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Health Risk Assessment of Hydrogen Sulfide (H_2S) Exposure Among Communities Near a Bioethanol Industry: A Case Study from Mojokerto, Indonesia

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ABSTRACT
The community of Gempolkerep village still smells an unpleasant odour indicated by the presence of H_2S gas in the bioethanol plant. Due to the unpleasant and pungent odour, people in Gempolkerep village experience complaints such as sore eyes, sneezing, coughing, sore throat, shortness of breath, and dizziness. This study aims to determine the effect of$_{H2}$S gas exposure on subjective complaints of the community around the bioethanol plant. This research is a quantitative research with cross sectional design. The population in this study were housewives of Gempolkerep village of 940 people and measurement of H_2S gas levels in ambient air in Gempolkerep village, Mojokerto district. The sample in this study was taken from a portion of the population with a sample size of 273 respondents. The sampling technique used in this study was purposive sampling method. Data analysis using chi-square statistical test. The results showed that the average measurement of hydrogen sulfide gas levels at the first point was 28.3 µg/Nm^3 and at the second point was 15 µg/Nm^3. The variables of age, length of exposure, and exposure distance have a significant relationship to subjective complaints with a value of (p-value = 0.000), (p-value = 0.008), and (p-value = 0.001) to the subjective complaints of the people of Gempolkerep Village, but there is no influence of medical history on the subjective complaints of the people of Gempolkerep Village in 2024. The conclusion of this study is that$_{H2}$S levels do not affect subjective complaints in the people of Gempolkerep Village in 2024. The advice given to the community is that they can plant ylang ylang trees which help reduce the level of pollutants in the air. In addition, the community must be able to maintain immunity by adopting a healthy lifestyle, eating nutritious foods, protecting the environment and conducting regular health checks.

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INTRODUCTION

Air pollution is one of the significant environmental problems in both urban and rural areas. It occurs when harmful substances are released into the atmosphere due to human activities or natural phenomena, leading to disruption of air quality and potentially endangering human health. Pollutants such as methane (CH_4), ammonia (NH_3), hydrogen sulfide (H_2S), carbon monoxide (CO), and nitrogen oxides (NO_x) have varying concentrations depending on

the region and the activities taking place in the vicinity. (Masita).

Globally, more than 90 per cent of the population is exposed to low-quality air, and air pollution contributes to more than 6 million deaths annually from respiratory and cardiovascular diseases. (Fithriyani et al., 2020). One activity that can contribute to air pollution is biogas processing. In the process of anaerobic fermentation of organic matter, several gases are produced, including H_2S which is known to be toxic, has a pungent smell like rotten eggs, and can cause health problems such as respiratory tract, eye and skin irritation, to more serious effects such as respiratory centre paralysis(Anissa et al.).

Some previous studies, such as by Haq *et al.* (2021), and Hidayatullah *et al.* (2021) has evaluated the relationship between H_2Sexposure around landfills and public health problems. The results of the study indicate a risk of H_2S exposure, especially in communities living in close proximity to emission sources.

In the local context, Gempolkerep Village, Gedeg Sub-district, Mojokerto District, is an important location to study due to the presence of a bioethanol factory that uses molasses waste as raw material for biogas production. The biogas production process is located only about 100 metres away from residential areas. Initial survey results in January 2024 showed that the surrounding community still smelled an unpleasant odour suspected to be from H_2S gas. Of the 15 people interviewed, 7 reported experiencing symptoms such as sneezing, coughing, sore throat, shortness of breath and dizziness.

While biogas processing has benefits as an alternative renewable energy, its potential negative impacts on air quality and public health cannot be ignored. Therefore, it is important to further assess the level of H_2S exposure in the environment around the bioethanol plant in Gempolkerep Village and its relationship with health complaints felt by the community. This research is expected to be the basis for better environmental and public health policy making in the area.

RESEARCH METHOD

This type of research applies quantitative methods with a cross-sectional design. This design was chosen because it allows researchers to identify the relationship between H_2S gas levels in the air and public health complaints at one specific time, without requiring long-term observation. The study was conducted in Gempolkerep village, Gedek sub-district, Mojokerto district, from January to June 2024. Research variables include H_2S levels in Gempolkerep village, air temperature, humidity, wind speed, age, length of exposure, history of disease, exposure distance, and subjective complaints in the community in Gempolkerep Village. The population in this study were housewives of Gempolkerep village of 940 people and measurement of H_2S gas levels in ambient air in Gempolkerep village, Mojokerto Regency. The sample in this study was taken from a portion of the population with a sample size of 273 respondents. The sampling technique used in this study was *purposive sampling* method. The questionnaire was filled out by the respondents, who filled out a list of questions created on an online media channel distributed through the head of the neighbourhood. Data analysis used the chi-square statistical test to test the relationship between exposure variables (such as H_2S levels, distance, and length of stay) and people's subjective complaints. The analysis steps included coding the data, cross-tabulation between variables, and calculation of p values to determine the significance of the relationship. The results of the analysis will be interpreted based on the p value (<0.05 is considered significant) to see if there is a statistically significant relationship between H_2S exposureand public health complaints.

RESULTS AND DISCUSSION

Hydrogen Sulfide (H_2S) Gas Levels inGempolkerep Village

Measurements of Hydrogen Sulfide levels were carried out on Saturday 29 June 2024 in the morning, afternoon, and evening at 2 points with the closest distance of about ± 100 m and the farthest distance of about ± 1000 m within the Gempolkerep Village area.

Table 1
Measurement Results of Hydrogen Sulfide Levels in Gempolkerep Village June 2024

Location	Distance (m)	Time (WIB)	H_2S Gas Level ($\mu g/Nm^3$)	Average ($\mu g/Nm^3$)
Point 1	100	08.00	33	28.3
		12.00	28	
		16.00	24	
Point 2	1000	08.00	17	15
		12.00	16	
		16.00	12	

Based on table 1, it can be seen that the measurement results of hydrogen sulfide levels in Gempolkerep village settlements are categorised as still below the threshold value in accordance with the East Java Governor Regulation No. 10/2009. East Java Governor Regulation No.10 Year 2009 on Ambient Air Quality Standards and Emissions from Non-Mobile Sources in East Java. Research shows that long-term exposure to H_2S

even at low levels (<100 ppb or about <140 µg/Nm³) can increase the prevalence of respiratory symptoms such as chronic cough and shortness of breath. (Bates et al.). At the first point conducted at the location closest to the source with an average of 28.3 µg/Nm^3. And the second point carried out at the farthest location from the pollutant source in the Gempolkerep village area with an average of 15 µg/Nm^3. The highest level was at the first point conducted in the morning at 33 µg/Nm^3.

Among the factors that influence the difference in H_2S levels is the distance of air sampling from the source. The further the measurement of hydrogen sulphide is from the source, the lower the concentration value in the ambient air. Meanwhile, meteorological factors such as temperature, humidity, and wind speed can also affect pollutant levels.

Measurement of the Physical Air Environment

The concentration of pollutants in ambient air can be affected by physical air quality factors such as air temperature, air humidity, and wind speed.

Table 2
Results of Physical Environmental Measurements in Gempolkerep Village in June 2024

Location	Time (WIB)	Temperature (^{0}C)	Humidity (%)	Wind Speed (m/s)
Point 1	08.00	27.3	79.4	0.6
	12.00	33.8	52.2	0.4
	16.00	29.5	61.6	1.1
Point 2	08.00	28.4	76.2	0.6
	12.00	34.1	57.2	0.6
	16.00	29.9	69.8	0.8

According to Table 2, the results of the measurement of air physical properties including temperature, humidity, and wind speed can be seen. Temperature is a measure of how hot and cold an environment is. Temperature is one component of the physical environment that affects H_2S levels in the air. The results of air quality measurements on air temperature obtained the highest value of 34.1^{0}C. This result can be categorised as not meeting existing standards in accordance with Regulation of the Minister of Health of the Republic of Indonesia Number 2 Year 2023, concerning Environmental Health. The regulation explains that the air temperature that meets the standard ranges from 20 ^{0}C-30^{0}C.

Low temperatures will make air conditions denser so that air pollution levels are high. Meanwhile, high temperatures will make air conditions become tenuous so that the concentration of air pollution becomes lower (Rohmah et al.).

High relative humidity not only impacts environmental comfort, but also affects the dynamics of secondary pollutant formation in the atmosphere. Secondary pollutants are pollutants formed from chemical reactions between primary pollutants (such as nitrogen dioxide, sulphur dioxide and volatile organic compounds) and other elements in the atmosphere, such as water vapour, sunlight and ozone.

Studies by (Zhang et al.) found that high humidity contributes to the formation of *secondary organic* aerosols (SOA), through the *aqSOA (aqueous-phase secondary organic aerosol formation*) process, where dissolved organic compounds react within atmospheric water droplets. This suggests that humidity exceeding the threshold may worsen air quality indirectly through the increase of secondary pollutants.

Thus, humidity levels that exceed the standard as measured in Gempolkerep Village (79.4% and 76.2%). These results can be categorised as not meeting the existing standards in accordance with PMK No. 2 Year 2023 on Environmental Health, which is 40%-70%. These measurement results have the potential to create atmospheric conditions that support the formation of secondary pollutants, which in turn can worsen public health impacts even though the levels of primary pollutants remain low.

Humidity is the amount of water vapour present in a mixture of air and water. As the temperature decreases, the humidity value increases. The humidity measurements exceeded the quality standard with the highest values of 79.4% and 76.2%. One factor that affects the amount of moisture in the air is air temperature. When the air is humid, air pollutants are trapped in water droplets, reducing the concentration of pollution.

Based on measurements, wind speed in Gempolkerep Village has a maximum value of 1.1 m/s and a minimum value of 0.4 m/s. This wind speed value is included in the category of breeze on the *Beaufort* scale (Rohmah et al.). Wind speed affects H_2S gas levels. Strong winds reduce H_2S gas levels. The stronger the wind, the larger the area that will be exposed to air pollutants, resulting in lower pollutant levels.

Identification of Characteristics of the Gempolkerep Village Community

The characteristics of the community in this study are age, length of exposure, history of illness, and exposure distance. The results of the study regarding age, length of exposure, history of illness, and exposure distance.

Table 3
Frequency Distribution of Gempolkerep Village Residents by Age in 2024

Variable	Category	Frequency		Total	
		n	%	n	%
Age	≤30 years	59	21.6	273	100
	>30 years	214	78.4		
Length of Exposure	≤8 hours/day	171	62.6	273	100
	>8 hours/day	102	37.4		
Disease History	Have	7	2.6	273	100
	Do not have	266	97.4		
Exposure distance	≤500 metres	152	55.7	273	100
	<500 metres	121	44.3		

Table 3 shows that in Gempolkerep village more housewives were aged >30 years as many as 214 people (78.4%) out of a total of 273 respondents. A person over 30 years of age is at higher risk of health problems. Studies indicate that as we age, more alveoli are damaged and the body's immune system is weakened, as well as a decline in breathing when over the age of 30. (Hudi, 2023). Age can be one of the reasons that can directly or indirectly influence the presence of disease, resulting in changes in morbidity and mortality rates in society.

Many people in Gempolkerep Village, especially mothers, do not work and only do activities around the house. There were 171 people (62.6%) who were exposed to or inhaled unpleasant odours ≤8 hours/day while 102 people (37.4%) were exposed to or inhaled unpleasant odours >8 hours/day. The length of exposure ≤8 hours/day is more than >8 hours/day. Long exposure can increase health hazards in the community. This is because the body becomes more sensitive to harmful substances that enter the body even at low levels.

There were 7 people in Gempolkerep Village who had a history of asthma/sickness (2.6%) while there were 102 people (97.4%) who did not have a history of asthma/sickness. Some of the main hazard factors that cause asthma are a combination of genetics and exposure to chemicals or environmental particles that cause allergic reactions or irritate the airways.

There were 151 people (55.3%) in Gempolkerep Village who owned houses with a distance of ≤500m, while there were 102 people (97.4%) who owned houses with a distance of ≤500m. Gempolkerep Village has a distance between houses and pollutant sources of around 100m-1000m. If people have houses closer to pollutant sources, the greater the risk of health problems.

Identification of Subjective Grievances of Gempolkerep Village Community

The results of the research on the subjective complaints of the people of Gempolkerep Village in 2024 are presented in the table below.presented in the table below.

Table 4
Frequency Distribution of Gempolkerep Village Residents Based on Community Complaints

Community Complaints	Frequency	Percentage (%)
Yes	142	52
No	131	48
Total	273	100

Table 4 shows that the results of the questionnaire obtained data as many as 142 people (52%) are experiencing subjective complaints. These complaints include coughing, dizziness, sore throat, and shortness of breath. Complaints from the community that there is environmental pollution due to an unpleasant odour are indicated to be due to H_2S gas from the bioethanol plant. Although H_2S levels are still below the NAB, exposure can still have an impact.

People who experience complaints are influenced by several factors such as age, length of exposure, medical history, and exposure distance. One of the most sensitive systems to H_2S is the respiratory tract and nervous system. According to Hidayanti (2024) H_2S exposure at small levels can cause eye, nose and throat irritation and headaches; at moderate levels digestive disorders such as nausea and vomiting; and high levels can cause seizures, breathing difficulties, fainting, and death.

Effect of Community Characteristics on Subjective Complaints

The following are the results regarding the effect of community characteristics on subjective complaints in Gempolkerep Village in 2024. The effect of age, length of exposure, disease history, and exposure distance on subjective complaints in the Gempolkerep village community is presented in the table below.

Table 5
Age Distribution of Subjective Complaints in Gempolkerep Village Community in 2024

Variable	Category	Subjective complaints		Total	P value
		Yes	No		
Age	≤30 years	19 (32,2%)	40 (67,8%)	59 (100)	0.001
	>30 years	123 (57,5%)	91 (42,5%)	214 (100)	
Total		142 (52%)	131 (48%)	273 (100)	
Length of Exposure	≤8 hours/day	75 (43,9%)	98 (56,1%)	171 (100)	0.000
	>8 hours/day	67 (65,7%)	35 (32,4%)	102 (100)	
Total		142 (52)	131 (48)	273 (100)	
Disease History	Yes	3 (42,9)	4 (57,1)	7 (100)	0.623
	No	139 (52,3)	127 (47,7)	266 (100)	
Total		142 (52)	131 (48)	273 (100)	
Exposure Distance	≤ 500m	90 (59,2)	62 (40,8)	152 (100)	0.008
	> 500m	52 (43)	69 (57)	121 (100)	
Total		142 (52)	131 (48)	273 (100)	

Based on table 5, it can be seen from the results of research that has been carried out in the Gempokerep village community that the most subjective complaints occur in people aged more than 30 years as many as 123 people (57.5%). The results of statistical tests using the Chi-Square test method obtained a value of P = 0.001 which means that the P value is smaller than 0.05, so Ho is rejected so it can be concluded that age affects subjective complaints in the community of Gempolkerep Village in 2024.

More people in this study are aged >30 years. According to the Indonesian Dictionary (KBBI), age means the length of time a person lives or is in the world from birth until his or her last birthday. Age is one of the respondent factors in this study, which can affect a person's resistance to toxic substances (chemicals). According to Ayathollah, Alchamdani and Waldah (2021) Increasing age has an impact on lung tissue, lung tissue elasticity function decreases and breathing ability decreases resulting in a decrease in exhaled air volume. The older a person is, the weaker their immune system and the more susceptible they are to health problems. The decline in functional capacity at the age of 30 years also increases as the age of respiratory function will also increase then decrease after reaching the point of adulthood (Haq *et al.*, 2021).

The length of exposure is the length of time the respondent is active in the research location, namely the village of Gempolkerep so as to make the respondent experience exposure to ambient air H_2S in one day. From the results of the study it was found that people who experienced the most complaints occurred in people exposed to >8 hours / day as many as 67 people (65.7%).

The results of statistical tests using the Chi-Square test method obtained a value of P = 0.000, which means that the P value is smaller than 0.05, so Ho is rejected, so it can be concluded that the length of exposure affects subjective complaints in the community of Gempolkerep Village in 2024.

The people of Gempolkerep Village have daily activities around the house, which means they are exposed to H_2S gas continuously. This exacerbates the level of health risk, even though the concentration is below the quality standard. The longer the exposure and the greater the health risk. Length of exposure is a factor that can influence the increasing severity of airborne pollutants. (Ayathollah et al.).

History of disease is the presence or absence of respiratory disease or asthma that has been or is being suffered by respondents. The results of

statistical tests using the Chi-Square test method obtained a value of P = 0.623, which means that the P value is greater than 0.05, so Ho is accepted, so it can be concluded that medical history has no effect on subjective complaints in the community of Gempolkerep Village in 2024.

There is no bridging between disease history and subjective complaints because based on the results of the questionnaire 266 out of 273 respondents did not have a history of respiratory disease or asthma. A history of respiratory disease is associated with a decrease in muscle quality in the respiratory system, which will affect the permeability of the respiratory tract, and cause a decrease in the function of the respiratory system organs, which in turn can cause respiratory complaints.

The exposure distance in this study is the distance between the respondent's activity or home and the location of the pollutant source. People who have a home distance of ≤ 500m with a bioethanol factory and experience the most subjective complaints of 90 people (59.2%). In this study the results of statistical tests with the Chi-Square test method obtained a value of P = 0.008 which means the value of P is smaller than 0.05 then Ho is rejected so it can be concluded that exposure distance affects subjective complaints in the community of Gempolkerep Village in 2024.

Exposure distance or the distance of respondents' homes from pollutant sources is a risk factor for health problems. This is because people who are closer to pollutant sources have a greater chance of inhaling contaminated air.

Effect of H_2S Gas on Subjective Complaints of the Gempolkerep Village Community

The measurement results of H_2S levels at all points are still below the NAB. Therefore, because of its constant nature, no statistical test of the relationship was carried out and only explained in descriptive form.

In this study, it has not been proven that there is a relationship between H_2S concentration and people's subjective complaints. However, based on the results of the questionnaire from 273 respondents, 142 respondents (52%) claimed to be experiencing subjective complaints.

According to Utami (2023) The adverse effects of H_2S inhalation include nausea, headache, and respiratory problems (bronchial constriction) seen in some asthmatics at 2 to 5 ppm exposure. Fatigue, dizziness, and loss of appetite may occur when exposed to 20 ppm. Respiratory irritation (1 hour exposure) occurs at 50-100 ppm exposure. Loss of smell occurs after 100-150 ppm. Exposure to 1000-2000 ppm can be fatal. Repeated or prolonged exposure to H_2S inhalation can cause chronic cough.

Temperature, humidity and wind speed are some of the physical environmental factors that can affect H_2S levels. At high temperatures, the air becomes less dense, which causes upward convection currents to transport different pollutants, resulting in lower levels of pollutants. At low temperatures, the air becomes denser, which causes the levels of pollutants in the atmosphere to increase. (Adriana).

Humidity can also affect the amount of dust present in the atmosphere. In high humidity situations, water vapour levels in the atmosphere are able to interact with air pollutants and change to form other safer compounds or secondary pollutants. In addition, low wind speeds may also affect the dispersion of H_2S gas, as H_2S gas does not disperse due to relatively low wind speeds. However, H_2S concentrationsbelow the NAB may still have an impact on exposed people.

CONCLUSIONS

The measurement results of H_2S levels at the first point with a distance of 100m obtained an average of 28.3 $^{\mu g}$ / Nm3 and at the second point with a distance of 1000m obtained $^{15\mu g}$ / Nm3 meeting the requirements based on East Java Governor Regulation No. 10 of 2009. There is an influence between age, length of exposure, and exposure distance on the subjective complaints of the people of Gempolkerep Village, but the history of illness does not show an influence on the subjective complaints of the people of Gempolkerep Village, Mojokerto District in 2024. Hydrogen sulphide levels have no effect on subjective complaints in the community of Gempolkerep Village in 2024.

SUGGESTIONS

The Environmental Agency can provide guidance to the industry to improve the performance of waste management resulting from the production of bioethanol plants. Bioethanol plants can conduct regular and continuous air quality monitoring, especially in residential areas around the industry, so that the concentration of harmful gases in the ambient air can be monitored. For the community, planting ylang ylang trees and other poly-leaved, small, dense, and branched barrier plants can help reduce the level of pollutants in the air. People must be able to maintain their immunity by adopting a healthy lifestyle, eating nutritious food and protecting the environment as well as conducting routine checks so that symptoms of disease are handled early. And there needs to be collaboration between the

factory, government, and community in maintaining air quality. Other researchers are expected to expand the study by adding sampling points around areas that are sensitive to the presence of H_2S gas with a certain distance so as to develop other pollution models. Further analyse the health impacts caused by exposure to gases in the bioethanol plant area.

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