Determination of Sulfur Dioxide (SO₂) Safe Duration in Residential Population Around the Fertilizer Industry X in Indonesia

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ABSTRACT

People who have lived more than 22 years in settlements around the fertilizer industry X are at risk of being exposed to SO₂ 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 SO₂ and to measure the duration of exposure to SO₂ 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 SO₂ emissions in the fertilizer industry X area. Data analysis was done using manual data calculations to determine the intake of SO₂ (non-carcinogenic), risk level or risk quotient (RQ), and safe duration (Dt safe) exposure to SO₂ in the population around the fertilizer industry X.

The results showed that the average non-carcinogenic intake of SO₂ 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 SO₂. The average safe duration of exposure to SO₂ 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 dioxide². Besides that, a related stakeholder policy is needed to periodically measure SO₂ concentrations in community residential areas around the fertilizer industry X, so that the air quality of people exposed to SO₂ 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 area⁶.

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

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Introduction

Everyone can be exposed to exhaust emissions of sulfur dioxide every day. The main uses of SO₂ 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 SO₂. People who lived in residential areas around the fertilizer industry for years were constantly receiving SO₂ exposure due to boiler exhaust emissions and power generation equipment from production activities. Sulfur dioxide (SO₂) 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. Significant health effects include breathing difficulty, asthma attacks, pulmonary edema, eye irritation, cardiopulmonary disease, and increased mortality. SO₂ is the main air pollutant that has a significant impact on human health. Effects of specific short-term exposure to SO₂ can cause cardiovascular disease (CVD). In addition, SO₂ also has a significant relationship with the occurrence of hand, foot, and mouth disease (HFMD). Based on previous research (Solichin, 2016) about SO₂ 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 SO₂ 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 SO₂. Then further research is needed regarding the measurement of the safe duration of SO₂ in residential communities around the fertilizer industry X, as well as to determine intake and risk quotient (RQ) exposure to SO₂ (non-carcinogens).

Material and Method

The type of this research is quantitative research with environmental health risk analysis methods. In this study focused on exposure to SO₂ 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 SO₂ samples in the laboratory refers to the reference SNI 19-7119.7.

The data were obtained by secondary data. Secondary data were obtained by collect of data measurements which included the concentration of SO₂ in the air, anthropometric conditions (respiration rate and weight), activity patterns (time, frequency, duration of exposure, daily average time period) of the respondent bet research of Solichin R, 2016. While secondary data also was obtained from related literature.

The variables studied were the intake, Risk Quotient (RQ) and safe duration (Dt Safe) from SO₂ (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 SO₂ exposure to respondents.

Findings

A. Intake: Determination of the amount of intake on SO₂ toxins that enter the body, the following formula is used:

\[
\text{Intake SO}_2 = \frac{C \times R \times \tau E \times f \times E \times \text{Dt}}{W_b \times T_{avg}}
\]

Notes:

\( C = \) Sulfur Dioxide Concentration (mg/m³)
\( R = \) Respiration Rate (m³/hour)
\( \tau_E = \) Time of exposure (hour/hour)
\( f_E = \) Frequency or Average exposure in year (day/year)
\( \text{Dt} = \) Duration of Exposure (year)
\( W_b = \) Weight (Kg)
\( T_{avg} = \) Average Exposure of Sulfur Dioxide (non-carcinogen) → 30 years x 365 day/year

Based on the results of measurements on the data, it is known that the average exposure concentration of SO₂ (C) is 0.248456 mg/m³. The average respiration rate (R) is 0.60 m³/hour. The average exposure time (τE) 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 SO₂...
(non-carcinogen) \( T_{\text{avg}} \) is 30 x 365 days/year. In Table 5. Explain the calculation of the average intake is 0.057427415 mg/kg/day.

### B. Risk Quotient (RQ):

**Risk Quotient (RQ)**: Determination of risk level for respondents to exposure to \( \text{SO}_2 \) or Risk Quotient (RQ) is formulated with \(^{17}\)(18):

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

Determination of risk categories is intended to determine whether exposure to \( \text{SO}_2 \) 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\(^{11}\):

\[
\text{SHD} = \text{NOAEL} \times \frac{\text{Animal Km}}{\text{Human Km}}
\]

According to The Office of Environmental Health Hazard Assessment (OEHHA), the value of No Observed Adverse Effect Level (NOAEL) \( \text{SO}_2 \) is 660 \( \mu \text{g/m}^3 \) or equivalent to 0.25 mg/kg. While Animal Km and Human Km are Km factors in animals and humans, with the following calculations:

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

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.

### 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\(^{17}(18)\):

\[
\text{Dt Safe} = \frac{RfC \times Wb \times T_{\text{avg}}}{C \times R \times tE \times fE}
\]

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

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Sulfur Dioxide Intake (mg/Kg/day)</th>
<th>Risk Quotient (RQ) (mg/Kg/day)</th>
<th>Safe Duration (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.056539305</td>
<td>1.398322252</td>
<td>36.47227949</td>
</tr>
<tr>
<td>2</td>
<td>0.128931156</td>
<td>3.188707721</td>
<td>18.81640001</td>
</tr>
<tr>
<td>3</td>
<td>0.013631756</td>
<td>0.337138702</td>
<td>32.62752077</td>
</tr>
<tr>
<td>4</td>
<td>0.046483183</td>
<td>1.149615652</td>
<td>21.74639842</td>
</tr>
<tr>
<td>5</td>
<td>0.137147641</td>
<td>3.391916467</td>
<td>15.6253848</td>
</tr>
<tr>
<td>Etc.</td>
<td>0.161140632</td>
<td>3.985307784</td>
<td>16.05898552</td>
</tr>
<tr>
<td>Average</td>
<td>0.057427415</td>
<td>1.420286877</td>
<td>23.47334979</td>
</tr>
</tbody>
</table>

### Discussion

Based on the results of measurements by the Institute for Environmental Health Engineering, the median value of \( \text{SO}_2 \) 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/m\(^3\) (2 ppm). When compared with the Ministry of Manpower Regulation No. 5 of 2018\(^8\), the \( \text{SO}_2 \) 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 \( \text{SO}_2 \) 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\textsubscript{2} quality standards of 365 \(\mu\)g/Nm\textsuperscript{3} (0.13 ppm). To prevent or minimize health risks to the human body, it is necessary to reduce the concentration of SO\textsubscript{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\textsubscript{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\textsuperscript{2}.

Based on the calculation of RFC SO\textsubscript{2} in this study was 0.04 mg/kg. The results of this calculation are smaller than RFC for exposure to SO\textsubscript{2} through inhalation based on the health risk assessment of SO\textsubscript{2} by Health Canada (2016) which is equal to 0.06 mg/kg\textsuperscript{2}. 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\textsubscript{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\textsubscript{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\textsubscript{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\textsuperscript{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\textsuperscript{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 SO\textsubscript{2})\textsuperscript{5}.

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

**Source of Funding:** This is an article “Determination of Sulfur Dioxide (SO\textsubscript{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.

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