International Journal of Advanced Health Science and Technology
Multidisciplinary : Rapid Review : Open Access Journal e-ISSN:2808-6422; p-ISSN:2829-3037

RESEARCH ARTICLE OPEN ACCESS

Manuscript received June 09, 2022; revised September 01, 2022; accepted September 01, 2022; date of publication October 30, 2022
Digital Object Identifier (**DOI**): https://doi.org/10.35882/ijahst.v2i5.117

How to cite: Afifa Katerina Juliadita, Khambali, Pratiwi Hermiyanti, John Peterson Myers , "Risk Assessment of NO2 and SO2 Gas Exposure for The Health of Leather Tannery Workers in Magetan", International Journal of Advanced Health Science and Technology, vol. 2, no. 5, pp. 285–291, October. 2022

Risk Assessment of NO_2 and SO_2 Gas Exposure for The Health of Leather Tannery Workers in Magetan, Indonesia

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"This work was supported in part by Poltekkes Kemenkes Surabaya."

ABSTRACT The burning of residues from the tanning industry in the Magetan leather tannery area produces pollutants in the form of NO_2 and SO_2 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 NO_2 and SO_2 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 NO_2 gas is 0.000555 g/m3 and that of SO_2 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 NO_2 gas are 0.00001003 mg/kg/day and for SO_2 0.00001255 mg/kg/day. The highest risk is found to be 0.0011721 (RQ<1) for NO2 and 0.00140775 (RQ<1) for SO_2 gas. The results of the study suggest that the air quality with respect to the parameters NO_2 and SO_2 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 NO_2 and SO_2 gases to workers.

INDEX TERMS ARKL (Environmental Health Risk Analysis) approach, NO_2 and SO_2 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]. NO_2 gas and SO_2 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.

SO_2 (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 SO_2 pollutants in the air, besides burning coal, fuel oil, gas and wood are also sources of SO_2 pollutants [10]. Sulphur dioxide can also come from the burning of diesel fuel used by vehicles to transport raw materials for industry [11].

NO_2 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 NO_2 gas is higher than that of NO_2 gas. The organs in the body that are sensitive to NO_2 gas pollution are the lungs. Lungs contaminated by NO_2 gas swell, making it difficult for people to breathe, which can lead to death [5]. The main sources of anthropogenic NO_2 emissions are burning processes, heating, power generation and transport [12].

The effects of NO_2 and SO_2 gases on human health have been extensively researched in international and national journals. The effects of exposure to NO_2 and SO_2 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 SO_2 gas can complicate the respiratory process and damage the human respiratory system [14]. People with asthma are most sensitive to the effects of SO_2 gas. According to information from the Material Safety Data Sheet, long-term exposure to SO_2 gas can cause irritation of the nose, throat and sinuses, pulmonary oedema and even death [15]. Breathing air with high NO_2 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 NO_2 concentrations can increase susceptibility to respiratory infections [16].

Based on research conducted by Alchamdani, the highest intake value for NO_2 in real time is 0.00635 mg/kg/day and for SO_2 in real time is 0.00057 mg/kg/day [17]. The highest risk value identified for NO_2 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 SO_2 > 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 NO_2 and SO_2 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 NO_2 and SO_2 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 (NO_2 and SO_2) 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 NO_2 and SO_2 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 NO_2 and SO_2. 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

Location	Time	Temp. (°C)	Humidity (%)	Wind direction	Wind speed (m/s)
Point 1	07.30	27,8	72	From west	1,31
	11.30	31,8	54	From west	1,51
	14.30	29,3	65	From south	0,97
Average		29,6	64	-	-
Lowest score		27,8	54	-	-
Highest score		31,8	72	-	-

TABLE 1 can be seen that the results of the measurement of air temperature in the magnetic leather tanning industry in the area of burning of the rest of the production of tanned leather obtained an average of 29.6°C, with the lowest air temperature of 27.8°C and the highest air temperature of 31.8°C. The results of the humidity measurements gave an average value of 63.6%, with the lowest humidity at 54% and the highest at 72%. The wind direction at the time of sampling was from the north and east. The lowest wind speed was 0.97 m/s and the highest was 1.51 m/s

TABEL 2
Measurement Results Of NO_2 And SO_2 Gas Concentrations In The Area Of The Burning Site Of The Remaining Tannery Products In The Tannery Industry Of Magetan In 2021

Parameters	Time Taking (WIB)	Gas concentration	
		ppm	mg/m^3
NO_3	07.30	0,000177	0,0003323
	11.30	0,000224	0,0004214
	14.30	0,000298	0,000555
Total average		0,000233	0,0004362
H_2S	07.30	0,000254	0,0006635
	11.30	0,000255	0,0006674
	14.30	0,000266	0,0006948
Total average		0,000258	0,0006752

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:

$$\frac{m}{2,5}\ \frac{w}{x}\text{PPM concentration} = \qquad (1)$$

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

Molecular weight of NO_2 gas: 46 g/mol
Molecular weight of SO_2 gas: 64 g/mol

The lowest NO_2 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 SO_2 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 NO_2 and SO_2 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 NO_2 and SO_2 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 NO_2 and SO_2 gases are used to calculate the intake value in the exposure assessment phase. The minimum concentration of NO_2 gas is 0.0003323 mg/m3 and the average concentration is 0.0004362 mg/m3.

TABLE 3
Identification Of NH3 And H2S Gas Hazards In Small-Scale Industries (LIK) In Magetan District In 2021

Source	Environment Potential Media	Risk Agent	Measured Concentration (mg/m^3)		
			ppm	mg/m^3	Mak
Emissions from burning of tannery residues, Magetan Leather Tannery Industry	Ambient air	Gas NO_2	3323×10^{-7}	4362×10^{-7}	555×10^{-6}
		Gas SO2	6635×10^{-7}	6752×10^{-7}	6948×10^{-7}

The measurement of the maximum concentration of NO_2 gas is 0.000555 mg/m3. The minimum concentration of SO_2 gas is 0.0006635 mg/m3, the average concentration is 0.0006752 mg/m3. The measurement of the maximum SO_2 gas concentration is 0.0006948 mg/m3.

The health effects of exposure to NO_2 and SO_2 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 4
Percentage Of Complaints Of Health Problems Among Workers Working In The Tanning Industry Near The Burning Area Of Tannery Products, Magetan In 2021

Complaints about health problems	N	Percentage (%)
Gas NO_2		
Eye irritation	10	55,6
Shortness of breath	8	44,4
Total	18	100
Gas SO2		
Shortness of breath	12	66,7
Eye irritation	6	33,3
Total	18	100

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 people (33.3%) experienced eye irritation.

IV. DISCUSSION

The air sampling in this study, namely NO_2 and SO_2 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 NO_2 and SO_2 gases were located near the burning area of the residues generated during leather tanning.

Based on the direct measurement of NO_2 and SO_2 gas, it is known that the location where the measurement is conducted does not exceed the environmental quality standard set in PP 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 NO_2 and SO_2 were lower than in the afternoon and evening. The NO_2 and SO_2 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 NO_2 and SO_2 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 2.30pm and 3.30pm with 0.000555 g/m3 for NO_2 gas concentration and 0.0006948 g/m3 for SO_2, 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 NO_2 and SO_2 gas from the burning process of the remaining tannery are still below the applicable quality standard, which is <200 g/m3 for NO_2 gas and <150 g/m3 for SO_2 gas.

The NO_2 and SO_2 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 NO_2 and SO_2 gases causes various health disorders such as eye irritation, respiratory system disorders, asthma and impaired lung function [17].

Based on the results of NO_2 and SO_2 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 NO_2 gas and 0.0006948 mg/m3 for SO_2 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 NO_2 and SO_2 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 NO_2 and SO_2 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 m3/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 0.000342 < 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 29.6oC, 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 SO_2 gas. Environmental health hazards in the burning area of the residual tannery, namely NO_2 and SO_2 gases generated by the burning process of the residual tannery.

The dose-response value (RfC) for the NO_2 pollutant risk factor is 0.00857 mg/kg/day and for the SO_2 pollutant risk factor is 0.01714 mg/kg/day. The highest intake value at the place of burning of the remaining tannery products for NO_2 gas is 0.00001003 mg/kg/day. The highest intake value for SO_2 gas was determined to be 0.00001255 mg/kg/day.

The potential exposure risk of NO_2 and SO_2 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 NO_2 as. The maximum value for the concentration of SO_2 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.

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