Risk Assessment of Nitrogen Dioxide Exposure in Palu City

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Article Info	Abstract
	BACKGROUND: Global Alliance on Health and Pollution (GAHP) research in 2021 revealed that Indonesia became the fourth largest contributor to air pollution deaths. AIM: This study aims to do a risk assessment of nitrogen dioxide exposure in Palu City in 2021. METHOD: The research method uses EHRA and is carried out in seven sites with 385 respondents. Respondents at locations 1, 2, 5, 6 dan 7 are street vendors, which was taken by purposive sampling. The sample size was calculated using the Slovin formula. While respondents at locations 3 and 4 are fuel refueling officers at the gas station around Palu City, the sample was taken by total sampling. NO_2 levels at locations 1 and 2 were carried out in accordance with SNI 19-7119.9-2005 (roadside air quality monitoring) and at locations 3 and 4 determined according to SNI 19-7119.6-2005 (ambient air quality monitoring). While at points 5, 6, and 7 NO_2 levels were measured using the Griess Saltzman method using a single gas detector. RESULTS: Laboratory analysis shows the average NO_2 concentration at each measurement point is 10,450 g/Nm³; 10.110 grams/Nm³; 9.020 grams/Nm³; 8,910 grams/Nm³; 10.455 grams/Nm³; 11.166 grams/Nm³; and 9.02 grams/Nm³. The risk quotient (RQ) value for all respondents is <1. CONCLUSION: The average concentration of NO2 at each measurement point in Palu City still meets Government Regulation Republic of Indonesia number 22 in 2021 (200 g/Nm3) and exposure to NO2 does not pose a risk of causing health problems.

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INTRODUCTION

Recently pollution has become a major problem, and the decline in air quality is an issue that is associated with various health problems and death. Air pollution can be caused by natural processes and human activities like burning fuels, dust from industrial activities, and motorized vehicles, which are the biggest contributors to air pollution in urban areas (1). Global Alliance on Health and Pollution (GAHP) in 2017 showed that pollution makes the death of 8.3 million people. Indonesia is the fourth largest contributor to pollution-related deaths, 232.9 thousand deaths have been linked to air pollution in 2017 as a producer of various pollutants including NO_2 (2). Based on data from the Statistics Centre of Palu City in 2019, the number of motorized vehicles is 233,656 units (3). One of the biggest sources of air pollution in urban areas is motorized vehicles which contribute 70% of NO_2 emissions (1).

A large number of motorized vehicles means the potential for NO_2 contamination in the environment will also increase. NO_2 can have adverse effects on health such as shortness of breath, irritation of mucus, sinuses, pharynx, ARI, pulmonary edema, and even fatal conditions to death (4). This research was conducted at 7 locations in Palu City, Location 1 (Teuku Umar Street), location 2 (Around Inpres traditional market), location 3 (gas station 74,942.07 Dewi Sartika Street), location 4 (gas station 74,942.09 I Gusti Ngurah Rai Street), location 5 (Around Lasoani traditional market), location 6 (Around Masomba traditional market) and location 7 (Around Palu Plaza). This location was chosen because of the dense activity of motorized vehicles which is exacerbated by traffic jams and is expected to trigger an increase in air pollutants at that location so that traders who sell have a high vulnerability to exposure to nitrogen dioxide gas (NO_2) and another pollutant that has the potential to trigger an adverse effect of chronic respiratory problems.

These locations are traffic areas that can increase levels of Nitrogen Dioxide so which has the potential to cause health problems for the community. In addition, in this area there are several home industries that are also operating. Therefore, it is necessary to conduct an Environmental Health Risk Assessment (EHRA) to determine the magnitude of the health risk due to NO_2 exposure on this site, by understanding the risks we can arrange risk management. Based on the description, the researchers are interested in conducting research on "Risk Analysis of Nitrogen Dioxide Exposure in the City of Palu in 2021".

METHOD

This is quantitative research with an Environmental Health Risk Assessment (EHRA) approach by determining the value of NO_2 intake to the respondents. In this study, as many as 385 were taken at 7 sites. Respondents at locations 1, 2, 5, 6, and 7 are street vendors throughout the study area, while respondents at locations 3 and 4 are fuel refueling officers at the gas station around Palu City. The value of the Risk Quotient (RQ) is determined by using the intake formula.

$$\text{Intake} : \text{Ink} = \frac{C \times R \times tE \times fE \times Dt}{wb \times tavg}$$

$$\text{RQ} : \text{RQ} = \frac{I}{RfC}$$

The data on the weight of the body was obtained through weighing of respondents. The data on inhalation rate, exposure time, frequency of exposure, and duration of exposure of respondents were obtained through interviews using a questionnaire. Air sampling at locations 1 and 2 was carried out in accordance with SNI 19-7119.9-2005 regarding sampling of roadside air quality monitoring tests and at locations 3 and 4 determined according to SNI 19-7119.6-2005 concerning sampling for ambient air quality monitoring tests. Sampling was guided by a laboratory assistant from UPT. Laboratorium Kesehatan Lingkungan Donggala District using an impinger. The sample collected analysis uses the Griess Saltzman method for the identification of NO_2 levels. Furthermore, the determination of NO_2 levels in air samples is carried out using the spectrophotometer. The technique for measuring nitrogen dioxide (NO2) levels at points 5, 6, and 7 using a Bosean BH-90A (single gas detector) in accordance with SNI 19-7119.2-2005 concerning how to test for nitrogen dioxide (NO_2) levels taking into account the factors Meteorology (wind direction and speed) is based on data from the BMKG, while measurements of humidity and air temperature use the Elitech DT-3 (digital weighing scale).

RESULTS AND DISCUSSION

Nitrogen Dioxide (NO_2) Level

Below are presented the results of NO_2 measurements at 7 research location points:

Table 1. The data of nitrogen dioxide (NO_2) level

Location	NO_2 Level (g/Nm³)						Mean (g/Nm³)
	1	2	3	4	5	6	
(1) Teuku Umar Street	0,01	0,01376	0,00737	0,01069	-	-	10.450
(2) Pasar Inpres Street	0,01	0,01356	0,0119	0,01074	-	-	1.110
(3) Gas Station 74.942.07	0,0142	0,00685	0,00601	-	-	-	9.020
(4) Gas Station 74.942.09	0,01096	0,01385	0,00221	-	-	-	8.910
(5) Pasar Lasoani Street	0,2	0,19	0,18	0,14	0,05	0,10	10,455
(6) Pasar Masomba Street	0,229	0,243	0,871	1,114	0,171	-	11.166
(7) Palu Plaza Street	0,15	0,45	0,1	0,7	-	-	9.02

Based on table 1 above, the average NO2 measurements carried out at 7 locations still meet the threshold value (PP No 22/2021). Even though the NO_2 value in this area still meets the threshold value, it will of course be more accurate if the measurement is carried out for 24 hours compared to measuring only 1 hour. The highest NO_2 levels were found at point 6 which is located around the Masomba Traditional Market with an average value of 11.166 g/Nm3. The reason is, its location is at a fork in the road so it is a meeting point for vehicles from both directions and often becomes the main point of traffic jams. Meanwhile, the lowest NO_2

levels were at point 7 located at Marka Palu Plaza with an average value of 9.02 g/Nm3. This is because motorized vehicles rarely pass around this point. This is because around that point is still rarely passed by motorized vehicles.

Increasing motorized vehicles operating around the measurement point will affect the concentration of NO_2 released into the ambient air. Handoko (2020) in his study explained that the density of vehicles passing around the Yogyakarta city tourist area has a significant effect on increasing NO_2 levels due (5). So that it can be explained that the low NO_2 level at the measurement points is caused in the city of Palu itself traffic jams are rare, however, based on data from the SAMSAT Provinsi Sulawesi Tengah (2020), it is known that the number of motorized vehicles in Palu City is 400,212 units, this number has increased by 51% compared to 2019. The increase in these vehicles is expected to continue in the future and this will be directly proportional to the increase in air pollution (6).

Anthropometric Characteristics and Activity Patterns of Respondents

Factors that influence the risk of nitrogen dioxide exposure to respondents in Palu City are anthropometric characteristics and activity patterns including body weight, inhalation rate, time of exposure, frequency of exposure, and duration of exposure (Table 2).

Table 2. The data of anthropometric and activity patterns of respondent at study site in Palu city in 2021

Location	Variable				
	Body Weight (Kg)	Inhalation rate (m³/Day)	Time of exposure (hour/Day)	Frequency of exposure (Day/Year)	Duration of exposure (Year)
1	36,45 - 95,78	0,83	5-18	312-365	2-41
2	43,18-98,11	0,83	6-24	312-365	3-36
3	52,4-78	0,83	8	240-288	2-15
4	45,4-78,9	0,83	8	240-288	1-13
5	40,3-85,2	0,83	2-8	96	1-27
6	44-81,25	0,83	5-18	365	2-25
7	30-81	0,83	5-10	359-365	2-17

The weight range of the respondents at location 1 is 36,45 – 95,78 Kg, at location 2 is 43,18 – 98,11 Kg, at location 3 is 52,4 – 78,0 Kg, location 4 is 45,4 – 78,9 Kg, location 5 is 40,3 – 85,2 Kg, location 6 is 44-81,25 Kg and location 7 is 30 – 81 Kg. The lowest weight value is 30 Kg and the highest weight value is 98,11 Kg. According to the U.S. EPA (2011), the standard adult weight is 70-80 Kg, so the average weight of these respondents is smaller than the standard adult weight set by the U.S. EPA (7).

The inhalation rate is the volume of air that enters the body every hour. The inhalation rate used in this study is the default value from the US EPA which is the adult inhalation rate of 0.83 m³/hour. Factors that can affect the inhalation rate are operator characteristics (age, body weight) and activity patterns (exposure time, exposure frequency, and duration of exposure) (8).

Time of exposure from shortest to longest is at location 1 is 5-18 hours/day, location 2 is 6-24 hours/day, locations 3 and 4 are 8 hours/day, location 5 is 2-8 hours/day, location 6 is 5-18 hours/day and location 7 is 5-10 hours/day. The smallest value is 2 hours/day at location 5 and the largest value is 24 hours/day at location 2. The difference in exposure time is due to differences in activity patterns, respondents at locations 1, 2, 5, 6, and 7 are street vendors, they are informal workers who are not related to regulations from an agency regarding a standard number of working hours in the day so that the time of exposure is calculated based on respondents information. while respondents in locations 3 and 4 are gas station officers related to the regulations of PT. Pertamina regarding the standard number of working hours in a day.

The frequency of exposures obtained at points 1, 2,5, 6, and 7 was 6-7 days/week while at points 3 and 4 was 5-6 days/week dependent on the shift of workers. The frequency of exposure is determined by the day of the year the respondent is at the study site, so the frequency of exposure at locations 1, 2, 5, 6, and 7 is 312-365 days/year, and locations 3 and 4 are 240-288 days/year.

Duration of exposure is the length of time the respondent breathes air containing NO_2 at work in units of years. The duration of exposure at point 1 was 2-41 years, point 2 was 3-36 years, points 3 and 4 were 1-13 years, point 5 was 1-27 years, point 6 is 1-25 years and point 7 is 2-17 years. The smallest value is 1 year at locations 3, 4, 5, and 6 and the largest value is 41 years at location 1.

Based on the data in table 2 the lowest weight body of respondents is 30 Kg and the highest is 98,11 Kg. According to the U.S. EPA (2011), the ideal adult weight is 70-80 Kg. The average weight of these respondents is smaller than the standard adult weight set by the U.S. EPA (7). In the EHRA, the weight will affect the magnitude of the risk quotient and theoretically the heavier a person is, the less likely it is to risk experiencing health problems according to mathematical calculations. The value of body weight will be inversely proportional to the RQ value (risk quotient), meaning that the low a person's weight, the greater RQ (risk quotient) that will be received as a result of exposure to nitrogen dioxide through inhalation (9). Differences in individual weight affect the body's chemical metabolism speed (10).

The inhalation rate is the volume of air that enters the body every hour. The inhalation rate used in this study is the default value from the US EPA which is the adult inhalation rate of 0.83 m^3/hour. Factors that can affect the inhalation rate are respondent characteristics like age, body weight, and activity patterns like time of exposure, frequency of exposure, and duration of exposure (8). The inhalation rate can be different, this is related to the metabolism rate. Metabolism is closely determined by the body's energy needs, so body weight is a determinant of the air oxygen needs that a person must breathe, meaning that the inhalation rate is also a function of body weight in addition to age, sex, and activity (11).

Time of exposure varies among the respondent in each study site, in locations 1,2,5,6, and 7 around of 2-18 hours/day, while in locations 3 and 4 is 8 hours/day. The varies in time of exposure is due to differences in activity patterns, respondents at locations 1, 2, 5, 6, and 7 as a street vendor, they are informal workers who are not related to regulations from an agency regarding a standard number of working hours in the day so that the time of exposure is calculated based on respondents information. while respondents in locations 3 and 4 are gas station officers, so they working activity is related to the regulations of PT. Pertamina regarding the standard number of working hours in a day. Based on the Decree of the Minister of Manpower (2004) the maximum standard working hours are 7-8 hours a day (40 hours/week), this indicates that at locations 1, 2, 5, 6, and 7 have been exceeded the standard. The length of exposure time greatly affects the amount of NO_2 exposure to traders while they work, although the value of NO_2 that enters the body of vendors street every day is lowest and the concentration of it is still below the threshold value, if chronic exposure continues then at the future may lead the health effect to them. There has been a lot of literature explaining the ideal working time in a day, this time setting is associated with the human body's rhythm where the human body's resistance level to work effectively in a day is a maximum of 8 hours. Anugrahany et al. (2024), explains that setting work time and rest time through a shift system is a form of protection for workers. However, in this study most of the respondents were street vendors without working hours standard, sometimes they worked more than 8 hours/day (12).

The frequency of exposure is the day of the year the respondent doing activity around of measured point. Based the data collected frequency of exposure at points 1, 2, 5, 6, and 7 was 6-7 days/week, it is depends on daily activity of a vendor's street around a traditional market. While at points 3 and 4 were 5-6 days/week dependent on the shift of workers. Ideally, the determination of working time requires a shift system, especially if it relates to workers in a company. Based on the data we can calculate the frequency of exposure at points 1, 2, 5, 6, and 7 as 312-365 days/year, and points 3 and 4 are 240-288 days/year. Exposure to NO_2 Continuously in the workplace will result in health problems such as symptoms of respiratory disorders, this occurs with age the body's metabolic function will decrease due to age, so it can affect the performance of the human respiratory muscles (13). If the exposure exceeds the frequency of standard working hours that have been set, the greater opportunity for the respondent to have an unsafe risk will have an impact on health.

Duration of exposure is the length of time the respondent breathes air containing NO_2 at workplace in units of years. Based the data obtained in table 2, the shorterms exposure of NO_2 is 1 year at points 3, 4, 5, and 6 and the longterms exposure is 41 years at point 1. A longterm duration of exposure make a roses of respondent health risk and may lead their health disorder's. The increased duration of exposure NO_2 pollutants is directly proportional to the increased risk of health problems, especially those related to respiratory disorders. EPA (2018), explained that short-term exposure of it may worsen respiratory diseases such as coughing and shortness of breath, while chronic exposure may lead to the development of asthma, especially in vulnerable groups likes children and the elderly. One of the factors that can affect respiratory problems in workers is a previous work history (14).

Risk Characteristics (Risk Quotient=RQ)

Below are presented the results of calculating the Risk Quotient (RQ) of respondents exposed to NO2 at the research location:

Based on the data in table 3, it can be seen that the Risk Quotient (RQ) of all respondents in study sites

Table 3. Intake values and risk quotient (RQ) of respondent at at study site in Palu city in 2021

Location of Respondent	Min – Max	
	Intake Values of Respondent	RQ of Respondent
(1) Teuku Umar Street	0.0002–0.0018	0,005- 0,093
(2) Pasar Inpres Steet	0.0002–0.0038	0,007- 0,190
(3) Gas Station 74.942.07	0.0001–0.0004	0,002- 0,017
(4) Gas Station 74.942.09	0.00002-0.00025	0.012-0.000
(5) Pasar Lasoani Street	0,00007-0,0047	0,003-0,237
(6) Pasar Masomba Street	0,0001-0,0020	0,005-0,099
(7) Palu Plaza Street	0,2617 – 4,4015	0,0136 – 0,2200

still safe or not yet a risk (RQ <1) with the lowest risk quotient is 0,000 at location 4 and the highest risk quotient is 0,2200 at location 7. This condition described the concentration of NO_2 around the measured point is still safe for the respondents toward their anthropometric characteristics and activity patterns. Based on the data in table 2 the lowest weight body of respondents is 30 Kg and the highest is 98,11 Kg. According to the U.S. EPA (2011), ideal adult weight is 70-80 Kg (13). The average weight of these respondents is smaller than the standard adult weight set by the U.S. EPA. In the EHRA, the weight will affect the magnitude of the risk quotient and theoretically the heavier a person is, the less likely it is to risk experiencing health problems according to mathematical calculations. The value of body weight will be inversely proportional to the RQ (risk quotient), meaning that the low a person's weight, the greater RQ (risk quotient) that will be received as a result of exposure to nitrogen dioxide through inhalation (9). Differences in individual weight affect the body's chemical metabolism speed (15).

Intake is the dose of risk agent (mg) that exposed the human body to a certain body weight (kg) in a day, non-carcinogenic intake is the dose of a substances or risk agent that has a non-cancer effect in an environmental media, that exposed the human body in a day, this is expressed in units of mg/kg/day (8). The intake of nitrogen dioxide exposure in the human body is affect by the NO_2 concentration, time of exposure, frequency of exposure, duration of exposure, body weight, and inhalation rate. The toxicity of NO_2 is four times stronger than the toxicity of NO gas, organs target as the parts of the body that are very sensitive to NO_2 exposed is a lung. Long-terms exposed of NO_2 will enlarge a lung and make a person will have breathing difficulty and even cause death (16).

The risk characteristics stated in the RQ are an attempt to determine the level of risk agent that enters the human body, whether it is a risk still within safe limits. Determination of risk is calculated comparing the value of the intake with the reference concentration (*RfC*). If RQ≥1 means that the NO_2 exposure has a risk to health problems. NO_2 has the potential to cause various health disorders, particularly those related to the respiratory system (17). Meanwhile, if RQ < 1, then NO_2 exposure is considered still safe for humans and other organisms likes animals.

A number of epidemiological studies have documented that in some developed countries, short-term exposure to NO_2 is associated with increased mortality, as well as an increase in hospitalization of patients with inhalation disorders. In China daily deaths have been linked to particulate and gas pollution. Outdoor air pollution is a major public health concern in China. This study described that short-term exposure to outdoor air pollution can lead to the occurrence or exacerbation of COPD (Chronic obstructive pulmonary disease), leading to substantial medical expenses for patients (18). NO_2 exposure in the long-term time may induce an increase a human risk of respiratory disorder experiencing, including street vendors and workers at the study site. In this study, it was known that RQ <1 (safe), however there were still health complaints related to respiratory disorders such as cough, sore throat, and shortness of breath in workers. This condition is considered a result of the respondent behavior. Other risk factors that can affect the level of health risk are smoking habits and the PPE uses of respondent during doing their activity in the study site. The most common respiratory problem encountered begins with coughing, it is one of the reflex actions of the respiratory tract that is used to clear the upper respiratory tract and is also the first symptom that appears from an illness (19). According to the U.S. EPA (2014) which states that the gas that can cause inflammation of the respiratory tract and increase the onset of cough symptoms comes from nitrogen dioxide (20).

In this study, the respondent's coughing symptoms could not be done directly with NO_2 exposure, because the RQ value <1. The smoking behavior of the respondents could be the cause of this condition. Cigarettes are addictive substances that when used will have a dangerous impact on health. One cigarette contains substances that are not needed for breathing such as nicotine, carbon monoxide, tar, and others when enter the body may lead a respiratory problem such as coughing, shortness of breath, and chest pain [21]. Smoking may cause respiratory disease and decrease lung function, smoking is known to cause pneumonia and all the symptoms of respiratory illness including cough, whooping cough, and phlegm [22].

The low awareness of the street vendors and a worker at the gas station in using masks can also be the cause of their experiencing symptoms of coughing and shortness of breath. The use of PPE (personal protective equipment) while working is very important to reduce the risk of health problems (Hapsari & Munawi, 2021). The use of PPE including masks has been regulated in the Regulation of the Minister of Manpower and Transmigration No. 8/Men/ VII/2010 concerning Personal Protective Equipment that workers who enter the workplace must wear or use PPE in accordance with the potential hazards. WHO (2020) explained that the use of the right type of mask for people who are in public places and physically fit is a non-medical mask or cloth mask. However, non-medical masks must be recommended to have a three-layer structure [22].

CONCLUSION

The research concluded that all sampling points had NO2 concentrations that were still below the quality standard. Apart from that, all respondents who were exposed to NO2 at the research location had an RQ value < 1, which means they had no risk of health problems due to NO2 exposure. Even though the RQ value is <1, an increase in the number of vehicles in the future has the potential to increase NO2 levels in the air.

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