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The Risk of Sulfur Dioxide Exposure and Its Correlation with the Incidence of Hypertension in Street Sweepers In Samarinda City

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ABSTRAK

Latar belakang: Emisi gas buang kendaraan bermotor merupakan sumber pencemaran udara yang paling signifikan, terutama di wilayah perkotaan. SO_2 merupakan salah satu polutan yang dihasilkan oleh emisi gas buang kendaraan bermotor. Kota Samarinda terkenal dengan pesatnya peningkatan jumlah kendaraan pribadi, terutama kendaraan berbahan bakar fosil, yang berpotensi meningkatkan konsentrasi SO_2 dan dapat berdampak pada kesehatan. Penelitian ini bertujuan untuk mengetahui risiko paparan konsentrasi SO_2 pada penyapu jalan dan hubungan antara kejadian hipertensi dengan asupan SO_2.
Metode: Penelitian ini menggunakan pendekatan penilaian risiko kesehatan lingkungan. Pendekatan EHRA akan memperkirakan risiko yang diterima oleh penyapu jalan akibat paparan SO_2 di jalan raya Kota Samarinda. Populasi dalam penelitian ini mencakup seluruh pekerja penyapu jalan yang bertugas pada empat lokasi jalan raya yang telah ditentukan. Sampel penelitian berjumlah 61 orang dan diperoleh melalui teknik total sampling. Teknik pengukuran konsentrasi SO_2 menggunakan impinger dengan analisis spektrofotometer. Tekanan darah diukur secara *real-time*. Uji chi-square digunakan untuk menunjukkan perbedaan proporsi antara variabel asupan dan hipertensi.
Hasil: Konsentrasi SO_2 masih di bawah batas baku mutu lingkungan yang dipersyaratkan (< 150 $\mu g/Nm^3$) yakni 18,18 $\mu g/Nm^3$. Hasil uji chi-square menunjukkan tidak ada perbedaan proporsi kejadian hipertensi dengan asupan SO_2 (nilai p = 1.000). Akan tetapi, pekerja dengan asupan SO_2 >0,0012 mg/kg/hari memiliki peluang lebih besar untuk mengalami hipertensi dibandingkan penyapu jalan dengan asupan >0,0012 mg/kg/hari (OR = 1,111).
Simpulan: Kualitas udara di jalan raya Kota Samarinda masih tergolong aman dan sehat, terutama pada parameter sulfur dioksida. Petugas penyapu jalan tidak berisiko mengalami gangguan kesehatan khususnya kejadian hipertensi.

Kata kunci: SO_2; EHRA; Transportasi; Penyapu Jalan; Hipertensi

ABSTRACT

Background: *Vehicle exhaust emissions are the most significant source of air pollution, especially in urban areas. SO_2 is one of the pollutants produced by car exhaust emissions. The number of private vehicles, especially fossil fuel vehicles, is increasing rapidly in Samarinda City. These vehicles have the potential to increase SO_2 concentrations and can have an adverse on health. This study aims to determine the risk of exposure to SO_2 concentrations among street sweepers and the relationship between the incidence of hypertension and SO_2 intake.*

Methods: *This study used an environmental health risk assessment approach. The EHRA approach estimated the risk faced by street sweepers due to exposure to SO_2 in Samarinda City highways. This study's population consisted of all street sweepers working at four specified roadways. The sample, comprising 61 participants, was selected using a to tal sampling technique. The SO_2 concentration measurement technique involved an impinger with spectrophotometer analysis. Blood pressure was measured in real-time. The chi-square test was used to show differences in proportions between intake and hypertension variables.*
Results: *The SO_2 concentration, measured at 18.18 $\mu g/Nm^3$, was found to be below the required environmental quality standard limit (< 150 $\mu g/Nm^3$). The results of the chi-square test showed no difference in the proportion of hypertension incidents with SO_2 intake (p-value = 1,000). However, workers with SO_2 intake of >0.0012 mg/kg/day showed a higher likelihood of developing hypertension than street sweepers with an intake of >0.0012 mg/kg/day (OR = 1.111).*
Conclusion: *The air quality in the highways of Samarinda City is deemed safe, especially in terms of the sulfur dioxide parameter. Street sweepers are not at risk of experiencing health problems.*

Keywords: SO_2; EHRA; Transportation; Street Sweepers; Hypertension

BACKGROUND

Population growth has an impact on the rising demand for transportation to support their activities, particularly in urban areas. Vehicle emissions contribute greatly to environmental pollution and have the potential to cause a greenhouse effect.[1] Apart from the use of transportations, industrial development can also contribute to air pollution.[2] Air pollution is defined as a condition where air quality deteriorates due to the presenof various elements, such as particles, gases and organic atoms, causing damage to the ozone layer and even global warming. Both natural and human activities can cause air pollution.[3]

Some studies show that the transportation sector is a major contributor to air pollution, especially in metropolitan areas.[4] According to the emissions inventory of the Ministry of Environment and Forestry of the Republic of Indonesia, the transportation sector contributes 70%-80% of the total pollutant load in metropolitan areas.[5] The continued use of fossil as vehicle fuel, the increasing number of vehicles due to increasingly rapid population growth, office activities, a centralized economy which has an impact on urban traffic patterns, and other contribute to air pollution from vehicle exhaust emissions.[6] Lead (Pb), suspended particulate matter (SPM), nitrogen oxides (NO_x), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO), and photochemical oxides (O_x) are among the pollutants inhaled from car exhaust fumes car.[6,7]

Sulfur dioxide is a colorless gas with a strong odor that is easily soluble in water.[8] The health effects of SO_2 molecule include irritation of the eyes, mucous membranes, skin, and respiratory tract. Even at low concentrations, inhaling SO_2 can cause chronic lung disorders such as asthma and emphysema.[9] Essentially, there is a close association between air pollution and the frequency of respiratory tract illnesses. A study conducted in Changsha, China found that short-term exposure to SO_2 at low concentrations increased the daily risk of ischemic heart disease and increased the chance of death in women.[10] Apart from having an impact on respiratory disorders, environmental ecology studies have proven that PM_{10}, $PM_{2.5}$, and SO_2 can increase cardiovascular risk. This is based on atherosclerosis and an increase in blood pressure due to exposure to the surrounding environment.[11]

Based on data from the Samarinda City Environmental Service, the concentration of sulfur dioxide (SO_2) in 2022 remained below the required ambient air quality level (150 $\mu g/Nm^3$). However, the Central Bureau of Statistics in the city indicated a population gap in East Kalimantan Province in 2022. The district area, which covers around 98.91% of the province, is inhabited by 53.85% of the total population. Meanwhile, the remaining 45.99% live in urban areas, which make up only 1.09%. This creates population density in urban areas such as Samarinda City, a city with the second highest population density in East Kalimantan Province, which is 1,160 people per km^2. [12] Increasing traffic in mobility modes and a growing population are likely to cause air pollution. People who live near highways, have high intensity and mobility on highways, and work near highways such as street sweepers, are at risk of experiencing health problems, especially those caused by air pollution. Therefore, this study focuses on investigating the risk of SO_2 exposure among street sweepers in Samarinda City. This can serve as an illustration of the risk linked to poor air quality in urban areas, which can affect public health or certain communities, and is associated with the incidence of hypertension cases. This study also explores the characteristics of tropical rainforest areas that influence the air quality in Samarinda City.

MATERIALS AND METHODS

This research used a quantitative approach to environmental health risk assessment (EHRA), which includes hazard identification, dose-response assessment, exposure assessment, and risk characterization.[13,14] The EHRA approach estimates the risk faced by street sweepers as a result of SO_2 exposure in Samarinda City highways. This research was carried out at four highway points in Samarinda City: the intersection of Lembuswana (Point 1), Jalan Juanda (Point 2), Jalan MT Haryono (Point 3), and Jalan Gadjah Mada (Point 4). The distance between Point 1 and Point 2 was 1 km, Point 2 and Point 3 was 2.2 km, and Point 3 and Point 4 was 3.6 km. The chosen sites were the city center intersection because they were known for their high levels of congestion and dense traffic activity. This makes them an ideal location for monitoring air quality, given the high potential for air pollution. This research was carried out from August to November 2023.

Total sampling was used, yet the provision of the research inclusion criteria was determined. The subjects of this study were street sweepers. They were selected based on an inclusion criterion which required them to have worked as street sweepers for at least one year, as measured through interviews using a questionnaire sheet. Meanwhile, for the variable of incidence of hypertension in street sweepers, real-time blood pressure was measured with a digital tensimeter. Blood pressure was measured during break times, following a 10-minute resting period to ensure physiological stabilization. It was measured twice (one repetition), during which that the respondents were instructed to remain still and not to speak.

The ambient air sampling locations were selected based on the following criteria: there were no compounds that produced SO_2, the locations had a dense vehicle intensity, and they were not blocked by buildings and trees. The SO_2 concentration was measured with an impinger with spectrophotometer analysis, which measured for 1 hour at each location point. The ambient air was measured in the morning (9 to10 am) and afternoon (1 to 2 pm). The collected data were then substituted and analyzed to obtain intake values and risk levels (RQ) using the following equation[13,15,16]

$$Ink = \frac{C\ x\ R\ x\ tE\ X\ fE\ X\ Dt}{Wb\ x\ tavg} \ldots\ldots\ldots\ldots..(1)$$

where:
Ink is SO_2 intake (mg/kg/day),
C is SO_2 concentration (mg/m^3),
R is inhalation rate (0.83 m^3/hour),
t_E is time of exposure (hours/day),
f_E is frequency of exposure (hours/year),
Dt is duration of exposure (real time, 30 years for lifetime years),
Wb is body weight (kg), and
Tavg is average time period (Dt x 365 days/year for non-carcinogenic substances) (days).

To calculate risk (RQ), the following formula is used:

$$RQ = \frac{I_{nk}}{Rfc} \ldots\ldots\ldots\ldots (2)$$

where:
RQ is risk quotient,
Ink is SO_2 intake (mg/kg/day),
Rfc is SO_2 reference concentration (mg/kg/day) (default : 2.6E-2 EPA/NAAQS 1990).

The calculation of the risk quotient yields risk characteristics (RQ > 1 and RQ ≤ 1). A RQ of > 1indicates that the SO_2 concentration in the ambient air of Samarinda City is at risk and causes health problems (non-carcinogenic), and vice versa. The chi-square test was used to determine whether there was a difference in proportion between intake and hypertension variables (p-value). The OR (odds ratio) value was used to determine the degree or strength of the relationship between the variables studied.

RESULTS AND DISCUSSION

Sulfur Dioxide (SO_2) Concentration and Meteorological Factors

The measurement time was determined based on the operational work schedule of street sweepers. Table 1 summarizes the SO_2 concentration in the ambient air in the highways of Samarinda City .

Table 1 SO_2 Concentration in Samarinda City

No.	Location	Time	Concentration μg/Nm^3	Concentration mg/m$^{3(1)}$	Air Quality Standard (μg/Nm^3)$^{(2)}$
1.	Point 1	Morning	7.22	0.007	150
		Afternoon	36.41	0.036	
2.	Point 2	Morning	9.03	0.009	
		Afternoon	26.17	0.026	
3.	Point 3	Morning	18.18	0.018	
		Afternoon	15.93	0.016	
4.	Point 4	Morning	18.67	0.019	
		Afternoon	12.53	0.013	

(1) SO_2 concentration was converted to mg/m^3 to calculate intake of SO_2.
(2) Quality standards refer to the Republic of Indonesia Government Regulation No. 22/ 2021 concerning Environmental Administration and Management.

As shown in Table 1, the concentration of SO_2 in all sampling points remained below the environmental quality standards of 150 μg/Nm^3, as stipulated in Government Regulation No. 22/2021 concerning Environmental Management and Protection. In Addition to measuring SO_2 concentration, meteorological factors were also measured, including temperature, humidity, and wind speed. Regional factors were also found to influence SO_2 concentration levels as East Kalimantan is in the tropical rain forest. Due to its geographical location, East Kalimantan has relatively high humidity and heavy rainfall. As a result, differences between seasons are not very visible. Apart from that, tropical rain forest has a humid climate or weather with high levels of evaporation.[17] The distribution of SO_2 concentrations and meteorological factors can be seen in Table 2.

Table 2 SO_2 Concentration and Meteorological Factors

Variable	Mean	Median	Min-Max	SD	Kolmogorov-Smirnov
SO_2 Concentration (mg/m^3)	0.018	0.017	0.007 – 0.036	0.009	0.200
Meteorological Factors					
Temperature (^{0}C)	35.93	35.75	33.40 – 38.60	1.65	0.200
Humidity (%)	48.44	46.25	39.0 – 58.0	6.47	0.183
Wind Speed (m/s)	1.25	1.23	0.75 – 1,69	0.32	0.200

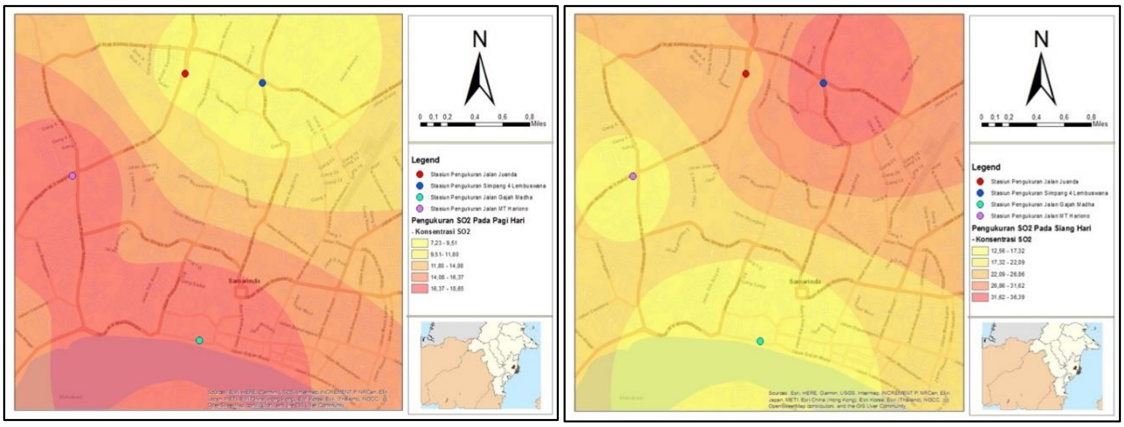
As shown in Table 2, the average concentration of SO_2 was 0.018 mg/m^3, with the lowest concentration being 0.007 mg/m^3 and the highest being 0.036 mg/m^3. The results of meteorological measurements showed that the average temperature was 35.93^{0}C, the average humidity was 48.44%, and the average wind speed was 1.25 m/s. SO_2 concentration can be influenced by humidity, wind speed, and temperature. The temperature can influence SO_2 concentrations much more effectively in the summer than in other seasons.[18] Meteorological conditions, such as temperature, relative humidity, and wind speed, also influence the concentration of air pollutants in China.[19] Additionally, studies in Erzurum, Turkey, show that higher TSP and SO_2 concentrations are strongly associated with cooler temperatures, lower wind speeds, higher pressure systems, lower precipitation, and higher relative humidity.[20] However, one study shows a negative correlation between SO_2 concentration and meteorological factors consisting of temperature, rainfall, and wind speed.[21]

Spatial analysis

To determine the distribution of SO_2 pollutant concentrations around the measuring stations, interpolation analysis using the Inverse Distance Weighted (IDW) method was used. The SO_2 distribution pattern was detected based on the SO_2 concentration values from the four SO_2 measuring stations. This study also used the ArcGIS Map application. The SO_2 distribution pattern is displayed in Figure 1.

As shown in Figure 1(a), the highest concentration of SO_2 pollutant in the morning was observed around the measuring station on Jalan Gadjah Mada and Jalan MT Haryono. Ambient air measurements in the morning (Central Indonesia Time, WITA) were conducted at the following times: Point-1 at 09:40, Point-2 at 11:10, Point-3 at 09:20, and Point-4 at 10:50. The SO_2 concentration value around the measuring station was between 16.37 µg/Nm^3 and 18.65 µg/Nm^3. In contrast to the measuring stations on Jalan Gadjah Mada and Jalan MT Haryono, the SO_2 concentration values around the measuring stations on Jalan Juanda and the Lembuswana intersection in the morning were in the range of 7.23 to 9.51 µg/Nm^3. The value was quite low when compared to the delivery stations on Jalan Gadjah Mada and Jalan MT Haryono.

The highest concentrations of SO_2 pollutant in the afternoon were observed around the measuring Jalan Juanda and the Lembuswana intersection (Figure 1 (b)). Ambient air measurements in the afternoon (Central Indonesia Time, WITA) were conducted at the following times: Point-1 at 14:15, Point-2 at 13:00, Point-3 at 14:18, and Point-4 at 13:15. The SO_2 concentration around the Lembuswana intersection had a higher value compared to the other three measurement stations. The value was in the range of 31.62 µg/Nm^3 to 36.39 µg/Nm^3. Meanwhile, at the measurement station on Jalan MT Haryono, the concentration value was in the range of 22.09 to 26.66 µg/Nm^3.



(a) (b)

Figure 1. Distribution of Sulfur Dioxide Concentrations in Four Locations in Samarinda City: (**a**) morning measurements; (**b**) afternoon measurements.

Meanwhile, the concentrations of SO_2 measuring stations on Jalan Gadjah Mada and Jalan MT Haryono in the afternoon were in the range of 12.56 to 17.32 µg/Nm^3. The distribution of pollutant concentrations is also influenced by traffic density, where higher levels of traffic density are associated with higher concentration of pollutant. The measurement conditions in areas near rivers will also have an impact on the level of pollutant concentration, which is influenced by wind speed.[22] The difference in SO_2 concentration between morning and afternoon might be caused by the weather conditions at the time of measurement. Other studies have shown that there is no significant difference in SO_2 concentration compared to the measurement time as the SO_2 concentration is much higher in the morning.[23] Similarly, in the study we conducted, higher concentrations were detected at two time points in the morning.

Anthropometrics and Activity Patterns

Before estimating the street sweepers' exposure to SO_2, anthropometric calculations, specifically body weight, was made, and activity patterns, including exposure time, exposure frequency, and exposure duration were assessed. Data about anthropometry and activity patterns were factors that may influence the level of street sweepers' exposure to SO_2 as they worked in areas with a potentially high level of air pollution from vehicles. The anthropometric distribution and activity patterns of street sweepers can be seen in Table 3.

Table 3 Anthropometric Distribution and Activity Patterns of Street Sweepers in Samarinda City

Variable	Mean	Median	Modus	Min-Max	SD	Kolmogorov-Smirnov
Anthropometric						
Body Weight	64.80	63.40	67.80	40.3 – 94.1	11.09	0.065
Activity Patterns						
Time of Exposure	5.52	5	5	3 – 7	0.89	< 0.001
Frequency of Exposure	363.03	365	365	317 – 365	8.25	< 0.001
Duration of Exposure	10.06	10	10	1.5 – 30	6.16	< 0.001

As shown in Table 3, the average body weight of street sweepers in Samarinda City was 64.80 kg, the average time of exposure was 6 hours with an exposure frequency of 363 days/year, and the average duration of work was 10 years. Body weight is a variable used in calculating pollutant intake because body weight is a divisor in the ratio of exposure values. The greater the body weight, the smaller the intake value. Body weight also affects the respiratory intake rate, as it influences the vital capacity of the lungs, which is related to the elasticity of the chest cavity walls.[24] The amount of exposure to particles or gases is influenced by various variables, including exposure time or working time. The longer the working time, the more gas is inhaled into the body. The long-term effect that may arise is an increased risk of health problems.[25]

Intake and Risk Characteristics

Intake of SO_2 of street sweeper respondents in this study was derived from SO_2 intake calculations based on the established formula. As shown in Table 4, 61 street sweepers in Samarinda City had an average SO_2 intake of 0.0012 mg/kg/day with the lowest intake being 0.0003 mg/kg/day and the highest being 0.0029 mg/kg/day. Previous studies have shown that 74.5% of ceramic workers in Plered, Indonesia experience respiratory disease symptoms when SO_2 intake exceeds 0.0126 mg/kg/day.[26] Meanwhile, in this study the average SO_2 intake was 0.0012 mg/kg/day, which is low enough to potentially cause health problems. However, further examination is needed to determine the health problems that may occur.

Table 4 Distribution of SO_2 Intake and Risk Characteristics of Street Sweepers in Samarinda City

Variable	n	Mean	Median	Min-Max	SD	Kolmogorov-Smirnov
Intake of SO_2 (mg/kg/day)	61	0.0012	0.0011	0.0003 – 0.0029	0.00065	0.059
Risk Characteristics (RQ)	61	0.0524	0.0420	0.012-0.400	0.0517	<0.001

Based on Table 4, the results of calculating the level of risk characteristics in street sweepers with an average of 0.0524 (RQ<1) and categorized as this condition illustrate that all street sweeping workers who were respondents are included in the group not at risk or safe from sulfur dioxide (SO_2) exposure. Although the level of SO_2 risk characteristics of road sweepers is considered safe, the RQ lifespan varies from 5 to 30 years and requires further calculations. In that period, the risk of SO_2 exposure of road sweepers increases and can lead to health problems.

Relationship Between Intake of SO_2 and Hypertension Among Street Sweepers

Table 5 shows an analysis of the relationship between SO_2 intake and the incidence of hypertension in street sweepers, taking anthropometric characteristics (body weight) and activity patterns (length of exposure, frequency of exposure, and duration of exposure) into consideration. The results of the analysis of the relationship between SO_2 intake and the incidence of hypertension. The number of street sweepers with an SO_2 intake of >0.0012 mg/kg/day who experienced hypertension was 18 (69.2%). Meanwhile, the number of respondents with an SO_2 intake of ≤0.0012 mg/kg/day who experienced hypertension was 25 (71.4%). The chi-square test obtained a value of p of 1.000, indicating that there is no difference between the incident rate of hypertension and SO_2 intake. The results of the analysis obtained a value of OR of 1.111 (OR > 1), suggesting that street sweepers with an SO_2 intake of >0.0012 mg/kg/day are 1.111 times more likely to develop hypertension than those with an intake of ≤0.0012 mg/kg/day.

Table 5. Distribution of Street Sweepers According to SO_2 Intake and Hypertension Incidence

SO_2 Intake (mg/kg/day)	Hypertension Incidence				Total		OR (95%CI)	p-value
	No		Yes					
	n	%	n	%	n	%		
>0.0012	8	30.8	18	69.2	26	100.0	1.111 (0.4-3.37)	1.000
≤0.0012	10	28.6	25	71.4	35	100.0		
Total	18	29.5	43	70.5	61	100.0		

Based on the analysis of the relationship between SO_2 intake and the incidence of hypertension, there was no relationship between SO_2 pollutant and the incidence of hypertension in street sweepesr in Samarinda City. This is in line with an ecological study conducted in East Java, which found no relationship between SO_2 and NO_2 on the number of hypertension cases in short-term exposure.[27] Meanwhile, a cohort study found that an increase in SO_2 concentration of 10 $\mu g/m^3$ was associated with a 76% higher risk of hypertension (hazard ratio: 1.76; 95% CI: 1.163 - 1.189).[28] The high incidence of hypertension in workers in our study is possibly due to other factors. Previous research shows that there is a relationship between the incidence of hypertension and smoking habits in terms of smoking age, duration of smoking and type of cigarette.[29] Apart from that, excessive intake of saturated fatty acids and trans fatty acids as well as high consumption of salt and sugar can trigger hypertension.[30]

CONCLUSION

The research has shown that the concentration of sulfur dioxide (SO_2) is below the ambient air quality standard (<150 $\mu g/m^3$) in the ambient air of Samarinda City, East Kalimantan. The average exposure time for workers is 5 hours/day. The frequency of exposure is 365 days, and the duration of exposure is 10 years. Meanwhile, the average body weight of a street sweeper is 64.8 kg. Tthe average SO_2 intake of street sweepers in Samarinda City is 0.0012 mg/kg/day with an average of 0.0524 (RQ≤1). Therefore, street sweepers in Samarinda City are still in a safe, with no risk of health problem. In additiont, this study found that there was no relationship between the incidence of hypertension in street sweepers and sulfur dioxide intake. However, higher intake levels have the potential to cause hypertension.

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