RISK ANALYSIS OF NO_2 AND SO_2 EXPOSURE IN FIVE AREA TOFU INDUSTRY

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ABSTRACT

Background: The combustion process during tofu production in Tropodo Village, Krian, has generated exhaust gas in the air like NO_2 and SO_2 which is dangerous that can impact public health, especially for those who lived near the factory. This study aimed to determine the risks analysis of NO_2 and SO_2 exposure in five area tofu industry.
Subjects and Method: This was a cross-sectional study conducted at five tofu industry in Krian, East Java. The data were collected from laboratory tests, observations, and interviews. Air sampling was carried out 10-meter from tofu industry. Air quality was measured to determine the pollution and analyzed using exposure assessment.
Results: NO_2 and SO_2 concentrations near tofu industry were below quality standard (5.62 µg/kg/day; RQ>1). People with weigh 55 kg and who lived near industry area with exposure NO_2 and SO_2 for 8 hours/day a year was unsafe or likely to have non-carcinogenic effects in the next 30 years.
Conclusion: NO2 and SO2 concentration near tofu industry still below quality standard that can causing health problems.

Keywords: carbonmonoxide, sulfuredioxide, nitrogendioxide, risk, industry.

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BACKGROUND

Department of Environment and Hygiene at Sidoarjo together with the Director General of Waste, Garbage and Hazardous Toxic Management Ministry of Environment, carried out an inspection of one of the tofu factories in Klagen Village, Krian, East Java. The inspection results obtained the use of plastic waste and aluminum foil as tofu production fuel. The use of that fuel can cause hazardous gases by waste combustion namely carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), Dioxin, and Furan gases. The Side effects of gasses on organism are can change the hormone system, fetal growth, decreased reproductive capacity, and suppression of the immune system (Taufik, 2022). In this study, risk assessment means characterizing potentially detrimental effects of exposure to environmental hazards on human’s health. Scientists and government collaborate to run the assessment to predict an increase in health risks due to exposure to toxic substances. Furthermore, it aims to assist decision makers and stakeholders (legislators and regulators, industry, and other stakeholders) with a scientific framework for solving environmental and health problems (Djafri, 2014).

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Risk analysis is characterization of potentially detrimental effects on human health by environmental hazard exposure (Arista et al. 2015). Risk analysis can be used as a management tool to assess the process of forecast increased health risks in humans exposed to toxic substances. The purpose of risk analysis is to provide a scientific framework to help make decisions by government legislators, regulators industries, or other concerned citizens to solve environmental health problems (Damara et al., 2017).

Whereas Management of risk is a decision making process involving consideration of political, social, economic, and technical factors which are relevant to the development, analysis, selection, and implementation of risk mitigation caused by environmental hazards. Risk management consists of three elements namely risk evaluation, emission and exposure control as well as risk monitoring. Risk analysis is divided into hazard identification, dose response assessment, exposure assessment, and risk characterization stages (Djafri, 2014). Environmental health risk assessment is essential for risk management and pollution control to protect populations from hazardous materials. Besides, it is an approach for calculating or predicting public health risks, identifying uncertainty factors, tracking specific exposures, and accounting for the inherent agent characteristics and the characteristics of specific targets (Maarufi, 2017). Risk assessment is performed in some stages of hazard identification, namely dose response assessment, exposure assessment, and risk characterization. An excessive level of carbon monoxide can cause local public health problems. This study aimed to determine the risks analysis of NO_2 and SO_2 exposure in five area tofu industry.

SUBJECTS AND METHOD

1. Study Design

This was an observational study with cross-sectional design, the observation and measurement on the variables to be linked are carried out at the same time or period. The research location is Tropodo Village, Krian Sub-District, Sidoarjo Regency. The study subject is tofu production process location. The research implementation stages are air sampling, measurement of air pollutants, inspection results, calculation of environmental risks, preparation of reports. Air sampling was carried out at a 10 meter distance from the pollution source in five locations. It was performed pointing the direction of the wind with an air sampler impinger for one hour. After the air sampling, air quality was measured to determine the pollution level. In this case, a pollution exposure assessment was used to determine the dose of toxic materials per person.

2. Inclusion Criteria

Air sampling was carried at a 10 meter distance from the pollution source in five locations. It was perfor-med pointing the direction of the wind with an air sampler impinger for one hour.

3. Exclusion Criteria

There was no exclusion criteria in this study.

4. Definition Operational of Variable

NO2: the hazardous gas by waste combustion namely nitrogen dioxide

SO2: the hazardous gas by waste combustion namely sulfur dioxide.

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5. Study Instruments

The data were collected from laborato tory tests, observations, and interviews. Air sampling was carried out 10 meter from tofu industry. Air quality was measured to determine the pollution.

6. Data analysis

Exposure analysis is used to determine the dose of risk agent that individuals receive as intake (I), calculated by the equation.

$$I = \frac{C\ x\ R\ x\ te\ x\ fe\ x\ Dt}{Wb\ x\ tavg}$$

I	=	Intake (mg/kg ×day)
C	=	Concentration of risk agents, mg/M3 for air medium, mg/L for drinking water, mg/kg for food
R	=	Rate of intake or consumption, 0.83 M3/hour for adults inhalation, L/day for drinking water, g/day for food
te	=	Exposure time (hour/day)
feDt	=	Exposure frequency (day/year)
Or	=	Exposure duration, year (real time or projection, 30 years to assess residential default)
Wb	=	Body weight (kg)
Tavg	=	Average time period (Dt × 365 days/year for non-carcinogenic substances, 70 days × 365 days/year for carcinogen

RESULTS

1. Concentration of NO_2, SO_2 at the Tropodo Village Tofu Industrial Settlement, Krian

Based on the primary data of air sampling, it can be known that the concentration of NO_2, SO_2 is as on Table 1. An average concentration of NO_2 12.96 g/m3, and SO_2 3.26 g/m3.

2. Exposure Risk Analysis

Environmental Health Risk Analysis (EHRA) is a study model to describe, understand, and predict an environmental conditions and characteristics which have the potential or may pose a risk to human health. EHRA aims to give and provide complete information and policyholders, especially to the government as a material consideration for the process of making policies (Indonesian Ministry of Health, 2012).

According to the Decision of Minister of Health No. 876/MENKES/SK/VIII/2001 concerning Technical Guidelines for Environmental Health Impact Analysis described Environmental Health Risk Analysis as one of the methods or ways to carry out approach in observing the magnitude of the potential hazard risks. The implementation of EHRA is start-ed by conducting identification of known environmental problems and involving the parties responsible for determining risks to human health related to the environmental problems concerned. Environmental Health Risk Analysis (EHRA) is usually related to the environmental problems that occur in the present or in the past (Indonesian Ministry of Health, 2001).

International Program on Chemical Safety (IPCS) Risk Assessment Terminology in the technical guide or manual of Environmental Health Risk Analysis (EHRA) Director General of Disease Control and Environmental Health Ministry of Health Republic of Indonesia in 2011 defined Environ-mental Health Risk Analysis (EHRA) as a process aims to calculate

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or predict the risk in human health including the identification of the presence of uncertainty factors, tracking of specific exposures, calculating the inherent characteristics of the agent of concern and the characteristics of the specific target. It should be noted that in conducting a risk assessment many things are uncertain, but the risk assessment should be done to provide information regarding hazard identification and distinguish between factors that affect the environment and their hazards to human health and environmental sustainability, analyzing risk in the present and predicting changes that may occur as a result of exposure to these risk factors. Ther-efore, by the presence of risk analysis can be used as an information to carry out preventive measure (Indonesian Ministry of Health, 2001). According to (Djafri, 2014) the risk is between definitely not happening and definitely happening (0<risk<1). Risk analysis is divided into four stages namely hazard identify-cation, dose response assess-ment, exposure assessment, and risk characterization.

Table 1. The Measurement Results of the Concentration of NO_2, SO_2 in the settlements around the tofu industry in Tropodo Village, Krian

Measurement Location	NO_2 Concentration ($\mu g/m^3$)	SO_2 Concentration ($\mu g/m^3$)
Government Regulation No. 41 of 1999	400	900
Location 1	13.96	2.98
Location 2	11.97	3.04
Location 3	12.97	3.18
Location 4	20.94	5.01
Location 5	4.98	2.11
Average	12.96	3.26

3. Hazard Identification

The measurement results data showed that the concentration of NO_2, SO_2 in the tofu industrial settlement of Tropodo Krian Village on five locations still below the quality standard but if the gas is inhaled every day it can cause respiratory problems. The source of exposure of NO_2, SO_2 in settlements not only come from the tofu industry, but several tofu industries.

4. Dose Response Assessment

Dose response analysis is a stage used to determine the correlation between the magnitude of the dose or level of exposure of chemical material with adverse effects on human health. This stage is a stage to determine the quality of the toxicity of the risk agent that has the potential to cause adverse health effects in the population at risk. As for toxicity of risk agent is stated by reference dose. For the inhalation exposures that are non-carcinogenic is stated by Reference Concentration (RfC). The reference dose is used to predict the amount of daily exposure in the human population that can be received without causing harmful effects over its lifetime. For the toxicity of SO_2, NO_2 is one of the risk agents with non-carcinogenic effect of inhalation then the dose response is stated by Reference Concentration (RfC).

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5. Exposure Assessment

The determination of exposure analysis is carried out by calculating the amount of intake of risk agents that enter the body through inhalation. Intake is stated as the amount of exposure received by individuals per kilogram of body weight per day. Exposure intake is calculated by lifetime. Lifetime exposure is the exposure duration calculated for lifetime. The lifetime exposure used is standard ex-posure duration (Dt) 30 years namely the time standard score for which non-carcinogenic effects are expected to manifest in humans. The concentration of NO2, SO2 used is the concentration measured on each measurement point in the Tropodo Krian tofu industrial settlements starting from locations 1, 2, 3, 4 and 5 as shown in Table 1 The exposure duration is obtained based on the calculation of combustion duration of tofu production namely 8 hour/ day and 48 hour/week for 6 working days/ week.

Based on the calculation results data in Table 2, it can be known that the biggest lifetime Intake received by individual is in the tofu industrial settlements, namely with the intakes of NO_2 as many as 2.161 µg/kg/day, and SO_2 as many as 0.517 mg/kg/day whereas the smallest lifetime Intake is in the tofu industrial settlements, namely with the intakes of NO_2 as many as 0.514 µg/kg/day, and SO_2 as many as 0.218 µg/kg/day. Whereas the average intake received in the tofu industry settlements for 5.625 µg/kg/ day, NO_2 as many as 1.338 µg/kg/ day, and SO_2 as many as 0.337 µg/ kg/day. This intake is not necessarily the same as the intake received by the actual individual. The intake received may be smaller or greater than the measurement of the concentration of NO_2, SO_2 that enters the body. Therefore, the exposure analysis calculation result is as follows:

Table 2. The Calculation Results of NO_2, SO_2 Intake Risk that entered the body at the Tropodo Krian Village Tofu Industrial Settlement

Location	NO_2 Concentration (µg/m³)	NO_2 Intake (µg/kg/day)	SO_2 Concentration (µg/m³)	SO_2 Intake (µg/kg/day)
Location 1	13.96	1.441	2.98	0.308
Location 2	11.97	1.235	3.04	0.314
Location 3	12.97	1.338	3.18	0.328
Location 4	20.94	2.161	5.01	0.517
Location 5	4.98	0.514	2.11	0.218
Average	12.96	1.338	3.26	0.337

6. Risk Characterization

Risk characterization is an effort carried out to determine whether the exposed population is at risk for the risk agent entering the body as stated by RQ (Risk Quotient). The RQ calculation is carried out by combining scores obtained on analysis of exposure or intake and dose response. The non-carcinogenic risk level can be obtained through the result of dividing daily intake through inhalation with a response dose value known as the reference Concentration (RfC). As for the calculation of RQ (Risk Quotient) is as follow:

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Table 3. The calculation results of RQ (Risk Quotient) at the Tofu Industrial Settlement in Tropodo Krian Village

Location	NO_2		SO_2	
	RQ (Risk Quotient)	RQ Criteria	RQ (Risk Quotient)	RQ Criteria
Location 1	72.03	Unsafe	15.38	Unsafe
Location 2	61.76	Unsafe	15.69	Unsafe
Location 3	66.92	Unsafe	16.41	Unsafe
Location 4	108.05	Unsafe	25.85	Unsafe
Location 5	25.70	Unsafe	10.89	Unsafe

Table 3 showed that the risk agent of NO_2, SO_2 in the air at all measurement locations in the tofu industry settlement has RQ score >1 which means that the exposure of NO_2, SO_2 inhaled by residents of tofu industrial settlements weighing 55 kg, exposure time of 8 hours/day for 312 days/year is not safe or at risk of non-carcinogenic effects in the next 30 years.

7. Risk Management

Based on the non-carcinogenic risk calculation results of NO_2, SO_2 exposure in tofu industrial settlement with RQ stated in Table 3, with the level of pollution as measured, the health risks at all locations of the tofu industry are unsafe or non-carcinogenic risk for the next 30 years. Therefore, the risk management to protect residents from these health risks really needs to be done as a preventive measure. Several risk control that can be carried out to reduce the non-carcinogenic risk of NO_2, SO_2 exposure to residents of tofu industrial settlements namely reduce concentration, reduce exposure time and reduce exposure frequency.

8. Safe Concentration of NO_2 and SO_2

From the number calculation above it can be known that the concentration of NO_2, SO_2 in the tofu industrial settlement with the score as in Table 1. Even though it is still below the predetermined quality standards. However, the concentration should be reduced.

$$C\ aman = \frac{RfC\ x\ Wb\ x\ tavg}{R\ x\ te\ x\ fe\ x\ Dt}$$

$$= \frac{\frac{0{,}02\frac{mg}{kg}}{hari} x 55\ kg\ x\ 30\ th\ x\ 365\ hr}{\frac{0{,}83 mg}{m3} x 8\ jam\ x\ 312\ hr\ x\ 30\ th}$$

= 0,194 mg/m3

9. Safe Exposure Time

From Table 4 it can be known that by using the average concentration in tofu industry settlement for NO_2 as many as 12.96 µg/m^3, SO_2 as many as 3.26 µg/m3. From the concentration of NO_2 obtain the result 0.120 hours which means that a person in a tofu industrial settlement weighing 55 kg who is exposed to NO_2 will be safe for the next 30 years if the daily exposure time is 0.120 hours/day or about 7.2 minutes. From the concentration of SO_2 obtain the result 0.476 hours which means that a person in a tofu industrial settlement weighing 55 kg who is exposed to SO_2 will be safe for the next 30 years if the daily exposure time is 0.476 hours/ day or about 29 minutes.

Table 4. The calculation results of safe exposure time in Tropodo kian Village Tofu Industrial Settlement

Variable	Average of Concentration ($\mu g/m^3$)	Safe exposure time (safe t_e) (hour/day)
NO_2	12.96	0.120
SO_2	3.26	0.476

10. Safe Exposure Duration

From Table 5 it can be known that a person weighing 55 kg exposed to NO_2 every day for 8 hours with the concentration of NO_2 as many as 12.96 μg/m3 then the safe exposure duration is 0.45 years (5 months) A person weighing 55 kg exposed to SO_2 every day for 8 hours with the concentration of SO_2 as many as 3,26 μg/m3 then the safe exposure duration is 1.78 years (21 months).

Table 5. The calculation results of safe exposure duration in Tropodo kian Village Tofu Industrial Settlement

Variable	Average of Concentration ($\mu g/m^3$)	Safe exposure duration (Safe Dt) (year)
NO_2	12.96	0.45
SO_2	3.26	1.78

11. Safe Exposure Frequency

From the results above it can be known that a person weighing 55 kg exposed to NO_2 every day for 8 hours with the concentration of 12,96 μg/m3 then the safe exposure frequency for the next 30 years is 5 days/year. A person weighing 55 kg exposed to SO_2 every day for 8 hours with the concentration of 3,26 μg/m3 then the safe exposure frequency for the next 30 years is 19 days/year. As for the risk control that can be conducted from the analysis results above is by reducing the concentration level of NO_2, SO_2 namely by 0,194 mg/kg/day and the safe exposure duration for NO_2 5 months and SO_2 21 months. The implementation of regulations for the quality standards of exhaust emissions in the air for every tofu industry and optimizing the performance of tools in controlling emissions. Socialization of industrial exhaust emission quality standards and application of OSH equipment at the factory site. Risk com-]munication is carried out as a follow-up to the implementation of EHRA whose role is to inform the local village head in a transparent and responsible manner regarding the process and results of risk characteristics as well as risk management options. As for the risk management option as a preventive measure is minimizing the exposure level with the exhaust gas emission control.

Table 6. The calculation results of safe exposure frequency in Tropodo kian Village Tofu Industrial Settlement

Variable	Average of Concentration ($\mu g/m^3$)	Safe exposure frequency (Safe Fe) (day/year)
NO_2	12.96	4.67
SO_2	3.26	18.55

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DISCUSSION

Based on the Government Regulation of the Republic of Indonesia Number 41 of 1999 concerning Air Pollution Control, it can be seen that the mea-surement results on five measurement locations, nothing exceeds the quality standard with an average concentration of NO_2 and SO_2. Although the concentration of this NO_2, SO_2 is still below the established quality standard, but the risk estimation due to the exposure of NO_2, SO_2 can occur due to differences in respondent characteristics and exposure patterns.

Environmental Health Risk Analysis (EHRA) is study model to describe, understand, and predict environmental conditions and characteristics which have the potential or may pose a risk to human health. EHRA aims to give and provide complete information and policy holders, especially to the government as a material consideration for the process of making policies (Indonesian Ministry of Health, 2012). According to the Decision of Minister of HealthNo.876/ MENKES/ SK/ VIII/ 2001 concerning Technical Guidelines for Environmental Health Impact Analysis described Environmental Health Risk Analysis as one of the methods or ways to carry out approach in observing the magnitude of the potential hazard risks. The implementation of EHRA is started by conducting identification of known environmental problems and involving the parties responsible for determining risks to human health related to the environmental problems concerned. Environmental Health Risk Analysis (EHRA) is usually related to the envi-ronmental problems that occur in the present or in the past (Indonesian Ministry of Health, 2001).

International Program on Chemical Safety (IPCS) Risk Assessment Terminology in the technical guide or manual of Environmental Health Risk Analysis (EHRA) Director General of Disease Control and Environmental Health Ministry of Health Republic of Indonesia in 2011 defined Environmental Health Risk Analysis (EHRA) as a process to calculate or predict the risk in human health including the identification of the presence of uncertainty factors, tracking of specific exposures, calculating the inherent characteristics of the agent of concern and the characteristics of specific target. It should be noted that in con-ducting a risk assessment many things are uncertain, but the risk assessment should be done to provide information regarding hazard identification and distinguish between factors that affect the environment and their hazards to human health and environmental sus-tainability, analyzing risk in the present and predicting changes that may occur as a result of exposure to these risk factors. Therefore, by the presence of risk analysis can be used as an information to carry out preventive measure (Indonesian Ministry of Health, 2001). According to (Djafri, 2014) the risk is between definitely not hapening and definitely happening ($0 < risk < 1$). Risk analysis is divided into four stages namely (a) hazard identification, (b) dose response assessment, (c)exposure assessment and (d) risk characterization.

NO_2, SO_2 have non-carcinogenic health risks namely can cause respiratory disorders. NO_2, SO_2 are irritants to the respiratory tract and can cause lung

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function disorders. SO_2 gas can cause irritating effect on the upper respiratory tract because it is easily soluble in water which results in increased mucus production resulting in narrowing of the respiratory tract (Ramdan et al., 2017). The combustion during tofu production, previously used plastic waste as fuel. However, when the research is conducted, tofu industry no longer use plastic waste as fuel. Based on the observation, tofu industry is every 5 houses that are densely populated.

RfC score is not an absolute dose of a risk agent, but only a reference dose. If the dose received by human population exceeds the RfC then the potential for the occurrence of health risks to be greater. The research by (Ramdan et al., 2017) regarding the exposure risk analysis of SO_2 on non-carcinogenic risk in street sweeper workers in Samarinda City showed that the exposure intake <RfC SO_2 as many as 0.0125 mg/kg/day with the concentration of SO_2 as many as 0.0043 mg/ m3. The research by (Fadilah, 2017) regarding the environmental health risk analysis of NO_2 ex-posure in street vendors at Gajah Mada highway, Padang City in 2017 showed that the concentration of NO_2 is 0.00547 mg/ m3.

Exposure assessment is a contact assessment aims to identify risk agent exposure pathways to calculate the amount of intake received in at-risk population (Rahman, 2007). The inhalation rate (R) used is standard inhalation rate for adults at the age of 21–61 years namely 0,83 m^3/ hour. The body weight used is the body weight of adults 55 kg (55 kg for Asian) from (Nukman et al., 2005).

The risk level (RQ) score is affectted by intake score, where the intake score is affected by several variables namely body weight, concentration of risk agent, exposure time, exposure frequency and exposure duration (Arista, Sunarsih and Mutahar, 2015). Intake score is affected by several factors namely concentration of risk agent, exposure time, exposure frequency, and exposure duration. Therefore, it is considered normal if the score of intake obtainned is quite low. This is because the concentration score of NO_2 and SO_2 from the measurement results is quite low as well as the normal average of exposure is 8 hours/day. This is also explained in the research by (Wahyuni, 2018) that the intake calculation needs a risk agent concentration in certain environmental media, anthropometric characteristics such as body weight, and inhalation rate or consumption patterns and activity patterns of contact time with risk agents. The research by (Wenas, et al., 2020) showed that the RQ score categorized at risk (above normal) is found in RQ score of real time NO2 as many as 1 respondent (2.0%) and the RQ score of lifetime NO_2 as many as 28 respondents (56.0%). The study by Arista et al. (2015) showed that the RQ= 1,5915 which means that Palembang Ampera Terminal area contains 0.2298 mg/ m3 sulfur dioxide is not safe (non-carcinogenic) for traders with an inhalation rate of 0.83/ hour for 362 days/ year for a period of 42 years and has a body weight of 62 kg. The research by (Ilza and Afandi, 2016) showed that the SO_2

levels of 5 ppm or more, can cause throat irritation to occur even in some

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individuals who are sensitive, irritation occurs at levels of 1-2 ppm.

Risk management is the choice made to minimize the impact of exposure to a risk agent on the health of workers by changing the score of the exposure factor so that the amount of intake that enters the body is smaller or at least equal to the reference dose of its toxicity (Rahman, 2007). The safe concentration of NO_2, SO_2 maximum of 0.194 mg/m^3 for the duration of exposure for the next 30 years. With the assumption that the frequency of working day exposure remains 312 days per year and the exposure time also remains 8 hours per day. From the research results obtained a result that the concentration of NO_2, SO_2 in the tofu industry settlement is below the quality standard but has a risk of being unsafe so that it can cause health problems, therefore, it is necessary to reduce exposure time and reduce exposure frequency for further research is expected to examine the exposure of SO2, NO2 from the source (industry) thereby the reduction of exhaust gas emission from the combustion during production can be carried out.

AUTHOR CONTRIBUTION

First and second author contribute to developed the theoretical formalism, performed the analytic calculations and performed the numerical simulations. All author contributed to final version of the manuscript. Second and third author supervised the project.

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CONFLICT OF INTEREST

There is no conflict interst in this study.

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