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ENVIRONMENTAL HEALTH RISK ANALYSIS OF SULFUR DIOXIDE (SO_2) EXPOSURE IN AMBIENT AIR ON LUNG FUNCTION OF OFFICERS AND COMMUNITIES AROUND PUBLIC FUEL FILLING STATIONS (SPBU)

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ABSTRACT
Air pollution is a serious problem globally, especially in urban areas where the transportation sector is one of the main contributors to sulfur dioxide (SO_2) emissions. Public filling stations (SPBU) that are centers of vehicle activity can produce SO_2 in ambient air that endangers lung function for individuals exposed in the long term, including workers and the surrounding community. This study examines SO_2 exposure at gas stations in Ogan Ilir Regency that can have an impact on health. The research method used two research methods, namely environmental health risk analysis (EHRA) with a deterministic approach and environmental health epidemiology with a cross-sectional approach. Sampling was conducted on 78 respondents using the Total Sampling method and air measurements using the *Impinger Air Sampler* tool. The average SO_2 concentration in the three gas station locations was 30,0 µg/m³ which exceeds the safe threshold. The daily intake level was 0,003 mg/kg/day, higher than the safe reference concentration (RfC) of 0.025 mg/kg/day, with a *Risk Quotient* (RQ) of 0,12, does not present a significant health risk. Furthermore, the results showed that impaired lung function was found in 73 respondents (93.6%), additional risk factors such as smoking habits and medical history were found to affect respiratory health. This research shows that there is no significant relationship between body weight, exposure, smoking, history of disease, or allergies and impaired lung function of officers and the community around the Ogan Ilir gas station.

Keywords: ARKL; air pollution; gas station; lung function; ogan ilir; sulfur dioxide (SO_2)

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INTRODUCTION

Air pollution is an environmental issue of growing global concern. According to the World Health Organization (WHO, 2022), about 99% of the population lives in places with air quality that does not meet WHO air quality guidelines. Air pollution causes an estimated 6.7 million premature deaths per year globally (WHO, 2022). In Indonesia, air pollution remains a significant national issue. Based on IQAir data, air quality in some major cities often exceeds safe thresholds (IQAir, 2024). Air pollution increases dramatically during the dry season, mainly due to land fires in several regions, such as Sumatra and Kalimantan (Septianingrum et al., 2018). The transportation sector is one of the largest contributors to air pollution (Rahmawati et al., 2023). According to data from the Central Bureau of Statistics (BPS), the number of vehicles in Indonesia increases by about 5% each year, which worsens air quality in urban areas. (BPS, 2023). This pollution can also occur in gas station areas. Research shows that activities at gas stations can increase the concentration of pollutants, especially sulfur dioxide (SO_2), which comes from fuel oil. Exposure to these pollutants poses risks to gas station staff and the surrounding community. Therefore, gas stations are one of the local pollution sources that need more attention, especially in pollution control efforts in urban areas (Setyono et al., 2020).

Sulfur dioxide (SO_2) is one of the most dangerous air pollutant gases, especially for vulnerable populations such as children, the elderly, and individuals with respiratory diseases (Sari, 2017). This gas is widely found in the ambient air around gas stations, especially in areas with heavy vehicle traffic. According to research, exposure to SO_2 can cause respiratory tract irritation, aggravate asthma, and decrease lung function. Gas station attendants who work in locations with high SO_2 concentrations have a greater risk of respiratory health problems. In addition, people living around gas stations are also exposed to the same risks, especially those with already vulnerable health conditions. Research conducted by Sunarsih et al. in 2019 shows that exposure to NO2, SO2, TSP, and PM10 is considered harmful to health and shows a correlation with lung capacity (Sunarsih et al., 2019). According to research conducted by Novitasari and Wijayanti shows the relationship between age, tenure, gender, and smoking habits and the impaired lung capacity of gas station officers (Novtasari et al., 2018). This research is important to do considering the serious health effects caused by sulfur dioxide (SO_2) exposure to workers and the community around gas stations.

In Ogan Ilir Regency, the presence of gas stations close to residential areas makes people vulnerable to exposure to this pollutant, especially those with respiratory disorders or chronic health conditions. Therefore, the study aims to analyze the environmental health risks of Sulfur Dioxide (SO2) exposure to the lung function of officers and communities around Public Fuel Filling Stations (SPBU) in Ogan Ilir Regency so as to understand the extent of SO_2 exposure in ambient air around SPBU, as well as its impact on the lung function of SPBU officers and surrounding communities.

METHOD

This research design cross-sectional approach with two research methods, the Environmental Health Risk Analysis (EHRA) study method with a deterministic and environmental health epidemiology with a. The method in this study was used to estimate the magnitude of the level of health risk to filling station workers in Ogan Ilir Regency due to inhalation of air containing Sulfur Dioxide (SO2). The Environmental Health Risk Analysis (EHRA) method consists of several steps, including hazard identification, dose-response analysis, exposure analysis, risk characterization, and risk management if the RQ result is >1. Research in the study to see the correlation between risk factors and impaired lung function. The number of human samples in this study used total sampling so that a total sample of 78 officers and the community was obtained. Furthermore, the air sample taken contained Sulfur Dioxide (SO2) at gas stations in Ogan Ilir Regency.

RESULT

SO_2 Concentration

Table 1.
SO2 Concentration in Gas Station Area

Location	Time	Measurement Result (µg/m³)		
		Min	Max	Average
Gas Station 24,306,137	08:00 – 10:00	31,2	35,4	33,3
Gas Station 24,306,177	11:00 – 13:00	24,2	26,4	25,3
Gas Station 24.306.33	14:00 – 16:00	30,5	32,6	31,5
Average Concentration				30,0

Tabel 1 show measurement of Sulfur Dioxide (SO_2) air pollutants in officers and communities around Ogan Ilir Regency gas stations using the Impinger Air Sampler tool, We can see that the measurements at the 3 gas station locations got relatively similar results, with measurements with the smallest results at gas station 24.306.177 with a result of 24,2 µg /m^3

and measurements with the largest results at gas station 24.306.137 which amounted to 35,4 µg /m^3 , and from the six points and 3 measurement locations obtained the average concentration of SO_2 in the ambient air around the gas station is 30,0 µg / m^3.

Table 2.
Anthropometric Characteristics and Activity Patterns

Characteristics	Mean	Median	Min	Max	SD
Age (Year)	31,97	28	16	63	11,498
Wb (Kg)	59,70	61	37	110	13,139
tE (Hour/Day)	9,12	8	4	24	4,1242
fE (Days/Year)	332,67	312	260	364	30,609
Dt (Year)	5,92	3,75	0,2	25	6,2076

Based on the data collected as shown in Table 2, it can be seen that the average age of officers and the community around the gas station is 31.97 years. The average body weight (Wb) of officers and the community around the gas station is 59.70 kg. The average daily exposure time (tE) for officers and the community around the gas station is 9.12 hours/day. The frequency of exposure in one year (fE) for officers and the community around the gas station is 332.67 days/year. While the average exposure duration (Dt) is 5.92 years.

Table 3.
Frequency Distribution Based on Gender

Gender	f	%
Laki-laki	50	64,1
Perempuan	28	35,9

The distribution of gender in respondents of officers and the community around the gas station looks dominated by men can be seen in table 3. Based on the observation of gender, the number of male respondents is 50 people (64%) and the number of female respondents is 28 people (35.9%).

Intake Non-Karsinogenik

Intake in this study was measured using the data we have obtained in Table 2 by entering it into the formula as follows:

$$ink = \frac{\mathrm{C} \times \mathrm{R} \times t_E \times F_E \times D_t}{Wb \times t_{AVG}}$$

the Intake Value of SO2 at gas stations in Ogan Ilir Regency is

$$ink = \frac{0{,}03\ \frac{mg}{m^3} \times 0{,}83\ \frac{m^3}{Hour} \times 9{,}12 \frac{Hour}{Day} \times 332{,}67 \frac{Day}{Year} \times 5{,}92\ Tahun}{59{,}70\ kg \times 5{,}28\ Year \times 365\ Day/Year}$$

$$ink = \frac{447{,}228561\ \mathrm{mg}}{115.053{,}84\ Day}$$

$$ink = 0{,}003\ \mathrm{mg/\ kg/Day}$$

The intake rate value of SO exposure$_2$ or the intake rate that can enter the body of officers and communities around gas stations in Ogan Ilir Regency is 0,003 mg/kg/day.

Non Carcinogenic Risk Level

RFC is used to see the risk characteristics of SO_2 exposure, which serves to determine the concentration of SO_2 obtained in this study is at risk of causing health problems in the community or not, the RFC value is calculated using the following formula

$$RFC = \frac{\mathrm{RFC}\ \left(\frac{mg}{m^3}\right) \times Inhalation\ Rate\ \left(\frac{m^3}{Day}\right)}{Wb\ (kg)}$$

So the RFC value of SO2 at gas stations in Ogan Ilir Regency is :

$$RFC = \frac{0{,}075\left(\frac{mg}{m^3}\right) \times 20\ \left(\frac{m^3}{Day}\right)}{59{,}70\ (kg)}$$

$$RFC = 0{,}025\ mg/kg/Day$$

In accordance with the above calculations that use the RFC SO value$_2$ multiplied by the Inhalation rate set by US-EPA, then divided by the average body weight of the officers and the community around the gas station in Ogan Ilir district, the RFC value is 0.025 mg/kg/day.

Risk Level Calculation

After obtaining the value of the intake rate (Intake) and the value of exposure characteristics (RFC), which becomes the value to determine the level of non-carcinogenic risk with the RQ formula, namely:

$$RQ = \frac{\text{ink}}{RfC}$$

$$RQ = \frac{0{,}003}{0{,}025}$$

$$RQ = 0{,}12$$

In accordance with the calculation of the RQ value of real time Sulfur Dioxide (SO_2) is 0,12, the RQ value of Sulfur Dioxide (SO_2) exposure to officers and the community around gas stations in Ogan Ilir Regency shows the RQ value < 1 or in other words, respondents' exposure to Sulfur Dioxide does not exceed safe limits and there is no need for risk management.

Table 4.
Lung Function Measurement Results of Officers and Communities

Lung Function	f	%
Disorder	73	93,6
Normal	5	6,4

The table above is a category distribution table of the results of measuring the lung function of officers and the community around gas stations in Ogan Ilir Regency, Based on the table above, there are 73 officers and the community have lung function with impaired categories (93.6%). While 5 officers and other communities with normal lung function (6.4%).

Table 5.
Factors Affecting Pulmonary Function of Officers and Communities Surrounding Gas Stations

Smoking Habit	f	%
Iya	36	46,2
Tidak	42	53,8
Disease History		
Iya	28	35,9
Tidak	50	64,1
Allergy History		
Iya	22	28,2
Tidak	56	71,8

The table above present the factors affecting the lung function of officers and the community around gas stations in Ogan Ilir Regency. According to the table above, there are 36 officers and people who have smoking habits (46.2%), 28 officers and people who have a history of disease (35.9%), and 22 officers and people have a history of allergies (28.2%).

Relationship between Anthropometry, Exposure Patterns, and Influencing Factors with Pulmonary Function

This study also explains the relationship between anthropometry, exposure patterns and factors that affect the lung function of officers and communities around gas stations in Ogan Ilir Regency.

Table 6.
Relationship between Anthropometry, Exposure Patterns, and Influencing Factors with Pulmonary Function

Body Mass Index	Lung Function				Total		PR (95%CI)	*p-value*
	Disorder		Normal					
	f	%	f	%	f	%		
Not Normal	28	38,9	2	2,6	30	38,5	0,996 (0,883-1,123)	1.000
Normal	45	57,7	3	3,8	48	61,5		
Total	73	93,6	5	6,4	78	100		
Duration of Exposure	Lung Function				Total		PR (95%CI)	*p-value*
	Disorder		Normal					
	f	%	f	%	f	%		
≤ 9,12	58	74,4	2	2,6	60	76,9	1,160 (0,939-1,434)	0,078
> 9,12	15	19,2	3	3,8	18	23,1		
Total	73	76,9	5	23,1	78	100		
Exposure Frequency	Lung Function				Total		PR (95%CI)	*p-value*
	Disorder		Normal					
	f	%	f	%	f	%		
≤ 332,67	42	53,8	1	1,3	43	55,1	1,103 (0,971-1,253)	0,168
> 332,67	31	39,7	4	5,1	35	44,9		
Total	73	93,6	5	6,4	78	100		
Exposure Duration	Lung Function				Total		PR (95%CI) %	*p-value*
	Disorder		Normal					
	f	%	f	%	f	%		
≤ 5,92	46	59	3	3,8	49	62,8	1,008 (0,892-1,139)	11000
> 5,92	27	34,6	2	2,6	29	37,2		
Total	73	93,6	5	6,4	78	100		
Smoking Habit	Lung Function				Total		PR (95%CI)	*p-value*
	Disorder		Normal					
	f	%	f	%	f	%		
Yes	35	44,9	1	1,3	36	46,2	1,075 (0,960-1,203)	0,366
No	38	48,7	4	5,1	42	53,8		
Total	73	93,6	5	6,4	78	100		
Disease History	Lung Function				Total		PR (95%CI)	*p-value*
	Disorder		Normal					
	F	%	f	%	f	%		
Yes	27	34,6	1	1,3	28	35,9	1,048 (0,940-1,168)	0,649
No	46	59	4	5,1	50	64,1		
Jumlah	73	93,6	5	6,4	78	100		
Allergy History	Lung Function				Total		PR (95%CI)	*p-value*
	Disorder		Normal					
	f	%	f	%	F	%		
Yes	21	26,9	1	1,3	22	28,2	1,028 (0,915-1,155)	1.000
No	52	66,7	4	5,1	56	71,8		
Total	73	93,6	5	6,4	78	100		

Table 6. describes the relationship between the pulmonary function of officers and the community around gas stations in Ogan Ilir Regency with anthropometric conditions, exposure patterns and influencing factors, by looking at the p-value in the table. A p-value > 0.5 means that it does not affect or have no relationship and a p-value < 0.5 means that it affects and has a relationship.

DISCUSSION

Sulfur Dioxide (SO_2) is a colorless, strong-smelling, water-soluble gas, formed from the combustion of fossil fuels such as coal and petroleum, as well as from industrial processes such as metal smelting (Putrakoranto, 2021). This gas is considered one of the major air pollutants that can cause various health and environmental problems. SO_2 also plays a major role in reducing air quality and affecting ecosystem balance (Hefnita et al., 2023).The concentration of Sulfur Dioxide (SO_2) in the ambient air of Ogan Ilir Regency gas stations based on the measurement results show that it does not exceed the Environmental Health Quality Standards (SBMKL), which obtained an average result of 30,0 µg/m3 while the Sulfur Dioxide (SO_2) SBMKL in ambient air according to the Minister of Health Regulation Number 2 of 2023 concerning the Implementation Regulation of Government Regulation Number 66 of 2014 concerning Environmental Health, which is 150 µg/m3 for an average of 1 hours conducted at 3 gas stations in Ogan Ilir Regency.

Based on the results of the calculation of the non-carcinogenic intake value of the risk agent concentration for the air medium is 0,030 mg/m³, the R value uses the determination of the adult inhalation rate of 0.83 m3/hour. Daily exposure time (tE) is 9.12 hours/day, exposure frequency (fE) is 332.67 days/year, and exposure duration (Dt) is 5.92 years. Body weight (Wb) uses the average body weight of respondents, which is 59.70 kg. The value of the average time period of non-carcinogenic effects in elementary schools (tavg) is 5.92 years x 365 days/year. Thus, the intake rate of SO_2 exposure around gas stations in Ogan Ilir Regency is 0,003 mg/kg/day. Furthermore, the RfC value in this study was derived from the default Sulfur Dioxide (SO_2) formula. The Sulfur Dioxide (SO_2) concentration value is taken based on the U.S. EPA default value, which is 75 ppb or 0.075 mg/m3. The R value uses the default value of the inhalation rate at 75 ppb = 0.075 mg/m3 which is 20 m3 / hour and the body weight value (Wb) uses the average body weight of the respondent which is 59.70 kg. So that the RfC Sulfur Dioxide ($SO_{2)}$ value is 0.025 mg/kg/day. The calculation of the risk level in this study or the Risk Quation (RQ) value of real-time SO_2 is 0,12 from Sulfur Dioxide (SO_2) exposure to officers and communities around gas stations in Ogan Ilir Regency

Measurement of lung function in officers at Ogan Ilir Regency gas stations was carried out in November 2024 using a Digital Spirometer. Impaired lung function is a lung disorder in the form of an inability to develop (elasticity) of the lungs or airway disorders, both structural (anatomical) and functional, which causes a slowdown in respiration airflow (Novtasari et al., 2018). Based on the results of lung function measurements, 73 respondents (93.6%) of 78 respondents had impaired lung function. The first factor that can affect lung function is smoking habits, based on the results of the interview, 36 officers have a habit of smoking (46.2%), while 42 others do not smoke (53.8%). The second factor is a history of disease; 50 officers have no history of disease (64.1%). Meanwhile, 28 other officers did not have a history of disease (35.9%). The third factor is allergy history, 22 officers have a history of allergies (28.2%), while 56 officers do not have a history of allergies (71.8%).

Calculation of indicators of pulmonary function of officers and the public based on body weight using Body Mass Index (BMI) obtained a PR value of 0.996 (0.883 -1.123) and a p-value of 1,000 (p-value> 0.05). P-value > 0.05 indicates that there is no significant relationship between Body Mass Index (BMI) and officer lung function. The PR value of 0.996 means that officers and communities with abnormal BMI are 0.996 times less likely to experience impaired lung function than respondents with normal BMI. The results of this study are not in line with research conducted by Lazovic-Popovi et al., which states that there is a significant positive correlation between anthropometry (age, weight, and height) and lung

capacity parameters (VC, FVC, FEV1, and PEF) (Lazovic-Popovic et al., 2016). It can be concluded that there is no relationship between body weight and impaired lung function in officers and the community around the gas station in Ogan Ilirm Regency.

Furthermore, the relationship between the length of exposure and lung function obtained statistical test results using chi-square showed a PR value of 1.160 (0.939-1.434) and a p-value of 0.078 (p-value> 0.05). P-value> 0.05 indicates that there is no significant relationship between the length of exposure and the lung function of the officers. The relationship between frequency of exposure showed a PR value of 1.103 (0.971 - 1253) and a p-value of 0.168 (p-value > 0.05). P-value > 0.05 indicates that there is no significant relationship between exposure frequency and lung function of officers. The relationship between exposure duration and lung function showed a PR value of 1.075 (0.960-1.203) and a p-value of 0.366 (p-value > 0.05). P-value > 0.05 indicates that there is no significant relationship between exposure duration and lung function of officers and the community. The results of this study contradict research conducted by Insani in 2023, which states that there is a relationship between exposure duration and fatal lung disorders (Insani, 2023). It can be concluded that the results of this study cannot prove the existence of a relationship between exposure patterns (duration of exposure, frequency of exposure, and duration of exposure) and the incidence of lung function disorders in officers and communities around gas stations in Ogan Ilir Regency.

The statistical test results of the relationship between smoking habits and function showed a PR value of 1.075 (0.960-1.203) and a p-value of 0.365 (p-value> 0.05). P-value > 0.05 indicates that there is no significant relationship between smoking habits and lung function of officers and the community. The results of this study are in line with research conducted by Wahyuni et al. in 2019, which states that there is no significant relationship between smoking habits and lung capacity in PT Makassar Tene boiler area workers (Wahyuni et al., 2019). Furthermore, the relationship between disease history and lung function shows a PR value of 1.048 (0.940-1.168) and a p-value of 0.649 (p-value> 0.05). P-value > 0.05 indicates that there is no significant relationship between disease history and lung function of officers and the community. This study is not in line with the research of Wulandari et al. in 2017, which states that there is a significant relationship between the history of previous diseases and impaired lung function (Wulandari et al., 2017). Then, the relationship between allergy history shows a PR value of 1.028 (0.915-1.155) and a p-value of 1 (p-value> 0.05). P-value> 0.05 indicates that there is no significant relationship between allergy history and lung function of officers and the community around gas stations in Ogan Ilir Regency.

CONCLUSION

Sulfur dioxide (SO_2) exposure at gas stations in Ogan Ilir Regency showed an average concentration of 30,0 µg/m³, exceeding the safe limit of the Environmental Health Quality Standard (SBMKL) of 150 µg/m³. The daily intake value reached 0,003 mg/kg/day, far exceeding the safe reference concentration (RfC) of 0.025 mg/kg/day, with a Risk Quotient (RQ) of 0,12. This does not pose a significant health risk, especially for gas station attendants and the surrounding community. In addition, the results also showed that impaired lung function was found in 73 Respondents (93.6%). Furthermore, the results of lung function measurements showed that 73 respondents (93.6%) out of 78 respondents had lung function disorders. However, based on the research results, no significant relationship was found between body weight, length of exposure, smoking habits, history of illness, or history of allergies and lung function disorders in officers and the community around the Ogan Ilir Regency gas station. So these factors do not significantly influence lung function capacity according to the statistical tests carried out.

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