Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 972-982 | ISSN:2251-6727

Consequence Analysis of Gas Release, Fire and Explosion in H_2S Removal Unit

Budi Sulistiyo Nugroho[1]*, Restu Ramadhani Pratama Putra[1]*, Zami Furqon[1], Farid Alfalaki Hamid[1], Arif Nurrahman[1], Annasit[1], Aprilia Indah Mandaka[1], Genoveva Lestari Kulaleen[1], Adhi Kurniawan[2]

[1] Oil and Gas Processing Engineering, Polytechnic of Energy and Mineral Akamigas, Jl. Gajah Mada No. 38, Cepu, Blora, Jawa Tengah, 58315, INDONESIA

[2] Upstream Oil and Gas Subsidiary X, Maspion Industrial Estate Unit C, Jl. Beta Maspion, Manyarsidomukti, Manyar Sido Mukti, Manyar, Gresik, Jawa Timur, 61151, INDONESIA

(Received: 14 April 2024 Revised: 1 May 2024 Accepted: 18 June 2024)

KEYWORDS

Gas Release,
H2S

ABSTRACT:

The oil and gas industry has a high risk of process accidents such as gas release, fire, and explosion that can cause death, injury, environmental damage, property damage, decreased company reputation, and financial losses. H2S removal unit has a high potential for process accidents, so it is necessary to analyze the consequences of gas release, fire, and explosion to determine the impact caused. This study aims to analyze the consequences of gas release, fire, and explosion in the H2S removal unit, identify hazardous zones, and estimate asset damage and production loss. The method used is consequence analysis based on simulation of gas release, fire, and explosion using Shell FRED software, with independent variables in the form of actual operating conditions, feed composition data, and meteorological data, and dependent variables in the form of radius or range of consequences of gas release, fire, and explosion. The results showed that corrosion of pipe joints, valves, or Amine Contactor structures is the most likely scenario to cause gas release, fire, and explosion. The results of the gas release consequence analysis state that the hazardous zone is the zone reached by H2S concentrations of 76 ppm to 41 ppm which has a radius of 17.1 m. The hazardous zone for jet fire consequence is the zone reached by jet flame up to the zone reached by thermal radiation of 37.5 kW/m² which has a radius of 60.53 m. The danger zone for flash fire consequences is the zone reached by 100% LFL concentration which has a radius of 40.84 m. The hazardous zone for vapor cloud explosion consequences is the zone reached by an overpressure of 0.7 bar to 0.34 bar which has a radius of 17.78 m. Asset damage is estimated at US$ 1,408,575.4387 and production loss at US$ 227,805.4751/day, bringing the total loss for one month to US$ 8,242,739.6916. Therefore, the company must prepare a preventive measure or mitigation of this consequence.

1. Introduction

The oil and gas industry is known as an industry with a very high level of risk, including the risk of work accidents and environmental pollution. Both types of risks, if not managed properly, can cause huge losses to the company. Among the two, occupational accident risk is considered the most dangerous as it is directly related to personnel safety. Work accidents often occur due to an unsafe work culture and the hazards of the oil and gas industry process. Statistics on work accidents in the upstream sector of the oil and gas industry in Indonesia from 2016 to 2021 show this clearly.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 972-982 | ISSN:2251-6727

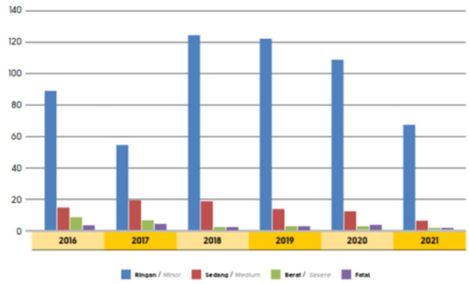

Fig. 1 *Statistics on occupational accidents in the upstream oil and gas industry in Indonesia [1]*

Based on Figure 1, it can be seen that work accidents in the oil and gas industry fluctuate, but most are minor accidents. Cases of fatal accidents are rare. One of the main causes of work accidents is the danger of process accidents, which have a devastating impact on the company. Examples of process accidents in the oil and gas industry include gas release, fire, and explosion. The following shows some examples of process accidents that occurred in the oil and gas industry in Indonesia.

Table 1 *Process accidents in the oil and gas industry in Indonesia [2]*

No.	Events	Date of Event	Losses
1.	Tank Explosion at PT Tawu Inti Bati in Karawang	November 21, 2016	Two people died and the roof of the tank came off.
2.	Explosion of City Gas Network of PT National Gas Company in Cimanggu Residence Housing Complex, Bogor City	February 14, 2018	The occupants of the house suffered burns and damage to the house.
3.	Fire and Tank Explosion at PT Pertamina International Refinery RU VI Balongan	March 29, 2021	Two villagers died, four were burned and four tanks caught fire.
4.	Gas Transport Module Explosion at SPBG PT Gagas Energi Indonesia	May 5, 2022	There were no casualties but there was property damage.
5.	Fire and Explosion at TBBM Plumpang, Koja, North Jakarta PT Pertamina	March 3, 2023	17 people died and 50 people were injured and there was property damage.

Based on Table 1, it can be seen that there are many cases of process accidents in the oil and gas industry, with various losses such as fatalities, injuries, property damage, and financial losses. Therefore, prevention and mitigation of process accidents are essential to avoid major losses to the company. One of the important process units in natural gas processing is the H_2S removal unit, which has high potential hazards and risks. These risks are caused by hazardous operating conditions and the treated H_2S gas is a hazardous gas. As a result, process accidents such as gas release, fire, and explosion are very likely to occur in this H_2S removal unit.

Many companies have taken steps to prevent and reduce process accidents by identifying hazards, setting up safety measures, and running process safety management programs. However, the possibility of process accidents still exists. The consequences of process accidents in the form of gas release, fire and explosion need to be known and analyzed further. This is because by knowing the consequences of gas release, fire and explosion in the H_2S removal unit, the risks that can be caused by these consequences can be estimated and the company can take the necessary policies.

Therefore, consequence analysis of gas release, fire and explosion is required to determine the consequences of the hazards of gas release, fire and explosion in the H_2S removal unit. If this consequence analysis is not carried out, there is a high possibility of risks arising from each consequence. In addition, personnel around the H_2S removal unit can be exposed to the consequences of gas release, fire and explosion. Therefore, the researcher is interested in analyzing the consequences of gas release, fire and explosion at the H_2S removal unit based on these considerations. The objectives of this study are to analyze the consequences of gas release, fire and explosion at the H_2S removal unit, determine the zones that are considered dangerous and estimate the asset damage and production loss caused by gas release, fire and explosion at the H_2S removal unit.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 972-982 | ISSN:2251-6727

2. Methods

This study lasted for three months, from January 2024 to March 2024, with the location at Upstream Oil and Gas Subsidiary X. The focus of this research is the H_2S removal unit. The variables studied include independent variables such as actual operating conditions, feed composition data on the H_2S removal unit, and meteorological data. The dependent variable is the radius or range of consequences of gas release, fire, and explosion. These variables are the inputs and outcomes of this study. Materials used in the study include actual operating condition data of H_2S removal unit, feed composition data, and meteorological data. The actual operating condition data required includes pressure, temperature, and feed flowrate at the device with the most fatal scenario. In this case, the scenario identification results show the Amine Contactor which has the most fatal consequences of gas release, fire, and explosion. The pressure is 33.48 barg, the temperature is 50.47°C, and the feed gas flowrate is 28.1 MMSCFD (Primary Data, 2024). The following is the H_2S removal unit feed composition data:

Table 2 *H_2S removal unit feed gas composition data (Primary Data, 2024)*

Composition	% mol or ppm
C_1	78.4886 % mol
C_2	6.7075 % mol
C_3	4.9615 % mol
iC_4	1.1972 % mol
nC_4	1.3622 % mol
iC_5	0.4386 % mol
nC_5	0.2570 % mol
C_{6+}	0.2481 % mol
N_2	2.3319 % mol
CO_2	3.9668 % mol
H_2S	406 ppm

Table 2 above shows the feed gas composition data used for the consequence analysis of gas release, fire, and explosion. From the table, it can be seen that the material specifications in the H_2S removal unit fall into the category of flammable and toxic gases. The hazards posed by these materials include highly flammable, explosive, corrosive, and toxic gases. Therefore, the material is categorized as hazardous gas in the H_2S removal unit. The meteorological data can be seen in table 3:

Table 3 *Gresik meteorological data (Primary Data, 2024)*

Parameter	Value
Temperature	30°C
Pressure	1 bar
Humidity	85%
Wind Speed	5 m/s

Table 3 above contains the meteorological data used for the consequence analysis of gas release, fire, and explosion. Other inputs, such as the hole diameter is assumed to be 100 mm, the size of the congested area; 243 m long, 48 m wide, and 6 m high, and the volume of combustible gas is 981.9 m³. These data will be used to analyze the consequences of gas release (H_2S dispersion), fire (jet fire and flash fire), and explosion (vapor cloud explosion). The working method of this research can be seen in Figure 2 below:

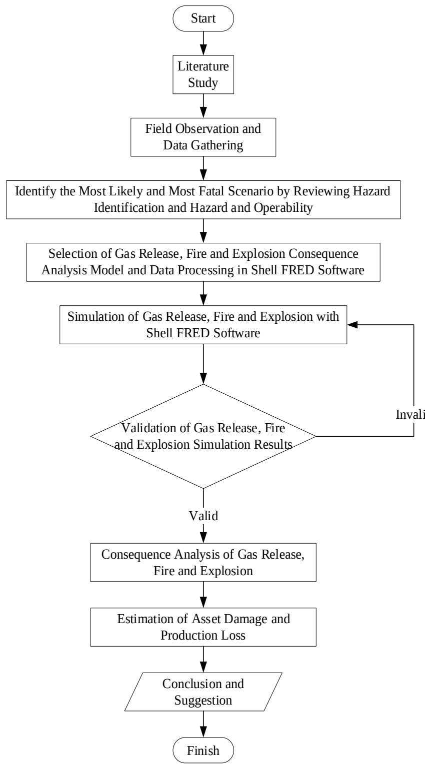

Fig. 2 *Working method for consequence analysis of gas release, fire and explosion*

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 972-982 | ISSN:2251-6727

This research begins with a literature study, followed by field observations and data collection as mentioned in the previous discussion. The data used is an average from January 2023 to February 2024. The average data aims to describe the real state of the H_2S removal unit. Then the most likely and most fatal scenarios were identified by reviewing the hazard identification of the gas processing facility and the hazard and operability of the H_2S removal unit. After that, the model selection was carried out to analyze the consequences of gas release, fire and explosion. Note that the consequences of gas release, fire and explosion simulated are toxic gas dispersion or H_2S dispersion, jet fire, flash fire and vapor cloud explosion. For the model used in the simulation of gas release and fire is Pressurized Release and for explosion is Congestion Assessment Method (CAM which is because the type is unconfined vapor cloud explosion).

After model selection, gas release, fire and explosion simulations were carried out. The simulation results are validated by brainstorming with experts. If the simulation results are valid, then proceed with consequence analysis and identification of zones that are considered dangerous. Then the estimation of asset damage and production loss due to the consequences of gas release, fire and explosion is carried out. Finally, conclusions and suggestions are drawn from the results of the consequence analysis. The analysis method used is consequence analysis based on simulation of gas release, fire and explosion in H_2S removal unit conducted using Shell FRED software.

3. Results and Discussion

Based on the hazard identification review of the gas processing facility and the hazard and operability of the H_2S removal unit, the most likely scenario to cause gas release, fire, and explosion is corrosion of the pipe joints, valves, or Amine Contactor structure. Due to this corrosion, holes are formed that can cause loss of containment of hydrocarbon gas and H_2S, which ultimately results in gas release (H_2S dispersion), fire (jet fire and flash fire), and explosion (vapor cloud explosion). The Amine Contactor was chosen as the tool with the most fatal scenario because this tool contains a lot of hydrocarbon gas, has a high H_2S content, and operates at a fairly high pressure and temperature. After the most fatal scenario is known, the consequence analysis of gas release, fire, and explosion at the Amine Contactor is carried out using Shell FRED software. For a more detailed discussion can be seen below:

3.1 Consequences of Gas Release (Toxic Gas Dispersion or H_2S Dispersion)

Based on the simulation results in Shell FRED software, the consequences of gas release specifically for toxic gas dispersion or H_2S dispersion are reviewed from the H_2S concentration parameter. The H_2S concentrations reviewed in this study are 10 ppm, 41 ppm and 76 ppm. The determination of this parameter is based on the reference AEGL chemical database, U.S. EPA and H_2S safety assessment from Upstream Oil and Gas Subsidiary X. Where each concentration has its own impact. For further discussion related to the consequence analysis of gas release can be seen below:

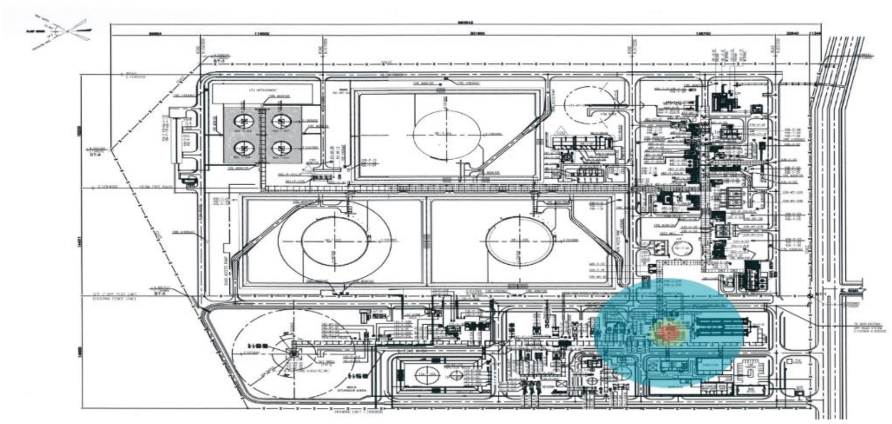

Fig. 3 *Simulation results of gas release (H_2S dispersion) and plotting on the onshore facility plot*

Based on Figure 3, the simulation results of gas release (H_2S dispersion), range and identified zones can be seen. The extent of the consequences of gas release is measured from the center of the release which is in the Amine Contactor. From the figure, it can be seen that there are 3 color zones visible on the plot of the onshore facility plant. The following is an explanation of each zone:

- **Red Zone**: Zone with H_2S concentration of 76 ppm. This zone can cause fatality to personnel. This zone has a range or radius of 9.12 m.
- **Yellow Zone**: Zone with H_2S concentration of 41 ppm. This zone can cause long term injury to personnel. This zone has a range or radius of 17.1 m.
- **Blue Zone**: Zone with H_2S concentration of 10 ppm. In this zone Toxic Gas Detector can detect the presence of H_2S. This zone has a range or radius of 75 m.

Based on the explanation above, it can be concluded that zones with H_2S concentrations of 76 ppm to zones with H_2S concentrations of 41 ppm are dangerous zones. This is because in these areas the possibility of fatality and long term injury to personnel is very large. Therefore, when there is a consequence of gas release, especially H_2S dispersion, personnel should not be in this zone if they are not using respiratory protective equipment. If personnel who do not use respiratory protective equipment are in this zone when the consequences of gas release occur, there is a high probability of fatality or long term injury.

3.2 Consequences of Fire (Jet Fire and Flash Fire)

Based on the simulation results in Shell FRED software, the consequences of fire are divided into 2 types, namely for jet fire and flash fire. The pool fire case is not reviewed in this study because the fluid in this unit is gas phase. For the first discussion, we will discuss the consequences of jet fire. The consequences of jet fire are reviewed from the thermal radiation parameter. Thermal radiation reviewed in this study is 4.7 kW/m^2, 11.7 kW/m^2 and 37.5 kW/m^2. This parameter determination is based on CMPT and API 521 references. Where each thermal radiation has its own impact. For further discussion regarding the analysis of the consequences of jet fire can be seen below:

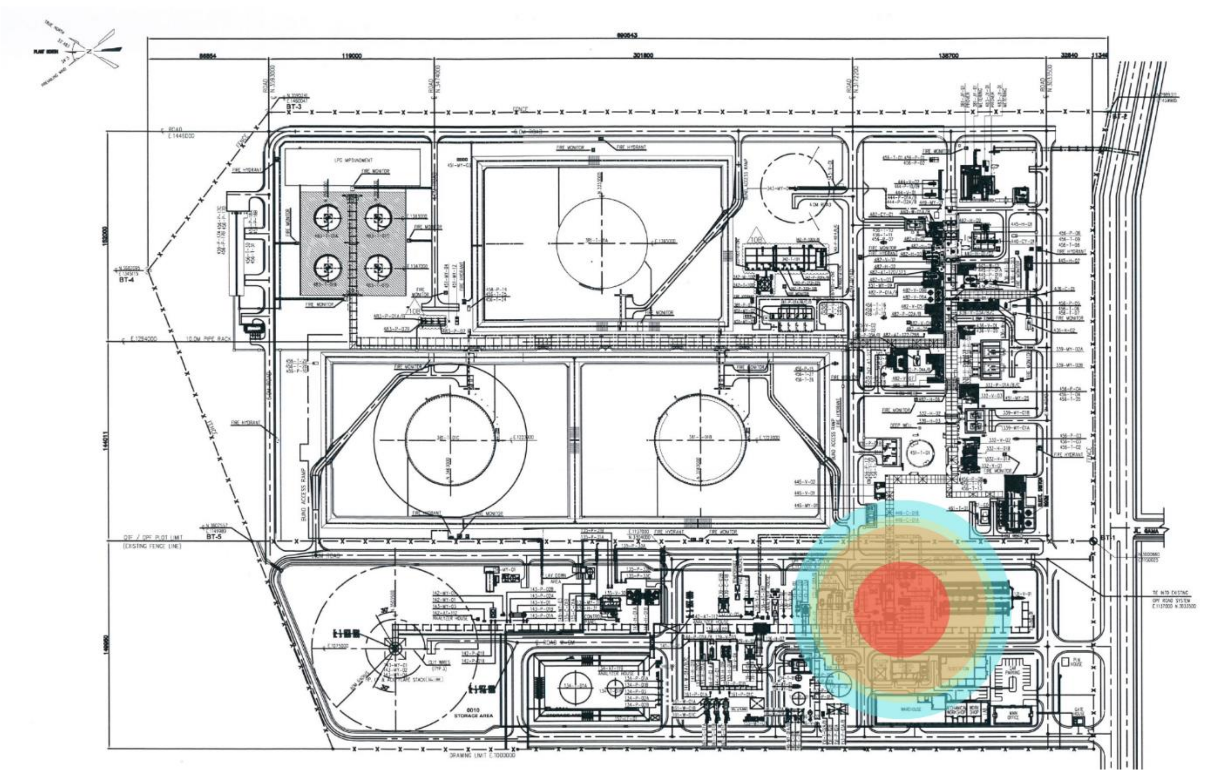

Fig. 4 *Jet fire simulation results and plotting on the onshore facility plant plot*

Based on Figure 4, the results of the jet fire simulation, the range and the identified zones can be seen. The extent of the jet fire consequences is measured from the center of the ignited release located at the Amine Contactor. From the picture, it can be seen that there are 4 color zones visible on the plot of the onshore facility plant. The following is an explanation of each zone:

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 972-982 | ISSN:2251-6727

- **Red Zone**: The zone reached by the jet flame. This zone has a range or radius of 35.06 m.
- **Orange Zone**: Zone with thermal radiation of 37.5 kW/m^2. This zone can cause immediate fatality. At this level, the pain threshold is virtually instantaneous. This zone has a range or radius of 60.53 m.
- **Yellow Zone**: Zone with thermal radiation 11.7 kW/m^2. This zone does not cause no immediate fatalities. Personnel might suffer pain after 3 seconds exposure, impairment of escape routes. This zone has a range or radius of 68.38 m.
- **Blue Zone**: Zone with thermal radiation 4.7 kW/m^2. In this zone Sufficient to cause pain if the person is unable to reach cover within 16 seconds. Limiting radiation intensity for escape actions lasting 2 to 3 minutes by personnel in appropriate clothing. This zone has a range or radius of 80.27 m.

Based on the explanation above, it can be concluded that the zone reached by the jet flame to the zone with thermal radiation 37.5 kW/m^2 is the most dangerous zone. This is because in these areas the possibility of fatality in personnel is very large. Therefore, when the consequences of jet fire occur, personnel should not be in this zone if they do not use special protective equipment from thermal radiation. If personnel who do not use special protective equipment from thermal radiation are in this zone when the consequences of jet fire occur, there is a high probability of fatality.

The second discussion is the consequences of flash fire. The consequences of flash fire are reviewed from the Lower Flammable Limit (LFL) parameter. The Lower Flammable Limit (LFL) reviewed in this study is LFL and ½ LFL. The determination of this parameter is based on the reference CCPS guidelines for chemical process quantitative risk analysis. Where each LFL has its own impact. For further discussion related to flash fire consequence analysis can be seen below:

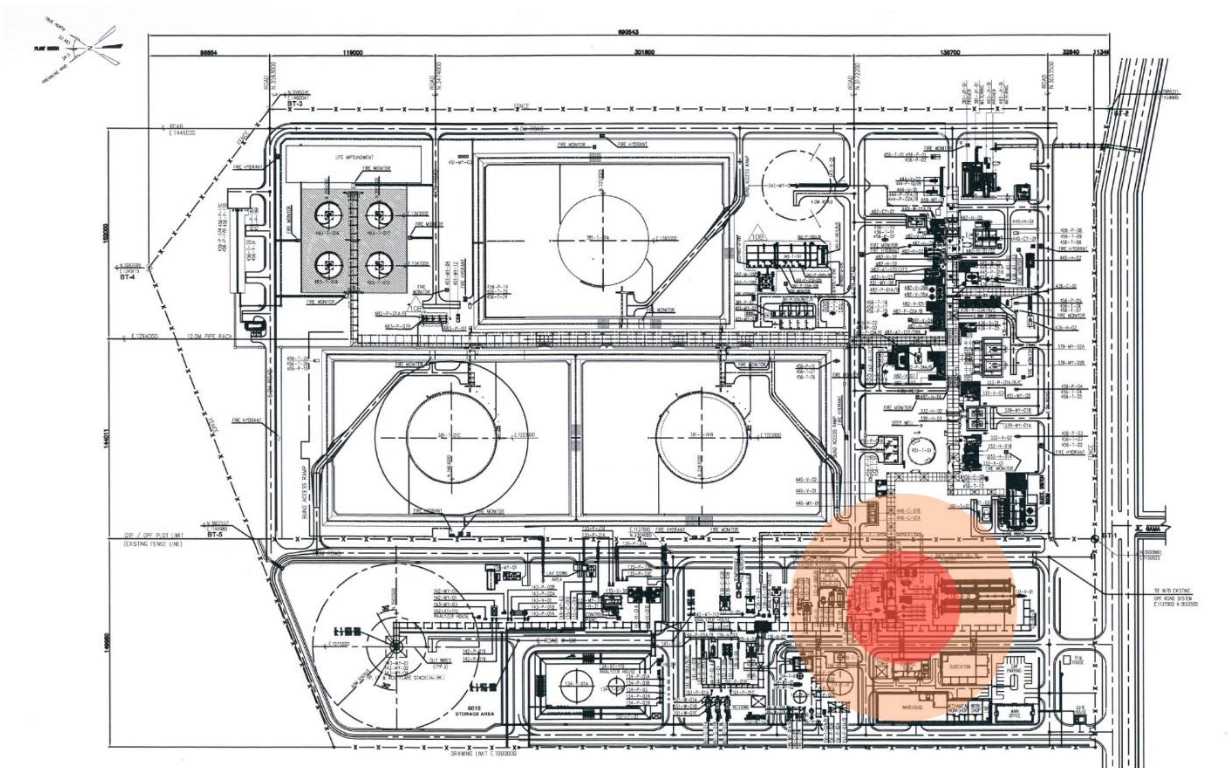

Fig. 5 *Flash fire simulation results and plotting on the onshore facility plant plot*

Based on Figure 5, the results of the flash fire simulation, the range and the identified zones can be seen. The extent of the consequences of flash fire is measured from the center of the release at the Amine Contactor. From the picture, it can be seen that there are 2 color zones visible on the plot of the onshore facility plant. The following is an explanation of each zone:

- **Red Zone**: Zone with 100% LFL or LFL concentration. This zone can cause flash fire if the gas is ignited and can cause injury or fatality to personnel. This zone has a range or radius of 40.84 m.
- **Orange Zone**: Zone with a concentration of 50% LFL or ½ LFL. In this zone it cannot cause flash fire. This zone has a range or radius of 70 m.

Based on the explanation above, it can be concluded that the zone with a concentration of 100% LFL or LFL is a dangerous zone. This is because in these areas flash fire can occur and the possibility of injury or fatality to personnel is very large. Therefore, when the consequences of flash fire occur, personnel should not be in this zone if they do not use special protective equipment. If personnel who do not use special protective equipment are in this zone when the consequences of flash fire occur, there is a high probability of injury or fatality.

3.3 Consequences of Explosion (Vapor Cloud Explosion)

Based on the simulation results in Shell FRED software, the consequences of explosion specifically for vapor cloud explosion are reviewed from the overpressure parameter. The overpressure reviewed in this study is 0.05 bar, 0.1 bar, 0.34 bar, 0.5 bar and 0.7 bar. The determination of these parameters is based on reference to the Shell FRED manual book, articles written by Kanokwan and the website of the office of response and restoration. Where each or range of overpressure has its own impact. For further discussion related to explosion consequence analysis can be seen below:

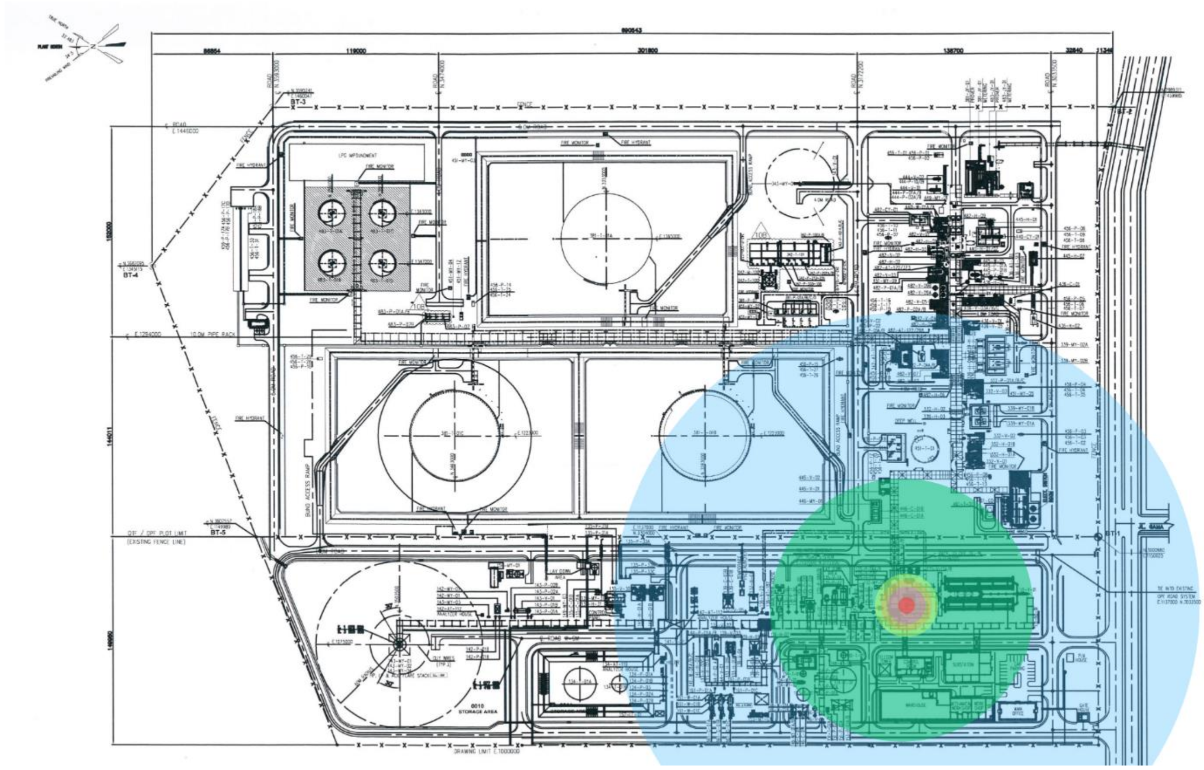

Fig. 6 *Vapor cloud explosion simulation results and plotting on the onshore facility plant plot*

Based on Figure 6, the results of the vapor cloud explosion simulation, the range and the identified zones can be seen. The extent of the consequences of vapor cloud explosion is measured from the center of the explosion in the Amine Contactor. From the picture, it can be seen that there are 6 color zones visible on the plot of the onshore facility plant. The following is an explanation of each zone:

- **Red Zone**: The zone reached by 0.7 bar overpressure. This zone can cause fatality if there are personnel in the area. This zone has a range or radius of 2.988 m.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 972-982 | ISSN:2251-6727

- **Orange Zone**: Zone reached by 0.5 bar overpressure. This zone can cause failure of connecting pipes, destruction of brick walls with a thickness of 0.2-0.3 m and shifting of tanks. This zone has a reach or radius of 8.576 m.
- **Orange Zone**: The effective explosion radius zone, the distance at which flammable gases are dispersed which in the event of ignition from ignition sources can result in an explosion. This zone has a range or radius of 12.98 m.
- **Yellow Zone**: The zone reached by an overpressure of 0.34 bar. This zone can cause damage to buildings and plants and can cause eardrum rupture to personnel in the zone. This zone has a reach or radius of 17.78 m.
- **Green Zone**: Zone reached by 0.1 bar overpressure. In this zone it can cause damage to buildings that can be repaired or can be referred to as minor damage to buildings. This zone has a range or radius of 86.82 m.
- **Blue Zone**: The zone reached by an overpressure of 0.05 bar. This zone can cause glass breakage. This zone has a range or radius of 184.6 m.

Based on the explanation above, it can be concluded that the zone with an overpressure of 0.7 bar to the zone with an overpressure of 0.34 bar is a dangerous zone. This is because in these areas the possibility of fatality or injury to personnel is very large. Therefore, when the consequences of vapor cloud explosion occur, personnel should not be in this zone. If personnel are in this zone when the consequences of vapor cloud explosion occur, there is a high probability of fatality or injury.

3.4 Estimation of Asset Damage and Production Loss

Estimation of asset damage and production loss is carried out based on the consequences of gas release, fire and explosion. For the estimation of asset damage is done by estimating the amount of equipment damaged by explosion. The reference overpressure is 0.34 bar. This is because at that overpressure damage to equipment in the plant can occur. The following shows the overpressure range of 0.34 bar in Figure 7:

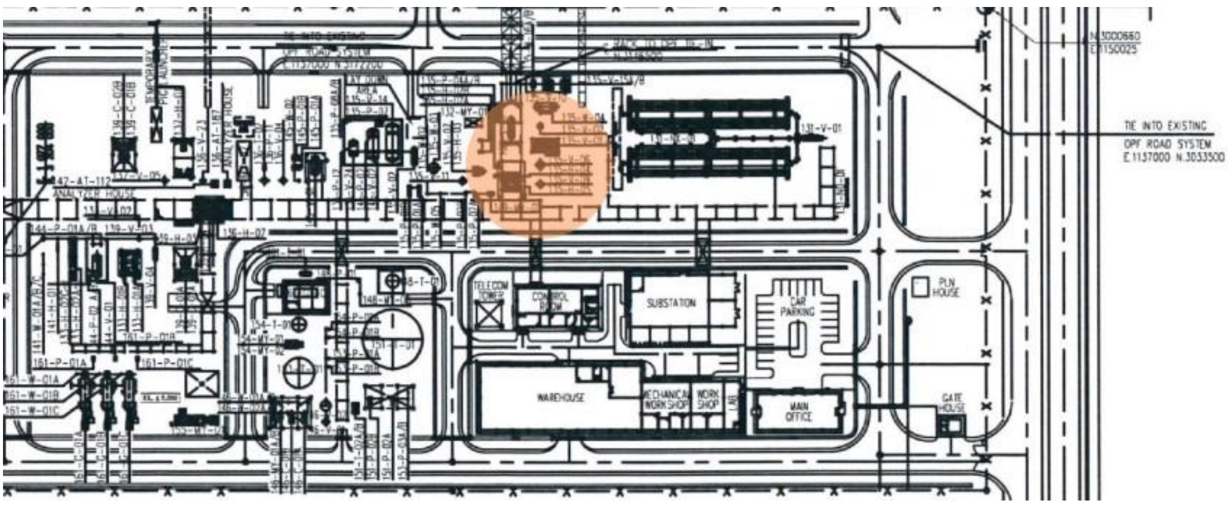

Fig. 7 *Equipment affected by explosion*

Based on Figure 7, the shaded area is an area that falls within the 0.34 bar overpressure range. If examined more deeply, there are 16 pieces of equipment affected by the explosion. The researcher assumes that the equipment is severely damaged so that it is necessary to replace the equipment. The price of the equipment affected by the explosion was estimated based on the equipment data sheet and the help of the equipment price estimation website. The website is matche. However, the estimated equipment price on the website needs to be

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 972-982 | ISSN:2251-6727

corrected again with the cost index to find out the price of equipment in the current year. The cost index that researchers use is the Nelson Farrar index. After correction, the total asset damage based on the amount of damaged equipment can be known. The following shows the results of the calculation of asset damage based on the results of the explosion consequence analysis on the H_2S removal unit:

Table 4 *Recapitulation of asset damage calculation due to explosion at H_2S removal unit*

Equipment	Number of Equipments	2014 Price/Equipment ($)	2024 Price/Equipment ($)	Total Equipment Price 2024 ($)
Amine Regenerator Reboiler (135-H-03)	1	93,000	107,887.9227	107,887.9227
Amine Reflux Drum (135-V-11)	1	84,300	97,795.1816	97,795.1816
Amine Regenerator (135-V-07)	1	156,500	181,553.3324	181,553.3324
Rich/Lean Amine Exchanger (135-H-02 A/B)	2	32,500	37,702.7687	75,405.5374
Hot Lean Amine Pump (135-P-04 A/B)	2	4,900	5,684.4174	11,368.8349
Amine Reflux Pump (135-P-02 A/B)	2	3,200	3,712.2726	7,424.5452
Rich Amine Flash Drum (135-V-10)	1	72,100	83,642.1423	83,642.1423
Amine Surge Vessel (135-V-02)	1	50,400	58,468.2936	58,468.2936
Amine Contactor Inlet KO *Drum* (135-V-01)	1	12,800	14,849.0904	14,849.0904
Amine Contactor (135-V-06)	1	465,500	540,019.6563	540,019.6563
Lean Amine Air Cooler (135-H-04)	1	45,600	52,899.8847	52,899.8847
Amine Overhead Gas KO *Drum* (135-V-09)	1	106,900	124,013.1069	124,013.1069
Amine Regenerator Overhead Cooler (135-H-05)	1	45,900	53,247.9103	53,247.9103
Estimated Asset Damage	**16**	**-**	**-**	**1,408,575.4387**

Based on table 4, it can be seen that the estimated asset damage due to explosion reaches US $ 1,408,575.4387. However, keep in mind that the asset damage is an estimate of the equipment that is considered damaged and the price is not based on the price in real conditions. Furthermore, the researcher also reviewed the production loss incurred due to production stoppage due to the consequences of gas release, fire or explosion. Production loss is reviewed from the revenue generated from the sale of gas sales. The average amount of sales gas produced is 28.1 MMSCFD with a sales gas price of 6.98 $/MMBTU (Primary Data, 2024). Based on Aspen HYSYS simulation results, the HHV value of sales gas is 1161.4551 MMBTU/MMSCF. So, from these data, the production loss can be calculated. The following shows the calculation of production loss:

$$Production\ Loss\ = Total\ Gas\ Sales\ \times\ HHV\ Sales\ Gas\ \times\ Sales\ Gas\ Price \qquad (1)$$

Production Loss = 28.1 MMSCFD × 1161.4551 MMBTU/MMSCF × 6.98 $/MMBTU
Production Loss = US$ 227,805.4751/day

Based on the above calculation, it can be seen that if there is a production stoppage for one day, it can cause a production loss of US$ 227,805.4751/day. If there is a production stoppage for 1 month then of course the production loss will be even greater. This can be seen in Figure 8:

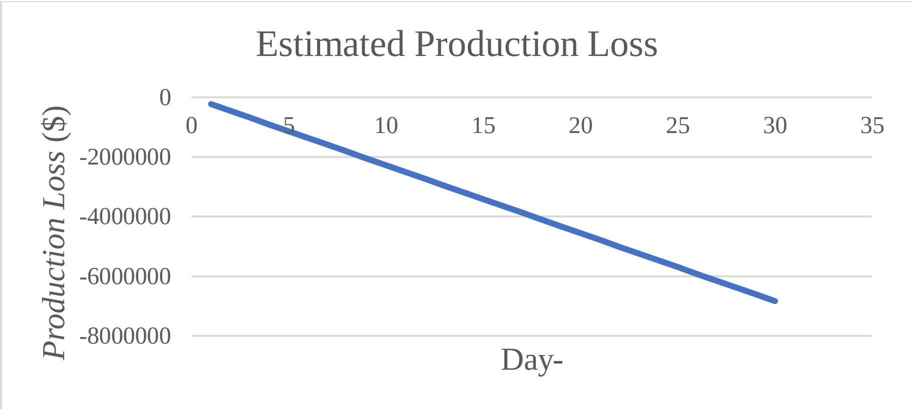

Fig. 8 *Estimated production loss in the event of a 30-day suspension of operations*

Based on Figure 8, it can be seen that if there is a production stoppage for 1 month, the production loss will increase. In fact, if even 1 month of production loss can reach US$ 7,000,000. If it is totaled between asset damage and production loss on a 1-month basis, the loss that can be borne by the company is US$ 8,242,739.6916. It should be noted that this loss only calculates from equipment asset damage and production loss, there are still many aspects of loss that are not reviewed such as compensation and other costs.

Based on the results of the consequence analysis of gas release, fire and explosion at the H_2S removal unit, it can be seen that the consequences of gas release, fire and explosion are very bad. The consequences can be in the form of fatalty or injury to personnel, asset damage, production loss or reputation loss. To prevent this from happening, the company must prepare appropriate prevention and mitigation measures in dealing with the consequences of gas release, fire and explosion. Actions that can be taken by the company can increase the existing system protection layer and evaluate and identify hazards that allow the consequences of gas release, fire and explosion. Thus, personnel will remain safe from the consequences of gas release, fire and explosion.

4. Conclusion

Based on the results of the analysis, corrosion of pipe joints, valves, or Amine Contactor structures is the most likely scenario to cause gas release, fire, and explosion. The results of the gas release consequence analysis state that the hazardous zone is the zone reached by H_2S concentrations of 76 ppm to 41 ppm which has a radius of 17.1 m and this zone can pose a high risk of fatality and long-term injury to personnel. The hazardous zone for jet fire consequences is the jet flame reach zone up to the zone reached by the thermal radiation of 37.5 kW/m² which has a radius of 60.53 m and this zone can increase the probability of fatalities. The hazardous zone for flash fire consequences is the zone reached by 100% LFL concentration which has a radius of 40.84 m and this zone is a high risk that can cause injury or fatality. The hazardous zone for vapor cloud explosion consequences is the zone reached by an overpressure of 0.7 bar to 0.34 bar which has a radius of 17.78 m and this zone also poses a risk of fatality or injury. Asset damage is estimated at US$ 1,408,575.4387, and lost production at US$ 227,805.4751/day. If the shutdown lasts for one month, the production loss could reach US$ 7,000,000, resulting in a total loss to the company of US$ 8,242,739.6916. The consequences of gas release, fire and explosion are devastating, including fatalities or injuries to personnel, damage to assets, loss of production and loss of reputation. To prevent this, the company should set up appropriate prevention and mitigation measures, including improving protective systems and evaluating and identifying hazards that can cause gas release, fire and explosion, to ensure personnel safety.

Acknowledgement

The researcher would like to thank Polytechnic of Energy and Mineral Akamigas and Upstream Oil and Gas Subsidiary X for their support in this research. The support you provide is very meaningful to researchers. Hopefully we can collaborate in the next collaboration.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 972-982 | ISSN:2251-6727

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Restu Ramadhani Pratama Putra, Budi Sulistiyo Nugroho, Zami Furqon, Aprilia Indah Mandaka, Genoveva Lestari Kulaleen; **data collection:** Restu Ramadhani Pratama Putra, Aprilia Indah Mandaka, Genoveva Lestari Kulaleen, Adhi Kurniawan; **analysis and interpretation of results:** Restu Ramadhani Pratama Putra, Budi Sulistiyo Nugroho, Zami Furqon, Aprilia Indah Mandaka, Genoveva Lestari Kulaleen, Adhi Kurniawan; **draft manuscript preparation:** Restu Ramadhani Pratama Putra, Budi Sulistiyo Nugroho, Zami Furqon, Aprilia Indah Mandaka, Genoveva Lestari Kulaleen, Adhi Kurniawan. All authors reviewed the results and approved the final version of the manuscript.

References

[1] Abdel-Aal, H. K. (2003). Petroleum Engineering. National Research Center Egypt.
[2] Abdima G. (2011). Analysis of Chlorine Deployment Consequences Using ALOHA Software In Container of A Ton Chlorine Leakage at PT Pupuk Kijang Cikampek. University of Indonesia.
[3] Buaprommart, K., Mahgerefteh, H., Martynov, S., & Striolo, A. (t.t.). Modeling of Thermal Radiation as a Result of Fires and Explosions Following a Well Blowout During Shale Gas Production.
[4] CCPS. (2012). Guidelines For Engineering Design For Process Safety (Second Edition). Wiley.
[5] Da Silva Rodrigues AJ, Da Silva MHLF, De Farias DO, Teixeira MM, De Brito Rocha MF, Lins GB, & Neto JDSC. (2017). Risk Reliability Analysis, Resulting From Explosions In Petrochemical Industries: A Case Study Using ALOHA Software. 12th Iberian Conference on Information Systems and Technologies (CISTI), 1-6.
[6] Directorate of Oil and Gas Engineering and Environment. (2022). ATLAS Oil and Gas Safety Vol. 4.
[7] Director General of Oil and Gas. (2022). Oil and Gas Statistics Semester I 2022.
[8] Matches. (t.t.). Equipment Costs. Retrieved May 26, 2024, from https://www.matche.com/default.html
[9] Mujiyanti, S. F. (2018). Design of Plantwide Control at Gas Processing Facility (GPF) Plant. Sepuluh November Institute of Technology.
[10] noaa Office of Response and Restoration. (t.t.). Overpressure Levels of Concern. https://response.restoration.noaa.gov/oil-and-chemical-spills/chemical-spills/resources/overpressure-levels-concern.html.
[11] Peters, M. S., Timmerhaus, K. D., & West, R. E. (2003). Plant Design and Economics for Chemical Engineers (5th ed.). McGraw-Hill.
[12] Rampuri, S. (2019). Hazard and Operabilty (HAZOP) Study in Process Industries. International Journal of Institution of Safety Engineers India, 2(3), 10-17.
[13] Rizky, S. A., Maharani, F. T., Amalia, R., & Fitri, A. M. (t.t.). The consequences analysis of fire and explosion scenario using ALOHA software on loading area at Company X in 2020.
[14] Roehan, K., R., A., Yuniar, & Arie Desrianty. (2014). Proposed Improvement of Occupational Safety and Health Management System (SMK3) Using Hazard Identification and Risk Assessment (HIRA) Method. Online Journal of the National Institute of Technology, 2(2), 1-10.
[15] S. Betteridge. (2018). Technical Guide (8th ed.). Shell Global Solutions.
[16] Shell Global Solutions. (2018). User Guide. Shell Global Solutions.
[17] Testbook Edu Solutions Pvt. Ltd. (2023). Hydrogen Sulphide: Properties, Structure, Production, Uses and Hazards.
[18] Towler, G., & Sinnot, R. (2008). Chemical Engineering Design. ELSEVIER.
[19] Vijay, A., S., H., & Sankar, S., S. (2023). Hazard and Operability (HAZOP) Study on LNG Skid. International Journal of Modern Developments in Engineering and Science, 2(4), 35-39.
[20] Willey, R. J. (2014). Layer of Protection Analysis. Procedia Engineering, 12-22.