ORIGINAL ARTICLE

Hydrogen Sulfide Measurement from Degraded Corrosion Inhibitor as Occupational Health Control in Oil & Gas Industry

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ABSTRACT

Introduction: Corrosion inhibitor (CI) is a chemical for pipe corrosion protection with sulfur-containing substances in the product. One type of substances is thioglycolic acid (TGA). Besides having benefits in maintaining pipe integrity, TGA can be decomposed to H_2S (hydrogen sulfide) due to changes in ambient temperature during storage, such as direct sunlight exposure. This irritant gas can pose a risk to the health of chemical workers. Therefore, this study aims to measure the concentration of H_2S in a CI product containing TGA. **Method:** The data were collected from an oil and gas company measurement report on 12 CI drums with 1-3%w of TGA content by using a glass tube detector. Measurements were performed by varying the measurement distance (0 and 10 cm from the mouth of the drum), observing the condition of the inflated drum surface, and determining the existence of internal pressure. **Results:** All samples contained H_2S, and the inflated drums had higher H_2S content than those that were not inflated up to more than 200 ppm in the drum bore. At this concentration, workers can experience pulmonary edema significantly prolonged exposure. Biological monitoring can be conducted by analyzing thiosulfate content in urine and blood after exposure or routine examination at the end of the work shift. Conclusion: Degraded CI with TGA content could contain H_2S and it will be risky for workers health. The H_2S concentration measurement is part of administration and engineering control in oil and gas industry.

Keywords:corrosion inhibitor, glass tube detector, hydrogen sulfide, thioglycolic acid

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INTRODUCTION

In oil and gas production facilities, pipes made of carbon steel are at risk of corrosion. Corrosion in iron pipes is the process of opening iron ions (Fe^{2+} or Fe^{3+}) due to electrochemical reactions (oxidation and reduction) so that the material is degraded (Alamri, 2020). To control the corrosion rate in pipes, the oil and gas company needs to implement Corrosion Management (Shafeek, Soltan and Abdel-Aziz, 2021). Corrosion Management is a series of programs or activities that are structured and planned to control the corrosion rate on an ongoing basis in metal facilities and equipment so that damage and losses caused by corrosion do not increase (Skovhus, Eckert, and Rodrigues, 2017). One of the strategies is a chemical additive injection, which is a Corrosion Inhibitor (CI) (Boulhaoua *et al*., 2021). The early step of this strategy is to determine the type and dose of CI that are right for the operating conditions so that the product can provide a corrosion-preventive coating on the internal parts of hydrocarbon pipelines that carry corrosive substances (such as carbon dioxide gas, hydrogen sulfide gas, produced water content, etc.). The performance of CI injection can be evaluated through the corrosion rate value in the pipe inspection program (Song *et al*., 2022). The value is expected to be as low as possible as an indicator of maintained pipe integrity. As a result, the possibility of pipe leakage and environmental pollution from oil and gas operations can be controlled.

There are various types of corrosion inhibitor (CI) substances. One of them is thioglycolic acid (TGA) or 2-mercapto-acetic acid (CAS number 68-11-1). This substance is one of the organic solvent acids containing sulfur (S) with the formula $C_2H_4O_2S$ or $HSCH_2COOH$. A colorless liquid with an unpleasant odor has a molecular mass of 92.1 and a density of 1.325 g/cm^3. TGA has been tested as a reducing agent for iron ions when used as a constituent of corrosion inhibitors (Saranya *et al*., 2020). TGA has an important role in reducing iron ions during a corrosion reaction and it could be combined with other substances to increase the effectiveness of anticorrosion (Faujdar and Singh,

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2021). However, besides having the benefit of maintaining carbon steel pipe integrity in Corrosion Management, TGA can be decomposed due to temperature changes, for example, exposure to direct sunlight. This substance can release toxic gases, including H_2S gas (hydrogen sulfide) (Chemical book, 2017). Based on an investigation in 2013 by an international oil and gas company in Indonesia, there were six CI products sold by chemical manufacturers in the world and identified as being able to produce H_2S gas from the degradation of TGA when stored, either in drum packaging, storage tanks, intermediate bulk containers, IBC tanks, and others. In one of the CI products, H_2S gas can reach up to 800 ppm when opening a 1,000 L capacity drum at a temperature of 35 ºC to 40ºC for 24 hours. 100 ppm of H_2S gas is found in other products, measured when used in the field. Due to this report, the company issued a warning regarding exposure to H_2S gas from CI products as one of the risk factors to be considered when storing, lifting, and injecting CI products in the production operation area. The formed H_2S gas can impact the health and safety of workers. Hydrogen sulfide gas is a corrosive explosive and can cause death if inhaled through human respiration. The lethal concentration of this gas is 800 ppm for 5 minutes (the National Center for Biotechnologogy Information, 2021). Occupational diseases that can be felt are rhinitis to acute damage to the respiratory system if exposed to low concentrations (0.007–0.011 mg/m^3) (Gorini *et al*., 2020). Some of the symptoms felt by workers when exposed to low doses of H_2S gas are irritation of the eyes and skin, runny nose, cough, dizziness, and nausea. If the dose is increased, the nervous system will be disrupted so that the worker will experience seizures, fainting, unconsciousness, and even death. Organ damage can be permanent in the cardiovascular, liver, hematological, and nervous systems (Rubright, Pearce, and Peterson, 2017). Moreover, the poisoning of H_2S is irreversible to the brain (Kenessary *et al*., 2017). Therefore, it became necessary to quantify the degree of the negative health impact from the excess of H_2S.

One of the control measures that can be taken is by examining the physical condition of the CI product packaging (inflated or not) and measuring the concentration of H_2S gas on the CI product packaging to determine the level of risk of H_2S exposure to the health of workers. This is important in operation because chemical manufacturers may not mention the details of the ingredients of CI products clearly on the product Safety Data Sheet (SDS). Therefore, chemical users will not be aware of the TGA substance, its concentration, and the risk of H_2S exposure if the chemical is decomposed. In addition, studies related to hazardous gas exposure to human health in oil and gas industries from other countries have been published (Lee *et al*., 2022); however, there are still few studies regarding the measurement of H_2S levels of a chemical in Indonesia and an analysis of the risks of chemicals to workers' health. By taking this necessity, this study aims to describe one H_2S concentration measurement application in a CI product containing TGA from the oil and gas industry. The health risk level to chemical workers and the recommendations at the workplace can be determined afterwards based on the H_2S level of concentration.

METHOD

This research design used a descriptive research method with a quantitative approach. The data were collected from an oil and gas company in Indonesia, which reported H_2S content from CI products routinely injected into production facilities. The SDS of the CI product mentioned the composition of the TGA content, which was around 1%-3%-w. The measurement, verification process, and reporting preparation were carried out in June 2018 – October 2019 for following up the report, risk identification process, and preparation of required corrective actions by the company. There were three measurement reports (June 2018, February 2019, and June 2019). This study used the first report (June 2018) as an initial step to follow up on the field operation team reports. Operators reported an unpleasant odor when opening the CI drums (such as rotten eggs). Some CI drums at the field were found to be inflated, and those had the same chemical production code in the June 2018 measurement report. The second and third reports (February and June 2019) had a similar measurement methodology to the first report. These measurements were conducted as part of the quality check system for each CI production entering the company's warehouse. Therefore, the primary report for this study was in June 2018 to determine the capability of the glass tube detector to identify H2S content in CI products.

The measurements were carried out at the chemical storage area by ensuring air circulation. Officers used personal protective equipment in a full-face mask equipped with a respirator. The method of measuring the H_2S content using a glass tube with the Drager Tube H_2S 1/c detector refers to the Drager Tube H_2S 1/c manual book (Dräger Safety AG & Co., 2001). The specification of the glass tube used was to have a measurement range in the range of 0-250 ppm with a standard deviation of 5-10%. The number of strokes that could be used was up to 10, and this tool's measurement duration was 3 minutes at a sample temperature between 0 and 40ºC. The tube color was visually changed from white to pale brown if the air sample contained hydrogen sulfide gas during measurement. This color change results from the reaction of the Pb^{2+} ion content in the tube, which is bound to the S^{2+} ion from hydrogen sulfide gas. The equation for the chemical reaction in the tube can be described in equation (1) as follows:

$$H_2S + Pb^{2+} \rightarrow PbS + 2H^+ \quad (1)$$

There were four steps of measuring H_2S levels in air samples around CI products. In the first step, CI products with TGA content from the same production batch were randomly selected, and each drum packaging was checked. The drums were divided into inflated or not, pressurized or not, and the measurement distances (0 cm and 10 cm from the mouth of the drum). The pressure in the drum was determined qualitatively while opening the lid of the drum. There was a sound of flowing "air" and a push from inside the drum. Based on the June 2018 measurement report, 100 CI drums with TGA content were stored with the same production batch (the storage period is about three months after the production date). The measurement operator selected five drums that were not inflated and seven that were inflated so that the total CI with TGA content as samples was 12 drums. There is no information about inflated drums with the same production code. The summary drum samples can be seen in Table 1. The second step, air sampling, was taken from the drum mouth by placing the detector tube at several sequence time stamps after opening the drum cap. The time codes were 1 second after opening (code: test 1), 20 seconds after start (code: test 2), and 30 seconds after start (code: test 3). In the third step, the air sample was transferred with a manual hand pump (Drager Accuro Pump) up to 33,3% of the tube with a stroke of 10 times. The tube must be avoided from entering solids or liquids into the tube at this stage. Last step, the measurement operator observed the color changes in the tube (from white to brownish) so that the gas content (ppm) could be determined at each measurement time using the following conversion (at 20ºC,1.013hPa):

$$1 \text{ ppm } H_2S = 1.42 \text{ mg } H_2S/m^3 \quad (2)$$
$$1 \text{ mg } H_2S/m^3 = 0.72 \text{ ppm} \quad (3)$$

Furthermore, the measured H_2S content of the CI product (in ppm) was utilized for its health risk

Table 1. Condition of CI containing TGA Drum Samples in the Company Warehouse (2018)

Drum Sample Code	Drum Inflation (Yes/No)	Drum with Internal Pressure (Yes/No)	Glass Tube Measurement Distance from Drum Cap
1	No	No	10 cm
2	No	No	10 cm
3	No	No	10 cm
4	No	No	0 cm
5	No	No	0 cm
6	Yes	No	10 cm
7	Yes	No	10 cm
8	Yes	Yes	10 cm
9	Yes	Yes	10 cm
10	Yes	Yes	10 cm
11	Yes	No	0 cm
12	Yes	No	0 cm

Table 2. H_2S Threshold Limit (OSHA, 2022)

OSHA	Perm Exposure Limit: General Industry Ceiling Limit: 20 ppm General Industry Peak Limit: 50 ppm (up to 10 minutes if no other exposure during shift) Construction 8-hour Limit: 10 ppm Shipyard 8-hour limit: 10 ppm Immediately Dangerous to Life and Health: 100 ppm/30 mins
NIOSH	Recommended Disable Exposure Limit (10 min ceiling): 10 ppm Immediately Dangerous to Life and Health: 100 ppm
ACGIH	threshold limit value (TLV®) as an 8-hour time-weighted average (TWA): 1 ppm Short Term Exposure Limit: 5 ppm / 15 min

Table 3. H_2S Effect to Human Health (Malone Rubright, Pearce and Peterson, 2017)

Concentration (ppm)	Effects
0.00011 – 0.00033	Typical background concentrations (OSHA)
0.0005	Lowest concentration detectable by human olfactory senses (ATSDR)
0.01 – 1.5	Odor threshold (when rotten egg smell is first noticeable to some) (OSHA)
2-5	Prolonged exposure may cause nausea, tearing of the eyes, headaches or loss of sleep. Airway problems in some asthma patients (OSHA)
20	Possible fatigue, loss of appetite, headache, irritability, poor memory, dizziness (OSHA)
50-100	Slight conjunctivitis (“gas eye”) and respiratory tract irritation after 1-h exposure (ANSI)
100	Eye and lung irritation; olfactory paralysis, odor disappear.
100-150	Loss of smell (olfactory fatigue or paralysis) (OSHA)
150-200	Sense of smell paralyzed; severe eye and lung irritation
250-300	Pulmonary oedema may occur, especially if exposure is prolonged (OSHA)
500-700	Staggering, collapse in 5 min (OSHA). Serious damage to the eyes. Loss of consciousness and possibly death in 30 min - 1 h (ANSI and OSHA)
700-1000	Breathing may stop within 1-2 breathes; immediate collapse (OSHA)
1000-2000	Unconsciousness at once, with early cessation of respiration and death in a few minutes. Death may occur even if individual is removed to fresh air at once (ANSI and OSHA)

analysis with comparison to H_2S threshold limits according to the Occupational Safety and Health Administration (OSHA) and the American National Standards Institute (ANSI Standard No. Z37.2-1972) in Table 2 (OSHA, 2022) and their effects on workers' health as per Table 3 (Rubright, Pearce and Peterson, 2017).

This research was conducted after obtaining approval from the Research and Community Engagement Ethical Committee, the Faculty of Public Health, Universitas Indonesia, with the certificate number Ket- 508/UN2.F10.D11/PPM.00.02/2021.

RESULTS

Based on the measurement results of 12 sample drums, all of the CI drums with 1-3%-w TGA components were detected as containing H_2S gas, since the first second after drum cap opening (Table 4), then the gas concentration at 10 out of 12 drums was decreasing after 30 seconds of the opening drum. Based on the observation on-site, the H_2S gas could be accumulated in the unopened-drums and built-up the internal pressure, so the drum surface became bulging, especially on the top side. However, the inflated drums did not occur evenly at all CI stock. On the drums that were not inflated and not pressurized (drums 1, 2, and 3), the measured H_2S concentration value was stable at 0.5 ppm for 20 seconds with a measurement distance of 10 cm from the mouth of the drum. In drums 4 and 5, the measured H_2S concentration at the drum mouth was 80 ppm and 50 ppm, respectively, and then it decreased around 98% in test 3 (1 ppm and 1.5 ppm respectively). On the inflated drums with no internal pressure (drums 6 and 7), the H_2S concentration at 10 cm from drum was 20 ppm and 25 ppm in the test 1, which was higher than drums no. 1-3, but lower than drums no. 4 and no. 5. On the test 3, the H_2S value in drums 6 and 7 decreased to 95-96%

Table 4. H_2S Concentration Measurement Result in Corrosion Inhibitor with TGA content (2018)

Test Code		1	2	3	H_2S Concentration Reduction
Sampling Time (second)		1	20	30	
Measured H_2S Concentration (ppm)	Drum 1	0.5	0.5	0.5	0%
	Drum 2	0.5	0.5	0	100%
	Drum 3	0.5	0.5	0.5	0%
	Drum 4	80	25	1.5	98%
	Drum 5	50	20	1	98%
	Drum 6	20	15	1	95%
	Drum 7	25	15	1	96%
	Drum 8	250	40	20	92%
	Drum 9	230	50	15	93%
	Drum 10	150	30	2	99%
	Drum 11	90	30	2	98%
	Drum 12	100	30	1.5	99%

(reaching 1 ppm at each drum), approaching the similar test 3 which results in drums 4 and 5.

In three inflated and pressurized drums (drums 8, 9, and 10), the measured H_2S concentration in test 1 was the highest content among other samples. The concentration of H_2S in drum 8 and drum 9 reached 250 ppm and 230 ppm in the test 1 of drum opening, and then it was decreased to 20 ppm and 15 ppm (92-93%) in the test 3. H_2S concentration in drum 10 was 150 ppm in test 1, then decreasing to 2 ppm in test 3 (99% H_2S concentration reduction). The H_2S level for inflated drums with but not pressurized (drums 11 and 12) also had a higher concentration of H_2S gas than drums that were not inflated (drums 1-5). The internal drum pressure was unknown because no intrusive pressure instrument was installed in the drum. The storage room was in company chemical storage with atmospheric pressure and ambient temperature conditions, but there was no record of storage room temperature conditions from the report.

This measurement result was continued by observing the injection operation and collecting some feedback from field workers (operators, technicians, supervisors, logistic transporters) through a simple questionnaire related to worker health effect during opening CI drum. Based on the response from 96 workers in the company regular handling CI, 2% of 96 total respondents answered that they had health problem experience during operation, such as eye irritation, dizziness, and strong smell. By comparing this condition to H_2S health effect (Table 3), it was possible that they were exposed to H_2S up to 20 ppm. The feedback was considered to develop the prevention and mitigation actions in the operation area.

DISCUSSION

H_2S Measurement with Glass Tube Detector

According to the result, the H_2S gas concentration measurement with a glass tube detector was suitable for monitoring the hazardous gas from CI products containing TGA. This measurement method is based on GPA Standard 2377 (Test for Hydrogen Sulfide and Carbon Dioxide in Natural Gas Using Length of Stain Tubes) revision 2019. When the gas sample from CI products entered the tube, the tube containing lead (Pb) changed from white to brown. The contrast of color change depends on the amount of H_2S in the gas, where the more significant the concentration of H_2S concentration, the more substantial the color change in the tube will be (GPA, 2019b). The results of the analysis with this method depend on several factors so that the user shall observe the specifications of each type of tube before taking measurements. Factors affecting measurement results include the temperature and moisture content of the tested product, ambient conditions, and several diluents and other contaminants. Activities and operating conditions may prevent the use of the stain tube, such as excessive heat or humidity in the ambient, so that the use of the tube is not suitable (GPA, 2019a). By reviewing the results of H_2S gas measurements on samples of CI products with the same drum conditions, the measured H_2S gas concentrations were not uniform. However, with the limited number of samples from the report, the magnitude of variation was not statistically analyzed and the relation between those factors and magnitude of gas concentration could not be evaluated.

Accumulated H_2S in the Degraded Corrosion Inhibitor Container

The formation of H_2S gas in the product occurs due to the chemical decomposition process of TGA, as the active ingredient of CI containing sulfur, which is influenced by changes in pressure and temperature (Marrugo-Hernandez, Prinsloo, and Marriott, 2019). In the oil and gas industry business process, CI products are generally produced and supplied by the chemical producer and delivered to the oil and gas operation area with a long distribution process, starting from the chemical plant, port-to-port transfer, and overland by trucks. Furthermore, the material is distributed from the company's warehouse to the injected points in the well and process area. During this distribution process, CI's products may expose to direct sunlight because the means of transportation do not have a dedicated shelter for chemicals.

Based on company experience, the delivery duration could be taken around 21-30 days for international shipments, continued with 7-14 days of storage, and finally distributed to the injection system on a remote location in the next seven days. The total duration would be around 50 days. During this time, CI products might experience ambient temperature changes above the room temperature (especially for the remote area in Indonesia that can reach up to 40ºC temperatures in the mid-afternoon). Due to this condition, the CI mixture with TGA content, which was stable at room temperature (Sigma-Aldrich, 2021), could be unstable and decomposed to produce H_2S. The increasing ambient temperature could raise the reaction rate of H_2S formation from sulfur-containing chemicals, such as TGA. This phenomenon was similar with other sulfur containing chemicals, such as 2,5-dimercapto-1,3,4-thiadiazole (DMTD) and 2-amino-1,3,4-thiadiazole (ATD) (Marrugo-Hernandez *et al*., 2019). Since the operations had a potential for temperature fluctuations, sulfur-containing chemicals, such as TGA, required specific mitigation to anticipate the acceleration of H_2S formation and flow into the ambient.

Although H_2S gas is not classified as a carcinogen, the acute effects of this gas can include sweating, coughing, eye pain, asthma, irritation, dizziness, nausea, headache, shortness of breath, and even death, depending on the concentration of inhaled hydrogen sulfide (Rubright, Pearce and Peterson, 2017). According to the observation and measurement results, the inflated drums would have a higher concentration up to 250 ppm. At this level, workers are prone to pulmonary edema's health risk, significantly prolonged exposure through the respiratory tract (Godoi *et al*., 2018). However, the workers handling CI chemicals could not estimate the H_2S concentration only based on CI packaging appearance (inflated or flat) because the flat drums (drums 4 and 5) also could release high H_2S concentration. This irritant gas could be contained in the drum up to 80 ppm without making any bulging appearance. By comparing the health effect in Table 2, this concentration had the potential to cause eye, lung irritation, olfactory paralysis so that workers could not feel odors if the breathing area was close to the H_2S source (Rubright, Pearce and Peterson, 2017). The other targeted organs are the brain, heart, liver, spleen, and kidneys. H_2S enters the body through the blood directly to the central nervous system. Sulfide is oxidized in the body into thiosulfate (in units of mol/l) as a biomarker, and this content can be detected in the brain, lungs, and kidneys through urine and blood samples (Maseda *et al*., 2017). Each incident of hydrogen sulfide poisoning can be seen by looking at the concentration of thiosulfate in the blood and urine, especially at lethal concentrations. The concentration of thiosulfate and urine can be used as a chronological reference for each event (Spagnolo *et al*., 2019).

H_2S from the Corrosion Inhibitor Health Risk Control to Workers

For activities related to H_2S gas, ACGIH® recommends a threshold limit value (TLV®) of 1 ppm as an 8-hour time-weighted average (TWA). If the duration of exposure of workers is approximately 15 minutes, then the recommended concentration threshold value is 5 ppm as Short-Term Exposure Limit (STEL). As the H_2S measurement in the study exceeded this threshold and the activity with this chemical could be around 30 minutes up to 1 hour as per refilling process, workers who handle the opening of the drum are required to use respiratory protective equipment. Following the Safety Data Sheet (SDS), the recommended PPE for the CI product as the sample was a full-face mask with a combination filter for vapor/particulate respirator (EN 141) type ABEKP. If a worker inhales H_2S gas released from CI products made from TGA, then the first aid is to move the victim to an area with fresh air, keep warm, and let the victim rest. The victim can be given supplemental oxygen through artificial respiration with a breathing bag (ambu bag) or a respirator if there is difficulty of breathing. In higher toxic doses where a patient may be altered or in severe respiratory distress secondary to pulmonary edema, treatment consists of sodium nitrite administration of 300 mg intravenous given over two to four minutes (Sawaya and Menezes, 2021). Therefore, before starting the operation with this CI, supervisors, and workers shall ensure proper respirator usage and the first aid action plans.

By considering the measurement result, the reduction up to 99% of H_2S content from the initial value of drum opening, workers are advised to stay away from the drum for the first 30 seconds so that the H_2S gas from inside the drum flows into the environment and is diluted in the air. The information regarding the safe distance and time after opening the drum is necessary to be added to mitigate the use of these chemicals. According to the OSHA standard on Hazardous Materials (Standard 1920.120), workers should be protected by maintaining a safe distance from opened drums. If personnel must be near the drum, OSHA recommends placing an explosion-proof plastic shield between the drum and drum to protect it in the event of an explosion. Before opening the drum, a control system needs to be prepared in drum opening equipment, monitoring equipment, and fire suppression equipment behind explosion-proof plastic as a shield.

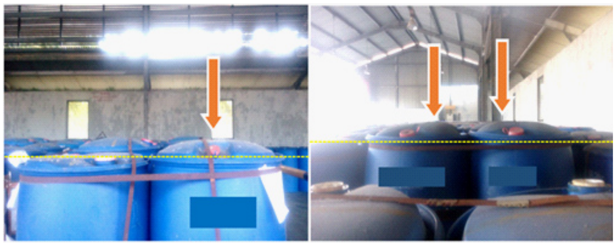

Figure 1. Inflated CI drums in Company Warehouse (2018)

Regarding the inflated CI drum, this study had limitations to measuring the drum surface's deviation from normal conditions. The observation was done only by visual (Figure 1). In addition, the drum did not have a pressure measurement system to determine the change in pressure inside the drum until it was inflated. As a result, the study did not obtain data that could be analyzed statistically to determine the relationship between the value of the H_2S content and the bulging process in the drum. However, workers still could detect changes in the appearance of drum surface inflated or not. If inflated, this condition could indicate CI degradation and higher H_2S gas content potential. Therefore, the company should apply administrative control by not moving any CI material to another place before further drum quality inspections. Hazard notification in the working area is necessary if there is a potential health and safety risk due to pressurized drums. This mitigation action would be in line with the recommendations issued by OSHA through the standard section 1910 subsection H (Hazardous Material, 1920.120) (OSHA, 2021).

In routine operations at oil and gas production facilities, control of occupational health and safety risks cannot depend on PPE and administrative controls only. When the TGA content in CI could not be eliminated or substituted based on technical laboratory corrosion test results, the application of engineering control on the CI drum is required to reduce the opportunity for H_2S exposure to the health and safety of workers. One mitigation to reduce the H_2S accumulation and pressure built-up is by installing an additional pressure-venting cap as simple "ventilation" on the drum. This device will support the implementation of OSHA standard 1910 (120), where the drum and housing must be opened slowly so that excess interior pressure can be safely removed. The size of the pressure-venting cap can be adjusted according to the rate of formation of H_2S. The decomposition reaction rate of TGA could not be calculated or estimated based on this study. It is recommended to measure the thermochemical sulfate reduction reaction (TSR), as the H_2S gas formation process from TGA, by analyzing through gas chromatography (Marrugo-Hernandez *et al*., 2019). By knowing the rate of formation of H_2S, the company evaluates a more appropriate capsize and provides recommendations to the chemical supplier to install it at each drum. As a result, the H_2S gas from CI products could be controlled and released safely without opening the drum by personnel.

CONCLUSION

Corrosion inhibitor products containing TGA can produce H_2S gas that needs to be monitored and controlled. Therefore, the impacts are minimized to occupational diseases. Measurement with the glass tube detector can provide concentration value data by observing the tube's color changes. The measured H_2S concentration of TGA-based CI products can vary more than 200 ppm. At this level, workers can be at risk of pulmonary edema through the respiratory tract and effects on other organs, especially the central nervous system, due to prolonged exposure. Even this level of effect was not identified based on field workers response, workers' risk control can be carried out by installing a pressure-venting cap, applying administrative controls, and appropriate PPE, especially for respiratory type. Initial gas testing and monitoring using portable gas detector with H_2S sensor are also applicable to assess the gas before starting a job and while working with the drums. In addition, the use of portable gas detector is very common practice in oil & gas industry so it could be considered as one of risk controls. Further studies are needed to support statistical analysis of future measurement methods with more CI drum samples, applying the same techniques and similar chemical storage locations. This study extension will support the research of the relationship between the variables and the results of measurements of H_2S gas from CI products containing TGA. In addition, simulations of TGA decomposition in the laboratory through gas chromatography can provide the basis of H_2S formation from TGA in CI packages. The drum venting system will be more accurate.

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