Kesmas

Volume 19
Issue 5 *Special Issue 1, July*

Article 8

7-31-2024

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Nuansa Dwika Aulia
Universitas Indonesia, Depok, nuansa.dwika@ui.ac.id

Budi Hartono
Universitas Indonesia, Depok, butoniu73@gmail.com

Recommended Citation

Aulia ND , Hartono B . Environmental Health Risk Analysis of SO2 and NO2 in Kemiri Muka Village, Depok City, Indonesia. *Kesmas*. 2024; 19(5): 56-60
DOI: 10.21109/kesmas.v19isp1.1310
Available at: https://scholarhub.ui.ac.id/kesmas/vol19/iss5/8

Aulia *et al. Kesmas: Jurnal Kesehatan Masyarakat Nasional (National Public Health Journal)*. 2024; 19 (Special Issue 1): 56-60
DOI: 10.21109/kesmas.v19isp1.1310

Kesmas: Jurnal Kesehatan Masyarakat Nasional (National Public Health Journal)

Environmental Health Risk Analysis of SO_2 and NO_2 in Kemiri Muka Village, Depok City, Indonesia

Nuansa Dwika Aulia[1,2], Budi Hartono[1*]

[1]Department of Environmental Health, Faculty of Public Health, Universitas Indonesia, Depok, Indonesia
[2]STIKes Bina Cipta Husada Purwokerto, Purwokerto, Indonesia

Abstract

Kemiri Muka is a village in Beji Subdistrict, Depok City, Indonesia. Based on a preliminary survey conducted in one of the neighborhood units of Kemiri Muka Village, the residential had a high density of houses and was close to traditional markets, toll roads, the main road of Depok City, and landfills. This caused the air quality in the village area to decline. This study aimed to analyze risks to public health and the environment from exposure to toxic substances, SO_2 and NO_2, which are high in the air due to transportation on the highway and population density. The sample from this study consisted of three age groups: 15 adults, 3 school-age children, and 5 toddlers. This study used the Environmental Health Risk Analysis to analyze the data. Based on the results, the risk quotient (RQ) of non-carcinogenic effects by exposure to inhalation of chemical agents, NO_2 and SO_2, were also included in safe risk because all RQ values were <1. The public should remain alert to their health conditions and continue to take preventive measures.

Keywords: Depok, Environmental Health Risk Analysis, NO_2, risk quotient, SO_2

Introduction

The transportation sector largely contributes to the air pollution in cities, mostly from emissions it produces, particularly SO_2 and NO_2, which contribute to air pollution in Depok City, Indonesia. Regarding pollution issues, temperature, and rainfall trends in this city basically can be seen from an analysis of the same trends within the last ten years in Bogor City and small waterfall areas directly bordering Depok City.[1] Observing types of pollutants is then necessary as a preventive measure to determine the pollution levels.

Environmental Health Risk Analysis (ERHA) is a scientific framework for solving environmental and health problems.[2] The United States Environmental Protection Agency defines the ERHA as a scientific evaluation of the potential health effects that may result from exposure to a particular substance or mixture thereof under specified conditions.[3] Apart from having a direct impact on human or individual health, air pollution also has an indirect impact on health. The effect of SO_2 on vegetation is known to cause blanching in the areas between veins or leaf edges. Emissions of Fluorine (F), Sulfur Dioxide (SO_2), and Ozone (O_3) interfere with the assimilation process in plants. Vegetable plants are exposed to/contain Pb pollutants, which ultimately have the potential to pose a public health hazard to vegetable plants.[3]

From monitoring via IQAir, the air quality status of Depok City is unhealthy, with an air quality index of 176 AQI US; hence, a public health risk analysis needs to be carried out to estimate health impacts resulting from exposure to environmental media contaminated with hazardous substances.[4] Depok City has some environmental problems, specifically in Kemiri Muka Village. Based on a preliminary survey conducted in the village, the residential location had a high density of houses and was close to traditional markets, toll roads, the city's main roads, and landfills.

One of the traditional markets in the subdistrict is Kemiri Muka Market. Based on the 2020 data on market hygiene and sanitation inspection in Depok City, Kemiri Muka Market received a score of 3604 with a percentage of 38.8%, below the scores for Sukatani Market and Cinere Fresh Market.[5] This shows that Kemiri Muka Market does not meet cleanliness and health requirements, which relates to the market's environmental conditions. This study aimed to carry out an environmental health risk analysis related to the toxic substances, SO_2 and NO_2, in Kemiri Muka Village, Beji Subdistrict, Depok City, West Java Province, Indonesia.

Correspondence: Budi Hartono, Department of Environmental Health, Faculty of Public Health, Universitas Indonesia, Depok 16424, Email: butoniu73@gmail.com. Phone: +62 819-3464-7604*

Received : March 12, 2024
Accepted : July 3, 2024
Published: July 31, 2024

Method

This study used ERHA, an approach to quantify or estimate risks to human health, including identifying the presence of uncertainty, tracing specific exposures, and taking into account the inherent characteristics of the agent of concern and the characteristics of a particular target to analyze the data. The ERHA includes four steps: hazard identification, dose-response analysis, exposure assessment, and risk characteristics to estimate health risks to monitor carcinogenic and non-carcinogenic effects.[2]

The population was 120 households living in Kemiri Muka Village, specifically in Neighborhood Unit 001, Community Unit 10. Random sampling was carried out with inclusion criteria, including residents staying at home for a minimum of 12 hours per day and living in the area for at least six months. While, exclusion criteria were residents of Kemiri Muka Village but were not based in the area. The number of respondents obtained was 23 people, consisting of five children aged 6-12 years, three adolescents aged 13-18 years, and 15 adults older than 19 years. In measuring air parameters, the air sampling location was determined at a point where the public frequently passes by either using vehicles or on foot.

This study measured the air quality of Kemiri Muka Village, which was close to the market area. Kemiri Muka Village has a traditional market with many environmental problems, including poor sanitation facilities.[5] The poor condition of Kemiri Muka Market would directly impact the health of residents living around, specifically residents at Neighborhood Unit 001, Community Unit 10. Therefore, a survey was conducted on anthropometric exposure factors, especially regarding activity patterns in the area.

Air chemical parameters were then examined by taking samples of SO_2 and NO_2 compounds. Besides, a physical inspection of dust was carried out using a dust track for one hour. The air samples were explained in the accredited Environmental Health Laboratory, Faculty of Public Health, Universitas Indonesia. Data on anthropometric exposure factors, activity patterns, and community health profiles were processed, analyzed, and collected in December 2023. Dose-response analysis was carried out to determine the quantitative value of the toxicity of a risk agent according to each form of chemical species listed in the RfC (for air/inhalation).

Table 1. Dose-Response to Inhalation Exposure Risk Chemical Agents[6]

Dose-Response Agent	Critical and Reference Effect
NO_2 0.02	Respiratory tract disorders
SO_2 0.21	Respiratory tract disorders

Exposure analysis is a step to determine the exposure route of a risk agent into the body, whether through inhalation, ingestion, or absorption so that the amount of intake received by the at-risk population can be calculated.[7] The intake of each risk agent (chronic daily intake (CDI) and lifetime average daily dose (LADD)) must be calculated for all exposure routes according to the anthropometric characteristics and activity patterns of the population at risk. When determining the inhalation of SO_2 and NO_2 in air, anthropometric parameters (body weight and inhalation rate) and activity patterns (time, frequency, and duration of exposure) were also needed. The level of risk can be calculated by the following equation:

$$\mathrm{I} = \frac{\mathrm{C}\ x\ \mathrm{R}\ x\ \mathrm{t}E\ x\ \mathrm{f}E\ x\ \mathrm{D}t}{\mathrm{W}b\ x\ \mathrm{t}avg}$$

Here is the explanation of the equation above: I was to describe the inhalation intake (mg risk agent/kg individual body weight/day), C means the concentration of risk agent in the air (mg risk agent/m^3 of air), R means the inhalation rate (m^3 air/hour), tE means the duration of exposure (hours/day), fE means the exposure frequency (350 days/year), and Dt means the duration of exposure. Meanwhile, Wb means individual body weight (kg), and tavg means the average time.

Health risk characteristics were expressed as the risk quotient (RQ) or hazard index (HI) for non-carcinogenic effects. The RQ was calculated by comparing or dividing the non-carcinogenic intake (CDI or LADD) of each risk agent by its reference dose (RfD). Health risk and the need for risk management are measured on water or air parameters if the RQ >1 for non-carcinogenic effects, which also means that the CDI exceeds the RfD/RfC.

Characterization of exposure risks to inhaled chemicals, particulates, and probability of pathogen microbiological illness. The health risk characteristics of exposure to SO_2 and NO_2, PM_{10}, and $PM_{2.5}$ to air were estimated as the RQ for non-

carcinogenic effects. The RQ was the division between inhalation intake (I) and RfC, with the following formula:

$$RQ = \frac{1}{RfC}$$

The results of the RQ calculation showed the level of public health risk due to inhaling air containing SO_2 and NO_2. If the RQ>1, the exposure inhaled by the public is dangerous, contains toxic gases, and can cause health problems if inhaled for a long time.

Results

Measurements of the characteristics of anthropometric exposure factors were carried out on 23 respondents from six households at Neighborhood Unit 01, Kemiri Muka Village. The household selection was based on inclusion criteria, including households whose family members were in the categories of adults (>=19 years), adolescents (13-18 years), and school-age children (6-12 years).

Table 2. The Respondents' Characteristics

Variable	Adult (n=15)	Adolescent (n=3)	Children (n=5)
Anthropometry			
Wb	53.67	50.33	23.8
fE	365	365	365
tE	21	13	8
Consumption rate			
Drinking water	1.5	1.5	0.9

Notes: Wb = individual body weight (kg), fE = exposure frequency (350 days/year), tE = duration of exposure (hours/day)

The hazard identification stage identifies the type, characteristics, and capabilities inherent in a risk agent that can negatively impact an organism, system, or sub/population.[7] The results of the SO_2 air contaminants were 750 mmHg of average air pressure and 29.6°C of average temperature, with 15 motorcycles passing by during 1 hour of measurement. In the Indonesian Regulation Number 22 of 2021 concerning Environmental Management and Protection, SO_2 per hour is 150 µg/Nm3; thus, the SO_2 air sample results still met quality standards.[7]

Meanwhile, the results of NO_2 air contaminants were 996.6 mmHg of average air pressure and 25°C of average temperature, with 15 motorcycles passing by during 1 hour of measurement. In the Indonesian Regulation Number 22 of 2021 concerning Environmental Management and Protection, NO_2 per hour is 200 µg/Nm3; thus, the NO_2 air sample results still meet quality standards.[7]

Characterization of exposure risks to inhalation of SO_2 and NO_2 chemicals. Air chemical parameter measurements were carried out by involving two compound elements, NO_2 and SO_2. The RQ value was calculated by dividing CDI by the RfD. The measurement results are shown in the table below:

Table 3. Estimated Chronic Daily Intake and Total Risk Quotient of Non-Carcinogenic Air Chemicals NO_2 and SO_2

Chemical Compounds	C	R	Fe	Wb	Dt	tavg	CDI	RfC	RQ
NO_2	0.0002032	0.83	365	53.67	21	7665	$3.1x10^{-6}$	0.02	$1.5x10^{-4}$
SO_2	0.000216	0.83	365	53.67	21	7665	$3.3x10^{-6}$	0.21	$1.5x10^{-4}$

Notes: C = concentration of risk agent in the air (mg risk agent/m^3 of air), R = inhalation rate (m^3 air/hour), tE = duration of exposure (hours/day), fE = exposure frequency (350 days/year), Dt = duration of exposure, Wb = Individual body weight (kg), tavg = average time.

Based on the table above, the RQ value for the chemical parameters NO_2 and SO_2 shows an RQ value of <1. This showed that no health risks were found from NO_2 or SO_2 compounds. Therefore, there was no need for control except to maintain SO_2 and NO_2 concentrations and activity patterns as they were at that time.[8]

Discussion

A previous study in the Kalianak Area of Surabaya City, Indonesia, using the ERHA, found that the risk agents NO_2 and SO_2 had non-carcinogenic effects, especially on breathing. The major source of chemical compound pollution comes

from mobile emission sources: transportation exhaust gases and motor vehicles. These exhaust gas emissions are often closer to the community, especially those living on the side of the main road with high traffic density.[9] Such conditions make people living in these areas more likely to be exposed to the risk agents NO_2 and SO_2 from the combustion of motor vehicle engines. NO_2 is a reddish-brown chemical compound with a sharp odor and is very toxic to the respiratory tract. Exposure to this gas in the human body will cause swelling of the lungs, resulting in shortness of breath, convulsions, and even death.[10]

The toxicity of NO_2 gas is four times stronger than the toxicity of NO gas. The body organs most sensitive to NO_2 gas pollution are the lungs. Lungs contaminated with NO_2 gas will swell so that sufferers have difficulty breathing, which can cause death. Air containing NO gas within normal limits is relatively safe and not dangerous, except for NO gas in high concentrations. High concentrations of NO gas can cause disturbances in the nervous system, resulting in seizures. If this poisoning continues, it can cause paralysis. NO gas will be more dangerous if the gas is oxidized by oxygen to become NO_2 gas. NO_2 is also highly reactive and has been reported to cause bronchitis and pneumonia, as well as increasing susceptibility to respiratory tract infections.[9]

SO_2 is a chemical compound that is colorless and has a sharp odor. When this gas accumulates in the body, it can cause respiratory problems, especially lung function, irritation, and asthma.[11] A dose-response assessment is used to determine the toxicity value of a risk agent and is the most important step because the ERHA study can only be carried out if the toxicity value is known.[12] SO_2 is a toxic sulfur oxide compound and a pollutant that is dangerous for health, particularly for the elderly and those suffering from chronic diseases of the respiratory and cardiovascular systems.[13]

This is because SO_2 gas, which easily turns into acid, attacks the mucous membranes in the nose, throat, and respiratory tract, some of which reach the lungs. SO_2 gas attacks cause irritation to the affected body parts. If irritation occurs in the respiratory tract, SO_2 and its particulates can cause swelling of the mucous membranes. The formation of mucosa creates obstacles to airflow in the respiratory tract. This condition will be more severe in sensitive groups, such as people with heart or lung disease, and the elderly.[14]

In urban areas, especially big cities in Indonesia, air pollution has become a serious problem. Without realizing it, the air quality in urban areas has reduced the citizens' quality of life, especially in the transportation and industrial areas.[15] The primary source of SO_2 is the burning of fossil fuels, such as motor vehicles, coal-fired power plants, and others.

Conclusion

The public should remain alert to their health conditions and continue to take preventive measures, such as using masks, doing activities outside the home as necessary, and planting more plants that can absorb pollutants from toxic substances in the air. Future studies and follow-up actions by relevant stakeholders are needed, specifically the Depok City Government, to pay attention to the population density and reduce the air pollution problem by providing more open green space.

Abbreviations

ERHA: Environmental Health Risk Analysis; SO_2: sulfur dioxide; NO_2: nitrogen dioxide; RfC: reference concentration; CDI: chronic daily intake; LADD: lifetime average daily dose; RQ: risk quotient; HI: hazard index; RfD: reference dose.

Ethics Approval and Consent to Participate

This study protocol was approved by the Ethics Committee of the Faculty of Public Health Universitas Indonesia number 706/UN2.F10.D11/ppm.00.02/2023. Before the survey, written informed consent was obtained from individuals aged 18 years or older. For individuals between 1 and 17 years, consent was obtained from caregivers.

Competing Interest

The authors declare that no significant competing financial, professional, or personal interests might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

Data were available upon request.

Authors' Contribution

NDA performed data collection, data analysis, and interpretation, as well as manuscript writing. BH provided scientific input on manuscript writing.

Acknowledgment

The authors would like to thank the Depok City Health Office and the Kemiri Muka Primary Health Care for granting permission for the research, as well as to the people of neighborhood unit 01, community unit 10, Kemiri Muka Village, who have been willing to support this research and become supportive respondents.

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