Determination of Sulfur Dioxide (SO_2) Safe Duration in Residential Population Around the Fertilizer Industry X in Indonesia

Yunita Tria Nur Latifa[1], Abdul Rohim Tualeka[1], Rois Solichin[2], Pudji Rahmawati[3], Syamsiar S Russeng[4], Atjo Wahyu4, Ahsan[5]

[1]Department of Occupational Health and Safety, Public Health Faculty, Airlangga University, Surabaya, East Java, Indonesia; [2]Faculty of Medecine and Health Science, State Islamic University Syarif Hidayatullah, Jakarta, Indonesia; [3]Department of Development of Islamic Society, State Islamic University Sunan Ampel, Surabaya, Indonesia; [4]Department of Occupational Health and Safety, Public Health Faculty, Hassanudin University, Makassar, Indonesia; [5]Faculty of Nurse, University of Brawijaya, Malang, Indonesia

ABSTRACT

People who have lived more than 22 years in settlements around the fertilizer industry X are at risk of being exposed to SO_2 from the increase in exhaust emissions produced by the boilers and power generation equipment in the fertilizer industry. The purpose of this study was to determine the Risk Quotient (RQ) due to exposure to SO_2 and to measure the duration of exposure to SO_2 that is safe in the residential area around the fertilizer industry X.

This research is a quantitative study with an environmental health risk analysis method, with a sample size of 297 adult population respondents in residential areas around the center of SO_2 emissions in the fertilizer industry X area. Data analysis was done using manual data calculations to determine the intake of SO_2 (non carcinogenic), risk level or risk quotient (RQ), and safe duration (Dt safe) exposure to SO_2 in the population around the fertilizer industry X.

The results showed that the average non-carcinogenic intake of SO_2 in settlements around the fertilizer industry X was at 0.057427415mg/kg/day. While the average risk quotient is 1.788347507 (RQ> 1), from a total of 297 respondents as many as 197 respondents with RQ> 1 and 100 respondents with RQ <1, it shows that> 50% of the population in settlements around the fertilizer industry X have health risks resulting from exposure to SO_2. The average safe duration of exposure to SO_2 in the population in settlements around the fertilizer industry X is 23.47 years, depending on the food intake and body condition of the respondents. The recommendation that can be given is to increase the weight of respondents and the right diet pattern by consuming nutritional intake that can detoxify the main toxin to reduce sulfur dioxide levels in the body, one example is the provision of vitamins E and C which can reduce oxidative effects such as lipid peroxidation and membrane damage in erythrocytes due to exposure to sulfur dioxide[2]. Besides that, a related stakeholder policy is needed to periodically measure SO_2 concentrations in community residential areas around the fertilizer industry X, so that the air quality of people exposed to SO_2 can be monitored and is still within safe limits. The company holds a CSR program involving the surrounding community by conducting routine health checks, greening programs around the fertilizer industrial area[6].

Keywords: *Sulfur Dioxide, Risk Quotient, Safe Duration, Settlements around Fertilizer Industry X*

Corresponding Author:
Abdul Rohim Tualeka
Department of Occupational Health and Safety,
Public Health Faculty, Airlangga University,
60115 Surabaya, East Java, Indonesia
Phone: +62-31-5920948
Email: abdul- r-t@fkm.unair.ac.id

Introduction

Everyone can be exposed to exhaust emissions of sulfur dioxide every day. The main uses of SO_2 are industrial sulfuric acid production, refrigerators, disinfectants for fruits and vegetables, the textile industry and fertilizer industry. The population in residential areas around the fertilizer industry has a high risk of exposure to SO_2[5]. People who lived in residential areas around the fertilizer industry for years were constantly receiving SO_2 exposure due to boiler exhaust emissions and power generation equipment from production activities[15]. Sulfur dioxide (SO_2) is a gas that is colorless and non-explosive, very soluble to water droplets and rain, has a characteristic odor and stinging acid taste and can irritate[16]. Significant health effects include breathing difficulty, asthma attacks, pulmonary edema, eye irritation, cardiopulmonary disease, and increased mortality [(7) (11)]. SO_2 is the main air pollutant that has a significant impact on human health[12]. Effects of specific short-term exposure to SO_2 can cause cardiovascular disease (CVD)[1]. In addition, SO_2 also has a significant relationship with the occurrence of hand, foot, and mouth disease (HFMD) [19].

Based on previous research (Solichin, 2016)[15] about SO_2 in the environment have not conducted research or measurements of safe duration (Dt Safe) for residential communities around the fertilizer industry that are exposed to SO_2 emission gases. This measurement is intended to make prevention and control efforts earlier before the respondent is estimated when symptoms of the disease arise in his body, so as to prevent health problems (non-carcinogenic) due to exposure to SO_2. Then further research is needed regarding the measurement of the safe duration of SO_2 in residential communities around the fertilizer industry X, as well as to determine intake and risk quotient (RQ) exposure to SO_2 (noncarcinogens).

Material and Method

The type of this research is quantitative research with environmental health risk analysis methods. In this study focused on exposure to SO_2 as an increase in exhaust emissions produced by boilers and power generation equipment in the fertilizer industry X.

The subjects of this study were human samples, namely adults aged 17 years and over who lived more than 2 years in the study area which were divided into 3 clusters, within a radius of 800, 1.050, and 1.300 meters from the center of the fertilizer industry X, so that a sample of 297 respondents was calculated. Whereas environmental samples are ambient air in residential areas around the fertilizer industry X, collected by the pararosanilin method using a spectrophotometer with impinger equipment by officers of the Center for Environmental Health. The procedure for analyzing SO_2 samples in the laboratory refers to the reference SNI 19-7119.7[3].

The data were obtained by secondary data. Secondary data were obtained by collect of data measurements which included the concentration of SO_2 in the air, anthropometric conditions (respiration rate and weight), activity patterns (time, frequency, duration of exposure, daily average time period) of the respondent bt research of Solichin R, 2016[15]. While secondary data also was obtained from related literature.

The variables studied were the intake, Risk Quotient (RQ) and safe duration (Dt Safe) from SO_2 (non-carcinogenic) exposure to respondents in residential areas around the fertilizer industry X. Data analysis was carried out by quantitative data analysis to determine the concentration and safe duration of SO_2 exposure to respondents.

Findings

A. Intake: Determination of the amount of intake on SO_2 toxins that enter the body, the following formula is used [(17)(18)]:

$$\text{Intake SO2} = \frac{C \times R \times tE \times f\,E \times Dt}{Wb \times Tavg}$$

Notes:

C = Sulfur Dioxide Concentration (mg/m^3)

R = Respiration Rate (m^3/hour)

t_E = Time of exposure (hour/day)

f_E = Frequency or Average exposure in year (day/year)

Dt = Duration of Exposure (year)

W_b = Weight (Kg)

T_{avg} = Average Exposure of Sulfur Dioxide (non-carsinogen) → 30 years x 365 day/year

Based on the results of measurements on the data, it is known that the average exposure concentration of SO_2 (C) is 0.248456 mg/m^3. The average respiration rate (R) is 0.60 m^3/hour. The average exposure time (tE) is 21 hours/day. The average frequency of exposure (fE) is 356 days/year. The average duration of exposure (Dt) is 31.3 years. The average respondent's weight (Wb) is 57.6 Kg. While the average exposure of SO_2

(non-carcinogen) (Tavg) is 30 x 365 days/year. In Table 5. Explain the calculation of the average intake is 0.057427415mg/kg/day.

B. Risk Quotient (RQ): Determination of risk level for respondents to exposure to SO_2 or Risk Quotient (RQ) is formulated with [(17)(18)]:

$$\text{Risk Quotient (RQ)} = \frac{\text{Intake}}{RfC}$$

Determination of risk categories is intended to determine whether exposure to SO_2 toxins is at risk or does not pose a risk to the health of the human body. Risk Quotient (RQ) is the result of a comparison between intakes with Reference of Concentration (RfC) or Safe Human Dose (SHD). The RfC value is obtained from the calculation formula namely[13]:

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

According to The Office of Environmental Health Hazard Assessment (OEHHA)[9], the value of No Observed Adverse Effect Level (NOAEL) SO_2 is 660 µg/m^3 or equivalent to 0.25 mg/kg. While Animal Km and Human Km are Km factors in animals and humans, with the following calculations:

$$\text{(Animal or Human) Km} = \frac{\text{W (Weight)}}{\text{BSA (Body Surface Area)}}$$

Based on Table 1. The results of the average value of Animal Km are 5.816471979 while the Human Km is 35.96304. Based on the SHD formula described above, an SHD value of 0.04 mg/kg is obtained.

Table 1: Measurement of Animal Km by White Mice and Human Km

	Animal Km	Human Km
Average	5.816471979	35.96304

After obtaining the intake value and SHD, then the average value of Risk Quotient (RQ) is obtained for the respondents of 1,420286877 mg/kg/day (RQ> 1).

C. Safe Duration (Dt Safe): Safe Duration (Dt Safe) is associated with a safe duration at work for one day and a safe duration (in years). The formula used in determining safe duration (Dt safe) is[(17)(18)]:

$$\text{Dt Safe} = \frac{RfC \times Wb \times Tavg}{C \times R \times tE \times fE}$$

Based on the results of the calculations in Table 2. It is known that the safe duration of the average respondent is 23.47 years, depending on the nutritional value of the food intake and the condition or body anthropometry of each respondent. While the smallest safe Dt value of the whole respondents is 12.87 years.

Table 2: Intake, Risk Quotient (RQ) and Safe Duration (Dt Safe) of SO2 Exposure (Non-Carcinogenic) in Settlements Around Fertilizer Industry X Area

Re-spon-dents	Sulfur Dioxide Intake (mg/Kg/day)	Risk Quotient (RQ) (mg/Kg/day)	Safe Duration (Years)
1	0,056539305	1,398322252	36,47227949
2	0,128931165	3,188707721	18,81640001
3	0,013631756	0,337138702	32,62752077
4	0,046483183	1,149615652	21,74639842
5	0,137147641	3,391916467	15,6253848
Etc.			
297	0,161140632	3,985307784	16,05898552
Average	0,057427415	1,420286877	23,47334979

Discussion

Based on the results of measurements by the Institute for Environmental Health Engineering, the median value of SO_2 concentrations contained in ambient air in the population around the fertilizer industry X was 0.246 mg/m^3 (0.0946 ppm). This value is in the category above the ATSDR Minimum Risk Level (MRL) value, which is from WHO (1979) explains that for 24-hour exposure limit the recommended exposure can be tolerated at 100-150 mg/m^3 (0.04-0.06 ppm) but under the ACGIH (1998) value TLV-TWA: 5.2 mg/m^3 (2 ppm) and NIOSH (1997) REL TWA: 5 mg/m3 (2 ppm)[2]. When compared with the Minister of Manpower Regulation No. 5 of 2018[8], the SO_2 concentration value in this study is the same as the permissible threshold value, which is equal to 0.25 mg/m^3 (0.095 ppm). While the value of SO_2 concentration in this study is still below the threshold when compared with the Government of the Republic of Indonesia Regulation No.41 of 1999[10] at 24-hour exposure limit with SO_2 quality standards of 365 µg/Nm³ (0.13 ppm). To prevent or minimize health risks to the human body, it is necessary to reduce the concentration of SO_2 exposure to the safe concentration limit.

It is known that the intake value is directly proportional to the chemical concentration value, frequency of exposure, duration of exposure and inversely proportional to the value of body weight. Then it can be interpreted for prevention and control efforts, the greater the weight, the smaller the occurrence of health risks. Likewise, if the lower chemical concentration value, frequency of exposure, duration of exposure, the intake of toxins that enter the body is also lower.

Based on the results of the calculation of NOAEL SO_2 in this study was 0.25 ppm. The results of this calculation are smaller than NOAEL (US EPA 1994, 1996a, Streeton 1997, ATSDR 1998, OEHHA 1999b, EC 2005, WHO 2006, US EPA 2008) of 1-2 ppm. This NOAEL calculation is also smaller than ATSDR which is equal to 5 ppm[2].

Based on the calculation of RfC SO_2 in this study was 0.04 mg/kg. The results of this calculation are smaller than RfC for exposure to SO_2 through inhalation based on the health risk assessment of SO_2 by Health Canada (2016) which is equal to 0.06 mg/kg[9]. So, the results of this research are safer for humans.

It is known that the average value of Risk Quotient (RQ) on respondents is 1,420286877 mg/kg/day (RQ> 1) or as many as 197 respondents have RQ> 1 and 100 respondents have RQ <1. This shows that of the total respondents,> 50% have a risk to health due to exposure to SO_2.

Based on the results of this study the Dt value is safe in the residential environment around the fertilizer industry X is 23.47 years. This number is smaller than the normal safe Dt, which is 30 years. Thus, the safe Dt rate is not healthy for both workers and the community and risks to health. To normalize Dt, the concentration of toxin must be minimized so that it is in accordance with the safe limits of toxin concentration. So prevention and control efforts are needed earlier before the respondent is estimated when the symptoms of the disease arise in the body, prior control measures are taken, namely periodic measurement and management of exposure to SO_2 toxins in the environment by the company and related stakeholders and healthy lifestyle in the community.

Conclusion

It was concluded that the population in settlements around the fertilizer industry X posed a health risk to exposure to SO_2 (non-carcinogenic). The safe duration of the average respondent is 23.47 years. The recommendations that can be given include the concentration of sulfur dioxide toxins to be reduced to reach the safe concentration limit. In this case, it is necessary to periodically measure gas emissions of sulfur dioxide by companies and related stakeholders (for example local related agencies). If there is information from the relevant office that the level of sulfur dioxide is high, it is necessary to encourage the public to limit outdoor activities[2]. EPA recommends that the concentration of sulfur dioxide should not exceed 0.03 ppm. For short periods of 24-hour exposure, the limit may not exceed 0.14 ppm more than once a year. Other controls can also be supported by increasing respondents weight and proper dietary patterns by consuming nutritional intake which can detoxify the main toxins to reduce sulfur dioxide levels in the body, for example is giving vitamin E and C can reduce oxidative effects such as lipid peroxidation and membrane damage in erythrocytes due to exposure to sulfur dioxide[2]. The company holds a CSR program involving the surrounding community by conducting routine health checks, urban greening programs around the fertilizer industry area (mainly using plants that are resistant to SO2) [6].

Conflict of Interest: All authors have no conflicts of interest to declare.

Source of Funding: This is an article "Determination of Sulfur Dioxide (SO_2) Safe Duration in Residential Population Around the Fertilizer Industry X in Indonesia" of Occupational Safety and Health Department that was supported by Activity Budget Plans 2019, Faculty of Public Health, Airlangga University.

Ethical Clearance: The study was approved by the institutional Ethical Board of the Public Health, Islam Negeri Syarif Hidayatullah University.

References

1. Amaslu et.al. Short-term Effect of Ambient Sulfur Dioxide (SO2) on Cause-Spesific Cardiofascular Hospital Admission in Beijing, China: A Time Series Study. Atmospheric Environment. 2019;208:74-81

2. ATSDR. Toxicological Profile for Sulfur Dioxide. ATSDR's Toxicological Profiles. Georgia: U.S. Department Of Health and Human Services Public Health Service; 2010.
3. Badan Standardisasi Nasional (BSN). Udara ambien – Bagian 7 : Cara uji kadar sulfur dioksida (SO 2) dengan metoda pararosanilin menggunakan spektrofotometer. Sni 19-7119.7-2005. Badan Standar Nasional Indonesia; 2005.
4. Drew, Roger. Health Risk Assessment (SO2&Arsenic) for Copper Smelter Extension Project at Mount Isa Mines.2015;1
5. Dwi K, Rose C, Tualeka AR. Penilaian risiko paparan asap kendaraan bermotor pada polantas polrestabes Surabaya tahun 2014. Indones J Occup Saf Heal. 2014;3:46–57
6. Jiuju Duan et.al. Response of Gas-Exchange Characteristics and Chlorophyll Fluorence to Acute Sulfur Dioxide in Landscape Plants. Ecotoxicology and Enviromental Safety. 2019;171:122-129
7. Lin C, Li C, Yang G, Mao I. Association between maternal exposure to elevated ambient sulfur dioxide during pregnancy and term low birth weight Environ Rese.2004; 96:41-50
8. Menteri Tenaga Kerja Indonesia. Peraturan Menteri Tenaga Kerja Nomor 5 tahun 2018 tentang Keselamatan dan Kesehatan Kerja Lingkungan Kerja. 2018.
9. OEHHA. The Office of Environmental Health Hazard Assessment. Science Discussion Document On The Development Of Air Standards For Sulphur Dioxide (SO 2) July 2016 Standards Development Branch Ministry of the Environment and Climate Change Executive Summary. Ontario; 2016.
10. Presiden Republik Indonesia. Peraturan Nomor 41 Tahun 1999 tentang Pengendalian Pencemaran Udara. Presiden Republik ind; 1999.
11. Rahila R, Siddiqui M (2014) Review on effects of Particulates; Sulfur Dioxide and Nitrogen Dioxide on Human Health Inter Rese J Environ Sci 3:70-73
12. Ranjie Chen et.al. Short-Term Exposure to Sulfur Dioxide and Daily Mortality in 17 Chinese Cities. The China Air Pollution and Health Effects Study (CAPES). Enviromental Research. 2012; 118: 101-106
13. Reagan-Shaw S, Nihal M, Ahmad N. Dose translation from animal to human studies revisited. FASEB J. 2007;22(3):659–61.
14. Saridewi, N. Tualeka, A. R. Penentuan Konsentrasi Aman Benzena di Stasiun Pengisian Bahan Bakar Umum (SPBU) di Pancoranmas Depok. Occup Heal Saf. 2019;1–5.
15. Solichin R. Analisis Risiko Kesehatan Pajanan Sulfur Dioksida (SO2) Pada Masyarakat di Pemukiman Penduduk Sekitar Industri PT. Pupuk Sriwidjaja Palembang Tahun 2016. Universitas Islam Negeri Syarif Hidayatullah. 2016.
16. SC GAD. Encyclopedia of Toxicology For Sulfur Dioxide. USA. 2014; Vol 4
17. Tualeka A. Toksikologi Industri. Surabaya: Graha Ilmu Mulia; 2013.
18. Tualeka A. Toksikologi Industri & Risk Assessment. Surabaya: Graha Ilmu Mulia; 2013.
19. Qiannan Wei et.al. Short-Term Exposure to Sulfur Dioxide and The Risk of Childhood Hand, Foot, and Mouth Disease During Different Seasons in Hefei, China. Science of The Total Environment. 2019;658:116-121