Determination of Reference of Concentration (RFC) from Hydrogen Sulfide (H_2S) Exposure in the Community Based on Weight in Industrial Area in Medan Indonesia

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ABSTRACT

Hydrogen sulfide (H_2S) is a colorless, highly toxic, flammable and rotten egg smelled gas. This gas can cause adverse effects on health, especially in the respiratory tract. Low concentrations of H_2S for long periods of time can cause permanent effects such as respiratory problems, headaches and chronic cough. Hydrogen sulfide can be formed naturally and from the process of human activity. One of these human activities is the process of processing animal food and marine products in Medan Industrial Area which produces exhaust gas in the form of H_2S gas.

The aim of the study was to calculate the value of RfC from H_2S exposure in communities in Industrial Area in Medan, Indonesia. This is an observational cross-sectional study with quantitative manual data analysis method. The study sample was 52 residents of industrial estates at a radius of 300m and 52 residents at radius of 800m. Research variables included H_2S concentrations in Medan Industrial Area, body weight, height, respiratory rate, length of day exposure time, body surface area, weight of white mice, body surface of white mice, highest dose of toxin without effect on experimental animals (NOAEL), factor Km in animal (Animal Km), factor Km in human (Human Km) and Reference of Concentration si (RfC).

The result showed that H_2S concentrations at a radius of 300 m was 0.022 ppm and at an radius of 800 m is 0.0064 ppm. This value is above the Threshold Limit Value according to ATSDR provision of 0,0005 ppm. Concentration of H_2S RfC in this study was 0.001 mg/kg; which is smaller than that of released by EPA 2003.[11] The results of the RfC in this study is safe for humans. However, H_2S gas around residential areas was close to NAB. This can increase at any time and can have a negative influence on public health. Therefore, control measures need to be carried out, including by installing additional air monitoring devices in several locations by waste management agencies. In addition, recording is also needed for all complaints of odor felt by the community, including nature, location, time and frequency of complaints. With these measures, air quality, exposure level, and health effects can be controlled.

Keywords: *RfC, Hydrogen sulfide, Industrial area*

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Introduction

Hydrogen Sulfide (H_2S) is a colorless, highly toxic, flammable gas that has the characteristic odor of rotten eggs.[1] The main absorption of H_2S is through the inhalation pathway. When air containing Hydrogen Sulfide is inhaled, it will be absorbed into the bloodstream and distributed throughout the body. Humans can usually smell H_2S at low concentrations in the air, between 0,0005 and 0.3 ppm.[2]

Hydrogen sulfide can be formed naturally like gas from volcano, sulfur springs, swamp, in crude oil and natural gas or as a result of human activities such as gas from sewage treatment plants, manure fertilizer handling operations, petroleum refinery industry, and petrochemical plants. At low concentrations, H_2S can cause dizziness, nausea, feeling of drifting, coughing, anxiety, drowsiness, dryness, pain in the nose, throat and chest and olfactory sensory paralysis.[3]

In determining the safe limits of toxin concentrations in the work environment, determining the Reference of Concentration (RfC) toxin in the human body is one of the important steps. Analysis of the risk of toxins in the work environment in Indonesia often uses RfC issued by researchers or institutions abroad, such as America and Europe. In fact, environmental conditions (air pressure and temperature) and human physical conditions (body surface area) differ between Europe and America and Indonesia. It is advisable to determine the risk analysis of toxins using RfC based on research results in Indonesia.[4]

Based on previous research on the Analysis of the Risk of Hydrogen Sulfide Exposure in Communities around Industrial Areas in Medan, the risk level of exposure to Mercury (Hg) through consumption of fish and drinking water in the community has not been performed. In this study, RfC was obtained based on the principle of dose response and toxicity test for determining the highest dose without causing effects on experimental animals or also called No Observed Adverse Effect Level (NOAEL).

The purpose of this study is to determine the RfC of H_2S in the communities around Medan Industrial areas that the results can be used as a reference to estimate the amount of exposure each day that can be accepted by the community without causing harmful effects during their lifetime.

Material and Method

This research was conducted around an industrial area in Medan, Medan Labuhan sub-district, Indonesia. This study was an observational cross-sectional. The population in this study was housewives who lived around industrial estates at a radius of 300 m and a radius of 800 m. The sampling technique used cluster techniques. The number of samples needed for the subject group was 52 people for each radius so the total sample was 104 people.

The data used are primary data including the measurement results of H_2S concentration, intake rate, duration of exposure, and body weight. H_2S concentration measurements used the SNI 19-7119.7-2005 method with a photometer spectrometer.

The variables in this study included the highest dose of toxin without causing effects (NOAEL) on H_2S experimental animals, weight of experimental animals (W animals), body surface of experimental animals (BSA experimental animals), community weight (W), human height (h), respiratory rate (BR), length of day exposure time (t), community body surface area (BSA), and reference concentration (RfC) of toxins in the human body. Data analysis in this study was carried out by using manual quantitative analysis to determine RfC in the community.

Result

A. Characteristics and Body Surface Area of Experimental Animals (White Mice): Toxicity test was carried out using experimental animals of white mice. In general, human response to toxicity is qualitatively similar to that of animals. This fact is the basis of extrapolation from animal data to humans.[5]

Table 1: Distribution of Characteristics of Experimental Animals (White Mice)

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	0,024165
Total	0,844	0,144991
Average	0,140666667	0,024165167

Based on data from table 1, the body surface area of white mice is calculated using the following formula.

$BSA = 0,09\ w^{0,67}$

Where

BSA: Body Surface Area (m^2)

W: Weight (kg)

B. Characteristics, Surface Area and Respiratory Rate of the Residence: The community characteristics in this study included the weight and exposure time of 104 respondents around Medan Industrial Areas at a radius of 300 m and 800 m. Based on Tables 2 and 3, the highest body weight is 79 kg with an average of 68 kg. The duration of the exposure, especially housewives who are exposed to H_2S gas at a radius of 300 m in a day was 18 hours and 15 hours at a radius of 800 m in a day. The height used was the average height of Indonesian adult women's height of 153 cm.

Based on data on body weight and height, BSA and respiratory rate were calculated using the following formula:

1. The surface area of a community's body

$$BSA = \sqrt{W \cdot \frac{h}{3600}}$$

Where:

BSA: Body Surface Area (m^2)

W: Weight (kg)

h: Height (cm)

Breathing Rate

$$BR = \frac{5,3 \ln W - 6,9}{24}$$

Where:

BR: Breathing Rate (m/jam)

W: Weight (kg)

Table 2: Distribution of Characteristics, Body Surface Area and Respiratory Rate on the Community around Medan Industrial Areas (Radius 300 m)

Resident	Wb (kg)	h (cm)	BSA (m^2)	t (hour/ day)	BR
1	69	153	1.71	15	0.65
2	63	153	1.64	14	0.63
3	56	153	1.54	16	0.60
4	71	153	1.74	18	0.65
5	68	153	1.70	12	0.64
Etc					
52	59	153	1.58	15	0.61
Average	69	153	1.71	15	0.6

Table 3: Distribution of Characteristics, Surface Area and Respiratory Rate of People around Medan Industrial Areas (Radius 800 m)

Resident	Wb (kg)	h (cm)	BSA (m^2)	t (hour/ day)	BR (m^3/ hour)
1	65	153	1.66	15	0.63
2	76	153	1.80	14	0.67
3	63	153	1.64	16	0.63
4	67	153	1.69	18	0.64
5	75	153	1.79	12	0.67
Etc					
52	78	153	1.82	15	0.67
Average	68	153	1.69	15	0.6

The average body surface area and community respiratory rate according to tables 2 and 3 are 1.71 m2 at a radius of 300 m and 1.69 m2 at 800 m. The average community respiratory rate is 0.6 m^3/hour.

C. Hydrogen Sulfide Concentration (H_2S): The measurement results of H_2S concentrations in the Industry Medan Area are different at 6 measurement locations in 2 radius, both in the industrial area (300 m) and outside the industrial area (800 m) which is 0.03 mg/m3 and 0.0093 mg/m3, each.

Based on the results of measurements, the concentration of hydrogen sulfide around Medan Industrial Area (radius 300 m) was 0.022 ppm with the highest concentration of 0.4 mg/m^3 (0.029 ppm) and the lowest of 0.2 mg/m^3 (0.01 ppm). H_2S concentration outside Medan Industrial Area (radius 800 m) was 0.0064 ppm, with the highest concentration of 0.2 mg/m^3 and the lowest 0.002 of mg/m^3 (0.001 ppm).

D. Animal KM and Human KM: Calculation of Animal KM and Human KM is the first step in determining the safe limits of toxin doses for the community.

1. Animal KM

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

Where:

Animal km: Km factor on animal

W : Weight of experimental animal

BSA : Body Surface Area of experimental animal

Table 4: Animal Km in White Mice

Reseach Object (White Rats)	W (kg)	BSA (m^2)	Animal km (W/BSA)
1	0,1405	0,024165	5.8141941
2	0,1405	0,024165	5.8141941
3	0,141	0,024223	5.820914
4	0,141	0,024223	5.820914
5	0,1395	0,02405	5.8004158
6	0,1415	0,024165	5.8555762
Average	0,1406	0,024165	5.81

Based on the calculation of Table 4, the average Animal Km in white animals is 5.81.

2. Human KM

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

Where :

Human Km : Km factor on human

W : Human weight

BSA : Body Surface Area of human

Table 5: Results of Human Km Calculation in Communities around Medan Industrial Areas (300 m)

Resident	Human KM
1	40.29
2	38.50
3	36.30
4	40.87
5	40.00
etc	
52	37.26
Average	40.263

Table 6: Results of Human Km Calculation for Communities Beyond Medan Industrial Areas (800 m)

Resident	Human KM
1	39.11
2	42.29
3	38.50
4	39.70
5	42.01
etc	
52	42.84
Average	39.959

E. NOAEL: Determination of safe limit of the concentration of a chemical begins with toxicity test determining the highest dose without causing effects on experimental animals or No Observed Adverse Effect Level (NOAEL). According to U.S. Environmental Protection Agency (EPA), NOAEL from H_2S is 1 mg/m³ (0.0074 mg/kg).[6] Calculation of the conversion from mg/m3 to mg/kg is as follows:

NOAEL H_2S = 1 mg/m³

$$= \frac{1 \times 0,00013 \times 8}{0.1405}$$

= 0,0074 mg/kg

F. Reference of Concentration (RfC): According to Saridewi and Tualeka (2017) the calculation of RfC is done using a formula from Shaw et al.[7]

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

Where:

Rfc: Reference of Concentration (mg/kg)

Animal Km: Km factor on experimental animal

Human Km:Km factor on human

Results of Reference of Concentration (RfC) obtained from NOAEL, Animal km averages, and Human Km averages are as follows:

1. Radius 300 m

$$\text{RfC} = 0,0074.\ \frac{5,821035}{39,496}$$

= 0.001090627 mg/kg

2. Radius 800 m

$$\text{RfC} = 0,0074\ \frac{5,821035}{39,198}$$

= 0.001098926 mg/kg

Discussion

Based on the measurement results, the concentration of H_2S around the industrial area (radius 300 m) is 0.022 ppm, while the concentration of hydrogen sulfide outside the industrial area (radius 800 m) is 0.0064 ppm. At a radius of 300 m and 800 m H_2S concentrations are above the Threshold Value (NAB) of 0,0005 ppm according to ATSDR provisions regarding the Odor Threshold

Value of Hydrogen Sulfide.[1] According to KepMenLH No.KEP-50/MENLH/1996 regarding the standard level of smell the value of the Threshold Limit Value (NAB) is 0.02 ppm.[8] At a radius of 300 m with a concentration of 0.022 ppm above the Threshold Limit Value (NAB)[8]. The concentration of air at a radius of 300m is greater than the concentration of air at a radius of 800m, this is due to differences in the distance from the source of pollutants. The closer the location of the study to the source of pollutants the greater the H_2S concentration received by the body.[9]

The results of this study indicate that the average value of the respondent's body weight is 68 kg, with the lowest weight of the respondent is 54 kg and the highest body weight is 79 kg. In this study, the respondent's body weight greatly influenced the intake rate where the greater the respondent's weight, the greater the intake rate of the respondent himself. This is in accordance with the theory which states that the greater a person's weight, the greater the volume capacity of a person's lung, which allows more air to enter the body.[10] The finding of the Laila's study (2018) showed that respondents with the greatest weight had lung volume capacity that big also that allows more air into the body, thereby increasing the potential for breathing air containing pollutant gases such as H_2S so that it impacts on health.[11]

According to EPA, NOAEL (No Observe Adverse Effect Level) or the highest dose without effect on animals is an experiment in determining doses that do not show an indication of a statistically significant effect on toxic effects or biological functions.[7] Based on the results of calculations, NOAEL hydrogen sulfide of 1 mg/m3 is equivalent to 0.72 ppm. This NOAEL result is smaller than the 2016 ATSDR of 2.5 ppm for medium exposure respiratory systems.[1]

After the NOAEL value of H_2S is determined, the calculation of RfC on H_2S exposure in the Medan Industrial Area area was carried out. The RfC value was sought from the risk agent of gas, which uses the reference dose of the chemical species inhalation pathway. The calculation of Inhalation Reference Concentration (RfC) used NOAEL from the U.S. Protection Agency (EPA) by 0.00109 mg/kg (radius 300m) and 0.00109 mg/kg (radius 800m). This value is greater than the H_2S RfC found in the previous study on Risk Analysis of Hydrogen Sulfide Gas Levels (H_2S) in the Community Around the Bioethanol Plant by 0,000571 mg/kg.[6]

According to IRIS US-EPA the value of hydrogen sulfide RfC gas is 0,000571 mg/kg/day.[12] Although the results of this study indicate that H_2S levels is still safe in accordance with the exposure limits of hydrogen sulfide in the air established by the EPA, the effects of low level exposure or long-term hydrogen sulfide at levels of less than 1 ppm in the air are more difficult to predict because the mechanism of chronic toxicity is has not been further studied.[2]

Preventive measures to avoid the chronic effects of H_2S gas exposure include routine waste management and air quality monitoring to see air quality conditions due to the production process. The relevant party needs to inform the people living around the Medan and surrounding Industrial Estates regarding H_2S concentrations. Installation of additional air monitoring equipment in several locations by the waste management agency is also needed to record all odor complaints that are felt by the community, namely the nature, location, and frequency of complaints so that air quality, exposure level, and health effects can be controlled.[1]

Conclusion

1. NOAEL of H_2S around Medan Industrial Area is 0.0074 mg/kg.
2. The average value of Human KM at a radius of 300 m is 40.3 and in a radius of 800 m is 39.9.
3. The value of RfC of H_2S in Medan Industrial Area at a radius of 300 m is 0.001090627 mg/kg and at a radius of 800 m is 0.001098926 mg/kg.

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