Risk Assessment of NO₂ and SO₂ Gas Exposure for The Health of Leather Tannery Workers in Magetan, Indonesia

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ABSTRACT The burning of residues from the tanning industry in the Magetan leather tannery area produces pollutants in the form of NO₂ and SO₂ gases, which may pose a risk to workers' health. Pollutants of NO₂ and SO₂ have a negative impact that is detrimental to the health of workers such as eye irritation, coughing, and respiratory tract disorders. The aim of this study is to analyze the extent of the risk of NO₂ and SO₂ gases emissions to workers' health in the Magetan tannery area. This study is a quantitative, descriptive study with a cross-sectional design and the ARKL (Environmental Health Risk Analysis) approach. The sampling technique used is a non-random sampling technique, namely an exhaustive sample that included the entire population. Air sampling is conducted in the burning area of the remaining leather tannery. The data analysis method uses risk analysis to determine the risk characterization of workers considered 'safe' when the RQ value is 1 and the level of risk is termed 'unsafe' when the RQ value is > 1. The results showed that the concentration of NO₂ gas is 0.000555 g/m³ and that of SO₂ gas is 0.0006948 g/m³. The measurement results do not exceed the NAV based on PP RI No. 22 in the year 2021. The highest intake values for NO₂ gas are 0.0001003 mg/kg/day and for SO₂ 0.0001255 mg/kg/day. The highest risk is found to be 0.0011721 (RQ<1) for NO₂ and 0.00140775 (RQ<1) for SO₂ gas. The results of the study suggest that the air quality with respect to the parameters NO₂ and SO₂ gases at the Magetan tannery is still safe and meets the national air quality standards in the short term, but poses a high health risk with prolonged and continuous exposure. The suggestion that the researchers can make is a call for the use of special masks to minimize the risk of NO₂ and SO₂ gases to workers.

INDEX TERMS ARKL (Environmental Health Risk Analysis) approach, NO₂ and SO₂ gases, leather tannery workers industry.

I. INTRODUCTION

Air is an important environmental component of life and therefore its quality needs to be maintained and improved so that it can optimally support life. Human activities in daily life can affect air quality. According to PP No. 22 of 2021, air polluted by gas emissions has a sufficiently high potential to affect human health and the environment [1].

Air pollution is the process of introducing foreign substances into the air that cause a change in the composition of the air from its original state [2]. Foreign substances that change the composition of the air affect human life and other living things if they persist for a long time[1]. Air pollution emissions are released from natural and anthropogenic sources. Human activities aimed at providing necessary goods and services to workers are responsible for the anthropogenic part of air pollution[3]. Air pollutant emissions occur at many stages of the life cycle of products and services, namely raw material extraction, energy generation, production and manufacturing, recycling and final disposal [4]. The resulting emissions undergo various types of physical and chemical transformations and contribute to a range of health and environmental impacts, including air quality degradation.

Air pollutants have the potential to cause air pollution and human health problems[5]. Air quality is a major concern in the industrial sector due to industrial activities such as the...
burning process that can cause air pollution [6]. NO₂ gas and SO₂ gas are air pollutants that can cause health problems for workers in the area. Workers' health and safety must be considered as guaranteed protection and an effort to prevent occupational diseases and accidents as regulated in the Regulation of the Minister of Labour of the Republic of Indonesia No. 05 of 2018, Article 1(1) on Occupational Safety and Health in the Working Environment.

Leather tanning is an industry concerned with the tanning of leather, a lengthy process of transforming rawhide (skin) into leather. The leather tanning industry contributes to one of the main problems of industrial activity, namely environmental pollution. These negative impacts are caused by liquid and solid wastes as well as hazardous gases produced during leather tanning [7]. The small tannery industry in Magetan is the largest leather tannery in East Java province with 43 plants and a leather production of ± 8,200,000 feet/year.

SO₂ (sulphur dioxide) is a gas with a pungent odour that is colourless, irritant, non-flammable and non-explosive. The effects that SO₂ can have are very dangerous to human health, in particular it can affect the respiratory system and lung function and cause eye irritation [8]. Inflammation of the respiratory tract causes coughing, mucus secretion, asthma and chronic bronchitis, and makes people more susceptible to respiratory infections [9]. Human activities such as throwing away rubbish by burning are anthropogenic sources of SO₂ pollutants in the air, besides burning coal, fuel oil, gas and wood are also sources of SO₂ pollutants [10]. Sulphur dioxide can also come from the burning of diesel fuel used by vehicles to transport raw materials for industry [11].

NO₂ gas (nitrogen dioxide) is an air pollutant that is easily recognised by its pungent odour and reddish-brown colour when it contaminates the air. The toxicity of NO₂ gas is higher than that of NO₂ gas. The organs in the body that are sensitive to NO₂ gas pollution are the lungs. Lungs contaminated by NO₂ gas swell, making it difficult for people to breathe, which can lead to death [5]. The main sources of anthropogenic NO₂ emissions are burning processes, heating, power generation and transport [12].

The effects of NO₂ and SO₂ gases on human health have been extensively researched in international and national journals. The effects of exposure to NO₂ and SO₂ gases can cause symptoms such as watery and sore eyes at low concentrations, while at high concentrations they can lead to respiratory diseases. Long-term exposure can worsen health status [13]. In a study conducted by Lavanya (2014), it was found that short-term exposure to SO₂ gas can complicate the respiratory process and damage the human respiratory system [14]. People with asthma are most sensitive to the effects of SO₂ gas. According to information from the Material Safety Data Sheet, long-term exposure to SO₂ gas can cause irritation of the nose, throat and sinuses, pulmonary oedema and even death [15]. Breathing air with high NO₂ concentrations can cause irritation of the human respiratory tract. Short-term exposure can aggravate respiratory diseases, especially asthma, and cause other respiratory symptoms such as coughing or shortness of breath as a side effect. Long-term exposure to high NO₂ concentrations can increase susceptibility to respiratory infections [16].

Based on research conducted by Alchamdani, the highest intake value for NO₂ in real time is 0.00635 mg/kg/day and for SO₂ in real time is 0.00057 mg/kg/day [17]. The highest risk value identified for NO₂ is 0.31775 with an RQ value <1, which means that it is still in the safety category but has the potential to cause chronic respiratory disease when exposed for a prolonged period of time, as the substance is an irritant. A study conducted by Arista (2015) shows that exposure to an RQ of SO₂ > 1 is 11.9%, which may pose a risk to human health [18]. Potential health effects include irritation of the nose, throat and sinuses, as well as pulmonary oedema, which can even lead to death [19]. Because of the above problems, it is necessary to make efforts to solve the problem. Therefore, it is necessary to conduct a study entitled "Risk Assessment of NO₂ and SO₂ Gas Exposure for The Health of Leather Tannery Workers in Indonesia".

This research is different from previous studies, because the sampling of this study specializes in the location of the tanning industry. Meanwhile, in previous studies, it used a location in a village area located in the city of Surabaya. Thus, this research can be used as a reference in monitoring ambient air quality in the tanning industry area. This research can be used as a reference for subsequent researchers as an effort to improve ambient air quality in the tanning industry area and as an information to the tanning industry management.

II. METHODS
This type of research is a quantitative, descriptive research, i.e. research that aims to describe and measure the concentration of NO₂ and SO₂ gases in the area where leather and household waste are burnt. Environmental Health Risk (ARKL), which consists of four steps. The purpose of the risk analysis is to evaluate and estimate the magnitude of the human health risk caused by exposure to the risk substances from particulate matter (NO₂ and SO₂) in the area of the magnetic leather tannery. In this study, a cross-sectional temporal approach was used because each person was observed only once [20]. The risk factors and effects are measured according to the circumstances and temporal status at the time of observation.

The sample used in this study was exhaustive sample. Exhaustive sample is a sampling technique by sampling the entire population. Exhaustive sampling is a technique of selecting samples by surveying the entire existing population. So the sample used is all workers who are in the production unit section.

To determine the sample respondents in this study using total sampling, it is a sampling technique by sampling the entire population yang based on certain characteristics. The
number of sample workers to be studied is 18 workers selected based on predetermined characteristics.

Determination of the location of the sampling point based on a representative location with the sample to be taken so as to get the exact measurement results. The air sampling point was taken in an area where the concentration of pollutants was high and represented the tanning industry area of Magetan.

Gas sampling of NO₂ and SO₂ is carried out using a midget impinger. The research parameters taken for the sample were NO₂ gas air sample, SO₂ gas air sample, temperature, humidity, wind speed and direction as well as weight measurements in workers who were the subject of the study.

Data collection techniques in this study are interviews, measurements, observations, and documentation. The data analysis used in this study is a univariate analysis which aims to explain or describe the characteristics of each research variable. In this study, univariate analysis was used to determine the magnitude of the average value, the largest value and the smallest value at the inhalation rate, the frequency of exposure, the duration of exposure, the time of exposure, the weight of the respondent, and the concentration of gases NO₂ and SO₂. Risk analysis was also used in this study which used all the data that had been obtained, these stages were: hazard identification, dose-response assessment, exposure assessment, then risk characterization calculations were carried out to determine the level of risk.

### III. RESULTS

The physical measurement of air carried out in the combustion area of the remaining leather production includes measurements of temperature, humidity, wind direction and wind speed. The following are the results of measurements of the physical environment of the air in the burning area in tanning industry area:

#### TABLE 1

Results Of Temperature, Humidity, Wind Direction And Wind Speed Measurements In The Magetan Tannery Industry In 2021

<table>
<thead>
<tr>
<th>Location</th>
<th>Time</th>
<th>Temp. (°C)</th>
<th>Humidity (%)</th>
<th>Wind direction</th>
<th>Wind speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point 1</td>
<td>07.30</td>
<td>27.8</td>
<td>72</td>
<td>From west</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td>11.30</td>
<td>31.8</td>
<td>54</td>
<td>From west</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>14.30</td>
<td>29.3</td>
<td>65</td>
<td>From south</td>
<td>0.97</td>
</tr>
<tr>
<td>Average</td>
<td>29.6</td>
<td>64</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lowest score</td>
<td>27.8</td>
<td>54</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Highest score</td>
<td>31.8</td>
<td>72</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### TABLE 2

Measurement Results Of NO₂ And SO₂ Gas Concentrations In The Area Of The Burning Site Of The Remaining Tannery Products In The Tannery Industry Of Magetan In 2021

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Time Taking (WIB)</th>
<th>Gas concentration ppm</th>
<th>mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂</td>
<td>07.30</td>
<td>0.000177</td>
<td>0.0003323</td>
</tr>
<tr>
<td>NO₂</td>
<td>11.30</td>
<td>0.000224</td>
<td>0.0004214</td>
</tr>
<tr>
<td>NO₂</td>
<td>14.30</td>
<td>0.000298</td>
<td>0.000555</td>
</tr>
<tr>
<td>Total average</td>
<td>0.000233</td>
<td>0.0004362</td>
<td></td>
</tr>
<tr>
<td>H₂S</td>
<td>07.30</td>
<td>0.000254</td>
<td>0.0006635</td>
</tr>
<tr>
<td>H₂S</td>
<td>11.30</td>
<td>0.000255</td>
<td>0.0006674</td>
</tr>
<tr>
<td>H₂S</td>
<td>14.30</td>
<td>0.000266</td>
<td>0.0006948</td>
</tr>
<tr>
<td>Total average</td>
<td>0.000258</td>
<td>0.0006752</td>
<td></td>
</tr>
</tbody>
</table>

The explanation of the equation (1) is as follows:

**Equation:**

\[ \text{PPM concentration} = \frac{m}{w} \times 2.5 \]

Where:
- \( m \): Weight measurements in workers who are or work in the vicinity of the burning area of the residues from tanning.
- \( w \): Number of sample workers to be studied

**TABLE 2** shows that the measurement results in the burning range of the other results of the Magetan leather tannery industry. The conversion of the gas concentration is done according to the following formula:

The lowest NO₂ gas concentration is found in the area where the tannery residues are burnt, 0.0003323 mg/m³ in the morning, increasing to 0.0004214 mg/m³ during the day. The measurements in the afternoon showed the highest readings, namely 0.000555 mg/m³. The lowest SO₂ gas concentration in the area where the tannery residues are burnt is measured in the morning at 0.0006635 mg/m³, during the day the gas concentration rises to 0.0006674 mg/m³. The measurements in the afternoon gave the highest readings, namely 0.0006948 mg/m³.

**TABLE 3** explains that NO₂ and SO₂ gases can pose a risk of health problems for workers in the tanning industry who are or work in the vicinity of the burning area of the residues from tanning. The NO₂ and SO₂ gases are caused by the burning of the residues from the leather tannery, which causes smoke to rise into the ambient air, which can pollute the air in the area. The results of measuring the average, minimum and maximum concentrations of NO₂ and SO₂ gases are used to calculate the intake value in the exposure assessment phase. The minimum concentration of NO₂ gas is 0.0003323 mg/m³ and the average concentration is 0.0004362 mg/m³.
The measurement of the maximum concentration of NO2 gas is 0.000555 mg/m3. The minimum concentration of SO2 gas is 0.00006635 mg/m3, the average concentration is 0.0006752 mg/m3. The measurement of the maximum SO2 gas concentration is 0.0006948 mg/m3. The health effects of exposure to NO2 and SO2 are the occurrence of respiratory diseases and eye irritation. Based on the results of the study, it was found that the percentage of health problems among workers who worked near the burning area of the remaining tannery products was as follows:

<table>
<thead>
<tr>
<th>Complaints about health problems</th>
<th>N</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye irritation</td>
<td>10</td>
<td>55.6</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>8</td>
<td>44.4</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>100</td>
</tr>
<tr>
<td>Eye irritation</td>
<td>6</td>
<td>33.3</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>12</td>
<td>66.7</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>100</td>
</tr>
</tbody>
</table>

TABLE 4 shows that workers working near the tannery residue burning area experienced health problems including NO2 gas: 10 persons (55.6%) had eye irritation, 8 persons (44 persons). 4% suffered from shortness of breath. For SO2 gas, 12 people (66.7%) experienced shortness of breath and 6 (33.3%) experienced eye irritation.

IV. DISCUSSION

The air sampling in this study, namely NO2 and SO2 gases, was conducted on 4 October 2021 with one sampling point at three different times, namely morning at 07.30 - 08.30 WIB, noon at 11.30 - 12.30 WIB and afternoon at 11.30 - 12.30 WIB. 14.30 - 15.30. Sampling in this study was conducted together with engineers from Surabaya Environment and Health Department, Health Poltekkes, Surabaya Department of Health. The sampling points for NO2 and SO2 gases were located near the burning area of the residues generated during leather tanning.

Based on the direct measurement of NO2 and SO2 gas, it is known that the location where the measurement is conducted does not exceed the environmental quality standard set in RI No. 22 Year 2021 [1]. The measurement results at different times may be influenced by differences in temperature, humidity and wind speed at the time of measurement. The measurements at the measuring point in the morning showed that the concentrations of the gases NO2 and SO2 were lower than in the afternoon and evening. The NO2 and SO2 lowest value of gas concentration occurs in the morning between 07.30 and 08.30, which is due to the fact that the burning process for the remaining tannery products has not yet taken place, in addition, the physical conditions of the environment may influence the concentration of NO2 and SO2 gases. This is in line with the study of Suwari, which states that the concentration of pollutant gases may be subject to various physical and chemical reactions in the presence of physical environmental factors [21].

From the measurement results, the highest gas concentration was reached in the afternoon between 2.30 pm and 3.30 pm with 0.000555 g/m3 for NO2 gas concentration and 0.0006948 g/m3 for SO2, which is due to the burning process of the remaining leather production. According to the Government Regulation of the Republic of Indonesia No. 22 of 2021, the results of the measurement of NO2 and SO2 gas from the burning process of the remaining tannery are still below the applicable quality standard, which is <200 g/m3 for NO2 gas and <150 g/m3 for SO2 gas.

The NO2 and SO2 gas parameters detected in the air quality measurements in the tannery residue burning area may pose a risk to tannery workers who are in this area, especially if they are exposed for a long period of time. The effects of burning leather tannery residues in the form of smoke, which can cause health problems and pollute the environment. According to a study conducted by Alchamdani, exposure to NO2 and SO2 gases causes various health disorders such as eye irritation, respiratory system disorders, asthma and impaired lung function [17].

Based on the results of NO2 and SO2 gas concentration in the burning area of the remaining tannery production in Magetan Tannery Industry, the highest concentration values were found in the afternoon, namely 0.000555 mg/m3 for NO2 gas and 0.0006948 mg/m3 for SO2 gas. According to [17] short-term exposure to air pollution can lead to symptoms of respiratory diseases, which can be associated with impaired lung function and more serious respiratory diseases with prolonged exposure.

The results of the measurements of NO2 and SO2 gas concentrations did not exceed the established quality standards at any time. Measurement results that do not exceed air quality standards during continuous exposure may influence the amount of NO2 and SO2 gas concentrations inhaled by workers. This is consistent with the intake formula, which has an exposure pattern that is directly proportional to the intake value.

Dose-response analysis is an analysis of the relationship between the total amount of an agent absorbed by a population
or system in the body [22]. Dose-response analysis is the second stage of environmental health risk analysis. The pollutant concentration is the dose absorbed by the body. The body's response to the onset of a dose in the form of initial changes in the body after the intake of the exposure is a reaction [23].

For NO$_2$ and SO$_2$ gases, a dose response based on the reference dose level (RfC) was used in this study. According to the reference [24] the measure of toxicity of a risk agent with non-carcinogenic effect by inhalation is expressed by the reference concentration (RfC). In this study, the reference concentration (RfC) value from the Integrated Risk Information System (IRIS), which can be accessed via the website https://www.epa.gov/criteria-air-pollutants/naaqs-table, is used. The RfC value for NO$_2$ gas is 0.00857 mg/kg/day and for SO$_2$ gas 0.01714 mg/kg/day.

The effect of exposure to NO$_2$ and SO$_2$ gas on human health is the disturbance of the respiratory system, characterised by symptoms such as coughing [25]. Coughing is a reflex of the body's defences to remove foreign bodies from the body. Another effect is a decrease in lung function. In addition to affecting the respiratory system, exposure to PM2.5 also causes eye irritation [26].

Based on the data and information obtained by the researchers during their observations, it is known that workers who work in the area of burning the rest of the leather tannery experience discomfort, namely respiratory problems, such as shortness of breath, and have other complaints, namely eye irritation. As they are used to the working conditions, workers think that this is not a problem that can cause health problems.

Exposure assessment is an assessment of pollutant exposure that aims to determine the route of entry of the risk substance into the body. The intake value is calculated at the exposure assessment stage so that the amount of intake received by each respondent can be calculated [23].

The calculation of non-carcinogenic intake was used in this study to be able to analyse exposure by inhalation. NO$_2$ gas and SO$_2$ gas in ambient air enter the bodies of workers who work in the burning area of the rest of the tannery production through the respiratory tract, which can lead to large accumulations during prolonged exposure, causing respiratory disorders, namely shortness of breath to pulmonary oedema [17]. Someone exposed to air pollutants for a long period of time and in high concentrations can affect the health effects on a person's body [27]. The higher the exposure dose, the more severe the symptoms that can lead to disorders of the respiratory system.

For the calculation of uptake, the minimum, average and maximum concentrations of NO$_2$ and SO$_2$ gas are used in this study. Based on the calculation results, the uptake value for each measurement parameter is the lowest uptake of NO$_2$ gas of 0.00000302 mg/kg/day, the average uptake value of 0.000005809 mg/kg/day and the highest uptake value of 0.00001003 mg/kg/day. The uptake value at the site of burning of the remaining tannery products for SO$_2$ gas showed, among others, the smallest uptake value of 0.00000461 mg/kg/day, the average uptake value of 0.000007975 mg/kg/day and the largest uptake value of 0.00001255 mg/kg/day. This is in line with the study of Gusti which states that the intake value is directly proportional to the concentration value, intake rate, frequency of exposure and duration of exposure, implying that the higher the pollutant concentration value, the greater the intake value and intake of a person [28].

Uptake is inversely proportional to body weight, meaning that the smaller a person's weight, the greater the internal dose and the higher the intake value [28]. This is because someone with a higher body weight has a greater nutrient content than someone with a lower weight, so they have a lower risk. The inhalation rate value used to calculate intake uses the US EPA default value of 0.83 m$^3$/hour.

The risk characteristics are a step in the analysis of environmental health risks (ARKL) used to identify potential risks or to determine whether or not the risk substances analysed at certain concentrations at the research site may cause health problems. The value of the risk characteristics results from the calculation of the risk characterisation (RQ) for non-carcinogenic effects, namely by comparing the intake value with the chemical reference value (RfC). The risk level is expressed in numbers divided into two categories, namely safe and unsafe. The risk level is classified as safe if the RQ value is 1, then NO$_2$ and SO$_2$ gas are still considered safe for humans, while an RQ value > 1 means that exposure to NO$_2$ and SO$_2$ gas is unsafe or poses potential risks to workers' health. The calculated value obtained from the risk characteristics (RQ) for each parameter in the area of burning of the rest of the leather tannery gave an RQ value of 0.00342 < 1 for the minimum concentration of NO$_2$ gas, while for the value of maximum concentration the RQ value was 0.00117 < 1. The minimum concentration of SO$_2$ gas gave an RQ value of 0.000269 < 1, while for the value of maximum concentration the RQ value was 0.001407 < 1.

The shortcoming in this study is that at the time of sampling the air did not use other parameters that represented the overall ambient air quality. The results showed that the risk value obtained was still categorized as safe. The highest risk level obtained for NO$_2$ is 0.0011721 (RQ<1) and SO$_2$ is 0.00140775 (RQ<1). Meanwhile, in previous studies, ambient air quality (NO$_2$ and SO$_2$) in the Kalianak area of Surabaya still meets quality standards, but in parameters NO$_2$ RQ>1 so that the level of risk is not safe. Efforts to control air pollution are needed to overcome air problems caused by human activities that produce pollutants, besides that plants can be planted that can reduce ambient air pollutants. The limitation of the problem in this study is that it is only focused on the levels of gas NO$_2$ and SO$_2$ parameters in the tanning industry resulting from the burning process of the remaining leather production and domestic waste. The results of the research can be a reference for industry management to prevent the impacts.
caused by NO2 and SO2 gas pollutants for the community and the environment.

IV. CONCLUSION
The results of the environmental physical measurements in the burning area of the remaining tannery production at an average temperature of 29.6°C, average humidity of 63.6% and the highest wind speed of 1.51 m/s with wind direction from north and east directions. The highest concentration values were measured in the afternoon, namely 0.000555 mg/m³ for NO2 gas and 0.0006948 mg/m³ for SO2 gas. Environmental health hazards in the burning area of the residual tannery, namely NO2 and SO2 gases generated by the burning process of the residual tannery.

The dose-response value (RfC) for the NO2 pollutant risk factor is 0.00857 mg/kg/day and for the SO2 pollutant risk factor is 0.01714 mg/kg/day. The highest intake value at the place of burning of the remaining tannery products for NO2 gas is 0.00001003 mg/kg/day. The highest intake value for SO2 gas was determined to be 0.00001255 mg/kg/day.

The potential exposure risk of NO2 and SO2 gas for workers who are in the area of burning of the remaining tannery products is still included in the safe category with the highest value of RQ 0.00117 < 1 for NO2, and the maximum value for the concentration of SO2 gas resulted in an RQ of 0.001407 < 1. In the next study, you can add other parameters to determine the ambient air quality at the research site so that more accurate research results can be obtained.

REFERENCES


