International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Environmental health risk analysis of exposure to ammonia (NH_3) and nitrogen dioxide (NO_2) gas in PT Ayam Makmur Jaya Tenggarong Seberang Livestock Cage workers

Mustika Bakri[1*], Anwar Mallongi[1], Hasnawati Amqam[1], Agus Bintara Birawida[1], Sukri Palutturi[2], Abdul Salam[3]

[1]*Department of Environmental Health, Faculty of Public Health, Hasanuddin University, 90245 Tamalanrea, Makassar, Indonesia*

[2]*Departement of Health Administration and Policy, Faculty of Public Health, Hasanuddin University, 90245 Tamalanrea, Makassar, Indonesia*

[3]*Department of science and nutrition, Faculty of Public Health, Hasanuddin University, 90245 Tamalanrea, Makassar, Indonesia*

Abstract

Livestock farming has been proven to be a major source of zoonotic pathogens and air pollutants including particulate matter, endotoxins, ammonia, volatile organic compounds. The aim of this study was to analyze the level of health risks due to exposure to Ammonia and Nitrogen Dioxide Gas as well as respiratory complaints in PT livestock cage workers. Ayam Makmur Jaya Tenggarong Seberang. This type of research is analytical observational research using the Environmental Health Risk Analysis (EHRA) approach with the aim of assessing or estimating the magnitude of human health risks caused by exposure to environmental hazards. Result shows the highest concentration of NH_3 and NO_2 at the research location is at point/location Delta 1 No. Cage 14 was 2 ppm and the lowest was at point/location Delta 1 No. Cage 1 was <0.009 ppm. Meanwhile, the highest NO_2 concentration at the research location was at the Doc 2 point/location at 95.87 ppm and the lowest was at the Delta 2C point/location at < 4.88 ppm. Health risks from exposure to NH_3 and NO_2 pollutant gases in PT livestock cage workers. Ayam Makmur Jaya Tenggarong Seberang was found to have all health risk locations because the RQ value was > 1. Risk management needs to be done by reducing the magnitude of the risk, the concentration of NH_3 and NO_2 pollutant gases in the chicken coop, namely the duration of exposure, time of exposure, and frequency of exposure.

Keywords: EHRA, NH_3, NO_2, Risk Management, Livestock Cage Workers.

Full length article **Corresponding Author*, e-mail: mustikabakri09@gmail.com

1. Introduction

Chicken farming is a livestock subsector that is currently developing very rapidly and has the highest demand compared to other types of poultry [1]. Livestock farming has been shown to be a major source of zoonotic pathogens and air pollutants including particulate matter, endotoxins, ammonia, volatile organic compounds, and greenhouse gases [2-6]. One of the negative impacts resulting from the livestock industry is environmental pollution in the form of odors and production waste. One of the factors that causes unpleasant odors is the high content of NH_3 and NO_2. In fact, chicken manure can decompose into other toxic gases such as H_2S, CO_2 and methane, but among these toxic gases the ones that cause the most health problems are NH_3 and NO_2 [7]. NH_3 is a toxic and corrosive gas and is an irritant to humans. NH_3 can enter the human body through inhalation, ingestion and dermal routes. On average, 78.3% of NH_3 enters the body via inhalation and 21.7% via ingestion. Chronic toxicity of ammonia at levels >35 ppm can cause kidney damage, lung damage, reduced growth and brain malfunction as well as decreased blood values which can cause throat cancer [8].

Based on research conducted by Annisa, S. (2019) on workers and communities in the Surya Laying Chicken Farm area in Padang, exposure to ammonia gas can cause respiratory problems [9]. At levels of 5-50 ppm ammonia gas causes dry nose, nervous exhaustion, at levels of 1000-1500 ppm it can cause dyspnea, chest pain, spasms in the respiratory tract and delayed pulmonary edema which can be fatal. Research on other ammonia gas which can cause respiratory problems was also carried out by Arini in communities around PT broiler chicken farms. Ciomas Padang City in 2018 showed that the average concentration of NH_3 at 4 sampling points was 0.308 mg/m3. The lifetime intake value of NH_3 exposure at four sampling points has an RQ value > 1, indicating that exposure is unsafe for people at risk of experiencing respiratory tract disorders so control needs to be carried out [10]. The development of chicken farming can have a negative impact on the surrounding environment. Nitrogen dioxide (NO_2) is one of the air pollutant components which is toxic, has a sharp smell that stings the nose and is brownish red in color which can affect human health [7]. Research conducted by Nopita et al., shows that from livestock activities there is NO_2 gas which has the characteristics of a poison with a sharp smell that stings the nose and is brownish red in color and can cause irritation to the walls of the respiratory organs and can cause narrowing of the airways in both healthy people and asthma sufferers [11]. Based on the results of research conducted by Pohl et al., (2017) estimated the exposure to various airborne pollutants for populations living near 10 poultry CAFOs located in Central Poland [12]. Ammonia (NH_3), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen sulfide (H_2S), methane (CH_4), nitrogen dioxide (NO_2), nitrous oxide (N_2O), sulfur dioxide (SO_2), and dust. While certain pollutant levels are estimated to exceed levels normally found in the environment, this does not result in a calculated hazard index exceeding unity. Environmental health risk analysis is the process of estimating the nature and likelihood of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future [13]. Environmental health risk analysis for livestock industry workers is important to determine the current and future environmental health risks of workers so that policies and risk mitigation efforts can be taken to reduce the number of Occupational Diseases (PAK) which can affect worker productivity and factory production capacity. PT Ayam Makmur Jaya is a large-scale laying hen farm with a number of ± 200,000 chickens and there are 33 cages with a manure volume of 2-5 sacks per day. The manure produced from the livestock is used and sold as fertilizer. Every day PT. Ayam Makmur Jaya always operates considering the condition of the chickens which always require special treatment. Cage workers on chicken farms are workers who are at risk of experiencing health problems. Based on a preliminary survey conducted by researchers on PT. Makmur Jaya chickens are known to complain of a strong smell from chicken droppings and experience signs of health problems such as dizziness, sore eyes, dry and hot throats, and coughing after or while doing work. Based on the description, the researcher wants to conduct research on environmental health risk analysis of exposure to ammonia and nitrogen dicocide gas in cage workers on PT farms. Ayam Makmur Jaya Tenggarong opposite.

2. Materials and methods

2.1. Type of Research

This type of research is analytical observational research using the Environmental Health Risk Analysis (EHRA) approach with the aim of assessing or estimating the magnitude of human health risks caused by exposure to environmental hazards [14]. This research includes field observations and interviews using a questionnaire. An analysis will be carried out by calculating or estimating the amount of environmental health risk received by cage workers as a result of exposure to ammonia and nitrogen dioxide gas on PT farms. Ayam Makmur Tenggarong Seberang. Taking samples and continuing with laboratory examination.

2.2. Population and Sample

The population of workers in this study were all 39 livestock cage workers who worked on PT farms. Ayam Makmur Jaya Tenggarong Seberang. The technique used in selecting research subjects is total sampling, namely a sampling technique by making all elements of the population into sample elements [15]. The sample that will be taken in this research is a total sampling, all livestock workers at PT. Ayam Makmur Jaya as many as 39 people. The environmental samples in this study were air quality parameters NH_3 and NO_2, at three different sampling points on the PT farm. Ayam Makmur Jaya Tenggarong Seberang

2.3. Research Instrument

2.3.1. Spectrophotometer

The ammonia sampling technique in this research refers to the Indonesian National Standard (SNI) [16].

2.3.2. Questionnaires and Interviews

Questionnaires and interviews in this study were used to obtain data on respondents' characteristics, exposure patterns (time of exposure, frequency of exposure, duration of exposure) such as number of hours worked in a day, body weight and identifying data such as name, age and gender, use of PPE (masks) and subjective health complaints felt by respondents.

2.3.3. Risk Analysis and Environmental Health Risk Management

$$ADD = \frac{C_{air}\ x\ InhR\ x\ ET\ x\ EF\ x\ ED}{BW\ x\ AT} \quad \text{Equality (1)}$$

Where:

- ADD=Average Daily Dose, average daily dose (mg/kg/day).
- C_{air}=Concentration of contaminate in air, concentration of pollutant in ambient air (mg/m^3).
- InhR=Inhalation rate, Inhalation Rate (m^3/hour).
- ET=Exposure time, exposure time (hours/day).
- EF=Exposure frequency, frequency of exposure in days of the year (days/year).
- ED=Exposure duration, duration of exposure, number of years the exposure occurred (years).
- BW=Body weight, Body weight (Kg).

- AT=Average time, average time period (days) of non-carcinogenic effects, 30 years x 365 days/year = 10,950 days

$$RQ = \frac{ADD}{RfC} \quad \text{Equality (2)}$$

Where:
- RQ=Risk characteristics.
- R_fC=Response concentration analysis.
- ADD=Intake (exposure).

The results of the RQ calculation will be known:
- An RQ value of > 1 indicates that non-carcinogenic effects are not a problem and conditions are maintained, and an RQ value of > 1 indicates that non-carcinogenic effects are serious and require risk management and in-depth toxicological effects [17].
- After carrying out an environmental health risk analysis and obtaining a Risk Quotient (RQ) value > 1, follow-up actions must be carried out. In risk management, a risk management strategy is carried out which includes determining safe limits, namely [18].

2.3.3.1. Risk agent concentration (C)

Decreased concentration to safe limits

$$C_{safe} = \frac{RfC\ x\ BW\ x\ AT}{InhR\ x\ ETx\ EF\ x\ ED} \quad \text{Equality (3)}$$

2.3.3.2. Exposure Time (ET), Exposure Frequency (EF) and Exposure Duration (ED)

Limit working hours, working days or length of work (years).

$$ET_{safe} = \frac{RfC\ x\ BW\ x\ AT}{C_{air}\ x\ InhR\ x\ EF\ x\ ED} \quad \text{Equality (4)}$$

$$EF_{aman} = \frac{Rfc\ x\ BW\ x\ AT}{C_{air}\ x\ InhR\ x\ ET\ x\ ED} \quad \text{Equality (5)}$$

$$ED_{safe} = \frac{Rfc\ x\ BW\ x\ AT}{C_{air}\ x\ InhR\ x\ ET\ x\ EF} \quad \text{Equality (6)}$$

2.4. Ethical approval of research

This research was conducted in accordance with ethical recommendations and received approval with financial support number: [5749/UN4.14.1/TP.01.02/2023].

3. Results

3.1. Study Area's

Livestock PT. Ayam Makmur Jaya is the largest laying hen farm in the Tenggarong area with a land area of 200,000 m2 and has 33 chicken cage and a livestock population of around ± 200,000 chickens. So, these farms produce large amounts of chicken manure and ammonia and nitrogen dioxide gas. The research included measuring the levels of ammonia and nitrogen dioxide gas in the cages and the risk to the health of cage workers. Based on the data in Figure 2, it shows that the results of measuring NH_3 and NO_2 concentrations at the research location, the highest NH_3 concentration was at point/location Delta 1 Cage 14 was 2 ppm and the lowest was at point/location Delta 1 Cage 1 was < 0.009 ppm. This quality standard refers to the 2016 USEPA of 25 ppm. Meanwhile, the NO_2 concentration at the research location was highest at Doc 2 point/location at 95.87 ppm and the lowest was at Delta 2C point/location at < 4.88 ppm. This quality standard refers to the 2018 Machdar of 200 ppm. Based on the data in Table 1, it shows that there are 65% more male respondents than 35% female respondents. For the age range of respondents, the largest age range was 31 - 40 years, 13 people (32%). For body weight, respondents with the highest weight range of 41 – 50 kg were 15 people (37%) and those with the lowest weight > 70 kg were 4 people (10%). Based on Table 2, it shows that the duration of work for all respondents was 26 days/month, for the duration of exposure the highest was in the range of 1-5 years working as many as 28 people (70%) and at least >10 years working as many as 5 people (12%) with the exposure time for all respondents was 8 hours/day at 100%. For the highest frequency of exposure during 305 days/work year, 30 respondents amounted to 75%. Table 3 shows that the results of the ADD (average daily dose) calculation for the NH_3 concentration at point 1 (Delta 1 cage 1) obtained a mean value of $1.2621x10^{-2}$. The ADD (average daily dose) results for the NH_3 concentration at point 2 (Delta 1 cage 14) obtained a mean value of $2.8023x10^{1}$. The ADD (average daily dose) results for the NH_3 concentration at point 3 (Delta 2D) obtained a mean value of $1.2621x10^{-1}$. The ADD (average daily dose) results for NH_3 concentration at point 4 (Employee Mess) obtained a mean value of $1.2621x10^{-1}$. The ADD (average daily dose) results for the NH_3 concentration at point 5 (Doc 2) obtained a mean value of $1.8643x10^{1}$. Meanwhile, the NH_3 concentration at point 6 (Delta 2C) obtained a mean value of $1.2621x10^{-1}$. Based on Table 4, it shows that the results of the ADD (average daily dose) calculation for NO_2 concentration at point 1 (Delta 1 cage 1) obtained a mean value of $2.5101x10^{1}$. The ADD (average daily dose) results for NO_2 concentration at point 2 (Delta 1 cage 14) obtained a mean value of $5.1069x10^{1}$. The ADD (average daily dose) results for NO_2 concentration at point 3 (Delta 2D) obtained a mean value of $8.6625x10^{1}$. The ADD (average daily dose) results for NO_2 concentration at point 4 (Employee Mess) obtained a mean value of $6.8360x10^{1}$. The ADD (average daily dose) results for NO_2 concentration at point 5 (Doc 2) obtained a mean value of $1.3438x10^{2}$. Meanwhile, the NO_2 concentration at point 6 (Delta 2C) obtained a mean value of $6.8360x10^{1}$. Based on Table 5, it shows that from all the locations where NH_3 concentrations were measured to determine the risk assessment of NH_3 exposure to public health, all location points were found to be at risk to health because the RQ value was > 1. Based on Table 6, it shows that from all the locations where NO_2 concentrations were measured to determine the risk assessment of NO_2 exposure to public health, all location points were found to be at risk to health because the RQ value was > 1. Based on the data in Table 7, it shows that NH_3 exposure risk management can be carried out by reducing the duration of exposure at the Delta 1 cage 1 location with a std deviation of $1.37654x10^{8}$, Delta 1 cage 14 with a std of $6.71775x10^{5}$, Delta 2D with a std deviation of $1.37654x10^{7}$, Employees Mess with a std deviation of $1.37654x10^{7}$, DOC 2 with a std deviation of $1.03280x10^{6}$ and in Delta 2C with a std deviation of $1.37654x10^{7}$.

For the exposure time variable, risk management can be carried out at the Delta 1 cage 1 location with a std deviation of $4.50981x10^{8}$, Delta 1 cage 14 with a std of $2.16882x10^{6}$, Delta 2D with a std deviation of 4.50981x10^7, Employee Mess with a std deviation of 4.50981x10^7, DOC 2 with a std deviation of 2.58554x10^6 and in Delta 2C with a std deviation of 4.50981x10^7. Meanwhile, for exposure frequency, risk management can be carried out in Delta 1 cage 1 with a std deviation of 1.28749x10^7, Delta 1 Kandang 14 with a std of 5.90554x10^4, Delta 2D with a std deviation of 1.28794x10^6, Employee Mess with a std deviation of 1.26749x10^6, DOC 2 with a std deviation of 9.14551x10^4 and in Delta 2C with a std deviation of 1.28749x10^6. Based on the data in Table 8, it shows that NO_2 exposure risk management can be done by reducing the duration of exposure at the Delta 1 cage 1 location with a std deviation of 4.64095x10^5, Delta 1 cage 14 with a std of 1.23101x10^5, Delta 2D with a std deviation of 8.00240x10^5, Employees Mess with a std deviation of 1.04728x10^6, DOC 2 with a std deviation of 5.85861x10^4 and in Delta 2C with a std deviation of 1.04728x10^6. For the exposure time variable, risk management can be carried out at the Delta 1 cage 1 location with a std deviation of 8.25724x10^5, Delta 1 cage 14 with a std of 4.39999x10^5, Delta 2D with a std deviation of 2.33027x10^6, Mess Employee with a std deviation of 2.51897x10^6, DOC 2 with a std deviation of 1.50162x10^5 and in Delta 2C with a std deviation of 2.51897x10^6. Meanwhile, for frequency of exposure, risk management can be carried out in Delta 1 cage 1 with a std deviation of 2.17576x10^4, Delta 1 cage 14 with a std of 1.03388x10^4, Delta 2D with a std deviation of 6.56799x10^4, Employee Mess with a std deviation of 8.08925x10^4, DOC 2 with a std deviation of 4.37499x10^3 and in Delta 2C with a std deviation of 4.37499x10^3

4. Discussion

4.1. NH_3 and NO_2 Concentrations in the Air

Ammonia (NH_3) is a dangerous gas, colorless, has a sharp odor and can be detected at low concentrations, namely 1-5 ppm [19]. Ammonia entering through breathing will be absorbed by the lungs. Then the ammonia will be related to the blood in the lungs [20]. Based on research conducted, the NH_3 concentration in chicken coop workers was obtained at point 1 of < 0.009 ppm, point 2 of 2 ppm, points 3, 4 and 6 of < 0.090 ppm and at point 5 of 1.33 ppm. Wind speed measured in the chicken coop area is in the range 1.4 m/s – 2.5 m/s. The composition of ammonia in clean air is 0.000001%. Ammonia (NH_3) is a gas resulting from the decomposition of nitrogenous waste materials in excreta, such as uric acid, unabsorbed protein, amino acids and other non-protein nitrogen (NPN) compounds due to the activity of microorganisms in the faeces [21]. Apart from polluting the environment, NH_3 gas can reduce the appearance of livestock, increase livestock sensitivity to disease and reduce the work efficiency of stable workers [22]. Excessive NH_3 levels in the cage can affect the health of chickens and cage workers. NH_3 levels in the cage should be no more than 25 ppm and the threshold NH_3 level for humans is 25 ppm for 8-10 hours [23]. In research conducted in Langkat Regency, the results of NH_3 measurements at four chicken farm points showed that there were no ammonia levels that exceeded the quality standards. Wind speed measured at chicken farms is in the range of 0.2 m/s – 0.3 m/s [24]. NH_3 levels that do not exceed the quality standard are influenced by several things, including the time of sampling. Before sampling NH_3 in the air, the chicken coop was clean. Some of the chicken droppings that have accumulated under the coop have been put into sacks to be used as fertilizer. This can affect the NH_3 concentration in the chicken farm. The farm uses open pens to allow sunlight to enter, providing good circulation. So, the smell caused by chicken droppings is not retained in the coop. One of the negative impacts is in the form of emissions that can pollute the air from chicken farming businesses, one of which is nitrogen dioxide (NO_2), which is a component of air pollution which is toxic, has a sharp smell that stings the nose and is brownish red in color which can affect human health. In research conducted by Nopita in 2021, nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza [7]. Exposure to NO_2 of 50 ppm can cause coughing, hemoptysis, dyspnea and chest pain. If exposed to NO_2 higher than 100 ppm, it can produce pulmonary edema which is fatal or can cause bronchiolitis obliterans. Based on research conducted, the concentration of NO_2 gas in chicken coop workers was obtained at point 1 of 17.91 ppm, point 2 of 36.43 ppm, point 3 of 6.18, points 4 and 6 of <4.88 ppm and at point 5 it is 95.87 ppm. Wind speed measured in the chicken cage area is in the range 1.4 m/s – 2.5 m/s. NO_2 concentration measurements were carried out for 1 hour at each sampling point. In the research, the risk agent taken came from exhaust gases during the decomposition process of chicken manure. The decomposition process of chicken manure produces various kinds of air pollutant gases such as ammonia and NO_2 gas. Excessive NO_2 levels in the cage can affect the health of chickens, especially cage workers, can cause irritation to the walls of the respiratory organs and can cause narrowing of the respiratory tract in both humans and asthma sufferers [11]. The concentration of NO_2 which does not exceed the quality standard is influenced by the livestock using open pens to allow sunlight to enter, and there is good circulation. So, the smell from chicken droppings doesn't last long in the coop. Research conducted at a laying hen farm in Bacukiki sub-district, Parepare city, the results of NO_2 measurements at chicken farm sample points showed that there were no NO_2 levels that exceeded the quality standard, namely 0.04 ppm.

4.2. NH_3 and NO_2 Intake in Cage Workers

Exposure analysis and risk characteristics. EHRA is an approach used to assess environmental health risks with the output being risk characteristics (expressed as risk levels) which explain whether risk agents/environmental parameters pose a risk to public health or not. Furthermore, the EHRA results will be managed and communicated to the community as a follow-up [14]. One of the steps in carrying out a health risk analysis is calculating intake or intake from risk agents. To calculate intake, a predetermined equation is used. The equation for analyzing non-carcinogenic environmental health risks for the inhalation route can be seen in the following equation [25].

4.2.1. Intake

Based on the results of the analysis, several results were obtained regarding the characteristics of individuals who work in the PT Ayam Makmur Tenggarong Seberang chicken farm cage. Characteristics of respondents in this study, age, gender, length of time working in the chicken coop in days/months. Most chicken farm workers are men. The number of male workers is influenced by the need for living expenses which is directly felt so that they are more motivated to work for living expenses. Respondents' ages were divided into 2, namely 21-40 years and 41-60 years. Most of the respondents were workers aged 21-40 years. The intake value is the amount of pollutant concentration that enters the human body with a certain body weight every day. The intake value for each individual is obtained using the Average Daily Dose (ADD) multiplication formula for each risk agent which is taken from measuring NH_3 and NO_2 concentrations. (C_{air}) Pollutant concentration in ambient air (mg/m3), (Inhr) inhalation rate (m3/hour) Adults = 0.83 m3/day as standardized by US-EPA, (ET) exposure time (hours/day), (EF) frequency of exposure (days/year), (DT) duration of exposure (years), divided by (BW) body weight (Kg) and (AT) average time period 30 x 365 days/year for non-carcinogenic. As for the results of calculating the concentration of NH_3 and NO_2 gas pollutants entering the body in Table 3 and Table 4, it can be seen that the ADD value of NH_3 and NO_2 is very varied and the average intake is a non-carcinogenic risk where for all samples the intake value is < 0.1. The research calculated the Intake (I) value for the duration of exposure, so that to calculate the intake value for each individual, real-time exposure duration (DT) was used. To calculate non-carcinogenic effects, they are calculated based on the ADD formula. Sitoresmi research in (2022) stated that the intake value is directly proportional to the chemical concentration value, exposure frequency, exposure time and exposure duration, which means that the greater the value, the greater the intake [26]. Meanwhile, the intake value is inversely proportional to body weight and average time. The low intake of ammonia exposure is due to the fact that farmers have not worked for too long, the NH_3 and NO_2 concentrations when measured are low and the NH_3 and NO_2 concentrations are below the threshold value. In line with research which states that the duration of exposure greatly influences a person's intake, so that the longer an employee works, the greater the intake and the risk of having detrimental effects on health.

4.2.2. Weight

Data collection on respondents' weight was carried out directly by measuring body weight directly from respondents based on Table 1. shows the percentage of body weight of cage workers at PT Ayam Makmur Jaya Tenggarong Seberang, the highest weight was 41 - 50 kg as many as 15 people (37%) and the lowest weight was > 70 kg as many as 4 people (10%). In risk analysis, body weight will influence the magnitude of the risk value or RQ, the greater a person's weight, the smaller the risk of experiencing health problems due to air pollution, the fat content tends to be greater in people with high body weight as well. affects the toxic substances that enter the body [27]. Research conducted by Alwi & Yasnani (2016) shows that body weight will affect the nutrients in the human body, people who have an ideal body weight will have sufficient nutrition so that the presence of heavy metals in the body to replace nutrients will be prevented [28]. Research by Girikallo et al., (2022) also shows that someone who has a large body weight will have a greater amount of fat in the body [29].

4.2.3. Duration, Time and frequency of Exposure

Exposure duration is the length of time of cage workers in years. In this study, the exposure duration used is real-time and lifetime (non-exposure duration) carcinogenic 1-30 years. In Table 2, the research results show that the highest duration of exposure was in the range of 1-5 years of work as many as 28 workers (70%) and at least >10 years of work as many as 5 workers (12%). Based on research conducted by Alwi & Yasnani (2016) which states that the longer a person is exposed to dangerous substances, the greater the possibility of health risks they will receive [28]. Even in low concentrations, in the long term it will cause health effects. Regulation of the Minister of Labor and Transmigration No. 5 of 2018 recommends that the number of working hours per day is 8 hours. If the concentration of pollutants in the air is still within normal limits, workers can be exposed to pollutants during 8 working hours, but on the other hand, if the concentration of pollutants in the air is above normal values, it is necessary to regulate the exposure time for workers. The longer workers are exposed, the greater their chances of being exposed to unsafe health risks [30]. The research results are shown in Table 2. The exposure time for workers is 8 hours/day because workers are required to live in the livestock area. In line with research conducted by Andarini (2017) where the exposure time of workers was 24 hours living in a livestock area. Exposure frequency is calculated as the number of days on which the respondent inhaled air [19]. The frequency of exposure will affect gas pollutants that enter a person's body against risk agents. The amount of pollutant received by the respondent in days or years is referred to as exposure frequency. Individuals with the same body weight, exposure duration and exposure time have different intakes and risk levels if the exposure is different. Based on Table 2, the lowest frequency of exposure is 298 days/year and the highest is 305 days/year. Where the longer the frequency of food exposure, the greater the level of risk posed by ammonia and nitrogen dioxide gas.

4.2.4. Risk Characteristics and Management

The final step in environmental health risk analysis is determining the risk characteristics. The way to determine risk characteristics is done by comparing or dividing intake by concentration (R_fC) obtained from USEPA. In this study, agents were studied with non-carcinogenic characteristics. The risk level is said to be safe, if RQ > 1. The risk level is said to be unsafe if the RQ value is < 1 to determine whether the risk agent at a certain concentration analyzed in EHRA is at risk of causing health problems in the community (with characteristics such as certain body weight, time, frequency, duration of exposure) or not [9]. Based on the research results, it was found that all types of samples examined had a non-carcinogenic risk level in NH_3 and NO_2 exposure concentrations at all measurement points/locations which were a risk to health with an RQ value of > 1 (risk needs to be controlled so that the RQ value is < 1).

The average non-carcinogenic Risk Quotient (RQ) calculation is higher due to differences in respondents' body weight, and real-time RQ values for NH_3 and NO_2 exposure. The health impacts that will occur if exposed to NH_3 and NO_2 are irritants to the respiratory organs, and long-term exposure will increase respiratory disorders or diseases such as chronic bronchitis, can cause kidney damage, lung damage, reduce brain growth and malfunction and decrease blood values, where a decrease in blood values can disrupt human physiological processes [31]. One of the benefits of health risk analysis of exposure to a risk agent is that it can predict the health risks a person will face at any given time and then determine preventive measures to minimize the risk [32]. After carrying out the four EHRA steps above, it can be seen whether a risk agent is safe (acceptable) or not. The research results show that risk management is needed to control the health effects caused by exposure to NH_3 and NO_2 in the cage area. According to the EHRA Technical guidelines created by the Director General of P2PL of the Indonesian Ministry of Health, risk management is not included in EHRA steps but rather follow-up actions that must be carried out if the results of risk characteristics show an unsafe or unacceptable level of risk. Risk management aims to control risk factors that can cause health problems due to breathing polluted air. Based on the results of risk level calculations during the RQ NH_3 and NO_2 research (real time), RQ > 1 was declared risky or unsafe for cage workers, so risk management needs to be carried out. In the risk analysis study using an agent-oriented approach, there are several variables that are measured to reduce the magnitude of the risk, the concentration of pollutant gases NH_3 and NO_2 in the chicken coop, namely duration of exposure, time of exposure, and frequency of exposure. In risk management, several of these variables can be controlled to avoid risks resulting from exposure to gas pollutants and disease agents in the environment. The final way that can be done to reduce the risk level of NH_3 and NO_2 pollutant gases for a long time is by using personal protective equipment in the form of a mask. Because masks can minimize the possibility of inhalation of exposure to pollutant gases in the air, so the health risks of cage workers can be prevented.

4.3. Research Limitations

This research has limitations in several aspects. The following limitations were found in this research:

- This research is only limited to the pollutant gases NH_3 and NO_2 and not to other types of pollutants.
- This research data is only based on the results of one measurement, it does not carry out repeated measurements of NH_3 and NO_2 concentrations.
- The concentration of NH_3 and NO_2 pollutant gases included in the Acceptable Daily Dose (ADD) calculation can change throughout the year, or there are differences in concentrations measured in the dry season and the rainy season.

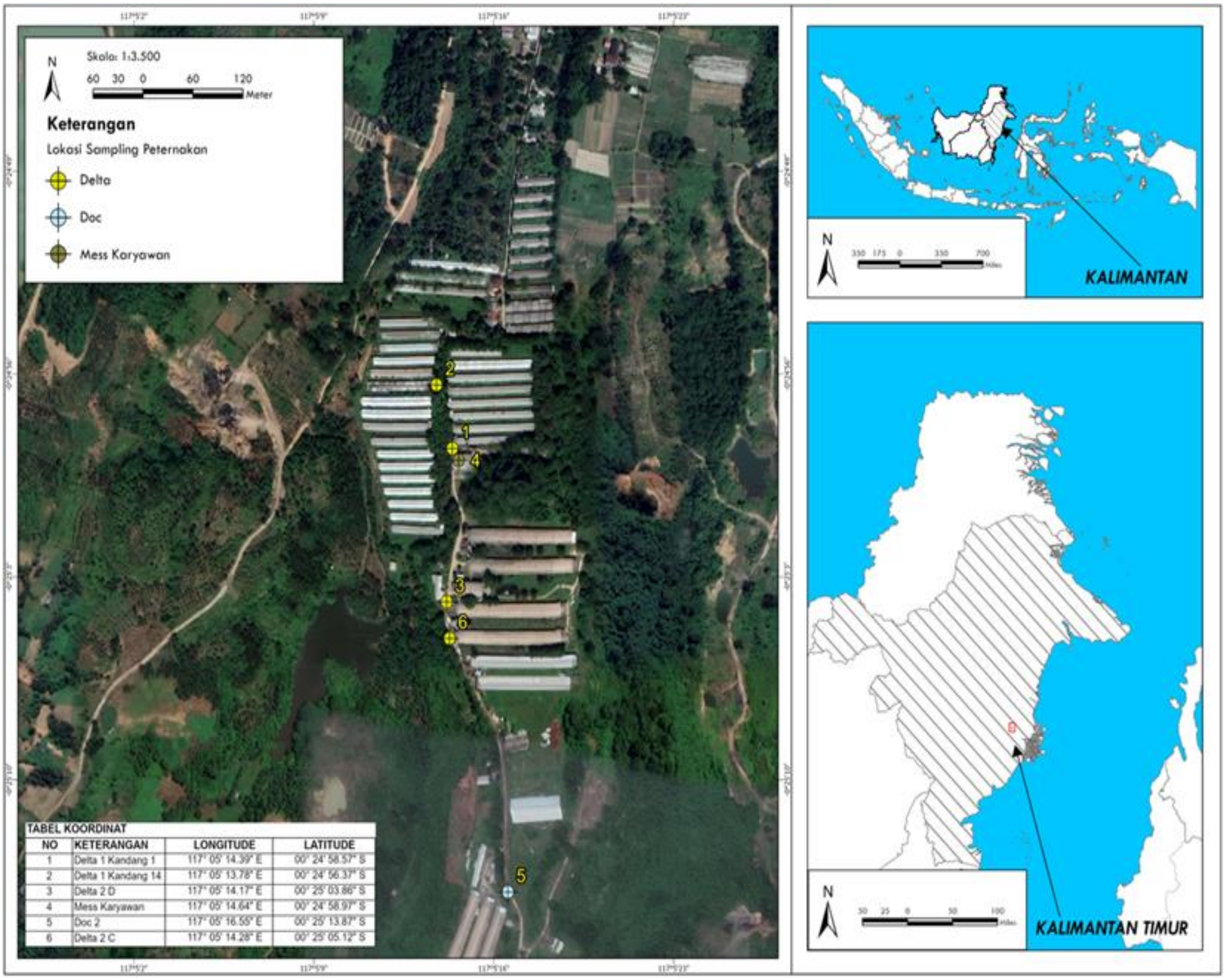

Figure 1: Sampling Point Location.

Table 1: Characteristics of respondents based on gender, age and weight.

Variable	Amount (n)	Percentage (%)
Gender		
Male	26	65.0
Female	14	35.0
Total	40	100.0
Age		
21 – 30 Years	12	30.0
31 – 40 Years	13	32.5
41 – 50 Years	12	30.0
51 – 60 Years	3	7.5
Total	40	100.0
Weight		
41 – 50 Kg	15	37.5
51 – 60 Kg	12	30.0
61 – 70 Kg	9	22.5
> 70 Kg	4	10.0
Total	40	100.0

Source: Primary Data, 2024.

Table 2: Characteristics of Respondents based on length of work, duration of exposure, time of exposure and frequency of exposure.

Variable	Amount (n)	Percentage (%)
Length of Work		
26 day/month	40	100
Duration of Exposure		
1 – 5 Years	28	70.0
6 – 10 Years	7	17.5
> 10 Years	5	12.5
Time of Exposure		
8 hour/day	40	100
Frequency of Exposure		
298 day/years	9	22.5
300 day/years	30	75.0
305 day/years	1	2.5

Source: Primary Data, 2024.

Table 3: ADD (Average Daily Dose) Calculation Results for NH_3 Concentration.

ADD (mg/kg/day)				
Location	**Min**	**Max**	**Mean**	**Information**
Point 1 (Delta 1 Cage 1)	$1.89x10^{-3}$	$4.79x10^{-2}$	$1.2621x10^{-2}$	TN
Point 2 (Delta 1 Cage14)	$4.20x10^{-1}$	$1.06x10^{1}$	$2.8023x10^{1}$	TN
Point 3 (Delta 2D)	$1.89x10^{-2}$	$4.79x10^{-1}$	$1.2621x10^{-1}$	TN
Point 4 (Employee Mess)	$1.89x10^{-2}$	$4.79x10^{-1}$	$1.2621x10^{-1}$	TN
Point 5 (Doc 2)	$2.79x10^{-1}$	$7.07x10^{1}$	$1.8643x10^{1}$	TN
Point 6 (Delta 2C)	$1.89x10^{-2}$	$4.79x10^{-1}$	$1.2621x10^{-1}$	TN

***Information** : Normal (N), Abnormal (TN). Source: Primary Data Has Been Processed 2024.

Table 4: Distribution of Mean Values, Min and Max Values and ADD (Average Daily Dose) Calculation Results for NO_2 Concentration.

ADD (mg/kg/day)				
Location	**Min**	**Max**	**Mean**	**Information**
Point 1 (Delta 1 Cage 1)	$3.76x10^{1}$	$9.52x10^{1}$	$2.5101x10^{1}$	TN
Point 2 (Delta 1 Cage 14)	$7.64x10^{1}$	$1.94x10^{2}$	$5.1069x10^{1}$	TN
Point 3 (Delta 2D)	$1.30x10^{1}$	$3.29x10^{1}$	$8.6625x10^{1}$	TN
Point 4 (Employee Mess)	$1.02x10^{1}$	$2.59x10^{1}$	$6.8360x10^{1}$	TN
Point 5 (Doc 2)	$2.01x10^{1}$	$5.10x10^{2}$	$1.3438x10^{2}$	TN
Point 6 (Delta 2C)	$1.02x10^{1}$	$2.59x10^{1}$	$6.8360x10^{1}$	TN

***Information** : Normal (N), Abnormal (TN). Source: Primary Data Has Been Processed 2024.

Table 5: Results of Risk Quotient (RQ) of NH_3 exposure.

Location	**Min**	**Max**	**Std Deviasi**	**Information**
Delta 1 cage 1	$3.26x10^{-1}$	$7.23x10^{1}$	$1.99208x10^{1}$	Risk
Delta 1 cage 14	$7.23x10^{1}$	$1.83x10^{3}$	$6.99310+10^{1}$	Risk
Delta 2D	$3.26x10^{1}$	$8.25x10^{1}$	$3.14976x10^{1}$	Risk
Employee Mess	$3.26x10^{1}$	$8.25x10^{1}$	$3.14976x10^{1}$	Risk
Doc 2	$4.81x10^{1}$	$1.22x10^{3}$	$4.65675x10^{1}$	Risk
Delta 2C	$3.26x10^{1}$	$8.26x10^{1}$	$3.14976x10^{1}$	Risk

Source: Primary Data Has Been Processed, 2024.

Table 6: Results of Risk Quotient (RQ) of NO_2 Exposure.

Location	Min	Max	Std Deviasi	Information
Delta 1 cage 1	$1.88x10^2$	$4.76x10^3$	$1.114980x10^3$	Risk
Delta 1 cage 14	$3.82x10^2$	$9.68x10^3$	$2.33861x10^3$	Risk
Delta 2D	$6.48x10^1$	$1.64x10^3$	$3.96340x10^2$	Risk
Employee Mess	$5.12x10^1$	1.30E+003	$3.13536x10^2$	Risk
Doc 2	$1.01x10^3$	$2.55x10^4$	$6.15897x10^3$	Risk
Delta 2C	$5.12x10^1$	$1.30x10^4$	$3.13536x10^2$	Risk

Source: Primary Data Has Been Processed, 2024.

Table 7: Min, Max and Std Deviation values in NH_3 Exposure Risk Management.

Variable/Location	Min	Max	Std Deviasi
Duration of Exposure			
Delta 1 cage 1	$6.00x10^8$	$1.00x10^9$	$1.37654x10^8$
Delta 1 cage 14	$3.00x10^6$	$5.00x10^6$	$6.71775x10^5$
Delta 2 D	$6.00x10^7$	$1.00x10^8$	$1.37654x10^7$
Employee Mess	$6.00x10^7$	$1.00x10^8$	$1.37654x10^7$
DOC 2	$4.00x10^6$	$8.00x10^6$	$1.03280x10^6$
Delta 2 C	$6.00x10^7$	$1.00x10^8$	$1.37654x10^7$
Time of Exposure			
Delta 1 cage 1	$8.00x10^7$	$2.00x10^9$	$4.50981x10^8$
Delta cage 14	$4.00x10^5$	$1.00x10^7$	$2.16882x10^6$
Delta 2D	$2.00x10^8$	$2.00x10^8$	$4.50981x10^7$
Employee Mess	$2.00x10^8$	$2.00x10^8$	$4.50981x10^7$
DOC 2	$1.00x10^7$	$1.00x10^7$	$2.58554x10^6$
Delta 2C	$2.00x10^8$	$2.00x10^8$	$4.50981x10^7$
Frequency of Exposure			
Delta 1 cage 1	$2.00x10^6$	$6.00x10^7$	$1.28749x10^7$
Delta 1 cage 14	$9.00x10^3$	$3.00x10^5$	$5.90554x10^4$
Delta 2D	$2.00x10^5$	$6.00x10^6$	$1.26749x10^6$
Employee Mess	$6.00x10^5$	$6.00x10^6$	$1.26749x10^6$
DOC 2	$1.00x10^4$	$4.00x10^5$	$9.14551x10^4$
Delta 2C	$2.00x10^5$	$6.00x10^6$	$1.28749x10^6$

Source: Primary Data Has Been Processed, 2024

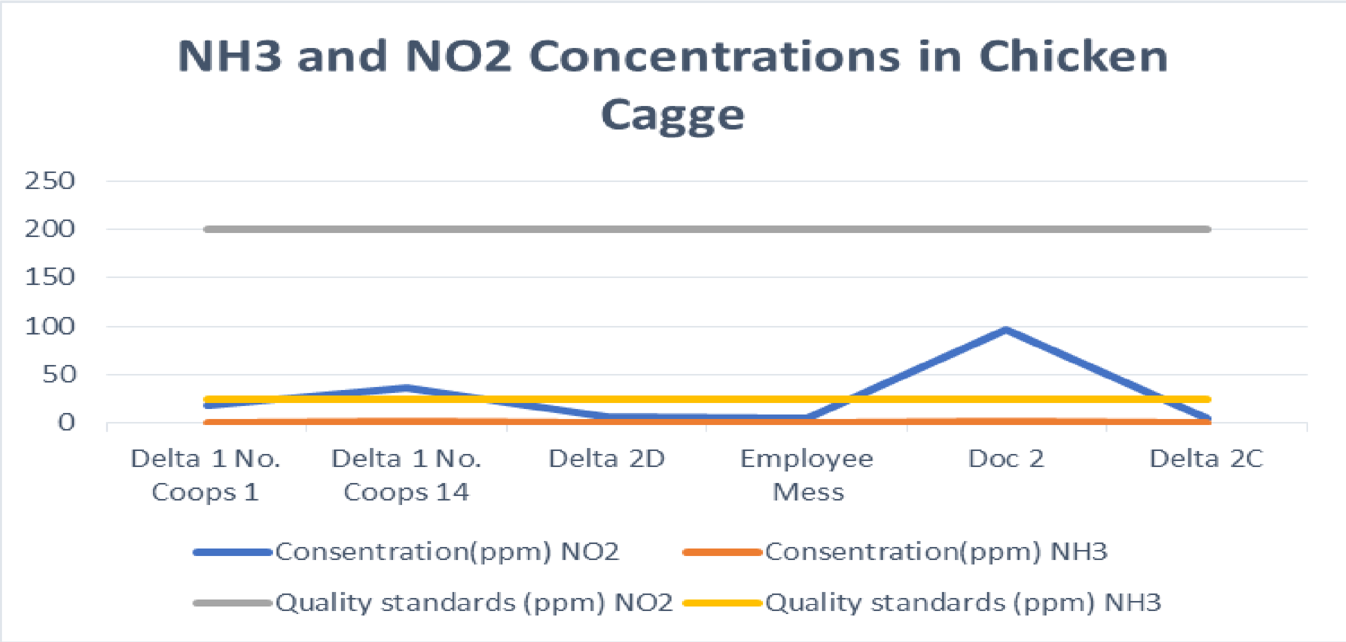

Figure 2: NH_3 and NO_2 Concentrations in Chicken Coops.

Table 8: Min, Max and Std Deviation values in NO_2 Exposure Risk Management.

Variable/Location	Min	Max	Std Deviasi
Durationof Exposure			
Delta 1 cage 1	$1.00x10^6$	$2.00x10^6$	$4.64095x10^5$
Delta 1 cage 14	$5.00x10^5$	$1.00x10^6$	$1.23101x10^5$
Delta 2 D	$3.00x10^6$	$6.00x10^8$	$8.00240x10^5$
Employee Mess	$4.00x10^6$	$8.00x10^6$	$1.04728x10^6$
DOC 2	$2.00x10^5$	$4.00x10^5$	$5.85861x10^4$
Delta 2C	$4.00x10^6$	$8.00x10^6$	$1.04728x10^6$
Time of Exposure			
Delta 1 cage 1	$1.00x10^5$	$4.00x10^6$	$8.25724x10^5$
Delta 1 cage 14	$7.00x10^4$	$2.00x10^6$	$4.39999x10^5$
Delta 2D	$4.00x10^5$	$1.00x10^7$	$2.33027x10^6$
Employee Mess	$5.00x10^5$	1.00E+007	$2.51897x10^6$
DOC 2	$3.00x10^5$	$7.00x10^5$	$1.50162x10^5$
Delta 2C	$5.00x10^4$	$1.00x10^7$	$2.51897x10^6$
Frequency of Exposure			
Delta 1 cage 1	$4.00x10^3$	$1.00x10^5$	$2.17576x10^4$
Delta 1 cage 14	$2.00x10^3$	$5.00x10^4$	$1.03388x10^4$
Delta 2D	$1.00x10^4$	$3.00x10^5$	$6.56799x10^4$
Employee Mess	1.00E+004	4.00E+005	8.08925E+004
DOC 2	7.00E+004	2.00E+004	$4.37499x10^3$
Delta 2C	1.00E+004	4.00E+005	$8.08925x10^4$

Source: Primary Data Has Been Processed 2024.

5. Conclusions

- The highest concentration of NH_3 and NO_2 at the research location is at point/location Delta 1 No. Cage 14 was 2 ppm and the lowest was at point/location Delta 1 No. Cage 1 was < 0.009 ppm. Meanwhile, the NO_2 concentration at the research location was highest at Doc 2 point/location at 95.87 ppm and the lowest was at Delta 2C point/location at < 4.88 ppm.
- Health risks from exposure to NH_3 and NO_2 pollutant gases in PT livestock cage workers. Ayam Makmur Jaya Tenggarong Seberang was found to have all health risk locations because the RQ value was > 1.
- Risk management with an agent-oriented approach has several variables that are measured to reduce the magnitude of risk, the concentration of pollutant gases NH_3 and NO_2 in the chicken coop, namely duration of exposure, time of exposure, and frequency of exposure. In risk management, several of these variables can be controlled to avoid risks resulting from exposure to gas pollutants and disease agents in the environment

6. Acknowledgments (All sources of funding of the study must be disclosed)

The author would like to thank all lecturers in the Department of Environmental Health, all parties who have participated in the research. The research was conducted in accordance with ethical recommendations and with consent.

References

[1] A. Erfina. (2022). Sistem Informasi Monitoring Kadar Gas Berbahaya Pada Peternakan Ayam Menggunakan Arduino Uno Berbasis IoT (Internet of Thing). In Prosiding Seminar Nasional Sistem Informasi dan Manajemen Informatika Universitas Nusa Putra. 1 (01): 217-222.

[2] M. Cambra-López, A. J. Aarnink, Y. Zhao, S. Calvet, A. G. Torres. (2010). Airborne particulate matter from livestock production systems: A review of an air pollution problem. Environmental pollution. 158 (1): 1-17.

[3] M. de Rooij, M. van der Leeden, J. Cheung, M. van der Esch, A. Häkkinen, D. Haverkamp, L. D. Roorda, J. Twisk, J. Vollebregt, W. F. Lems, J. Dekker. (2017). Efficacy of tailored exercise therapy on physical functioning in patients with knee osteoarthritis and comorbidity: a randomized controlled trial. Arthritis care & research. 69 (6): 807-816.

[4] C. S. Lopes, D. C. Firmino-Winckler, C. F. Wilcken, J. M. S. Bento, C. Lopes, D. C. Firmino-Winckler, C. Wilcken, J. Bento. (2006). Longevidade de Psyllaephagus bliteus (Hymenoptera: Encyrtidae), parasitóide do psilídeo-de-concha, em diferentes recipientes e formas de alimentação. Resumos.

[5] L. C. Lin, A. H. Berger, R. L. Martin, J. Kim, J. A. Swisher, K. Jariwala, C. H. Rycroft, A. S. Bhown, M. W. Deem, M. Haranczyk, B. Smit. (2012). In silico screening of carbon-capture materials. Nature materials. 11 (7): 633-641.

[6] N. Indriolo, D. A. Neufeld, M. Gerin, P. Schilke, A. O. Benz, B. Winkel, K. M. Menten, E. T. Chambers, J. H. Black, S. Bruderer, E. Falgarone. (2015). Herschel survey of galactic OH+, H2O+, and H_3O^+: Probing the molecular hydrogen fraction and cosmic-ray ionization rate. The Astrophysical Journal. 800 (1): 40.

[7] W. A. Wardhana. (2004). Dampak pencemaran lingkungan. Yogyakarta: Andi, 2004.

[8] A. Andinni. (2021). Hubungan paparan gas amonia terhadap gangguan pernapasan pada pekerja peternakan ayam. Jurnal Medika Hutama. 2 (02 Januari): 750-756.

[9] S. Annisa. (2019). Analisis risiko kesehatan lingkungan pajanan gas amoniak (NH_3) terhadap pekerja dan masyarakat di kawasan peternakan ayam petelur surya ps kecamatan guguak tahun 2019 (Doctoral dissertation, Universitas Andalas).

[10] P. Arini. (2019). Analisis Risiko Pajanan Gas Amoniak (NH_3) Pada Masyarakat Di Sekitar Tpa Regional Payakumbuh Tahun 2019 (Doctoral dissertation, Universitas Andalas).

[11] V. Nopita, R. Amir, M. I. Nusu, H. K. Hengky. (2021). Analisis Risiko Pajanan Nitrogen Dioksida (NO_2) Pada Peternakan Ayam Petelur di Kecamatan Bacukiki Kota Parepare. Jurnal Ilmiah: J-HESTECH. 4 (2).

[12] H. R. Pohl, M. Citra, H. A. Abadin, I. Abadin, A. Kozajda, L. Ingerman, A. Nguyen, H. E. Murray. (2017). Modeling emissions from CAFO poultry farms in Poland and evaluating potential risk to surrounding populations. Regulatory Toxicology and Pharmacology. 84: 18–25.

[13] U. S. Environmental Protection Agency. (2016). Health Risk Assessment of Chemical Mixtures.

[14] A. Mallongi. (2021). Polutan Penyebab Pemanasan Global dan Analysis Risiko.

[15] A. N. Darnah. (2013). Penelitian Kualitatif dan Kuantitatif. Jakarta: PT. Gramedia Pustaka Utama

[16] Badan Standarisasi Nasional 2005 Emisi Gas Buang – Sumber Tidak Bergerak-Bagian 6: Cara Uji Kadar Amoniak (NH_3) dengan Metode Indofenol Menggunakan Spektrofotometer (Jakarta: BSNI) SNI 19-7117.6-2005

[17] Agency for Toxic Substances and Disease Registry. (2022). Calculating Hazard Quotients and Cancer Risk Estimates. Public Health Assessment Guidance Manual.

[18] Direktorat Jenderal PP dan PL Kementerian Kesehatan. (2012). Pedoman Analisis Risiko Kesehatan Lingkungan (ARKL)

[19] D. Andarini, M. Lestari, M. Bahruddin. (2017). Risk Analysis of Ammonia Exposure at Chicken Farm Workers in Lembak, South Sumatera. Jurnal Ilmu Kesehatan Masyarakat. 8 (2): 74–82.

[20] Arisman. (2010). Manfaat Pemberian Suplement Zinc Terhadap Ensefalopati Hepatikum Pada Pasien Sirosis Hepatis. Fakultas Kedoktertan Universitas Airlangga.

[21] F. Manin, E. Hendalia, Y. Yusrizal. (2010). Penggunaan Simbiotik yang Berasal dari Bungkil Inti Sawit dan Bakteri Asam Laktat Terhadap Performans, Lingkungan dan Status Kesehatan

Ayam Broiler. Laporan Penelitian Strategi Nasional. Jambi (ID): Universitas Jambi.
[22] R. T. Charles, B. Hariono. (1991). Pencemaran lingkungan oleh limbah peternakan dan pengelolaannya. Bull. FKH-UGM. 10 (2): 71-75.
[23] A. M. Backes, A. Aulinger, J. Bieser, V. Matthias, M. Quante. (2016). Ammonia emissions in Europe, part II: How ammonia emission abatement strategies affect secondary aerosols. Atmospheric Environment. 126: 153–161.
[24] D. I. Jayanti. (2014). Analisis Kadar Amoniak di Udara Dan Sanitasi Peternakan Serta Keluhan Kesehatan Pada Pekerja di Peternakan Ayam di Desa Sei. Limbat Kecamatan Selesai Kabupaten Langkat. Lingkungan dan Keselamatan Kerja. 3 (1): 14468.
[25] A. Mallongi. (2021). Penilain Risiko Mikroba, Bahan Kimia dan Ekologi Terhadap Status Kesehatan.
[26] G. P. Sitoresmi. (2022). Analisis Risiko Pajanan Benzene, Toluene, Dan Xylene Di Lingkungan Kerja Unit 1 Pt. X.
[27] E. Wahyuni, Y. H. Darundiati, O. Setiani. (2018). Analisis Risiko Kesehatan Lingkungan Gas Karbon Monoksida pada Pedagang Kaki Lima (Studi Kasus Jalan Setiabudi Semarang). Jurnal Kesehatan Masyarakat (Undip). 6 (6): 87-93.
[28] J. Alwi, Y. Yasnani. (2016). Analisis Risiko Kesehatan Lingkungan Akibat Pajanan Timbal (Pb) pada Masyarakat yang Mengonsumsi Kerang Kalandue (Polymesoda Erosa) dari Tambak Sekitar Sungai Wanggu dan Muara Teluk Kendari (Doctoral dissertation, Haluoleo University).
[29] G. G. Girikallo, W. B. Joseph, S. S. Maddusa. (2022). Analisis Risiko Kesehatan Lingkungan Paparan Logam Berat Cadmium (Cd) pada Masyarakat Sekitar Sungai yang Mengonsumsi Ikan Nilem (Ostoechillus Vittatus) dari Sungai Desa Bakan Kecamatan Lolayan Kabupaten Bolaang Mongondow. KESMAS: Jurnal Kesehatan Masyarakat Universitas Sam Ratulangi. 11 (2).
[30] Y. T. N. Latifa, A. R. Tualeka, R. Solichin, P. Rahmawati, S. S. Russeng, A. Wahyu. (2019). Determination of sulfur dioxide (SO_2) safe duration in residential population around the fertilizer industry X in Indonesia. Indian Journal of Public Health Research & Development. 10 (10): 2766-2770.
[31] K. Nauval. (2023). Analisis Pencemaran Udara Di Kota Banda Aceh Pada Tahun 2019-2022 Dengan Menggunakan Alat Passive Sampler (Doctoral dissertation, UIN Ar-Raniry Banda Aceh).
[32] A. Rahman. (2007). Public Health Assessment. Pusat Kajian Kesehatan Lingkungan dan Industri FKM-UI. Depok