Environmental Health Risk Assessment (EHRA) of Ammonia (NH_3) Exposure to Scavengers at Tamangapa Landfill

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ABSTRACT

Based on the National Waste Management Information System data, the percentage of waste volume in Tamangapa landfill, the biggest landfill in Makassar City, is dominated by organic waste (38.82%) and plastic waste (16.29%). An increase in the waste volume, especially organic waste, which is not followed by an effective management system will cause foul odors and produce ammonia gas (NH_3) which can be a risk factor for respiratory disease. This study aimed to estimate the risk level or risk quotient (RQ) due to NH_3 exposure through scavengers' inhalation at Tamangapa landfill. This type of study was observational with Environmental Health Risk Analysis (EHRA). Data collection was carried out with questionnaires and weighing 177 scavengers and direct measurement of ambient air using *imprinter* in 5 zones at Tamangapa landfill in the morning, afternoon, and evening. The results indicated that the average concentration of NH_3 in each zone 1,2,3,4, and 5 is 1.89mg/m^3, 0.94mg/m^3, 0.32mg/m^3, 2.6mg/m^3, and 1.4mg/m^3. The calculation of risk quotient (RQ) in real-time projections shown that as many as 171 scavengers (96.7%) were declared unsafe (RQ> 1) while those declared safe (RQ≤1) were only 6 scavengers (3.3%). Based on these calculations, it can be concluded that the presence of NH_3 in the Tamangapa landfill is unsafe for scavengers' inhalation although the concentration of NH_3 in the ambient air is still below the threshold value. Therefore, the researchers suggest that risk management is needed to control health effects in various ways through technological, socio-economic, public health, and institutional approaches.
Keywords: EHRA (Environmental Health Risk Assessment), Landfill, Ammonia, NH_3

INTRODUCTION

The air plays a very important role not only for the continuity of human life but also for other living things on this earth. Clean air needs to be protected for survival, both now and in the future. However, over time and the development of technology causes the quality of clean air especially in urban areas to decline. Air pollution affects all regions of the world. However, populations in low-income cities are the most impacted. According to the latest air quality database, 97% of cities in low- and middle- income countries with more than 100,000 inhabitants do not meet WHO air quality guidelines(1). The highest urban air pollution levels were experienced in low-and middle-income countries in WHO's Eastern Mediterranean and South-East Asia Regions, with annual mean levels often exceeding 5-10 times WHO limits(2).

Indonesia is a developing country in Southeast Asia where the air quality is quite alarming. Low air quality is caused by high air pollutants. One of the pollutants is ammonia gas (NH_3). Ammonia gas can be sourced from industrial activities, as well as decomposition of impurities or natural processes such as those that occur in places that cause a foul odor, such as a landfill.

Makassar City, the tenth-largest city in Indonesia, only has one final disposal site, the Tamangapa Landfill. The accumulation of waste volume in TPA Tamangapa in 2018 has reached 284,070,768 m^3/year(3). The percentage of waste volume is dominated by food waste (38.82%) and plastic waste (16.29%)(4). The volume of waste generation will increase every year due to an increase in population and activities which take place every day.

Increasing the volume of waste, especially organic waste that is not followed by an effective management system will cause a foul odor and produce ammonia gas which is very risky for the health of people who work and live around the landfill. Ammonia gas that enters via inhalation pathway causes irritation in the respiratory tract accompanied by coughing, vomiting, and paleness. High concentration can cause chapped lips, chest tightness, foamy phlegm (an indication of swelling of the lungs), rapid and weak pulse, can also burn the skin (Mallongi, 2015). (5) As the results of a preliminary survey with 12 scavengers working at Tamangapa Landfill, 7 of them complained of coughing, chest pain and some were often itchy.

Based on the previous background, the researchers are interested in conducting research aimed at finding out the level of risk (RQ) due to ammonia (NH_3) exposure via inhalation pathway to scavengers in the TPA Tamangapa, Makassar City. Risk analysis is a risk management tool, which is an assessment process to predict an increase in health risks to humans exposed to toxic substances.

METHODS

The study design used in this study is the Environmental Health Risk Assessment (EHRA) which consists of several steps, that is: 1) hazard identification, 2) dose-response analysis, 3) exposure assessment, and 4) risk characterization (Dirjen P2PL Kemenkes, 2007). [6] The location of this study was in Tamangapa Landfill, Manggala District, Makassar City. This study was conducted from March to April 2019. The populations were scavengers and ammonia (NH_3) in ambient air in Tamangapa Landfill. There were 177 scavengers as the samples of this study. A sampling of subjects was done by purposive sampling technique with the following inclusion criteria: 1) Aged ≥18 years who worked as a scavenger in the TPA Tamangapa; 2) Have worked at TPA Tamangapa for at least 1 year; 3) Willing to be weighed and interviewed. Meanwhile, the environmental sample in this study was ammonia in the air using the Active Sampling technique in 5 sampling zones which is the place where the scavengers do the most activities.

This study includes field observations and interviews using questionnaires, sampling, and laboratory analysis at the Makassar Center for Health Laboratory, and then analyzing the level of risk using the following formula:

$$\mathbf{I} = \frac{\boldsymbol{C R t}_{\mathrm{E}} \boldsymbol{f}_{\mathrm{E}} \boldsymbol{D}_{\mathrm{t}}}{\boldsymbol{W}_{\mathrm{b}} \boldsymbol{T}_{\mathrm{avg}}}$$

Explanation:

I = Intake, mg/kg/day

C = Concentration of risk agent (mg/m^3),

R = Rate of inhalation (m^3/day)),

fE = Frequencyof annual exposure (day/year),

Dt = Duration of exposure, year (real time or projection),

Wb = Weight (kg),

t_{avg} = Average time period (Dt x 365 days per year for non-carcinogenic substances, 70 years x 365 days per year for carcinogenic substances).[7]

Estimation of the level of health risks derived from calculations using Risk Quotient (RQ) is calculated through the equation:

$$\mathbf{RQ} = \frac{\boldsymbol{I}}{\boldsymbol{RfC}}$$

The interpretation of the RQ value obtained from the formula calculation is if RQ> 1 means having a health risk. RfC (Reference Consentration) is the amount of chemicals that can be consumed daily in a lifetime that is not anticipated to cause non-cancer health effects. The riskant contaminant studied, ammonia, has a quantitative toxicity value (RfC) obtained from US EPA (United States Environmental Protection Agency).[8] The RfC value for NH_3 was 0.002 mg/kg for inhalation exposure through air.[9]

RESULTS

General Description of Tamangapa Landfill and Characteristics of Respondents

Tamangapa landfill was established on January 1, 1992, but began operating actively in 1993.[3] The wide of area is ± 16.3 Ha.[3] The garbage at the Tamangapa landfill site is processed using an open dumping system, which is the simplest disposal system where the garbage is just dumped in a landfill without further treatment. Characteristics of respondents taken in this study were age, gender, and level of education, and health problems shown in Table 1 and Table 2.

According to Table 1, the characteristic distribution of respondents based on age, gender and education level, most of the respondents are in the age group of 18-25 years old (32,2%), most of the respondents are men (63,8%). Most of the respondents graduated from elementary school (59,3%).

According to Table 2, it can be inferred that from 177 respondents the most types of health problems that have ever been experienced are coughing as many as 134 respondents (75,5%), and the lowest type of health problems is bleeding cough as much as 7 respondents (4.0%).

Table 1. Characteristic Distribution of Respondents Based on Age, Gender, and Education Level

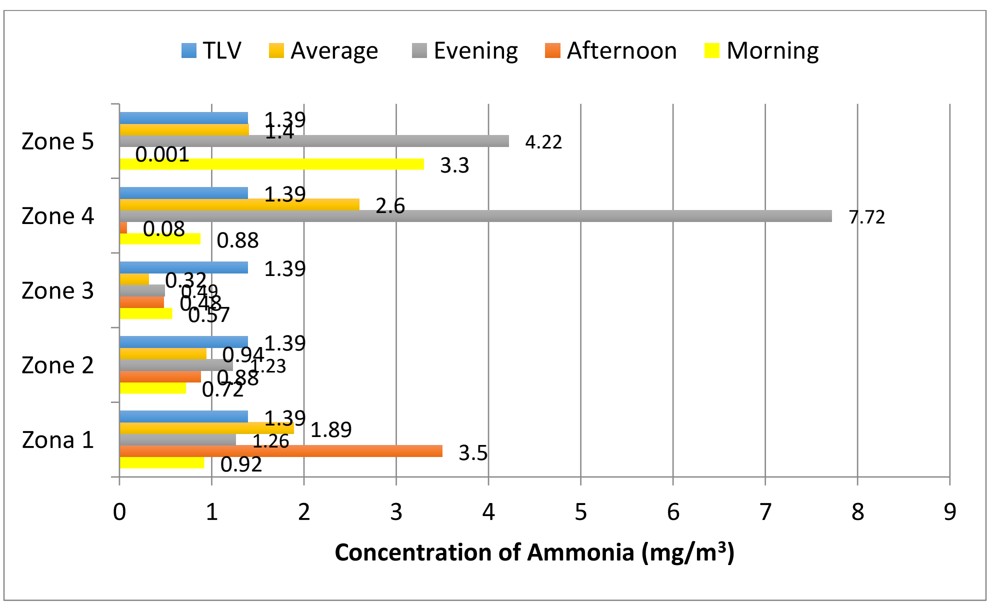
Characteristic	Frequency	Percentage
Age (year)		
18-25	57	32,2
26-35	35	19,8
36-45	44	24,9
46-55	31	17,5
56-65		5,6
Gender		
Men	113	63,8
Women	64	36,2
Level of Education		
Not completed in primary school	24	13,6
Elementary School Graduate	105	59,3
Junoir High School/ equivalent Graduate	34	19,2
Senior High School/ equivalent Graduate	14	7,9

Table 2. Characteristic Distribution Based on Health Problems of Respondents

Health Problems	Frequency				Total	
	Yes	%	No	%	n	%
Coughs	134	75,7	43	24,3	177	100
Blown	53	29,9	124	70,1	177	100
Chest pain	35	19,8	142	80,2	177	100
Bleeding cough	7	4,0	170	96,0	177	100
Throws up	37	20,9	140	79,1	177	100
Eyes irritation	70	39,5	107	80,5	177	100
Skin irritation	86	48,6	91	51,4	177	100

Hazard Identification

Hazard identification is the first step in EHRA. This includes measurement data on the concentration of ammonia gas (NH_3) present in the environment obtained through laboratory analysis. The Figure 1 shown the sampling points, while the Graph 1 shows the results of measurements of ammonia gas concentrations at Tamangapa Landfill.



Graph 1. Comparison of Ammonia (NH_3) Measurement Results in TPA Tamangapa with Threshold Limit Value (TLV)

Based on graph 1 it can be seen that the concentration of ammonia in all zones in the morning, afternoon, and evening when compared with Minister of the Environment Decree No. 50 of 1996, the concentration of ammonia in Tamangapa Landfill was not eligible at all. (10) Ammonia concentrations that do not meet Minister of Environmental Decree requirements were ammonia concentrations in zone 5 in the morning and evening, zone 1 in the morning, and zone 4 in the evening.

Figure 1. Sampling Points in Tamangapa Landfill, Makassar City, Indonesia

Explanation:

- : UPTD Tamangapa Landfill Office
- : Compost processing plant
- : Nur Ilham Mosque
- : Sampling Points

Exposure Assessment

Exposure assessment is counting intake from risk agents. Intake (I) is the amount of concentration of risk agents (mg) entering the human body with certain body weight (kg) every day. The intake value (I) of each individual is obtained using the multiplication formula between the concentration of ammonia in the environment (C), inhalation rate (R), time of exposure (tE), frequency of exposure (fE), and duration of exposure (Dt) divided by individual body weight (Wb) and time average (t_{avg}). [6]

Based on Table 3, the respondents' average time of exposure (tE) is 10 hours/day with a range of 2 hours to 24 hours. The average frequency of exposure is 330 days/year with a range of 214 days/year to 365 days/year. The average duration time is 8 years with a range of 1 year to 26 years. The weight of respondents is 57,75 kg with a range of 33 kg 107 kg.

Based on table 4 it can be seen the calculation results of intake (I) are very varied. When viewed from the group of zones that are often occupied by respondents, the highest average (mean) intake of respondents are respondents who frequently did an activity in zone 4 then zone 1 in the second position, then zone 2 in the third position, then zone 5 in the fourth position and the smallest average intake is in zone 3. This is caused by the concentration of ammonia in zone 4 is higher compared to other zones.

Table 3. Distribution of Inhalation Rate, Activity Pattern, and Body Weight of Scavengers in Tamangapa Landfill

Variable	Minimum-Maximum	Mean	Median	SD	*p-value*	Distribution**
Inhalation Rate R (m^3/day)*	-	0,83	-	-	-	-
Activity Pattern tE (hours/day) fE (day/year) Dt (year) t_{avg} (day)*	 2-24 214-365 1-26 -	 10,12 327,49 9,91 10950	 10,0 330 8,00 -	 4,36 33,3 7,35 -	 0,000^ 0,000^ 0,000^ -	 Abnormal Abnormal Abnormal -
Body weight Wb (kilograms)	33-107	57,75	56,00	11,22	0,147^	Normal

*use default value
**Normality (*Kolmogorov - Smirnov* (n ≥ 30)

Table.4. Intake Values of Respondents in Tamangapa Landfill
at Zone 1, Zone 2, Zone 3, Zone 4 and Zone 5

Zone	Intake (mg/kg x days)			
	Mean	Median	Minimum	Maximum
Zone 1	0,08	0,06	0,0045	0,2296
Zone 2	0,05	0,03	0,0018	0,3458
Zone 3	0,01	0,0	0,0012	0,0329
Zone 4	0,16	0,16	0,0137	0,4008
Zone 5	0,05	0,03	0,0011	0,2888

Risk Characterization

Table 5. Risk Quotient (RQ) Distribution of Respondents in Tamangapa Landfill
at Zone 1, Zone 2, Zone 3, Zone 4, and Zone 5

Variable	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
RQ ≤ 1*	0	0	1	0,54	4	2,25	0	0	1	0,54	6	3,3
RQ > 1*	38	21,5	54	30,5	18	10,3	33	18,6	28	15,8	171	96,7

Based on table 5, the level of risk represented by Risk Quotient (RQ) of ammonia gas exposure for real-time exposure in all zones that were declared safe was only 6 respondents (3.3%), while those 171 respondents (96.7%) were unsafe.

DISCUSSION

Hazard Identification

The risk agent analyzed in this study was ammonia (NH_3) in ambient air at the Tamangapa Landfill. Waste spoilage and. Ammonia is a colorless, corrosive, and very sharp odor at ambient pressure. Generally, people can recognize the smell at 25°C. Ammonia gas has not been classified by the EPA and IARC (International Agency for Research on Cancer) as a cause of cancer so the effects used in the analysis were non-carcinogenic or systemic. Ammonia gas exposure that exceeds 50 ppm causes direct irritation to the nose and throat. Chronic ammonia gas exposure can cause irritation of the respiratory tract, chronic cough, asthma, and pulmonary fibrosis, chronic irritation of the eye lining, and dermatitis[11].

The results showed that the concentration of ammonia was not much different between morning and afternoon, while in the evening there was a significant difference between zone 3 and zone 4. The difference in ammonia concentration in the morning, afternoon, and evening was influenced by meteorological conditions like temperature and wind speed. However, when taking samples at the study site, meteorological conditions were not measured. So, researchers only use meteorological condition data from the South Sulawesi BMKG. Atmospheric stability at night causes the measured ammonia concentration to be greater[12.] In addition to meteorological conditions, the high and low concentrations of ammonia also depend on the accumulation and type of waste that is available at each sampling location. When viewed from the type of waste, zone 3 is the lowest zone of ammonia concentration because the waste in that location is dominated by plastic waste that has accumulated for dozens of years so that the odor level is the lowest. The zone with the highest average ammonia concentration is zone 4, one of the causes is because around the zone there is a lot of organic food waste. The organic waste will undergo a process of decomposition by bacteria in the soil which will then undergo a nitrogen cycle that is not all nitrified, some others will evaporate so that NH_3 compounds can be contributors to air pollution.[5] The results of this study are in line with the study in the Air Dingin Landfill in Padang, which states that the average ratio of ammonia concentration at night is 1,16 times greater than during the daytime[13].

Exposure Assessment

From 177 respondents, the value of real-time intake of respondents with the initial FH is the highest among all respondents. FH has a weight of 56 kg working at the landfill for 12 hours/day and most active in zone 4 with an exposure frequency of 365 days/year for 26 years.

Exposure duration of >8 years can affect the amount of ammonia that enters the body through inhalation which will have a major impact on respiratory organs as the Lubis thesis research (2018) shows, that respondents who breathe air containing NH3 > 8 hours/days have 21 times the chance have the risk of experiencing health problems compared to respondents who breathe air that contains NH_3 less than 8 hours/day.[14]

Meanwhile, the respondents with the minimum or lowest value of intake among all respondents were respondents with the initial HS, but HS had lower body weight compared to FH. This is not in line with the theory which states that the lower the weight, the higher the intake value. So, this indicates that the level of intake is not only determined by the weight of the respondent but also strongly influenced by the concentration of the risk agent, as well as the time, frequency, and duration of exposure.

The exposure time (tE) is obtained by asking how long the respondents' daily habits are in the landfill. The longest exposure time is 24 hours, but that does not mean that the respondent collects trash for 24 hours, but their house is in the landfill area which causes the respondent to inhale the air for 24 hours.

Likewise for the frequency of exposure (fE), obtained by reducing the total days in a year with the total holidays in a year or the number of days when the respondent is not in the Tamangapa Landfill. Total holidays in a year are obtained by asking for holidays in the week, holidays in a month, and holidays during feast day. For the duration of exposure (Dt), it must be known how long the respondents' real-time is at the Tamangapa Landfill until the time the study is conducted. For the variable of body weight obtained from direct weighing. When compared with the average Asian normal weight according to the EPA which is 55 kg, the weight of respondents in the study showed 1% heavier than the normal weight of adults in Asia.

Risk Characterization

The level of risk is obtained by comparison between each respondents' intake with the Reference Concentration (RFC). Actually, after identifying hazards (risk agents, concentration, and environmental media), the next step is to conduct a dose-response analysis that is looking for the RFC value of the risk agent. Yet, analysis of the dose-response is not necessarily by conducting experimental research alone, but enough to refer to the available literature. Therefore, at the dose-response analysis step, the RFC value derived from the Tualeka (2013) study was used. This is based on the consideration that the study was conducted in Indonesia so it is considered more appropriate than the default value of EPA conducted in America. The difference in RFC values of Tualeka's findings with EPA is due to differences in NOAEL (No Observed Effect Level), physical condition (body weight and height), temperature, and air pressure in Indonesia and Western countries.[9]

Based on the calculation results, most respondents obtained an RQ value of >1 which means, ammonia gas exposure (NH_3) can indicate health problems especially in the decline in respiratory organ function, as according to ATSDR (2004) that exposure to ammonia gas can irritate the respiratory tract, eyes, and skin[11]. As has also been presented in table 2. that some health complaints that have been experienced by the scavengers while working at the TPA are coughing, shortness of breath, chest pain, bleeding cough, vomiting, eye irritation, skin irritation.

However, the presence of ammonia in the air in this study cannot be justified as the sole cause of the high distribution of health problems related to the respiratory tract because other factors can also be risk factors for health problems such as smoking. After all, in this study most respondents were male and when data collection was taken, mostly scavenger smoked.

CONCLUSION

Based on the result of the study, it can be concluded that the presence of NH_3 in the Tamangapa landfill is unsafe for most scavengers' inhalation although the average concentration of NH_3 in the ambient air is still below the threshold value. It means that most scavengers from the five zones are at risk in real-time exposure. Therefore, the researchers suggest that risk management is needed to control health effects in various ways through technological, socio-economic, public health, and institutional approaches. Because, if the duration of real-time exposure has indicated a health problem, it can be estimated that the risk of the respondents' health disorder in the lifetime duration (the next 30 years) will be even bigger.

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