



Analysis the Potential of Fire and Explosion at Ammonia Storage Tank

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Abstract

The increase in fertilizer industry in the world made the growth up of the ammonia industry as well. Ammonia was used as a nitrogen source in fertilizer industry and stored in ammonia storage tank. This industry had two ammonia storage tanks with capacity 10,000 MT and 5,000 MT, respectively. This study aimed to analyze the impact of fire/explosion at ammonia storage tank and find the root cause of ammonia released from ammonia storage tank. The impact of fire/explosion was analyzed using Dow's Fire & Explosion Index (DFEI), which resulted in the radius effect due to the ammonia storage tank explosion of 10,2 meters. The actual probable property damage was US\$ 144,405 and US\$ 62,576 for each ammonia storage tank. Possible daily outage for this fire/explosion was at least 2 days. Software ALOHA (Areal Location of Hazardous Atmospheres) resulted in the toxic area radius up to 3700 meters if ammonia was released from the tank. Moreover, the explosive area for this condition up to 118 meters.

Keywords: ALOHA, Ammonia, DFEI, Explosion, Fire,

1. INTRODUCTION

The increasing world fertilizer demand for nitrogen year by year demands is more significant than ammonia plant. According to data from the IFA (International Fertilizer Industry Association) in June 2018, world fertilizer demand in 2018 was 185 MT and is predicted to increase in 2023 up to 200 MT. The primary function of ammonia is to provide nitrogen in its ready-to-use form.

The ammonia industry is one type of industry that is classified as a major hazard. Major hazard generally consists of fires, explosions, and chemical leaks. One of the units that had this hazard was ammonia storage tank. Ammonia storage tank had high pressure or low temperature (-33,3°C) to keep ammonia in the liquid phase (Ojha and Dhiman, 2010).

Ammonia gas is toxic, corrosive and can rapidly penetrate the eye even in low concentration (below 20 PPM-parts per million). At high concentrations, it can react with moisture in the skin, eyes and respiratory systems to cause tissue burns, blindness or potentially-fatal pulmonary edema. The maximum exposure limit of ammonia gas is recommended by ACGIH as much as 25 PPM (17mg/m³) for 8 hours and short-term exposure limit is 35 PPM (24mg/m³) for 15 minutes. The release of toxic anhydrous ammonia is harmful to the environment. Ammonia that diffused into water bodies would increase pH and have an adverse impact on the overall aquatic ecosystem. Fishers already found plenty of dead fish from nearby contaminated ponds.

As a basis for efforts to control risks of hazards in ammonia storage tank, an assessment of the potential hazards is needed. The hazard identification method applied is Fault Tree Analysis (FTA). The FTA method is used to find how toxic gases can release into the environment (Woodside *et al.*, 1997).

Risks that arise due to the fire/explosion on the ammonia storage tanks are calculated by using the Dow's Fire & Explosion Index (DFEI). DFEI provides information about the radius of the fire/explosion impact, workday and financial loss due to the fire/explosion. Based on the DFEI guidelines issued by the American Institute of Chemical Engineers (1994), step for assessing fire and explosion hazards potential begin with selecting the processing unit, determining the material factor (MF), determining the processing unit hazard factor (F3) by calculating the general processing hazard factor (F1) and unique process hazard factor (F2), and determining the fire and explosion index (F & EI). The use of ALOHA (Areal Location of Hazardous Atmospheres) software provides information about the area that includes red, orange and yellow zones based toxic area.

2. METODOLOGY

2.1. Research Site

The industry used as the object of research was one of the chemical fertilizer industries in Cikampek. This industry has an ammonia plant capacity of around 660,000 MT/year. The raw material used in the form of natural gas was obtained from Pertamina, water was obtained from the ParungKadali River and Cikao River, and free air was obtained from around the plant as a source of nitrogen. The location of the study can be seen in **Figure 1**.

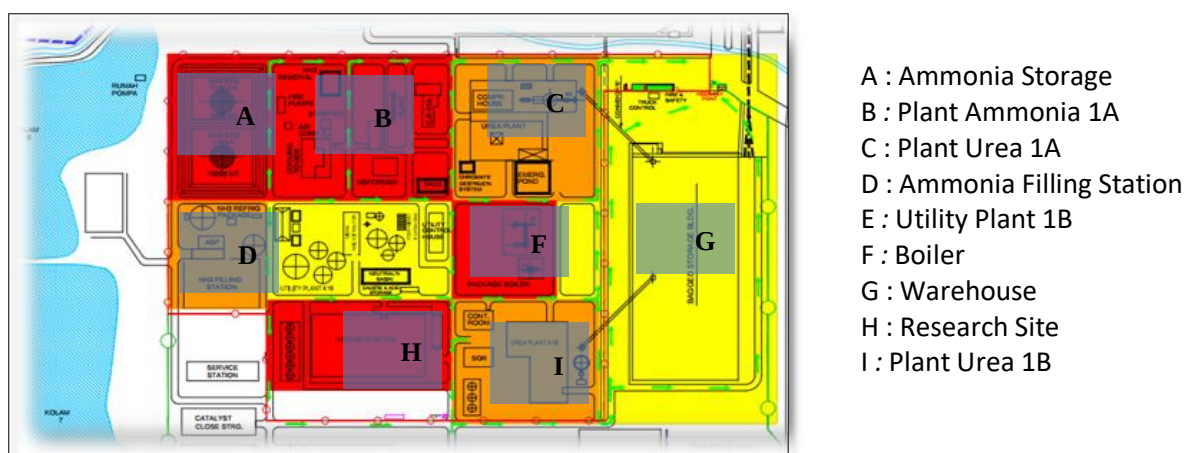


Figure 1. Ammonia Storage Location

The study was focused on the Ammonia Storage (A) that acts as a tank to store ammonia produced by the plant. This fertilizer industry had two ammonia storages with capacity 5000 MT and 10000 MT, respectively.

1.2. Fire/Explosion Risk Analysis Using Dow's Fire Explosion Index (DFEI)

Fire/explosion risk analysis was carried out using Dow's Fire & Explosion Index (DFEI). The stages of this method can be seen in the Dow's Chemical Exposure Index Guide Manual set by NFPA (National Fire Protection Association) in 1994. DFEI aims to determine the extent areas affected by the fire/explosion, the number of working days lost to the company's financial loss.

In order to achieve the purpose of using the DFEI, several equations are used. The radius of the affected areas is formulated in equation 1. The value of financial loss due to damage to factory facilities can be seen in equation 2. In addition, financial loss due to the cessation of the production process can be calculated using equation 5.

$$R = 0.256 \times F\&EI \quad (1)$$

$$VoE = 0.82 \times \text{Original Cost} \times \text{Escalation Factor} \quad (2)$$

$$\text{Base MPPD} = DF \times VoE \quad (3)$$

$$\text{Actual MPPD} = LCCF \times \text{Base MPPD} \quad (4)$$

$$BI = MPDO \times (VPM/30) \times 0.70 \quad (5)$$

Description

R	: Impact radius
F&EI	: Constants resulted from the DFEI process
VoE	: Value of Exposure
Original Cost	: Asset value of secondary reformer
Escalation Factor	: Decree from CEPCI (Chemical Engineering Plant Cost Index)
MPPD	: Maximum Probable Property Damage
LCCF	: Loss Control Credit Factor
BI	: Business interruption
MPDO	: Working days lost
VPM	: Production value/month

1.3. Risk Analysis using ALOHA (Area Location of Hazardous Atmospheres) Software

ALOHA is a software used to model the dispersion of affected areas due to the release of chemicals, including toxic areas and explosive areas. Toxic area was divided into three categories of ammonia concentration: 1,100 ppm, 16 ppm and 30 ppm as well as flammable area. The concentrations of flammable area are 65,000 ppm, 31,500 ppm and 15,000 ppm.

ALOHA is a software that is easy to learn and can be arranged according to the scenario created (ALOHA user's manual, 2007). Besides, this software is also not paid so that it can be easily downloaded on the internet. In this study, the ALOHA software used was version 5.4.5 released by NOAA (National Oceanic and Atmospheric Administration).

3. RESULT AND DISCUSSION

3.1 Fire/Explosion Risk Analysis of Ammonia Storage

DFEI analysis was carried out using the ammonia storage technical specification data analyzed, the economic value of each study unit, and security tools around the processing unit in an emergency. The use of the DFEI method was performed with two scenarios. The chosen scenario was the ammonia storage explodes partially. The results of the DFEI analysis in the study unit can be seen in Table 1.

Based on Table 1, it is known that the DFEI value for ammonia storage with capacity 10,000 MT and 5,000 MT was 40.12 and 39.44, respectively. This value indicates that the fire/explosion impact at ammonia storage tanks is classified as light. Table 1 also informs that the minimum working day loss was 4 and 2 days for each ammonia storage tank.

Table 1 Analysis result of Ammonia Storage Using DFEI

Unit	DFEI point	Radius impact (m)	Base Value of MPPD (US\$)	Actual Loss (US\$)	Working Days Lost (days)	Bisnis Interruption (IDR)
Ammonia Storage Tank 10000 MT	40,12	10,3	335,414	144,405	4	386.579
Ammonia Storage Tank 5000 MT	39,44	10,2	145,346	62,576	2	96.645

This value did not include trauma treatment for employees, the ability to raise the company, and other non-technical factors (Roshan and Gredaragh, 2013). The number of workdays lost was analyzed based on the assumption that the company can immediately rise and rebuild the ammonia storage tank unit after the explosion. In the ammonia storage tank, the explosion/fire impact just for the tank and not included the other unit but, ammonia is very dangerous to the environment and death to the human being.

Severity level of the impact due to an fire/explosion can be seen from the F&EI value obtained. This hazard level based on F & EI values can be seen in **Table 2**.

Table 2 Hazard analysis based on F&EI value

F&EI	Degree of Hazard
1-60	Light
61-96	Moderate
97-127	Intermediete
128-158	Heavy
>158	Severe

Source: AICHE. *Dow's Chemical Exposure Index Guide* 1994

In the ammonia storage tank unit, the MPPD base value reached 335,414 USD. The MPPD base is the value of the company's loss based on the value of the damage factor obtained. The damage factor value is based on the type of chemical analyzed using the equations in the Dow's Fire & Explosion Index guide from NFPA (Jensen and Jorgensen, 2007). Actual MPPD is the value of losses suffered by the company after considering the security factors in the units analyzed. In the ammonia storage tank unit, this value reached 144,405 USD.

The area affected by fire/explosion of the ammonia storage tank can be seen in **Figure 2**. Based on Figure 2, it is known that the risk area of being affected by fire/explosion is only around the ammonia storage tank area without spreading to other plants.

The losses obtained in this analysis are theoretical calculations using the DFEI method (Javari *et al.*, 2012). This loss value can be even greater considering that there are still external parameters that are not included in the DFEI method and affect the analysis results. Therefore, Table 1 is only used as a basis for the company in determining the number of losses due to fire.

3.2 Analysis of Explosion Risk Based on Explosion Strength on Ammonia Storage Tank

This analysis was carried out using ALOHA software with data in the form of ammonia storage tank technical specifications, process conditions within the unit, and scenarios for explosions. Data requirements for ALOHA software can be seen in **Table 3**.

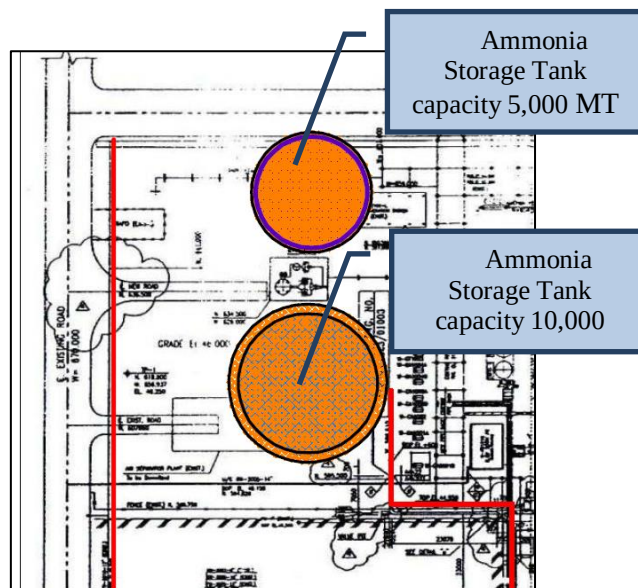


Figure 2. Fires Radius Exposure on Ammonia Storage Tank

Table 3 Parameter for ALOHA analysis

Parameter	Value
Chemical material	Ammonia (NH ₃)
Capacity	10,000 MT and 5,000 MT
Air stability	B (Unstable)
Wind velocity	2.07 m/s
Wind direction	Southwest
Temperature	28°C

There were two selected scenarios for this analysis. The first scenario occurs when the ammonia spill channel to the PT. X does not work, so spilled ammonia will remain stagnant so that ammonia can be released into the surrounding environment. The second scenario occurs if there is a leak in the ammonia tank and the sprinkler around the ammonia tank unit which functions to dissolve ammonia does not function optimally. The results of the analysis can be seen in **Table 4**.

Table 4 Analysis of toxic area at Ammonia Storage Tank

Capacity (MT)	Wind speed (m/s)	Wind Direction	Radius of Exposure (meter)		
			AEGL-1	AEGL-2	AEGL-3
Scenario 1					
10.000	2,07	West	3700	1900	845
	2,23	Northeast	3700	1900	846
5.000	2,07	West	2900	1500	653
	2,23	Northeast	2900	1400	656
Scenario 2					
10.000	2,07	West	520	1800	4400
	2,23	Northeast	508	1700	4300
5.000	2,07	West	488	1700	4200
	2,23	Northeast	477	1600	4000

The results of the ALOHA analysis in Table 4 are the worst risk that will be accepted by the company and the surrounding community. It can happen if the water that has been mixed with ammonia is not

immediately flowed to the waste treatment system of PT. X. This puddle will cause ammonia to evaporate again and be dispersed in the air.

Based on Table 4, the difference in toxic area coverage between a tank with a capacity of 10000 MT and 5000 MT is about 50 m and increases when the number of AEGL increases. This condition is influenced by the value of the ammonia concentration released into the surrounding environment. For each tank, the toxic radius value did not differ significantly between the two seasons, especially for the AEGL-1 value. The impact of the ammonia storage tank explosion and fire can be seen in **Figure 3**.

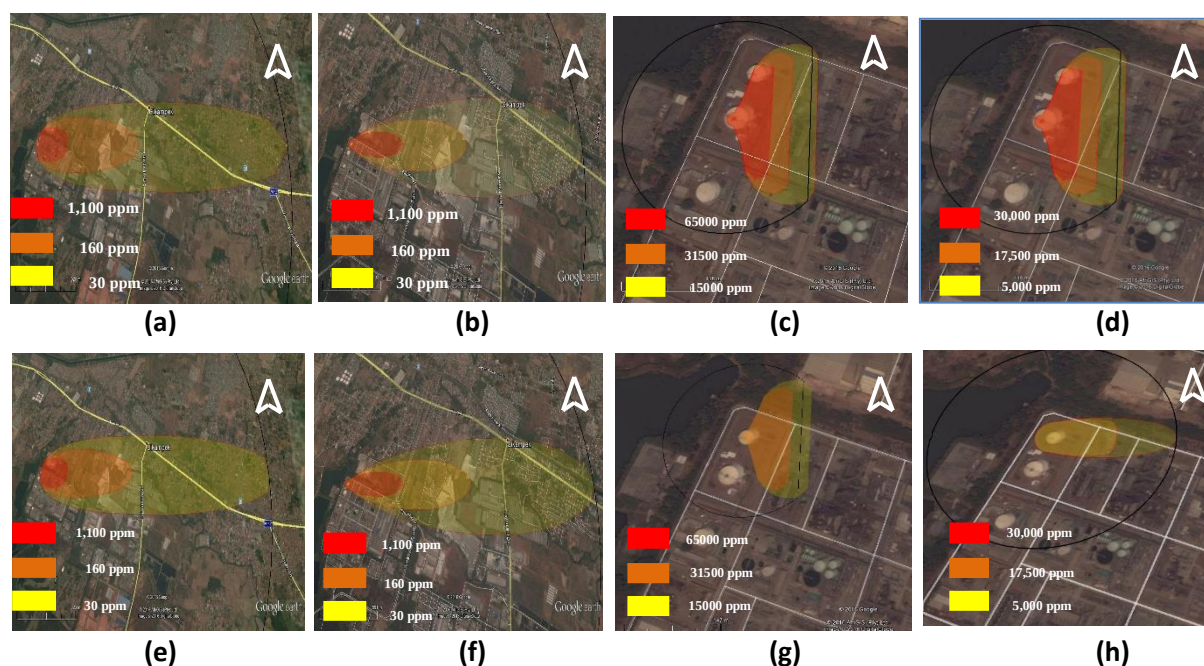


Figure 5. ALOHA Analysis (a) Toxic Area Scenario 1 (10,000 MT) (b) Toxic Area Scenario 2 (10,000 MT) (c) Flammable Area Scenario 1 (10,000 MT) (d) Flammable Area Scenario 2 (10,000 MT) (e) Toxic Area Scenario 1 (5,000 MT) (f) Toxic Area Scenario 2 (5,000 MT) (g) Flammable Area Scenario 1 (5,000 MT) (h) Flammable Area Scenario 2 (5,000 MT)

The toxic area reached the surrounding area, including a residential area, to be very dangerous for public health. Ammonia has a high value on health effects, with point 3 (maximum point is 4). The radius of the toxic area in the rainy and dry season is not significantly different.

Atmospheric stability also affects the dispersion of ammonia. The atmospheric was at level B (unstable), so that the gas dispersion is not in a straight line. An unstable atmosphere is more favorable for the level of ammonia dispersion because the ammonia will mix with the air so that the ammonia concentration can be reduced (Inanloo and Tansel, 2010). If the case in stable atmospheric conditions (level D-F), ammonia will be difficult to disperse by the wind, which is very dangerous for health. The gas dispersion during stable atmospheric conditions will be illustrated in a straight line.

Air stability in category B (unstable) also affects the size of the affected area. Unstable air conditions can dilute chemicals so that air can reduce the amount of chemicals present in the air (Vairoet *et al.*, 2014). Ammonia diluted in the air by the wind direction. Therefore, unstable air conditions in the affected area will be smaller than the stable air condition (E or F). The level of air stability is particles' ability to move up or down after being released into the atmosphere (Inanloo and Tansel, 2015). The more stable atmospheric conditions, the more immovable the particles in the atmosphere.

4. CONCLUSION

The occurrence of explosions/fires on the ammonia storage tank is caused by technical and non-technical aspects described in the FTA. The company suffers the minimum actual loss due to the ammonia storage tank fire/explosion reaches US \$ 144,405 with a minimum workday loss of 4 days. In addition, the toxic area reaches residential areas that can cause death to the community

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