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Safeguarding Surrounding Communities: Comprehensive Risk Assessment of H₂S and NH₃ Exposure near Benowo Landfill, Surabaya, Indonesia

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ABSTRACT Final waste processing in Indonesia adopts a landfill system. The Benowo landfill employs this system, which has a weakness in producing H₂S and NH₃ gases. the objective of this research is to evaluate the potential health risks posed by H₂S and NH₃ gases from the Benowo landfill. The study design used was quantitative descriptive with a cross-sectional approach. The sample size consisted of 93 housewives selected using simple random sampling techniques, and gas measurements were conducted at two locations. The data analysis methods employed were univariate analysis and Environmental Health Risk Analysis (ARKL). The findings of this research demonstrated that the level of hydrogen sulfide (H₂S) gas measured 0.02 ppm, while the concentration of ammonia (NH₃) was 0.006 ppm. which were still below the quality standards set by East Java Governor Regulation No. 10 year 2009 regarding ambient air quality standards and stationary source emissions in East Java, where the limits for H₂S were 0.03 ppm and NH₃ were 2.00 ppm. The response dose value (Rfc) for H₂S was 0.002 mg/m³, and for NH₃ it was 0.5 mg/m³. The RQ value for H₂S was greater than 1, indicating a potential risk, while the RQ value for NH₃ was less than or equal to 1, indicating safety for the community. H₂S gas poses a risk, whereas NH₃ does not pose a risk to the communities in the Benowo landfill environment. It is recommended that the local government, actions might involve air quality monitoring, educational campaigns, and tree planting around the Benowo landfill area. For the public wear masks and adopt a healthy lifestyle by consuming nutritious food and engaging in physical activities such as respiratory exercises.

INDEX TERMS Risk Analysis, Exposure H₂S and NH₃, Benowo Landfill

I. INTRODUCTION

Air pollution poses the greatest environmental threat globally due to population growth and global warming, presenting a significant challenge for humanity in the 21st century [1]. The health impacts associated with air pollution include respiratory disorders, eye irritation, heart disease, asthma, and skin diseases [2]. Air pollutants such as sulfur oxides (SO), hydrogen sulfide (H₂S), and ammonia (NH₃) are commonly released by landfills [3]. These gases, which contain various organic compounds, can have detrimental effects on the health of workers and communities in the landfill environment, leading to issues such as headaches, eye irritation, asthma, and decreased lung function [4]

Indonesia is the world's fourth most populous country, with a population of 278 million [5]. The large population

leads to a significant amount of waste generated, necessitating proper waste management [6]. According to the Environmental Agency in 2022, the generated waste amounted to 26.58 million tons/year. Indonesia has faced waste overcapacity due to the increasing waste production. According to [7] Indonesia's waste management system relies on sanitary landfills, constituting 65% of the total. This system results in gas emissions and leachate pollution [8]. Such pollution can lead to respiratory issues like coughing and shortness of breath, as well as skin diseases [9]. The environmental impacts of sanitary landfill processing include a decrease in water quality, an increase in vector-borne diseases, and greenhouse gas emissions [10].

Hydrogen Sulfide (H₂S) is released during the decomposition process of organic waste, particularly from

domestic sources rich in organic compounds, resulting in its evaporation and the production of odors [11]. The waste processing at Super Depo Sutorejo Surabaya has identified the presence of H₂S gas, leading to complaints of shortness of breath and coughing [12]. Health effects are contingent upon the duration of exposure to the gas concentration. [13] A concentration of 0.06 ppm of H₂S has led to respiratory disturbances among the community near the Tanjung Pinang Landfill [14].

Ammonia (NH₃) is generated through the decomposition of organic waste in landfills [15]. Exposure to ammonia can cause health issues such as respiratory tract irritation, throat and eye irritation, coughing, bronchitis, pneumonia [16]. The Benowo landfill is a landfill that operates using the landfill system, with a daily intake of approximately 1,200-1,500 tons of waste [17]. The Benowo landfill emits air pollutants, including H₂S and NH₃ gases [18]. The study conducted [18] resulted in H₂S levels of 0.04 ppm and NH₃ levels of 1.89 ppm in the Benowo Landfill environment in 2021. Continuous exposure to these gases in the Benowo landfill environment can lead to health complaints among the local community. According to [19] 64% of individuals in the Benowo landfill environment have reported experiencing health issues. Based on the aforementioned issues, the objective of this research is to evaluate the potential health risks posed by H₂S and NH₃ gases from the Benowo landfill.

II. METHODOLOGY

The research conducted in this study was descriptive quantitative in nature, aiming to provide a depiction of the situation in the Benowo landfill community environment. A cross-sectional design was employed, where each research subject was observed only once and at the same time. This choice was made to ensure time efficiency. The study was conducted in the Pondok Benowo Indah settlement, located adjacent to the Benowo landfill. This location was chosen due to the community's exposure risk to gases emitted from the landfill, which was influenced by meteorological factors.

The methodology employed a simple random sampling technique to select respondents, with a total sample size of 93 housewives. Given the extended duration of household activities conducted within the landfill environment, housewives face a potential risk of being exposed to H₂S and NH₃ gases. Air samples were collected at two specific locations to assess the levels of H₂S and NH₃ gases, as well as factors such as temperature, humidity, wind speed, and wind direction. Housewives were selected for the study through interview sessions. This study employed univariate analysis to analyze the research variables and Environmental Health Risk Analysis (ARKL) to determine the level of human health risk exposed to toxic substances, utilizing the Eq. (1):

$$\text{Ink} = \frac{C \times R \times t_E \times f_E \times D_t}{W_b \times t_{\text{avg}}} \quad (1)$$

Where:

Ink :Intake

C :Concentration

R :Intake value

t_E : Exposure (hours/day)

f_E : Exposure (Day/year)

D_t :Duration of exposure in years

W_b :Weight

t_{Avg} : Average time period

After obtaining the intake value, then determining the risk characteristics using the following formula:

$$\text{RQ} = \frac{I}{R_{fc}} \quad (2)$$

where:

RQ : Risk level

I : Intake

R_{fc}: Reference dose

III. RESULT

Air quality measurements were conducted in the Benowo landfill environment, and the following were the results of the measurements of H₂S and NH₃ gases:

TABLE 1
Results of H₂S and NH₃ gas concentrations in the Benowo landfill environment in 2023

Point	Measurement Location	Time	H ₂ S (mg/m ³)	NH ₃ (mg/m ³)
1	Diva store, distance from Benowo landfill is 1.15 km	10.05- 11.05	0.0348	0.001
		11.10- 12.10	0.0334	0.004
Overall average			0.034	0.003
2	In front of Barokah stall, distance from Benowo landfill is 1.22 km	12.50- 13.50	0.0376	0.004
		13.55- 14.55	0.0362	0.003
Overall average			0.037	0.004

Table 1 presents the maximum recorded concentration values of 0.0376 mg/m³ for H₂S and 0.004 mg/m³ for NH₃ at point 2, whereas at point 1, the minimum concentration values were 0.0346 mg/m³ for H₂S and 0.001 mg/m³ for NH₃. These concentration levels were found to be compliant with the permissible limits set forth by East Java Governor Regulation no. 10 of 2009, which establishes the standards for ambient air quality and emissions from stationary sources. The results of the air's physical quality in the Benowo landfill environment are displayed in Table 2 showing an average temperature of 35.8°C, with a minimum value of 31.6°C and a maximum of 37.9°C. The average humidity was 48%, with a minimum of 39.5% and a maximum of 56%. The average wind speed was 1.05 m/s, with a minimum of 0.8 m/s and a maximum of 1.4 m/s, and the wind direction was towards the west. The

concentration of emitted gases could be influenced by the specific characteristics of air quality. Table 3 presents the average concentration of H₂S at point 1 was 0.034 mg/m³ and NH₃ was 0.003 mg/m³. At point 2, the average concentration of H₂S was determined 0.037 mg/m³, and NH₃ was reported as 0.004 mg/m³. These concentrations indicate the potential sources of danger originating from the Benowo landfill in the ambient air.

TABLE 2

Results of physical parameters of air (temperature, humidity and wind speed)

Point	Sampling Time	Temperature °C	Humidity (%)	Wind speed (m/s)	Wind direction
1	10.05-11.05	36.5	56	1.4	West
	11.10-12.10	37	54	1.2	West
2	12.50-13.50	37.9	39.5	0.8	West
	13.55-14.55	31.6	42.6	0.8	West
Minimal		31.6	39.5	0.8	-
Maximum		37.9	56	1.4	-
Average		35.8	48.0	1.05	-

The results of the air's physical quality in the Benowo landfill environment are displayed in Table 2 showing an average temperature of 35.8°C, with a minimum value of 31.6°C and a maximum of 37.9°C. The average humidity was 48%, with a minimum of 39.5% and a maximum of 56%. The average wind speed was 1.05 m/s, with a minimum of 0.8 m/s and a maximum of 1.4 m/s, and the wind direction was towards the west. The concentration of emitted gases could be influenced by the specific characteristics of air quality. Table 3 presents the average concentration of H₂S at point 1 was 0.034 mg/m³ and NH₃ was 0.003 mg/m³. At point 2, the average concentration of H₂S was determined 0.037 mg/m³, and NH₃ was reported as 0.004 mg/m³. These concentrations indicate the potential sources of danger originating from the Benowo landfill in the ambient air.

TABLE 3

Hazard identification in the Benowo landfill environment

Environmental Media	Risk agent	Location	Concentration (mg/m ³)		
			Minimal	Average	Maximum
Ambient air	H ₂ S	1	0,0334	0,034	0,0348
		2	0,0362	0,037	0,0376
	NH ₃	1	0,001	0,003	0,004
		2	0,003	0,004	0,004

TABLE 4

Dose-Response Analysis of H₂S and NH₃

Risk agent	Effect	Response dose RfC (mg/m ³)	Critical Effects
H ₂ S	Non Carcinogenic	0,002	Nasal lesions of the mucosa and olfactory disorders
NH ₃	Non Carcinogenic	0,5	Decreased lung and respiratory function

The reference dose value (RfC) based on table 4 H₂S was 0.002 mg/m³ and NH₃ was 0.5 mg / m³ based on EPA 2016 data accessed on December 12, 2022.

TABLE 5

Variable calculation of Intake Value of H₂S and NH₃ concentration in Benowo Landfill Environment

No	Variable	Result
1	H ₂ S concentration (mg/m ³)	Point 1:
		C min: 0.334
		C average: 0.34
		C max: 0.348
2	NH ₃ concentration (mg/m ³)	Point 2
		C min:0.362
		C average:0.037
		C max:0.376
3	Intake (R)	0.83 m ³
4	Frequency of exposure (f _E)	350 days/year
5	Duration of Exposure (D _E)	Average 15 Years
6	Weight (W _b)	Average 60 Kg
7	Time of exposure (t _E)	24 hours/day
8	Mean time period for non-carcinogen (t _{Avg}) effects	10,950 days

Table 5 presents the variables to obtain individual intake values. The research findings at point 1 indicate the highest intake concentration of H₂S at 0.013 mg/kg/day and lowest at 0.0027 mg/kg/day, while the highest intake concentration of NH₃ was 0.0014 mg/kg/day and the lowest was 0.00009 mg/kg/day. At point 2, the findings show the highest intake concentration of H₂S at 0.012 mg/kg/day and the lowest intake value at 0.003 mg/kg/day. The highest intake concentration of NH₃ is 0.0013 mg/kg/day and the lowest intake value was 0.00003 mg/kg/day.

TABLE 6

RQ H ₂ S and NH ₃ values in Benowo Landfill Environment				
	Nilai RQ H ₂ S		Nilai RQ NH ₃	
	Point 1	Point 2	Point 1	Point 2
Minimal	1,4	1,9	0,0001	0,0006
Maximum	6,4	6,2	0,002	0,002

According to Table 6, an RQ value greater than 1 for H₂S poses a health risk to household mothers in the Benowo landfill environment, while an RQ value of NH₃ ≤ 1 indicates no risk.

IV. DISCUSSION

The measurement locations for H₂S and NH₃ gas concentrations are at distances of 1.15 km and 1.22 km from the Benowo landfill, respectively. These locations do not comply with the requirements stated in the Regulation No. 829 of 1999 issued by the Ministry of Health in Indonesia. about health requirement incidental, which specifies a minimum distance of 3 km between residential areas and landfills. H₂S and NH₃ concentrations are influenced by meteorological factors [20]. H₂S and NH₃ levels increase during high air temperatures and low wind speeds. This study aligns with [21] which states that the increase or decrease of pollutants in the air is influenced by temperature and wind speed. According to a research study [22], it has been suggested that decreased humidity levels was linked to increased air pollution. Furthermore, the study found a correlation between low humidity and elevated levels of H₂S and NH₃.

In the Benowo landfill environment, the concentrations of H₂S and NH₃ have decreased compared to previous studies, which reported concentrations of 0.04 ppm and 1.89 ppm. This decrease is attributed to the implementation of control measures, such as using a geomembrane cover, to mitigate waste odor and reduce greenhouse gas emissions [23]. Geomembrane covers are widely used worldwide and can last up to 75 years at a temperature of 50°C in landfills [24]. Additionally, an EM6 solution is applied to further reduce odor and accelerate the decomposition process [25]

This study demonstrates that the concentrations of H₂S and NH₃ gases remain below the permissible limits; however, they still pose health risks due to the air pollution generated by the landfill management system. This situation can have an impact on households residing in the Benowo landfill environment. This research is supported by [26] who indicated that the prolonged duration of community exposure in the Palembang City landfill throughout the years poses health risks. According to [27], this is because with prolonged exposure, the body may not be able to reject substances entering the body, even at low concentrations.

H₂S and NH₃ have adverse effects on human health, impacting the cardiovascular, respiratory, and central nervous systems [28]. Their presence can cause chronic cough, asthma, throat and eye irritation, as well as phlegm discharge [14], chronic exposure to H₂S gas can lead to

respiratory disturbances, coughing, and this gas is not classified as carcinogenic[29] while NH₃ causes irritation to the respiratory tract, nose, throat, and eyes [30]. Both gases enter the human body through the air. At high concentrations, H₂S gas at 250 ppm can cause sudden death and loss of consciousness[31] Several studies have associated chronic exposure to low concentrations of 10 ppm (13.93 mg/m³) with odor aversion, effects on the eyes, nose, respiratory tract, and nervous system.[32] Meanwhile, NH₃ gas at a concentration of 50 ppm causes irritation to the eyes, nose, and throat.

Research conducted at the Pakusari Jember landfill [33] demonstrated respiratory issues such as coughing and shortness of breath, even though the concentrations of H₂S and NH₃ remained below the permissible limits. Further research is recommended to investigate the relationship between the concentrations of H₂S and NH₃ and respiratory disturbances in the Benowo landfill environment.

The intake values for each individual were determined using the concentrations of H₂S and NH₃. In addition to the concentrations of H₂S and NH₃, other factors such as intake rate, exposure frequency, duration, time, and body weight were taken into account. Higher body weight results in lower intake values [34]. While longer exposure to these gases leads to higher intake values [35]. An H₂S risk value greater than 1 poses a health risk to households in the Benowo landfill area, whereas an NH₃ RQ value less than or equal to 1 is considered non-risky. This study is consistent with [36] where H₂S poses health risks while NH₃ does not. Although the concentrations of H₂S are still below the standard limits and NH₃ is considered safe at low concentrations, the high or low levels of pollutant gas concentrations still pose risks to the community when exposed continuously [37]. As the RQ value for H₂S is greater than 1, risk management measures are necessary. The risk management strategy in determining safe limits. The safe limit value for H₂S concentration is 0.02 mg/m³, community exposure time is 12 hours/day, exposure frequency is 175 days/year, and the maximum exposure duration is 7 years.

The risk management approach to achieve these safe limits [38] Technological approaches, such as those carried out by the Surabaya City Environmental Agency, involve air quality monitoring and the planting of trees in the Benowo Landfill area, specifically Trembesi Samanea and Angsana species. Socio-economic approaches encompass the local government's organization of respiratory exercises for housewives in the Benowo Landfill vicinity. An institutional approach entails the Department of Health educating the community residing near the Benowo Landfill about potential health hazards associated with air pollution originating from the landfill. The use of masks while outdoors is recommended to minimize exposure to harmful gases that could enter the body through respiration, while also promoting a healthy lifestyle among the community. This lifestyle is characterized by nutritious food consumption and physical activities such as respiratory exercises.

V. CONCLUSION

The environment of the Benowo landfill was found to have a concentration of H₂S gas at 0.03 mg/m³ and NH₃ gas at 0.004 mg/m³. The levels of these concentrations are still within the permissible boundaries established by The Governor of East Java Regulation No. 10 year 2009. However, it is important to note that continuous exposure to these gases still poses health risks. The research conducted in settlements located at distances of 1.15 and 1.22 km from the Benowo landfill revealed that the risk value for H₂S exceeds 1, This finding suggests that individuals who are consistently exposed for 24 hours a day, 350 days a year, and over an average duration of 15 years, might face potential health risks. Conversely, the risk assessment for NH₃ was below 1, indicating no significant respiratory health risks when subjected to the same exposure conditions. Therefore, it is crucial to implement risk control measures to mitigate the impact of H₂S gas. The findings of this research offer several suggestions to the Environmental Agency. These recommendations encompass the implementation of air quality monitoring within the Benowo landfill vicinity and the cultivation of pollution-absorbing tree species, such as Trembesi Samanea and Angsana, in the residential zones proximate to the Benowo landfill site. Additionally, the Health Department can play a pivotal role by disseminating information to the local community concerning the potential health hazards linked to air pollution originating from the Benowo landfill. In terms of community-level actions, proactive measures are advised to alleviate the adverse health effects. This includes the utilization of masks while in the Benowo landfill area, as well as the adoption of a health-conscious lifestyle characterized by the consumption of nutritious foods and engagement in physical activities like breathing exercises.

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