Health Risk Assessment on Human Exposed of Nitrogen Dioxide in Adults Around Steel Industry

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Abstract

Background: Nitrogen dioxide (NO_2) is a pollutant gas that can cause symptoms that are bad for the environment and human health. As a result of exposure to nitrogen dioxide in humans through inhalation will cause acute and chronic respiratory disorders. Sources of nitrogen dioxide emissions can come from repeated combustion processes in the steel industry using coal as an iron reducing agent in the furnace.

Objectives: This study aims to evaluate the public health risks around the steel industry in the village of Sukadanau, West Cikarang sub-district.

Method: Anthropometric characteristics and activity patterns are used to calculate intakes. Intake (I*nk*) and Reference Concentration (R*f*C) produce RQ (*Risk Quotion*) with RQ *real time*> 1 indicating the existence of health risks so that risk management is needed.

Results: Adults who live around the steel industry are at risk of exposure to nitrogen dioxide gas in the surrounding air. The study found that at a radius of <500 meters from the industry having RQ*real time* > 1 and found signs respiratory disorders to respondents.

Conclusion: With the method of analyzing environmental health risks from exposure to nitrogen dioxide, it is known that there are significant health risks for the community that can be used as preventive measures to prevent worse health problems.

Keywords: *Nitrogen dioxide, health risk, steel industry, human exposure.*

Introduction

Indonesia is the 3rd largest steel importer in the world, at 11 million tonnes in 2016 for all steel product[1]. One of steel industries that plays a role in Southeast ASIA is located in West Cikarang and is in the center of community settlements in the administrative area where the industry is located has 25,817 people who have the potential to have an effect from emissions released by the industry into ambient air. The use of fossil fuel in the iron and metal (steel) industry will increase greenhouse gas emissions. Production activities in the iron and steel industry tend to go through high temperature processes with very large fuel consumption, as a result most of these processes are sources of NO_2 emissions especially those produced from equipment technology such as boilers and furnaces[2].

Previous and recent epidemiologic studies consistently indicate associations between short-term increases in ambient NO_2 concentrations and increases in respiratory effects aggregated across specific conditions such as asthma, COPD, and respiratory infections[3]. This study is going to use health risk assessment method of U.S. EPA is used to evaluate heath risk from a model prediction data following four steps as Hazard

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identification, Dose-response, Exposure assessment and Risk characterization. Normally, health assessment includes health issues that can be measured,such as chemical and pollution exposure concentrations while focusing less on qualitative information such as community perceptions of health issues[4].

Materials and Method

This research is descriptive with a study design in *cross sectional* which exposure and outcome are collected at the same time or in a certain time.

The population is adults who live around the location of the steel industry. Samples taken were adults, with criteria aged> 18 years and living at least 1 year in a location around the industry, Cikarang Barat, Bekasi. The sample in this study was determined using the calculation of estimation of proportions. Based on the calculation the sample size in this study was 94 samples. Samples in this study were divided based on Radius < 500 m, 500 - 1000 m and > 1000 m with the steel industry. From each radius, the population of each radius is calculated using the formula proportional stratified random sampling.

This research uses a method approach in the form of Environmental Health Risk Analysis which is based on the Guidelines for assessing human health risks from environmental hazards by enHealth (2012) consisting of 4 stages namely Hazard Identification, Exposure Analysis, Dose-Response Analysis and Risk Characterization. This method cannot see the correlation between variables so it is limited to the presence or absence of health risks that will arise in humans.

Frequency distribution analysis is carried out to see the size of the mean, minimum and maximum values for nitrogen dioxide concentration data, age, activity pattern data and anthropometric data. Conduct a health risk analysis by calculating the NO_2 exposure intake to respondents to calculate the amount of intake received by an individual by the formula:

$$Ink = \frac{C \times R \times t_E \times f_E \times D_t}{W_b \times t_{avg}}$$

Ink : Intake (intake), the number of risk agents entering the human body ($mg/m^3/day$)

C : concentration of risk agents (mg/m^3)

R : rate of intake (0.83 m^3/hour)

t_E : time of exposure (hour/day)

f_E : frequency of exposure (day/year)

D_t : duration of exposure, length of stay (years)

W_b : respondent's weight (kg)

t_{avg} : average time period (30 x 365 days/year for non-carcinogenic substances)

Next look at the risk characteristics expressed by RQ. Individuals are declared to have a health risk if RQ> 1 and declared not to have risk if RQ <1. The RQ formula is as follows:

$$RQ = \frac{Intake}{RfC\ (\textit{Reference Concentaration})}$$

Risk management needs to be done in risk groups with RQ > 1 by calculating the maximum NO_2 concentration limit, t_E, f_E and D_t with the following equation:

Concentration limit	$C_{max} = \frac{RfC \times W_b \times t_{avg}}{R \times f_E \times t_E \times D_t}$
Time limit	$t_E = \frac{RfC \times W_b \times t_{avg}}{R \times C \times f_E \times D_t}$
Frequency limit	$f_E = \frac{RfC \times W_b \times t_{avg}}{R \times C \times t_E \times D_t}$
Duration limit	$D_t = \frac{RfC \times W_b \times t_{avg}}{R \times C \times t_E \times f_E}$

Results

Hazard Identification:

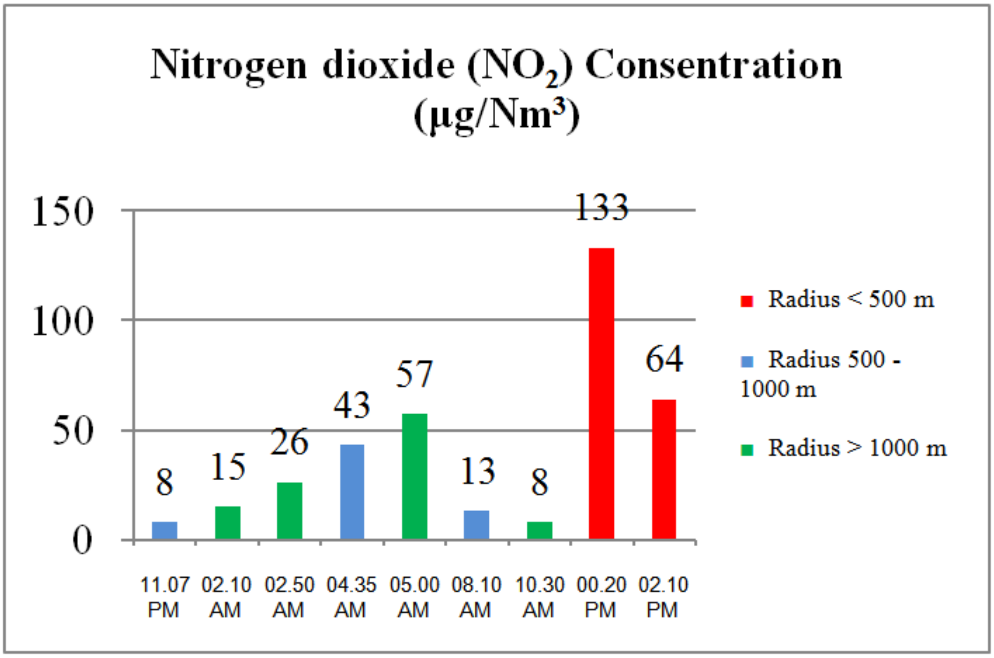

Fig. 1: NO_2 Consentration in 9 Location

Exposure Analysis: Based on the results of the study, several results were obtained regarding the characteristics of 94 adult respondents. Characteristics of respondents in the studyinclude: weight, daily exposure, frequency of exposure, exposure duration and intake NO_2 *real time* calculated using the *Kolmogorov-smirnov test*in table 1.

Table 1. Univariate Analysis Results

No.	Anthropometric Variables & Activity Patterns		Min	Max	Mean / Median	SD	p-value Kolmogorov-smirnov
1	Weight (kg)	(W_b)	41	100	66.35* 64.50	13.21	0.060
2	Daily exposure (hours/days)	(t_E)	7	24	21.53 24.00*	4,08	0.000
3	Frequency of exposure (days/year)	(f_E)	305	365	357.33 359.00*	11.92	0.000
4	exposure Duration (years)	(D_t)	1	65	20.24 23.00*	15.47	0.000
5	Intake NO_2 real time (mg/kg/day)	(I)	0.0000	0.3567	0.0037 0.0018*	0.0057	0.000

Note: *mean used

The distribution of anthropometric characteristics of adult respondents is shown in table 2 based on test *Kolmogorov-smirnov*.

Table 2. Distribution of Anthropometric Characteristics of Adult respondents

Anthropometric Characteristics	Amount (Person)	Percentage (%)
Weight (Kg)		
<66.35	50	53.2
≥ 66.35	44	46.8
Exposure Time (hours/day)		
<24 hours	33	35.1
24 hours	61	64.9
Frequency of Exposure (day/year)		
<359	43	45.7
≥ 359	51	54.3
Duration of Exposure (year)		
<23	46	48.9
≥ 23	48	51.1
NO_2 $intake_2$ real time (mg/kg/day)		
<0.0018	43	45.7
≥ 0.0018	51	54.3

Dose-Response Analysis: A dose-response analysis is carried out to establish quantitative values of the toxicity of a risk agent for each form of chemical species. The size of the toxicity of a *risk agent* with the effects of non-carcinogens in Environmental Health Risk Analysis (EHRA) for inhalation represented by R*f*C *(Reference Concentration)*. Rated R*f*C for NO_2 has been available in the EPA/NAAQS 1990 of 0,02 (mg/kg/day) with crisis effects of respiratory tract disorders.

Risk Characterization: Risk characterization are efforts to determine whether the exposed population has a risk of *risk agents* entering the body expressed as RQ *(Risk Quotient)*. Health risk is stated to exist and needs to be controlled if RQ> 1.

Table 3. Risk Level of NO_2 Exposure based on Radius from Steel Industry Point

Radius	Level of Risk		Total
	RQ ≤ 1 real time (n)	RQ > 1 real time (n)	
< 500 m	3 (50%)	3 (50%)	6
500 – 1000 m	20 (100%)	0 (0%)	20
> 1000 m	68 (100%)	0 (0%)	68
Total	91	3	94

In the RQ *real time* from the number of 6 respondents in the radius < 500 there are 3 people (50%) respondents who have a RQ *real time* value > 1 which means the need for risk control or management.

Risk Management: Risk management is a way of controlling risk by selecting and implementing risk mitigation caused by environmental hazards[5]. Some possible risk controls to reduce the risk of non-carcinogenic exposure to NO_2 in adults around the steel industry namely reducing concentration of NO_2, reduce exposure time, reduce the frequency of exposure and duration of exposure. The calculation respondents that has a$RQ_{real\ time}$> 1 is as follows:

Table 4. Maximum Limit Value for Risk Management

	Respondent	1	2	3
Individual Characteristic	C(mg/m^3)	0.133	0.133	0.133
	RfC(mg/kg/day)	0.02	0.02	0.02
	W_b(kg)	64	65	73
	t_E(hour/day)	24	24	24
	f_E(day/year)	337	365	365
	D_t(years)$_{life\ span}$	30	30	30
Maximum Limit Value	C_{max}(mg/m^3)	0.070	0.065	0.073
	t_E(hour/day)	12.56	11.78	13.23
	f_E(day/year)	176	179	201
	D_t(years)	15.7	14.7	16.5

Discussion

The steel industry in Sukadanau Village is one of the largest industries and plays an important role in the Southeast Asian region. In one year the industry can produce 1.2 million tons of steel. In line with this, emissions from production activities from boiler and furnace machines are produced continuously. The repeated heating activity of steel production and the use of large fuels can produce pollutants sources of NO_2[2]. In accordance with Yu Liu's research, that in his research found the most prominent source of NO_2 comes from fossil fuels that are burned from industrial processes[6].

Based on WHO's Global Air Quality Guideline in 2005 on the guideline value for NO_2 the normal limit of the concentration of NO_2 is 200 $\mu g/Nm^3$ in air ambient[7]. It can be seen that from nine measurement locations none exceeded the normal limit with the highest value in the location <500 m of the steel industry with a value of 133 $\mu g/Nm^3$ or equivalent to 0.133 mg/m^3. However, the estimated risk due to exposure to NO_2 can occur due to differences in anthropometric characteristics and activity patterns.

Evidence shows that adverse health effects remain at concentrations of pollutants that are below current air quality standards and at low air pollution levels in many countries. In addition, air pollution is an important concern in many developing countries, where emissions have increased without strict air quality policies. This has added to the worsening air quality conditions, especially in urban areas[8].

Nitrogen dioxide concentrations aretaken for one hour at each point of measurement location. Starting at 11:00 pm until 03.10 pm in the morning. The concentration of NO_2has increased starting from the first measurement in the morning until late afternoon, and increasing at night with measurements at 00.10 pm. This diurnal trend of NO_2 is consistent with EPA's explanation for NO_2 that this is caused by meteorological influences, with concentrations increasing at night when atmospheric mixing decreases due to low wind speeds and low mixing layer heights[3].

In table 1 it can be seen that the frequency of respondent exposure is 24 hours/day on average. In table 2 it is also known that the highest frequency of exposure is 24 hours/day. This is because most of the study respondents were housewives in residential locations so that most of their activities were in the area where they lived.

Calculations *Intake* there are variations from each respondent due to differences in anthropometric characteristics and activity patterns. The highest value of intake on respondents obtained from respondents with the duration of exposure (D_t) 24 years exceeds the average of 23 years.

In the calculation of RQ (*Risk Quotion*) there are 3 respondents who have a value of $RQ_{real\ time}$> 1. Of all respondents who have an $RQ_{real\ time}$> 1 are respondents who live in a radius of <500 m from the steel industry. This is influenced by the concentration of NO_2 at a radius of <500 m from the steel industry which is very high at 0.133 mg/m^3 and decreases after more than 500 m distance. This is consistent with the theory that the concentration of NO_2 will decreases at a distance of 500 m from the source of emissions[3]. This is not much different from the results of Masito's research which says that the distance of 300 m is the area affected from the point of taking NO_2[9].

$RQ_{real\ time}$> 1 is where the result is an insecure value (potentially causing non-carcinogenic effects) in the surrounding community in the steel industry area. So that there is a need for risk management measures using an economic and social approach, a technology approach and stakeholders[10]. Based on the calculation it can be seen that the maximum safe concentration for a period of 30-year exposure (projected *lifespan*) is taken from the respondents most at risk with the highest f_E value and the lowest concentration of 0.065 mg/m^3. The limit is the safe concentration limit to avoid health risks. Furthermore,at the concentration of exposure using a maximum value of 0.133mg/m^3, then the maximum safe time is 11.78 hours/day the frequency of safe exposure is 176 days/year and the duration of safe exposure is 14.7 years. The difference in values is due to the different anthropometric characteristics and activity patterns of the respondents. The risk group can do this by managing the time, frequency and duration of exposure so as not to pose a health risk.

The effects arising from exposure to NO_2 tend to cause respiratory disturbances because the dominant exposure pathway is through inhalation. In this study it was found that respondents with $RQ_{real\ time}$ > 1 experienced symptoms of respiratory disorders such as coughing and phlegm. Research in Italy shows that there is a relationship between the concentration of NO_2 and impaired lung function using a spirometer. FER statistical test results ($FER = FEV_1/FVC$) have a significant correlation with NO_2 (p<0.001)[11]. Further evidence supporting the short-term relationship between NO_2 and an increased risk of death from respiratory disease has also been widely reported, especially in urban areas of China[12,13].

Conclusions

Measurement of health risks from the concentration of NO_2 in adults around the steel industry in Sukadanau Village, Cikarang Barat District resulted in RQ $_{real\ time}$> 1 at a radius of <500 m. Respondents with RQ $_{real\ time}$> 1 are known to experience symptoms of respiratory disorder in the form of coughing and phlegm, so there is a need for risk management to anticipate worse health problems. Risk management can be done by reducing the exposure time to no more than 11 hours/day and the frequency of exposure to 176 days/year.

Efforts of relevant institute to reduce emissions in ambient air are needed to overcome health problems that are getting worse. Local government efforts in reducing industrial exhaust emissions can be done by making and realizing policies for industries that do not conduct periodic audits and issue emissions exceeding the normal limits.

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Ethical Clearance: Taken from the Research And Community Engagement Ethical Committee Faculty of Public Health Universitas Indonesia.

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