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Determination of Safe Sulfur Dioxide (SO_2) Concentration among Street Vendors of Ampera Bus Station, Palembang, Indonesia

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ABSTRACT

Sulfur dioxide is a corrosive substance harmful to humans. In the form of gas this substance has a pale color, nearly invisible and has a strong odor. Transportation activities in the bus station produces SO_2 exhaust gas which is dangerous for street vendors. The purpose of this study was to determine the safe concentration of sulfur dioxide at street vendors at Palembang's Ampera Terminal, Indonesia. This is an observational, cross sectional and descriptive study. The study population was street vendors at Ampera Terminal Palembang, Indonesia. The sampling technique used a total population of 84. Data analysis was conducted manually quantitative to determine the safe concentration (C safe) of sulfur dioxide for workers obtained from the data of experimental white mice (W animals) weight, body surface area of white mice (BSA animals), workers' body weight (W), workers' height (h), workers' body surface area (BSA), workers' respiratory rate (BR), working time (t), concentration of sulfur dioxide (C), animal km, human km, NOAEL and reference of concentration (RfC).

From data processing, the concentration of sulfur dioxide in Ampera bus station, Palembang was 0.2298 mg/m^3 (0.08771 ppm). This value is under (SNI) 19-0232-2005 of 5.2 mg/m^3 (1.98 ppm). Based on the manual calculation, the safe limit of sulfur dioxide concentration in Ampera bus station, Palembang is 0.395 ppm. This value exceeds the value set by Permenaker No. 5 of 2018 of 0.25 mg/m^3 (0.09542 ppm). From these findings, control from the adverse effects of sulfur dioxide on workers' health is needed. Control recommendations include routine inspection of vehicle exhaust emissions and improvement efforts to reduce SO_2 emission levels to reduce health risks. In addition, health consultation facilities need to be provided for street vendor workers in Ampera Palembang

Keywords: *sulfur dioxide, bus station, safe concentration, street vendor*

Introduction

SO_2 is the most common toxic substance in large cities and is a very strong pollutant in relation to respiratory diseases (Farisi, 2018)[1]. Effects of exposure to sulfur dioxide in adults include problems in breathing, changes in breathing ability, as well as burning sensation in the nose and throat (ATSDR, 2010)[2].

One of the vehicle exhaust gases produced from activities is SO_2 gas. Emission of vehicles in the bus station when engine is running but the vehicle stops (idling) is twice higher than that of the emissions of exhaust gases when the vehicle is running normally (EPA, 2011)[3]. Transportation in large coal-fueled cities contributes 32.5% SO_2 in national pollutants (Rao V et al, 2013)[4].

According to (SNI) 19-0232-2005 the permissible TLV of sulfur dioxide is 5.2 mg/m^3 (1.98 ppm)[5].

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According to Permenaker No. 5 of 2018 Threshold Limit Value (TLV) of sulfur dioxide is 0.25 mg/m^3 (0.09542 ppm)[6]. ACGIH in 2005 set a threshold limit value (TLV) of sulfur dioxide of 2 ppm[7].

The safe concentration of sulfur dioxide is not a reference in determining the threshold value of sulfur dioxide that it often has an effect on workers even though the concentration is below the threshold. A study found that lung cancer incidence was 1.3% higher in areas of high concentration of sulfur dioxide (≥0.008 ppm) than in areas with low concentration of sulfur dioxide (<0.005 ppm) (ATSDR, 2010)[2]. Changes in lung function were found in workers exposed to 0.4-3.0 ppm sulfur dioxide in 20 years or more. Sensitive breathing such as asthma can result from exposure to low concentrations (0.25 ppm) of sulfur dioxide (ATSDR, 2010)[2]. Based on the results of the research, the concentration of sulfur dioxide below the specified TLV (ATSDR, 2010 of 3 ppm) has had a health effect on workers. Thus TLV needs to be improved based on the results of research on the safe limits of sulfur dioxide concentrations in the work environment. The average weight, height, temperature and air pressure conditions in a place are the reasons for safe concentration and TLV of a different chemical. Based on calculations, the concentration is safely influenced by body weight, respiratory rate, and length of work time.

The research was carried out by determining the safe limits of sulfur dioxide concentration in the work environment based on workers'body weight, respiration rate and duration of daily work. Respiration rate is influenced by workers' body weight.

This research aims to determine the safe concentration of sulfur dioxide at street vendors in Palembang's Ampera bus station, Indonesia. This study began with the determination of NOAEL in white rats and RfC. The benefit of the research is as a reference in determining sulfur dioxide TLV in the work environment in Indonesia, i.e the Ampera Palembang bus station as an improvement from the existing TLV.

Material and Method

This study was an observational, cross sectional and descriptive study. The population of this study is street vendors around the Ampera Terminal Palembang.

The sampling technique was a total population of 84 people. The study began with the collection of primary data including concentrations of sulfur dioxide in the air, length of work, and workers' body weight. Primary data of experimental animals is the weight of white mice. Data on the concentration of sulfur dioxide in the air obtained by direct measurement at the Ampera bus station in Palembang, Indonesia refers to SNI 19-7119.2-2005. Measurements were made using the midget impinger and Griess Saltzman method and spectrophotometer analysis technique.

The research variables include the concentration of sulfur dioxide in the workplace, workers' weight, height, respiration rate, length of work daily, body surface area, weight of white rats, body surface of white rats, highest dose of toxin without effect on experimental animals (NOAEL), Km factor in animals (Animal Km), Km factor in workers (Human Km), safe limit of toxin dose for workers (RfC), and benzene concentration safe for workers (C safe).

NOAEL of sulfur dioxide from μg/m^3 to mg/kg, where 1 mg/kg equivalent to 1 ppm obtained from calculations using the following formula[8].

$$\text{NOAEL} = \frac{n \times \text{BeratMoleckul}}{24,45} \times 1000$$

Determination of safe dosage of toxin for workers (RfC) is calculated using the following formula (Shaw et al, 2017 in Tualeka, 2013)[8]:

$$\text{RfC} = \text{NOAEL}\ \frac{\text{Animal Km}}{\text{Human Km}}$$

Where:

RfC :References of concentration (mg/kg)

Animal Km : Km factor on animal

Human Km : Km factor on human

Determination of safe concentration using the following formula (William et al, 1985 in Tualeka, 2013)[8]:

$$\text{C safe} = \frac{(\text{R}fc)(\text{W}b)}{(\delta)(\text{BR})(t)}\ \text{mg/m}^3$$

Conversion of units of mg/m^3 to ppm was performed by using the following formula (Tualeka, 2013) (9):

$$\text{C safe (ppm)} = \frac{mg/m3}{(\text{MV})}\ 24{,}5$$

Where :

C safe : concentration of toxin in the air safe for workers (mg/m3)

RfC : Inhalation Reference Concentration (mg/kg)

W : Weight (kg)

δ : % substances absorbed by the lungs

BR : Human respiratory rate (m^3/hour)

t : Working duration (hours/day)

MW : Molecular Weight

Data analysis was performed by using quantitative data analysis manually to determine safe sulfur dioxide concentrations for street vendors at Ampera bus station, Palembang, Indonesia.

Findings

A. Characteristics and the Surface Area of Try Animals (White Mice): Human response to toxicity is generally similar to animal responses qualitatively, thus, test on animal becomes the basis for extrapolating animal to human data (Tualeka et al, 2019)[9]. Toxicity test is carried out by using white rats.

Table 1: Distribution of Experimental Animal (White Mice) Characteristic

ANIMAL KM		
Research Object (White Rats)	**W (Kg)**	**BSA (m^2)**
1	0,1405	0,024165
2	0,1405	0,024165
3	0,141	0,024223
4	0,141	0,024223
5	0,1395	0,02405
6	0,1415	0,02428
Total	0,844	0,145105
Average	0.140667	0.024184

Based on white rat body weight data, the body surface area (BSA) was calculated using the following formula:

Animal $BSA = 0{,}09\ W^{0{,}67}$

where:

BSA : Body Surface Area (m^2)

W : Weight (kg)

B. Workers' Characteristics, Body Surface Area and Breathing Rate: The characteristics of the workers in this study include weight and duration of work from 84 street vendors at Palembang's Ampera bus station, Indonesia. Based on Table 2, the highest body weight was 100 Kg, the lowest weight was 37 Kg, and the average body weight was 65.57 Kg. The average working duration in a day is 8 hours, the shortest duration of work in a day was 5 hours/day and the longest duration of working in a day was 12 hours/day. The height used in the research was the average value of Indonesian adult height of 159 cm.

Based on data on body weight and height of workers, body surface area and worker respiratory rate were calculated using the following formula:

1. Workers' Body Surface Area

$$BSA = \sqrt{\text{W}.h/3600}$$
$$= \sqrt{65,57.159/3600}$$
$$= 1{,}448\ m^2$$

where:

BSA : Body Surface Area (m^2)

W : Weight (kg)

h : Height (cm)

2. Workers' Breathing Rate

$$BR = 5{,}3 \ln W - 6{,}9/24$$
$$= 5{,}3 \ln 65{,}57 - 6{,}9/24$$
$$= 0{,}63627\ m^3/\text{hour}$$

where :

BR : Breathing Rate (m^3/hour)

W : Weight (kg)

Table 2: Average Distribution of Workers, Breathing Rate and Working Duration of Street Vendors of Ampera Bus Station, Palembang, Indonesia

HUMAN KM					
Number of workers	**Wb (kg)**	**h (cm)**	**BSA (m^2)**	**t (hour /day)**	**BR (m^3/ hour)**
84	65,57	159	1,448	8	0,63627

The results of the calculation of body surface area and worker respiratory rate were 1,448 m^2 and 0.63627 m^3/hour, respectively.

C. Sulfur Dioxide (SO_2): Measurement of the concentration of Sulfur Dioxide was obtained through measurements at 4 predetermined points (Arista et al, 2015)[10]. The average value of SO_2 concentration in Ampera Terminal Palembang was 229.8µg/Nm^3 or equivalent to 0.2298 mg/m^3 (0.08771 ppm). The concentration of sulfur dioxide is under (SNI) 19-0232-2005 of 5.2 mg/m^3 (1.98 ppm). The concentration of sulfur dioxide is below the threshold (TLV) value of sulfur dioxide according to ACGIH in 2005 of 2 ppm. However, the average concentration of sulfur dioxide is very close to the highest level allowed by Permenaker No. 5 of 2018 of 0.25 mg/m^3 (0.09542 ppm).

D. Animal Km and Human Km

1. Animal Km

$$\text{Animal Km} = \frac{\text{W animal}}{\text{BSA animal}}$$

where:

Animal Km : Km factor on animal

W : Weight (white rats)

BSA : Body Surface Area (white rats)

Table 3 shows the calculation result of Animal Km in white rats of 5.81.

Table 3: Animal KM of White Rats

ANIMAL KM			
Research Object (White Rats)	**W (Kg)**	**BSA (m^2)**	**Animal Km = W/ BSA**
1	0.1405	0.02416	5.81421
2	0.1405	0.02416	5.81421
3	0.141	0.02422	5.82102
4	0.141	0.02422	5.82102
5	0.1395	0.02405	5.80052
6	0.1415	0.02428	5.82783
Total	0.844	0.14510	34.8988
Average	0.14066	0.02418	5.81647

2. Human Km

$$\text{Human Km} = \frac{\text{W human}}{\text{BSA human}}$$

where:

Human Km : Km factor on human

W : Weight (Kg)

BSA : Body Surface Area (m^2)

The average Human Km of street vendors in Palembang's Ampera terminal is shown in the table of 45,283.

Table 4: Workers' Average Human Km Calculation

Number of workers	Wb avg (Kg)	BSA avg (m^2)	Human Km avg
84	65,57	1,448	45,283

E. No Observed Adverse Effect Level (NOAEL): Toxicity test is used to evaluate the safety of a substance. The safe limit of the concentration of a chemical can be determined by the toxicity test for determining the highest dose without causing effects on experimental animals or No Observed Adverse Effect Level (NOAEL).

NOAEL of sulfur dioxide was 660 µg/m^3 (OEHHA, 2016)[11] or equal to 0.25 mg/kg (0.25 ppm) obtained from the following calculation[8]

$$\text{NOAEL} = \frac{n \times \text{Berat Molekul}}{24{,}45} \times 1000$$

$$660\ \mu g/m^3 = \frac{n \times 64{,}06}{24{,}45} \times 1000$$

n = 0,25 mg/kg

F. Reference of Concentration (RfC): Calculation of Inhalation Reference Concentration for street vendors in Ampera Palembang, Indonesia based on NOAEL values, on average Animal Km, the average Human Km is as follows.

$$\text{RfC} = \text{NOAEL}\ \frac{\text{Animal Km}}{\text{Human Km}}$$

$$= 0{,}25\ \frac{5{,}81}{45{,}283}$$

$$= 0{,}032 \text{ mg/kg}$$

Where:

RfC : References of concentration or Inhalation Reference Concentration (mg/kg)

Animal Km : Km factor on animal

Human Km : Km factor on human

From the calculation of the formula, the RfC calculation result is 0.032 mg/kg.

G. Safe Concentration of Sulfur Dioxide (C safe): The results of the calculation of safe concentration of sulfur dioxide in street vendors of Ampera Palembang bus station based on RfC values, average workers' weight, percentage of substance absorption, average workers' breathing rate and average duration of work are as follows:

$$C\ safe = \frac{(Rfc)(Wb)}{(\delta)(BR)(t)}$$

$$= \frac{(0,032)(65,57)}{(40\%)(0,63)(8)}$$

$$= 1,034134\ mg/m^3$$

$$C\ safe\ (ppm) = \frac{mg/m3}{(MV)}\ 24,5$$

$$= \frac{1,034 mg/m3}{(64,06)}\ 24,5$$

$$= 0,395\ ppm$$

Where :

C safe : Toxin concentration in the air safe for worker (mg/m^3)

RfC : Inhalation Reference Concentration (mg/kg)

W : Weight (kg)

δ : % substances absorbed by the lungs

BR : Human Breathing Rate (m^3/hour)

t : Working duration (hour/day)

MW : Molecular Weight

The results of safe limits in the air for workers calculation can be used to predict the concentration of toxins in the air a safe work environment for workers if the determination of the Threshold Limit Value (TLV), and to be compared with TLV has been determined by various institutions either by the Ministry of Manpower and Transmigration, ACGIH, NIOSH and OSHA (William, 1985 in Tualeka, 2013)[8].

Discussion

Based on the calculation, NOAEL of sulfur dioxide is 0,25 ppm. The NOAEL is lower than that of NOAEL determined by ATSDR in 1998 by 3 ppm for respiratory system with intermediate exposure.

The result of the calculation of the reference dose (RfC) exposure to sulfur dioxide was 0.032 mg/kg. RfC in the present study is smaller than the RfC determination at studies of human exposure controls in a population of 0.067 mg/kg. At this rate, human health includeing populations that have sensitive breathing such as asthmatics still protected[12]. Thus, the RfC of the present study is safe for humans.

Based on the results of this study, the safe concentration of sulfur dioxide in the street vendors of Ampera bus station, Palembang was 0.395 ppm. This value is lower than sulfur dioxide threshold value according to (SNI) 19-0232-2005 of 5.2 mg/m^3 (1.98 ppm) and ACGIH in 2005 of 2 ppm. Thus, the value of the result of this study can be used as a reference in determining the threshold value of Sulfur Dioxide in the Ampera bus station, Palembang and is safe for those who were exposed to it.

Conclusion

The measurement result of the average concentration of sulfur dioxide in street vendors around the Ampera bus station in Palembang, Indonesia was 0.2298 mg/m^3 (0.08771 ppm), which means below the threshold according to the Indonesian National Standard (SNI) 19-0232-2005 about the Threshold Limit Value (TLV) in the workplace air of 5.2 mg/m^3 (1.98 ppm). However, the average concentration approached the highest level permitted according to Permenaker No. 5 of 2018 of 0.25 mg/m^3 (0.09542 ppm). In contrast to the predetermined threshold value of 0.095 ppm, the concentration of sulfur dioxide in the present study was 0.395 ppm. This value is lower than that of specified in the 2005 ACGIH Threshold Value of 2 ppm. Therefore, control efforts are needed that the communities are protected from the adverse effects of sulfur dioxide on health.

Control recommendations include routine inspection of vehicle exhaust emissions and improvement efforts to reduce SO_2 emission levels so as to reduce health risks. In addition, health consultation facilities need to be provided for street vendors in Ampera bus station, Palembang.

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Ethical Clearance: The study was approved by the institutional Ethical Board of the Public Health, Universitas Airlangga.

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