ARI as the number one disease among the top 10 diseases in 2020-2021. One of the air pollutants is Sulfur Dioxide (SO<sub>2</sub>). SO<sub>2</sub> is a pollutant gas that is colorless and has a sharp odor. SO<sub>2</sub> can negatively affect human health by causing respiratory tract irritation and decreased lung function. Symptoms that may occur include coughing, shortness of breath, and asthma (Muziansyah et al., 2015). Previous studies have assessed air quality in several areas of Manado City. Research by Wenas et al. (2020) around the Manado Shopping Center area showed that SO<sub>2</sub> levels in the air around the Manado Shopping Center are still below the Threshold Limit Value. Meanwhile, research by et al. (2020), Analysis of air SO<sub>2</sub> levels in the Malalayang Terminal area of Manado City in 2019 showed that the SO<sub>2</sub> levels in the Malalayang Terminal area of Manado City are still well below the standard quality limits.

## **LITERATURE RIVIEW**

Research by Tiwa et al. (2024) on ambient air SO<sub>2</sub> quality at bus terminals in Manado City and by Ponga et al. (2018) on ambient air SO<sub>2</sub> quality in Tuminting District, Manado City, shows that SO<sub>2</sub> concentrations are still below the existing thresholds. This is reinforced by the results of the Air Quality Index (AQI) measurement, which showed a score of 25 on July 21, 2024, indicating good air quality with minimal pollutants. This means that Manado City is still considered one of the cities with the lowest air pollution levels (BPS, 2024).

However, based on risk analysis using the Environmental Health Risk Assessment (EHRA) method, conducted based on the calculation of intake values, reference dose (RfD), and characteristics of the exposed population, it can indicate an impact on the communities surrounding the measurement location.

This refers to the standards of the WHO (2021), US EPA (2022), as well as national regulations. The results of this analysis will show the level of health risk posed, whether it is still within the safe category (acceptable risk) or has exceeded the safe limit (unacceptable risk), so it can be used as a basis for policy formulation and environmental health mitigation measures.

Bersehati Market Area is one of the traditional markets located in the city center of Manado. Its strategic location and easy accessibility from various directions, as well as being reachable by different types of transportation such as cars and motorcycles, make this market one of the main trade centers for the local community. This condition has the potential to cause a buildup of air pollutants, including SO<sub>2</sub>. Traders who work daily around this area have a higher risk of exposure to pollutants compared to the general public. The aim of this study is to determine the concentration of SO<sub>2</sub> in ambient air and the health risks for traders exposed to air containing SO<sub>2</sub> at Bersehati Market in Manado City in 2025.

## METHODOLOGY

Jenis penelitian ini yaitu observasional dengan metode pendekatan analisis risiko kesehatan Environment. The research was conducted in the Pasar Bersehati area of Manado City, located on Suprpto Street, Pinaesaan sub-district, Wenang district, Manado City, North Sulawesi. This location falls within an area dense with economic, social, and transportation activities, making it one of the strategic points in the city center. The research location map can be seen in Figure 1.



Figure 1. Research Location Map in the Bersehati Market Area

The research was conducted from May to August 2025. The population in this study consisted of traders who are active around the Bersehati Market area in Manado City. The sample in this study was taken purposively by determining

the number of ambient air sampling points and the number of trader respondents who became the subjects of the study. Since the total population of traders is unknown, the researchers took 10 traders at each point (three points) as research subjects. The criteria for research subjects were traders who have been active for at least 1 year in the study location. Therefore, in total, there are 30 traders who became the research subjects. The ambient SO<sub>2</sub> air quality analysis was conducted with a team from the Manado Public Health Laboratory (BLKM). The variable in this study is the Risk Quotient (RQ) value, which represents the potential non-carcinogenic health risk arising from SO<sub>2</sub> exposure among vendors in the Bersehati Market area of Manado City.

## RESULT

This section explains the distribution of respondent characteristics, the concentration of SO<sub>2</sub> in ambient air, intake rate, exposure frequency at the study site, body weight and exposure duration, SO<sub>2</sub> concentration among vendors, and Risk Quotient (RQ) values. This can be seen in Tables 1-7.

Table 1. Distribution of Respondent Characteristics

<b>Respondent Characteristics</b>	<b>category</b>	<b>N</b>	<b>%</b>
<b>Age</b>	17-25	5	16,7
	26-35	9	30,0
	36-45	6	20,0
	46-55	6	20,0
	56-65	2	6,7
	>66	2	6,7
	<b>Total</b>		30
<b>gender</b>	Male	14	46,0
	Female	16	53,3
	<b>Total</b>		30

Table 1 shows that the majority of respondents are in the 26-35 age group (30.0%) and female (53.3%). It further explains the distribution of respondents based on duration and timing of exposure. This is shown in Table 2.

Table 2. Distribution of Respondents Based on Duration and Timing of Exposure

<b>Characteristics</b>	<b>Category</b>	<b>N</b>	<b>%</b>
Exposure Duration (hours/ days)	6	2	6.7
	7	4	13.3
	8	5	16.7
	10	1	3.3
	12	6	20.0
	14	3	10.0
	15	8	26.7
	18	1	3.3

Exposure Time (days/ years)			
	309	4	13.3
	310	1	3.3
	251	1	3.3
	256	1	3.3
	365	23	76,7
<b>Total</b>	<b>30</b>	<b>30</b>	<b>100</b>

Table 2 shows that based on the number of hours worked per day, traders most often work 12 hours per day (20.0%) and the least amount is 10 and 18 hours per day (3.3%). Traders who work 365 days per year (76.7%) indicate that most traders do not have fixed days off and work every day throughout the year. Next, the distribution of the respondents' length of stay is explained. This can be seen in Table 3.

Table 3. Distribution of Length of Stay

Length of Stay	n	%
1	4	13.3
2	4	13.3
3	1	3.3
4	1	3.3
5	3	10.0
6	1	3.3
10	2	6.7
12	1	3.3
15	1	3.3
20	2	6.7
25	2	6.7
27	1	3.3
30	6	20.0
33	1	3.3
<b>Total</b>	<b>30</b>	<b>100.0</b>

Table 3 shows the highest number of traders being at 30 years of work experience (20.0%) and the lowest number of traders being 1 person (3.3%) in the work experience categories of 3, 4, 12, 15, 27, and 33 years.

Table 4. SO2 Concentration in Ambient Air

Location	Time Measurement	Standard Quality	Result ( $\mu\text{g}/\text{m}^3$ )	Method/ Tool
<b>Titik 1</b> N : 1°29'51,9" E : 124°54'30,8"	Morning 09:00-10:00	150 (1 Hour)	10	SNI 7119.7-2017
	Day 11:05-12:05	150 (1 Hour)	5	SNI 7119.7-2017
	Evening 15:30-16:30	150 (1 Hour)	8	SNI 7119.7-2017
<b>Titik 2</b> N : 1°29'51.7" E : 124°50'28.1"	Morning 08:15-09:15	150 (1 Hour)	17	SNI 7119.7-2017
	Day 11.45-12.45	150 (1 Hour)	9	SNI 7119.7-2017
	Evening 15:05-16:05	150 (1 Hour)	17	SNI 7119.7-2017
<b>Titik 3</b> N : 1°29'52.3" E : 124°50'25.4"	Morning 08:40-09:40	150 (1 Hour)	19	SNI 7119.7-2017
	Day 11.30-12.30	150 (1 Hour)	6	SNI 7119.7-2017
	Evening 15:00-16:00	150 (1 Hour)	14	SNI 7119.7-2017

Table 4 shows that the measured SO2 concentrations ranged from 5-19  $\mu\text{g}/\text{m}^3$ . The highest concentration was recorded at a point during the morning measurement (08:40-09:40) at 19  $\mu\text{g}/\text{m}^3$ , due to the location and time of sampling, which was busy with vehicle activity. The average SO2 concentration was 11.66  $\mu\text{g}/\text{m}^3$ . This value is still within the Threshold Limit Value (TLV) of 150  $\mu\text{g}/\text{m}^3$ .

Table 5. Values of Exposure Duration, Exposure Frequency and Exposure Time

Value size	Duration of SO2 Exposure (Hours/day)	Exposure Frequency (Days/year)	Exposure Duration (Years)
Average	11,4	354,9333	13,9
Median	12	365	10
Minimum	6	309	1
Maximum	18	365	33

Table 5 shows that the duration of SO<sub>2</sub> exposure ranges from 6-18 hours/day with an average value of 11.4 hours/day. The exposure frequency ranges from 309-365 days/year with an average value of 354.9333 days/year. The exposure duration ranges from 1-33 years with an average value of 13.9 years.

Table 6. Real-Time and Lifetime SO<sub>2</sub> Intake Value Measurements Among Traders

<b>Value size</b>	<b>SO<sub>2</sub> Value Intake Real Time</b>	<b>SO<sub>2</sub> Value Intake Life Time</b>
Average	0,001784	0,001784087
Median	0,001705	0,001704827
Minimum	0,000517	0,00051695
Maximum	0,003633	0,003633367

Table 6 shows that the SO<sub>2</sub> intake values for real-time range from 0.000517 to 0.003633 with an average of 0.001784. Furthermore, the SO<sub>2</sub> intake values for lifetime range from 0.00051695 to 0.003633367 with an average of 0.001784087.

Table 7. Measurement of Real-Time and Lifetime RQ Values of SO<sub>2</sub> in Traders

<b>Value size</b>	<b>RQ SO<sub>2</sub> Real Time</b>	<b>RQ SO<sub>2</sub> Life Time</b>
Average	0,068619	0,00470268
Median	0,06557	4,4326E-05
Minimum	0,019883	1,344E-05
Maximum	0,139745	0,1397449

Table 7 shows that the SO<sub>2</sub> RQ values for real-time range from 0.019883 to 0.139745 with an average of 0.068619. Furthermore, the SO<sub>2</sub> RQ values for lifetime range from 1.344E-05 to 0.1397449 with an average of 0.00470268. Based on existing theory, if the RQ value <1, it falls into the normal or no-risk category, and if RQ >1, it is categorized as above normal or at risk over a lifetime. Based on the data in the Table, it can be seen that the calculated RQ results are <1, so SO<sub>2</sub> exposure among traders in the Bersehati Market Area is still within the safe threshold and does not pose a non-carcinogenic risk.

## DISCUSSION

### Hazard Identification

Hazard identification is the first step in analyzing environmental health risks. This stage is conducted to determine pollutant agents or chemical substances that have the potential to impact human health. Sulfur dioxide (SO<sub>2</sub>) in the air can dissolve in water to form sulfuric acid, which causes respiratory tract irritation, lung function disorders, and decreased lung capacity, especially for traders who are continuously exposed. (Ministry of Health of the Republic of Indonesia, 2012). In this study, the concentration of sulfur dioxide (SO<sub>2</sub>) was measured for 1 hour at three points at three different times (morning, noon, and evening) in Bersehati Market, Manado City, with the measurement duration and

Threshold Value (NAB) based on the Ministry of Health Regulation (PERMENKES) of the Republic of Indonesia No. 02 of 2023.

The results of this study indicate that the average concentration of SO<sub>2</sub> is 0.01167 mg/m<sup>3</sup>. The highest SO<sub>2</sub> concentration is 0.0143 mg/m<sup>3</sup>, while the lowest SO<sub>2</sub> concentration is 0.0077 mg/m<sup>3</sup>. These values are still within the Threshold Limit Value (TLV) of 150 µg/m<sup>3</sup>. Research by Ponga et al. (2018) in Tuminting District showed that the SO<sub>2</sub> concentration at 5 locations analyzed in Tuminting District was still far below the quality standard of 900 µg/Nm<sup>3</sup>. The average SO<sub>2</sub> concentration was 21.01 µg/Nm<sup>3</sup>, which is still considered good. This condition is due to the presence of green trees in Tuminting District and the surrounding areas, which reduces vehicle accumulation at certain points that could cause an increase in SO<sub>2</sub> pollutants in the air.

### **Dose-Response Analysis**

The dose-response analysis at this stage involves searching for values such as Reference Dose (RfD), Reference Concentration (RfC), and/or Slope Factor (SF) of the risk agents that are the focus in determining the Environmental Health Risk Threshold (EHRT). The RfC value indicates the ambient concentration of a chemical in the air that can be accepted by humans without causing harmful health effects over a lifetime of exposure. According to data from the United States Environmental Protection Agency (US EPA, 1995) in the Integrated Risk Information System (IRIS), the RfC value for sulfur dioxide (SO<sub>2</sub>) is 0.026 mg/m<sup>3</sup>. This value indicates the safe limit for long-term exposure to SO<sub>2</sub> in the air, where exceeding this value can cause lung function disorders and respiratory tract irritation.

### **Exposure Analysis**

Exposure analysis was carried out based on data on SO<sub>2</sub> substance concentration, activity patterns, and respondent anthropometric characteristics, such as body weight (Wb), daily exposure duration (tE), exposure frequency (tE), exposure duration (Dt), and inhalation rate (R), which in this study used a value of 0.83 m<sup>3</sup>/day. The result of this analysis is called Intake, which serves to determine the risk level in the risk characterization phase. Based on the results of SO<sub>2</sub> concentration measurements at the research site, the highest concentration value obtained was 14.3 µg/m<sup>3</sup>, which was converted to 0.0143 mg/m<sup>3</sup>. This value is used to calculate the real-time SO<sub>2</sub> exposure intake for respondents with the highest exposure value. Vendors in the Bersehati Market area of Manado City have a daily exposure of 12 hours per day. According to interviews, on average, vendors start working at 06:00 WITA until 18:00. The study also found that the average trading duration for workers is 10.40 hours/day and if following the standards set by the US-EPA for ideal working hours, this has certainly exceeded the standard time, which should be 8 hours of work per day. The exposure frequency in this study is 365 days, with an average worker spending 354.93 days working per year. This study aligns with the research conducted by Maherdyta et al. (2022), where the workers' exposure frequency was 350 days. The duration of work is calculated from the first year of employment up to the time the study was conducted. In this study, the exposure duration is 10 years, with an average exposure duration of 13.9 years. Personal exposure concentration (intake) of SO<sub>2</sub> refers to the amount of SO<sub>2</sub> concentration received and entering the human body,

averaged per sample by body weight (kg) per day. In this study, the calculation of intake will be differentiated into three calculations according to the measurement points of SO<sub>2</sub> concentration in the Bersehati Market area of Manado City. In this study, non-carcinogenic intake was used, calculated based on the duration that traders spend at the location or selling in the Bersehati Market area of Manado City up to the time this research was conducted, and the projected intake for the next 30 years (lifespan).

#### **Risk Characterization**

Risk characterization was carried out to determine the extent of risk experienced by respondents due to exposure to SO<sub>2</sub>, using the Risk Quotient (RQ) formula, which compares the intake or exposure value of the respondents with the reference dose (RfC). The calculated risk values are for current exposure (real-time) and for 30 years (lifetime). The risk category can be seen from the RQ value: if  $RQ < 1$ , it is considered not at risk but should be maintained so that the RQ value does not exceed one. If  $RQ \geq 1$ , the respondent has a risk and it needs to be controlled to prevent it from exceeding the limit. From the results of the research that has been conducted on Merchants in the Bersehati Market area of Manado City indicated that the average real-time RQ value was 0.068619 and the lifetime RQ was  $4.63863 \times 10^{-5}$ . CONCLUSION The conclusion of this study is that the concentration of SO<sub>2</sub> in the ambient air of the Bersehati Market area in Manado City is below the National Ambient Air Quality Standard, which is 150 µg/m<sup>3</sup>. ARKL results indicate that there is no health risk posed by SO<sub>2</sub> exposure to merchants in the Bersehati Market area (RQ value < 1). Therefore, regular air quality measurement efforts are required.

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